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The gain of additional sampling methods for the fish-based assessment of large rivers

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ABSTRACT

Fishes serve as indicators in ecological assessments of European large rivers. Electrofishing is the standard fishing method although it is restricted to the shallow littoral shoreline. Fish occurring in the open water zone of the main channel remain consequently underestimated. Additional sampling methods that cover the mid-channel of rivers could close the electrofishing-gap, but strengths', weaknesses and gains of both electrofishing and additional sampling methods for fish-based assessments of large rivers have not been contrasted yet. We analyzed a unique dataset consisting of 2693 fish samplings in European large rivers and compared electrofishing with the additional sampling methods trawling, seining, and drift-netting. We compiled fish metrics commonly used in fish-based assessments yielded by the different gears and highlight the differences in fish species, biodiversity metrics (Shannon Index, Evenness, Simpson Index), the Fish Region Index (FRI) and densities of fish in selected guilds (eurytopic, rheophilic, lithophilic, phytophilic, psammophilic, potamal) that are considered indicative for the degradation of habitats in large rivers. Electrofishing yielded overall highest numbers of species, biodiversity metrics and densities of fish guilds, except for the number of migratory and Habitat Directive species, the FRI and densities of potamal fish. The additional gears, predominantly trawling, captured additional rheophilic and lithophilic species. Trawling also assessed most migratory and Habitat Directive species and yielded higher densities of potamal fish as well as larger fish than electrofishing. Trawl catches further estimated higher biodiversity compared to seining, while the latter yielded higher densities of eurytopic, rheophilic, lithophilic and phytophilic fish. Drift-netting yielded the lowest estimates overall but sample size was very low. We suggest that electrofishing is an appropriate method to assess and evaluate the effects of hydromorphological degradation and rehabilitation on fish, and to guide river management. It sufficiently well represents the typical fish assemblage of large rivers despite its restriction to the shoreline. In contrast, assessing specifically Habitat Directive, migratory and rare species, as well as obtaining complete species inventories, e.g., for biodiversity assessments, requires complementary sampling of the mid-channel of large rivers by additional gears such as trawling.

1. Introduction

Representative sampling is a crucial challenge in ecological assessments of large rivers (De Leeuw et al., 2007; Poikane et al., 2014), i.e., in rivers with a catchment size > 10,000 km^2 (Berg et al., 2004). Challenges arise from the pure size of the water body (Flotemersch et al., 2011), the complexity of the riverine ecosystem (Ward et al., 2002) with its variety of habitat structures (Loisl et al., 2013), the varying suitability and selectivity of different sampling methods and the diversity of fish assemblages with broad requirements on specific habitats (Penczak and Jakubowski, 1990). The shoreline and the open water zone of the main channel are two distinct meso-habitats of large rivers. The littoral shoreline is rather shallow and therefore has a great variety of differently structured micro-habitats such as sand banks, gravel bars or areas loosely to densely colonized by emerged or submerged vegetation (Erős et al., 2008; Lechner et al., 2014). Complex structures such as large wood provide refuge, both for fish and prey organisms (Lynch and Johnson, 1989) and also aquatic vegetation and can strongly influence fish community dynamics (Casselman and Lewis, 1996; Jacobsen and Perrow, 1998; Weaver et al., 1997). Hence, highest fish production and diversity are observed at the shoreline (Randall et al., 1996). The open water zone of the main channel is rather unstructured with higher flow velocities, greater depths and it further covers the major part of the river by both area and water volume (Szalóky et al., 2014). Though Wolter et al. (2004) have shown that the open water zone of the main channel has distinct fish assemblages, its

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importance as an relevant meso-habitat for riverine fishes (Loisl et al., 2013; Szalóky et al., 2014), especially for potamal species (Wolter and Bischoff, 2001) has long been neglected (Dettmers et al., 2001b; Galat and Zweimüller, 2001).

Electrofishing is a standard method to sample fish, even in large rivers (e.g., Beier et al., 2007; Dußling, 2009; Aparicio et al., 2011). Electrofishing efficiency is however limited to shallow areas (Bohlin et al., 1989) and decreases even in small streams with increasing river width (Kennedy and Strange, 1981). It is well suited to sample complex habitat structures such as aquatic vegetation or large wood, which harbor high concentrations of fish (Erős et al., 2008; Lewin et al., 2014), but may be obstacles for most other sampling methods. However, fish occurring in the open water zone of the main channel are underestimated by electrofishing.

Additional methods such as trawling (e.g., Wolter et al., 2004), seining (e.g., Neebling and Quist, 2011), gill-netting (e.g., Goffaux et al., 2005), drift-netting (e.g., Fladung, 2002), and long-lining (e.g., Loisl et al., 2013) can be applied in the open water zone of the main channel and could therefore be beneficial for the fish-based assessment of large rivers (Flotemersch et al., 2011). However, besides long-lining, these fishing gears are prone to entanglements and therefore less suitable for application in complex, structured habitats.

Biodiversity measures enhance understanding of the complex components driving ecosystems (Morris et al., 2014). Biodiversity can however be biased because abundance of species and densities of fishes can change in identical habitats during ontogeny (Blondel, 2003), between seasons (Dettmers et al., 2001a; Wolter and Bischoff, 2001) and even between day and night (Erős et al., 2008; Wolter and Freyhof, 2004). Many fish species are further either stationary or mobile throughout their lifecycle (Radinger and Wolter, 2014). Composition of fish assemblages is accordingly variable even within identical habitats, which makes assessments aiming to compare fish communities across large spatial extents rather challenging.

Multiple sampling of identical sampling sites is beneficial (Dußling et al., 2004a; Kucera-Hirzinger et al., 2008) to increase sample size and to minimize natural and temporal variation due to, for example, sampling methodology, migration or habitat patterns (Wolter et al., 2004). Repeated samplings over time (Magurran and Henderson, 2003) and over large spatial extents (Tokeshi, 1993) further decrease sampling error and increase estimates of species richness. On the other hand, repeated samplings lead to some challenges in statistical analyzes (Poikane et al., 2014). Different approaches regarding sampling or analytical methodology combined with variable fish traits can result in contrasting conclusions on ecological states (Heino et al., 2013), requiring a certain standardization, especially when large-scale data are considered.

The main objectives of this study were to evaluate commonly used fish sampling methods and identify the gain of additional methods for the fish based assessment of large rivers while accounting for the heterogeneity due to field sampling data. To achieve our objectives, we:

i) compiled a dataset of 2693 fish sampling occasions in European large rivers and calculated various fish assemblage metrics commonly used in fish-based assessments;
ii) compared fish metrics based on electrofishing with those based on trawling, seining, and drift-netting in a first analysis comprising 849 fish samplings. Further, we tested electrofishing against each additional method in three independent comparisons standardized to similar sites sampled by both gears;
iii) identified strengths, weaknesses and gains of applying additional sampling gears in large rivers; and
iv) evaluated whether electrofishing is sufficient for the fish-based assessment of large rivers

We hypothesized that fish metrics depend on the sampling method used and that even though additional sampling methods constitute valuable tools, the application of electrofishing is superior for the fish-based assessment of large rivers. We further hypothesized that additional sampling gears capture additional species and therefore complete the species inventory, specifically concerning potamal fish. Thus, selection of sampling gears and use of complementary sampling methods strongly depend on the study objectives. While obtaining complete species inventories probably requires applying several sampling methods, the evaluation of a rehabilitation structure in the littoral zone of a large river may not.

2. Methods

2.1. The large river database (LRDB)

The LRDB has been compiled within the EU project “Improvement and Spatial Extension of the European Fish Index” (EFI+, EC 044096) and further completed since. It consists of 2693 sampling occasions from 358 sampling sites located in 16 European large rivers, i.e., rivers with a catchment size > 10,000 km^2 (Berg et al., 2004). The LRDB is structurally comparable to the Fish Database of European Streams, described in detail by Beier et al. (2007). In contrast to the latter, it contains multiple samplings of identical sampling sites using different gears, which allows for analysis of the improvement of fish metrics by applying additional gears in large rivers.

The LRDB contains rivers Aller, Danube, Elbe, Ems, Havel, Ijssel, Lek, Meuse, Narew, Oder, Rhine, Saale, Spree, Tisa, Vistula and Weser. River Danube and its tributary river Tisa drain into the Black Sea. All other rivers drain into the North Sea or the Baltic Sea (Fig. 1). Rivers were sampled in the main channel, in backwaters and in mixed locations (i.e., covering both the straight channel and oxbows) across an average length of 2221 m, 866 m and 951 m, respectively. Assessments took place over several years (1996–2010), during different seasons and a few samplings were conducted at night. The most frequent sampling methodology was electrofishing (E: 1862) and trawling (T: 710), followed by seining (S: 48) and drift-netting (D: 47). The remaining 26 samplings using gill-netting (23), long-lining (2) and fyke-netting (1) had to be excluded from further analyses due to a lack of comparability. Fished length and fished width had been recorded for each sampling occasion for electrofishing, trawling and drift-netting and fished area is given for seining which allowed determining species densities assessed by each method. Further, total length of captured fish had been recorded for some samplings and species, which allowed to considering size selectivity between electrofishing and trawling for frequently captured species.

2.2. Data standardization protocol

To standardize data, we selected only sampling occasions:

A located in rivers draining into the North Sea and Baltic Sea. Rivers draining into the Black Sea were excluded because they contain too distinct and more species-rich fish communities biasing the comparisons;
B covered a fished length of at least 400 m for electrofishing, trawling and drift-netting to ensure that at least 95% of the species inventory were captured (Wolter et al., 2004). Seining covered an area of at least 4000 m^2;
C captured at least 100 fish to fulfill national sampling standards (Dußling et al., 2004a) while maintaining reasonable sample sizes for the gear comparisons;
D conducted during daytime; and
E conducted in the main channel.

The remaining dataset consisted of 849 samplings at 159 sites in 14 rivers. Electrofishing (59.7%) and trawling (35.5%) were the most commonly applied gears followed by seining (4.5%) and drift-netting