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Requirements for representative sampling for fluvial fish assemblages – literary review

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Abstract. Fish are good indicators of long-term changes of fluvial ecosystems therefore, assessment of fish assemblages is frequently used in evaluation of the ecological status of surface waters, especially since the implementation of the EU Water Framework Directive. Long-term changes of fish fauna and old-time abundance of fish populations in the Danube can be documented by historical data of fisheries. Direct detection of long-term changes of fish populations in large rivers is a difficult task due to large-scale temporal and spatial variability of fish distribution. The present study provides a review of river fish sampling methods, with special attention to approaches based on electrofishing. Our goal is to develop a standard monitoring method in large rivers to get more reliable and consistent data for description of long-term changes of fish populations.

Keywords. Monitoring, standard sampling, electric fishing, Danube.

INTRODUCTION

Fish are sensitive indicators of the environmental changes of rivers. The continuously changing water regime, as well as hydraulical and hydromorphological characteristics of large rivers have significant impact on composition and spatial distribution of fish assemblages (Amoros *et al.* 1987, Welcomme 1985, Fausch *et al.* 1990, Sheehan & Rasmussen 1999, Guti 2002a, Lapointe *et al.* 2006). Growing needs of human population have had a major impact on river ecosystems, leading to the loss of aquatic habitats and providing several threats to fish populations and biodiversity since the 18th century. The long-term changes of the Danube fish fauna and abundance are detectable in the differences between the historical records of fisheries documented in the Middle Ages (Herman 1887, Khin 1957) and those of present times, as well as in the decreasing trends of annual catch of traditional fishing in the second half of the 20th century (Guti 1993, 2008, Schiemer et al. 2004, Guti & Gaebele 2009).

In the qualification of surface waters the assessment of biological integrity or ecological status has gained more and more emphasis in the latter decades (Angermeier & Karr 1986, Karr *et al.* 1987, Schmutz *et al.* 2007a). Fish-based methods of the assessment of ecological integrity of water bodies began to appear in the 1980s, *eg.* Index of Biotic Integrity (Karr 1981) and European Fish Index (Schmutz *et al.* 2007b). Fish are essential objects in evaluation of ecological status of freshwater ecosystems, as the organisms on the top of the aquatic food web, because they integrate the changes taking place on lower trophic levels. Their habi-tat needs change continuously on the course of their ontogenesis, thus occurrence of self-sustaining populations may indicate the diversity and connectivity of aquatic habitats (Copp 1989, Wel-comme 1995, Jungwirth, Schmutz & Weiss 1998, Schmutz & Jungwirth 1999). In Europe, in relation with the Water Framework Directive (WFD) (EC 2000), the assessment methods elaborated to qualify surface waters place great emphasis on biological examinations, in which fish take an essential role, opposed to traditional physical and chemical monitoring.

Trends of long-term changes of fish populations indicate alteration of the ecological integrity of rivers. One of the essential criteria of detection of long-term changes in fish populations is the establishment of a dataset, based on the consistent and representative surveys of the abundance and composition of fish assemblages (Guti 2002b). One of the crucial design problems of the fish monitoring of large rivers is determination of the appropriate temporal and spatial scale of sampling, which need to fit into extent of expected impacts. In this case variability of sampling results indicates the actual changes of the fish populations.

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The database of annual catches of the commercial fishermen, who fish more than 200 days per year in the Danube, are based on a large scale "observation" in space and time (Jancsó & Tóth 1987, Guti 2008). The robust data of fisheries are indicative to the interannual changes, because less dependent on the local environmental (water level, flow velocity, *etc*.) and biological (diurnal and seasonal movements, *etc*.) factors, which can result sampling distortion in smaller scale long-term studies. If the methods and intensity of fishing is unchanged for many years, data of annual catches can be treated as a consistent dataset in case of some fish species. However, the traditionnal commercial fishing is a disappearing occupation along the Danube in Hungary, so catch statistics of fisheries becoming less and less evaluable for the indirect monitoring of the fluvial fish populations.

In the case of direct monitoring of the long-term changes of fish populations, the consistency of datasets can be secured on the one hand by precise definition of sampling methods (equipment and techniques), on the other hand by elaboration and application of an appropriate sampling strategies (spatial and temporal scale of sampling, timing, *etc*.), which reduce the "disturbing" environmental and biological factors (Peterson & Rabeni 1995, Noble *et al.* 2007).

The applicability and effectiveness of fish sampling methods is influenced by numerous environmental factors, such as water depth, flow velocity, weather conditions, *etc.* Nevertheless, the composition and quantitative metrics of the fish assemblages of large rivers can only be examined to a limited degree on the basis of a single survey, because of several biological factors, as the diurnal and seasonal variation of spatial distribution of fish, which reduce the sampling representtativeness on a given section of the river (Ericksen & Marshall 1997, Specziár 2001). The diurnal movements of fish between the feeding area and shelters usually depends on the ligth conditions (Hayward *et al*. 1989, Gaygusuz *et al.* 2010), while changes of seasonal activity are often related to migratory movements between spawning, feeding and wintering areas (Harden Jones 1968, Anras *et al.* 1999). Differences can be considerable in the lateral extension of floodplain rivers between droughty and flood-rich years, so the reproductive success and the recruitment of the fish populations are quite different in single years (Welcomme 1985, Guti & Gaebele 2009).

In this study the topic of fluvial fish sampling methods is discussed with reviewing of literature data, paying special attention to the factors affecting the application of electrofishing in large rivers.

METHODS

When selecting from the literary articles concerning the various sampling methods of fish surveys and the factors influencing their effectiveness, the more important research results of the past few decades (1979–2012) were taken into consideration.

We studied the number of publications dealing with electrofishing in the database of ScienceDirect, with directed search on several key words. With the evaluation of literary data, the conditions and problems of fluvial electrofishing were characterized, with special regard to the spatial and temporal variability of the fish distribution (diurnally and seasonally), and the environmental factors affecting the efficiency of electrofishing (water depth, flow velocity, turbidity, conductivity, *etc.*).

RESULTS

In the ScienceDirect, 811 publications were found by the „electrofishing" key word. The annual number of articles shows an increasing trend from the middle of the 1970s (Fig. 1). At the same time there are only few literature data about requirement of representative sampling methods with electric and other fishing tools.

In the literarture analyis, 68 publications were examined which deal with the assessment of fish assemblages of rivers, streams, lakes, reservoirs *etc.* and the comparative analysis of the effectiveness and applicability of fishing gears.

According to the studies reviewed, most of the electrofishing surveys were implemented on lakes and reservoirs (43%), as well as small streams (42%), but sampling in large rivers (15%) is less frequent, presumably due to lower efficiency of electrofishing under fluvial conditions (Casselman *et al.* 1990, Penczak & Jakubowski 1990, Grossman & Ratajczak 1998) (Fig. 2).

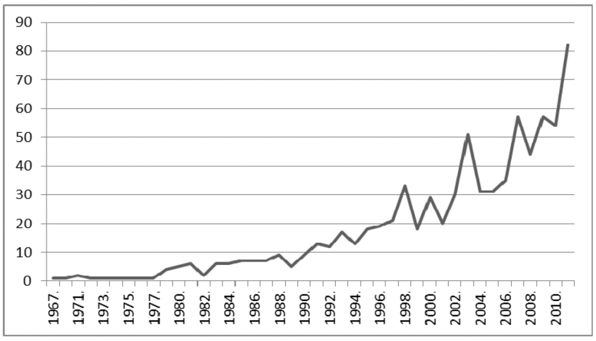

Figure 1. The annual number of publications dealing with electrofishing.

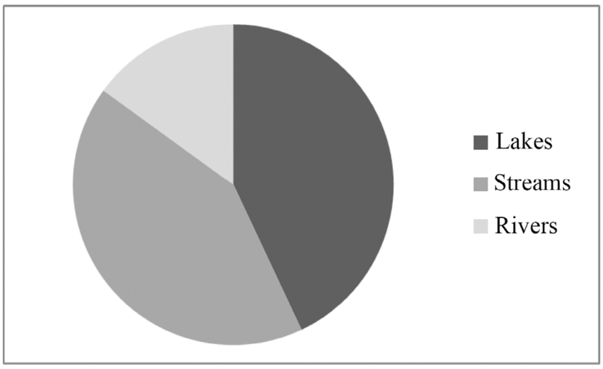

Figure 2. Proportion of main types of surface waters in literature of electrofishing.

Electrofishing is one of the most widely used sampling methods in routine ichtyological surveys of fluvial fish assemblages all over the world (Cowx & Lamarque, 1990, Hendricks *et al.* 1980, Harvey & Cowx 1996, Reynolds, 1996). The advantage of electrofishing in large rivers and streams is its utility for the examination of the spatial distribution of fish. Its usage is not limited by the roughness of the riverbed and trees fallen into the water, and it is simply applicable along the shoreline, where fish are often accumulated in larger numbers (Reynolds 1996). Nevertheless, its application and effectiveness is affected by numerous environmental, biological and technical factors (Bagenal 1979, Bohlin *et al.* 1989, Cowx 1990, Zalewski & Cowx 1990, Rodgers *et al.* 1992, Bayley & Dowling 1993, Reynolds 1993, Lobón-Cerviá *et al.* 1994, Anderson 1995, Peterson *et al.* 2004, Beamount 2011), as shown in Table 1.

Comparisons of the sampling efficiency of different fishing gears (Thurow & Schill 1996, Wildman & Neumann 2003, Goffaux *et al.* 2005, Lapointe *et al.* 2006, Benejama 2012 *etc.*) and the diurnal sampling variability (Sanders 1992, Thurow & Schill 1996, Gaygusuz *et al.* 2010, Vasek *et al.* 2009, Riha *et al.* 2011 *etc.*) are common subjects in the articles, but issue of representative sampling of fluvial fish is a neglected area of reearch, according to our literature analysis.

For example, in comparison of effectiveness of four different sampling gear (seine net, ring-framed fish trap, Windermere trap and electrofishing), seine net seemed to be the most efficient in abundance and species richness, in an American survey carried out on the Detroit river (Lapointe *et al.* 2006). At the same time, electrofishing is described as the most effective way of assessing fluvial fish assemblages in other publications (Goffaux *et al.* 2005). In a survey of the Belgian section of the river Meuse, electrofishing were compared to gillnetting, and electrofishing proved to be more efficient, althuogh less selective for larger individuals of fish. With regard to the different efficiency of the various fishing gears, the elaboration of combined sampling methods is recommendable (Goffaux *et al.* 2005). For the more complete exploration of the fish assemblages of varied water types combination of different tools was suggested by several studies: combined application of electrofishing with gillnets (Mehner e*t al.* 2005), or combination of electrofishing with trammelnet (Fischer & Eckmann 1997, Paukert 2004).

For sampling of shorline fish assemblages in the Danube Guti (2009) suggested a combinated application of two types of electrofishing units. On the one hand, a conventional design, medium powered (5 kW) electrofishing unit, with hand held anode placed in boat, for the shallow (<1,5 m) stretches along the shoreline of the river. On the other hand, a high powered (13,5 kW) electrofishing boat with fixed anodes is advised getting farther from the shoreline, in deeper (<2,5 m) water.

ENVIRONMENTAL	BIOLOGICAL	TECHNICAL
1. Abiotic Conductivity Water quality Water clarity	**1. Community structure** Species diversity Species composition	**1. Personnel** Size of crew Experience Motivation
2. Habitat Habitat structure Habitat dimensions Substrate Water velocity	**2. Population structure** Density Size distribution Age structure	**2. Equipment** Design Maintenance
3. Seasonality Temperature Weather	**3. Species specific** Behavior Physiology Morphology	**3. Organization** Site selection Standard effort

Table 1. Factors affecting electrofishing (adapted from Zalewski & Cowx 1990).

Night sampling by electrofishing in large rivers is usually more effective than in daytime, because of the diurnal changes of the activity and spatial distribution of the fluvial fish (Witt & Cambell 1959, Paragamian 1989, Sanders 1992, Reynolds 1993). The species richness and abundance of fish in the night samples is usually significantly higher than in the daytime samples, according to surveys carried out on the Ohio and Muskingum rivers, because at night, fish move from the deeper locations of the riverbed to the shallower inshore zone to feed, and all fish seem less apt to avoid capture (Graham 1986, Sanders 1992).

DISCUSSION

For the standardized monitoring of the European fish fauna, the CEN's regulation for electrofishing (CEN 2003) it has to be taken into consideration. The sampling protocol of national ichthyologcal monitoring network in Hungary (NBmR, Natura 2000, *etc.*) was elaborated taking into account the instructions of the international standards. At the same time the problem of taking representative sampling arose increased on larger rivers, especially on the Danube, that is why it is so important the examination of reliability of information got by the recently accepted monitorring methods, with consideration of further developments.

One direction of the relevant research projects is the comparative examination of the efficiency and selectivity of the electrofishing tools applied in standardized surveys. Another important direction in research is the revision of the sampling strategy, with special attention to the issues of spatial and temporal scaling of sampling. Further tasks are among others: study of impact of hydrological changes (raising or dwindling water level, *etc.*) on spatial distribution of fish, evaluation of impacts of hydraulic patterns and geomorphology of river bed, assessment of diurnal and seasonal changes, *etc.*

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