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# ASSESSING THE EFFICIENCY OF CONNECTIVITY MEASURES WITH REGARD TO THE EU-WATER FRAMEWORK DIRECTIVE IN A DANUBE-TRIBUTARY SYSTEM


A. Zitek, S. Schmutz & M. Jungwirth

Department of Water, Atmosphere and Environment, Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Applied Life Sciences, Max-Emanuelstraße 17, 1180 Vienna, Austria


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*Correspondence: A. Zitek, Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Applied Life Sciences, Max-Emanuelstraße 17, 1180 Vienna, Austria (Fax + 43 1 47654 5217; email andreas.zitek@boku.ac.at)*

## ABSTRACT

The effect of restoring connectivity for fish by the construction of 11 fish ladders in the Pielach and Melk rivers, both tributaries to the Danube in Austria, was monitored using electric fishing and fish traps between 1999 and 2004. To assess the efficiency of connectivity rehabilitation measures pre- and post-project data combining electric fishing and trap catch data were analysed by means of three fish-based assessment methods: a MUlti-Level concept for a Fish-based, river-type-specific Assessment of ecological integrity (MULFA), the Fish Index Austria (FIA) and the European Fish Index (EFI). The effect of adding qualitative trap catch data to electric fishing data on metrics and indices was also tested and the magnitude of the effect was related to the distance of the sites from the river mouth. The results clearly demonstrated the significant contribution of connectivity rehabilitation measures to the ecological integrity of rivers like the River Pielach where morphological conditions are good, whereas remaining channelisation still limits the success of connectivity measures in the River Melk. Trap catch data were found to represent an essential source of additional information to assess the efficiency of connectivity measures shortly after their implementation. The negative correlations of the magnitude of the effect of different indices and metrics with the distance of assessment sites from river mouths obviously underline the importance of the river Danube as a source for the re-colonisation process. While the indices tested were found to have limited ability to reflect short term response of fish assemblages to continuum rehabilitation, guild metrics were able to detect improvements of the ecological status shortly after the implementation of connectivity measures. Six metrics showed significant differences between pre and post-project data reflecting the expected increase of the ecological integrity: (1) Fish Region Index (FRI; FIA, MULFA), (2) number of subdominant species and (3) number of flow-guilds (FIA), (4) number of type specific species (MULFA), (5) number of benthic species and (6) number of potamodromous species (EFI); the FRI differences were only significant when trap catch data were added. The EFI indicated a decline of ecological integrity through increases in the density of omnivorous species and the relative number of tolerant species as well as a decrease in the relative number of intolerant species. Significantly decreasing responses with the distance from the river mouth were documented by the EFI and MULFA-index, the FRI (FIA, MULFA), total biomass and for the number of type specific species (MULFA).


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## INTRODUCTION

Freshwater ecosystems have suffered the most intense intervention of all ecosystems over the past 100 years of human history, with severe consequences on fish biodiversity (Cowx & Collares-Pereira, 2002). Many fish species are now extinct, rare or endangered; the need for conservation action is paramount and the conservation of fish diversity remains one of the most difficult challenges facing the EU in preserving our natural biological diversity (Delpeuch, 2002).

In 2000 the European Union launched the Water Framework Directive (WFD, http://www.euwfd.com) (WFD, 2000). The main focus of the WFD is the management of river basins, the natural geographical and hydrological unit. One of the key objectives of the WFD is to achieve "good ecological status" of running waters by 2015. The re-establishment of longitudinal (and lateral) connectivity for fish on the catchment level is thought to be crucial for achieving the central targets of the WFD.

As the term "restoration" usually describes a total return to an original state and to a state that is perfect and healthy, the term rehabilitation as "action of restoring a thing to a previous condition" without the implication of perfection (Bradshaw, 1996) is probably more appropriate for the efforts, undertaken for fulfilling the EU-WFD requirements. With regard to interruptions in connectivity, the total removal of a barrier would be the restoration of the longitudinal continuum; building fish ladders is usually rehabilitation, because in most cases fish migration (up- and downstream) remains affected by the barrier in certain ways. Therefore within the present paper the term "rehabilitation" will be used.

Although Roni et al. (2002) rank the re-connection of stream habitat as the most important of rehabilitation activities in their prioritization hierarchy due to its high cost-effectiveness, studies are not available describing the effectiveness of connectivity restoration in contributing to the overall ecological integrity of rivers with regard to the EU-WFD. Detailed information and deep understanding of the potential contribution of different types of measures on the ecological integrity of rivers are necessary to define the most effective combination of rehabilitation measures.

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Out of nearly 200 European freshwater fish species, 67 are now considered to be threatened by a variety of human activities. Major causes have been identified for 48 of these, and over half of these are associated with obstructions to migration pathways at dams and weirs (Northcote, 1998). The main consequences of continuum interruptions on riverine fish include increased vulnerability to stochastic processes and loss of genetic variability (Meldgaard et al., 2003; Habicht et al., 2004; Laroche & Durand, 2004), the reduction of population size and the loss of species (Backiel, 1985; Utzinger et al., 1998; Rieman & Dunham, 2000; Gehrke et al., 2002; Morita & Yamamoto, 2002; Cumming, 2004). Rheophilic species are known to be especially sensitive to connectivity problems (Penczak et al., 1998). As fish are adapted to the four dimensional nature of rivers (Ward, 1989) connectivity influences fish distribution at different spatial and temporal scales (Jungwirth, 1998) and migration has been often regarded as an adaptive phenomenon to increase growth, survival and abundance (Northcote, 1978).

The establishment of fish migration facilities (Ackerbauministerium, 1891) and fish migration monitoring (Scheuring, 1949) have a considerably long tradition in Austria with currently increasing importance (Jungwirth et al., 1998). In recent years, various types of constructions have been used to re-establish the river continuum in Austria (Jungwirth, 1996; Eberstaller & Gumpinger, 1997; Unfer & Zitek, 2000). Until recently the focus was mainly on the technical details of fish passes construction related to the biological features of migrating fish (Clay,

1995; Larinier et al., 2002), and standardized approaches for evaluating the individual functionality of fish passes are still rare and mainly available only at the national scale (Woschitz et al., 2003; Ebel et al., 2006; Schwevers & Adam, 2006).
Increasingly nowadays the re-establishment of connectivity is seen as a catchment wide task integrating various spatial and temporal scales (Wiesner et al., 2006), that only can be fulfilled using integrated approaches (Schmutz et al., 2002). Although fish are well known as good indicators for the ecological integrity of rivers (Schiemer, 2000), especially for the connectivity of habitats at different spatial/temporal levels (Jungwirth et al., 2000), information on the overall effect of connectivity measures on the targeted populations and assemblages is widely lacking (Bryant et al., 1999). An efficient fish pass might be of little value, if habitat to which fish are migrating for spawning, feeding or survival, is either not available or is severely degraded (Northcote, 1998). On the other hand, habitat restoration measures might not lead to a full recovery of the type-specific fish fauna if barriers still act as “press disturbances” to delay or preclude recovery of fish assemblages (Niemi et al., 1990; Detenbeck et al., 1992). The term “press disturbance” is widely used to describe those human pressures that involve significant long term modifications of instream habitat shifting the whole system to an alternate state, like land-use change, channelization, loss of connectivity and flow regulation. In the absence of press disturbances, recovery processes of fish populations can potentially take place very fast, mainly influenced by the presence of source populations in undisturbed stretches upstream or downstream of impacted sites (Niemi et al., 1990; Detenbeck et al., 1992).

Standardized approaches based on the assessment of the deviation of the present status of the ecological integrity from undisturbed river-type-specific conditions were developed to assess the ecological status of rivers and the effect of rehabilitation measures on fish with regard to the EU-WFD. In Austria, a first approach involved the development of a MUlti-Level concept for a Fish-based, river-type-specific Assessment of ecological integrity (MULFA) (Schmutz et al., 2000). This uses a five-tiered normative scheme following the reference approach. Based on this, the Fish Index Austria (FIA) was developed by Haunschmid et al. (2006). It is a multi-metric index which measures the deviation of a type-specific reference fish community using nine metrics pre-selected by expert judgement and thoroughly tested on their reaction to different pressures taking into account species composition, abundance and age structure. On a European scale the European Fish Index (EFI) represents the first fish-based assessment method applicable on a large geographical scale (Pont et al., 2006).

To assess the effect of connectivity measures in a Danube/tributary network shortly after implementation, pre- and post-project data combining electric fishing and trap catch data were analysed by means of the three fish-based assessment methods, MULFA, FIA and EFI. The following hypotheses were tested:

(1) the reestablishment of the river continuum leads to significant differences between pre- and post-project data measured by the reaction of the different indices and metrics.
(2) trap catch data contribute significantly to the reactions of indices and metrics.
(3) the magnitude of the effects of connectivity measures shortly after implementation is highest at low distances from “source” populations of the river Danube.

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## MATERIAL AND METHODS

### STUDY AREA

The study area is situated about 90 km west of Vienna between 15°30'38" East, 48°14'24" North and 15°14'28" East, 48°09'03" North (WGS84) and consists of the Pielach and Melk, both medium sized tributaries discharging into the Danube at river kilometre 2034 (distance from the Black Sea) (Table 1). The continuum in the Pielach and Melk rivers within the study area is disrupted by four artificial falls as a result of river engineering measures and six weirs built for hydroelectric power production. Within the frame of the LIFE-Nature project "Living space of Danube salmon" (LIFE99 NAT/A/006054) six interruptions to the continuum in the Pielach (P1-P6, Fig. 1) and four in the Melk (M1-M4, Fig. 1) were bypassed by different types of fish passes between 01.10.2000 and 24.06.2003 (Table 2). While the Melk is mostly channelised, the Pielach has retained some of its natural morphological characteristics, such as meandering sections, side arms, dynamic gravel bars, large woody debris, small oxbows, inundation areas and floodplain forests (Schmutz et al., 2002). Both, the Pielach and Melk rivers are affected by water abstraction (37%, 5%) and impoundment (15%, 26%) within the study area and are situated at the transition from hyporhithral to epipotamal zones, whereas lowland river characteristics prevail in the Melk(Schmutz et al., 2002).

**Insert Table 1 here**
**Insert Table 2 here**
**Insert Figure 1 here**

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### ASSESSMENT

An extensive monitoring programme was carried out between 1999 and 2004 using electric fishing and traps to evaluate the efficiency of measures to improve connectivity in the Pielach and Melk rivers (Zitek & Schmutz, 2004). Fish stocks within the study area at the Pielach and Melk rivers were estimated prior to (1999) and after the implementation of the measures (2003) at representative mesohabitats using electric fishing and the removal method. For the analyses, neighbouring mesohabitats were combined into stretches with lengths of 10-20 times the river width except in two stretches of the Melk where 4.5 and 7 times the river width were used (Table 3 and Table 4). The methodology generally followed the CEN directive "Water analysis – fishing with electricity" (EN 14011) and the national standard (Haunschmid et al., 2006). Small-sized species and juveniles were probably underestimated due to the selectivity of electric fishing. In the Pielach sampling in 2003 was restricted to the lower section of the study area (~ 8 km length below P4, see Fig. 1) as the fish pass at P4 was finished only at the end of the monitoring period. In total three sampling stretches at the Pielach and six at the Melk were used for analyses (Fig. 1).

**Insert Table 3 here**
**Insert Table 4 here**

Between 2001 and 2004 nine restored interruptions to the continuum were monitored using fish-traps (see Tab. 2 for details). The trap system used was an adaptation of the resistant board weir described by Tobin (1994) with 1 cm screen spacing (Mühlbauer et al., 2003). A quantitative assessment of immigrating fish from the Danube was conducted directly upstream of P1 in 2001 and 2002 using the same system with 2 cm spacing focusing on larger individulas conducting the spawning migration (Mühlbauer et al., 2003; Zitek & Schmutz, 2004). At this site, downstream migration was also assessed in 2001 using downstream oriented nets (mesh size: 1 cm). Trap catch data were qualitatively merged with electrofishing data by arbitrarily adding one individual per ha (MULFA, FIA) and one individual per run (EFI) to electrofishing data for species only recorded in traps in order to anticipate the ongoing recolonisation process, assuming that these species might also be found by electric fishing in future. As all surveyed fish ladders were found to be functioning well (Zitek, unpublished data); quantitative effects of the type of fish ladder on the re-colonisation process have not yet been integrated into the analyses.

### DATA ANALYSIS

Data were analysed using three different assessment methods: the MULFA-System (Schmutz et al., 2000), the FIA (Haunschmid et al., 2006) and the EFI (Pont et al., 2006). In principle all three approaches follow the EU-WFD as they are based on the assessment of the deviation of the present status from undisturbed river-type-specific conditions. Therefore, the definition of the undisturbed river type-specific fish fauna (the "reference"-situation) is a pre-requisite for all three methods. Both, the FIA and MULFA fully meet the requirements of the EU-WFD as they include different metrics describing species composition, abundance and age structure; the EFI does not include any information on the age structure and is therefore, strictly speaking, not in conformity with the WFD.

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### MULFA.

The MULFA-approach uses seven criteria at five different biological organisation levels (Schmutz et al., 2000). A five-tiered normative scheme is used to assess the deviation of each parameter from the reference condition (status class=1) based on a qualitative verbal judgement. Except for the Fish Region Index (FRI), which may have both positive and negative responses, all other metrics are expected to respond positively to rehabilitation measures. The type specific fish assemblages for the Pielach and Melk rivers were defined based on historical abiotic data, historical fish data, data of reference sites and reference models. River specific species were divided into dominant, abundant and rare species. Only dominant and abundant species were treated as species with self sustaining populations in the reference condition. Species, that were supposed to immigrate into river tributaries from the river Danube only during spawning time were treated as rare species at the lowest river sections at both rivers (P1-P2 and M1-M2, Fig.1). Biomass and density values for the reference condition were defined on the basis of national studies conducted at similar rivers and at relatively undisturbed river sections within the study area (Jungwirth, 1984; Kaufmann et al., 1991). The FRI and the guild composition for the reference condition were calculated as weighted means using arbitrarily relations of dominant, abundant and rare species of 100:10:1. Species were classified as self sustaining by roughly estimating the number of adults within the study area and interpreting the age structure. Population age structure was interpreted only on the basis of dominant or abundant species and classified using absolute catch data divided into three age classes (0+, juveniles and adult) by expert judgement. The total MULFA-index was calculated as an arithmetic mean of the single metric indices. To translate the qualitative verbal scheme of class boundaries described in Schmutz et al. (2000) into absolute standardized numbers, cut values for the different status classes were defined by expert judgement (Table 5).

**Insert Table 5 here**

**FIA**

The Fish Index Austrian (FIA) (Haunschmid et al., 2006) analyzes the deviation of the actual fish assemblage from historically and actually pre-defined reference fish assemblages according to river types using nine metrics: percentage of dominant species, percentage of subdominant species, percentage of rare species, presence of reproductive guilds, presence of flow preference guilds (further named as number of flow-guilds), FRI, biomass, population structure of dominant species and subdominant species. The metrics were tested according to reaction of reference and impaired sites and redundancies by statistical analysis. Except for the FRI with possible reactions in both directions all other metrics are expected to react positively to rehabilitation measures. The total index is calculated by a weighted mean of single categories: 2x species composition index ((4x dominant species + 2x subdominant species + rare species + flow-guilds + spawning-guilds) / 9) + 3x population age structure index ((2x reproducing dominant species + reproducing subdominant species) / 3) plus 1x FRI divided by six. Biomass is defined as an additional knock-out criterion and leads to a status class of four or five if below 50 or below 25 kg/ha respectively. The same applies to significant deviation of the fish region index regarding reference values. Deviations larger than 0.6, 0.9 or 1.2 lead to total status classifications of 3, 4 or 5 respectively. It is possible to adapt the type-specific reference fish assemblage that is pre-defined within the available software programme, if reliable additional historical information is available. For the present analysis the pre-defined reference fish assemblage was changed based on the reference assemblage developed for the MULFA. Dominant species were determined as dominant, abundant species as subdominant ones and rare species as rare species. Species only immigrating from the Danube into both tributaries during spawning were defined as rare species for the lowest river sections (P1-P2 and M1-M2, Fig. 1).

**EFI**

The EFI measures the deviation of the actual fish fauna from a predicted river type specific fish assemblage using ten metrics (Pont et al., 2006); the assemblage structure of the river type specific fish fauna is predicted by 13 abiotic variables. Generally most of the ten fish metrics are expected to be positively linked to rehabilitation measures except the density of omnivorous and phytophilic species as well as the relative number of tolerant species that are supposed to be positively related to human disturbances and therefore expected to react negatively (with decreasing values) to rehabilitation measures. For the EFI calculation a software programe freely available on the web (http://fame.boku.ac.at) was used.

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**Statistical analyses**

Differences of the overall indices and the observed individual metrics between pre-project electric fishing data ("pre"), post-project electric fishing data ("post") and post-project electric fishing data merged with trap data ("post/trap") were analyzed using the Mann-Whitney-test (Sokal & Rohlf, 2001). All tests were carried out individually and results then summarized in a table. Potential correlations of the effect size of connectivity measures with the distance of sites from the river mouth were tested using Spearman rank correlation. To calculate the magnitude of the effect, an un-weighted approach was chosen using the "log response ratio", ln(effect magnitude), which is the natural logarithm of the ratio between the values of the experimental ("post/trap") and control group ("pre") (Gurevitch & Hedges, 2001). Due to the low sample size at the Pielach, statistical tests are of limited explanatory power there. Statistical analyses were conducted using SPSS® 12.0 (Bühl & Zöfel, 2004). Statistical significance levels were set at ≤0.05 ("strong significance") and ≤0.1 ("weak significance").

## RESULTS

A total of 39 species and 8 guilds out of the reference fish assemblage (42 species and 8 guilds) were documented from the study area (Table 6). Species presently not documented and probably extinct from the study area are *Carassius carassius* (L.), *Lampetra planeri* (Bloch) and *Leuciscus souffia agassizi (Val.).* In total 30 species (77%) were caught by electric fishing and 37 (95%) species by traps (Table 6). 10 to 18 species and 10 to 16 were found inhabiting the sampling reaches in the Melk and Pielach rivers prior to rehabilitation of connectivity; 11 to 21 species (Melk) and 13 to 19 species (Pielach) were found within the sampling reaches during monitoring of the situation after the measures had been implemented (Tables 6-8). In traps 9 to 31 species (Melk) and 11 to 29 species (Pielach) were caught. In total, more species (39 versus 32) were found in the Melk than in the Pielach (Tables 7 and 8). Species documented in most sampling reaches were *Alburnoides bipunctatus* (Bloch), *Barbatula barbatula* (L.), *Barbus barbus* (L.), *Chondrostoma nasus* (L.), *Cottus gobio* (L.), *Gobio gobio* (L.), *Hucho hucho* (L.), *Leuciscus cephalus* (L.), *Leuciscus leuciscus* (L.), *Phoxinus phoxinus* (L.) and *Salmo trutta f.f.* (L.) and species occurring in most of the traps were *B. barbus, C. nasus, C. gobio, Cyprinus carpio* (L.), *G. gobio, L. cephalus, L. leuciscus, P. fluviatilis, S. trutta f.f.* and *Thymallus thymallus* (L.) (Table 6).

**Insert Table 6 here**
**Insert Table 7 here**
**Insert Table 8 here**

Sixteen species only were found after the implementation of the connectivity measures: out of these, nine species (23%, *Abramis ballerus* (L.), *Abramis sapa* (Pallas), *Blicca bjoerkna* (L.), *Gobio albipinnatus* (Lukasch), *Gymnocephalus baloni* (Holcik & Hensel), *Gymnocephalus schraetser* (L.), *Leuciscus idus* (L.), *Sander lucioperca* (L.) and *Silururs glanis* (L.)) were only documented by traps, six species were found during the post-project monitoring by electric fishing and in traps (*Abramis brama* (L.), *Alburnus alburnus* (L.), *Cobitis taenia* (L.), *Gymnocephalus cernuus* (L.), *Tinca tinca* (L.) *and Vimba vimba* (L.)) and one species was only documented during the post-project electric fishing programme (*Rhodeus sericeus amarus* (L.)).

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### INDICES

Strong significant differences between pre:post and pre:post/trap data were documented with the EFI at both rivers, but the decreasing index values reflected a reduction of the ecological integrity, as the EFI is scaled between zero and 1 (=excellent condition); with the MULFA a weakly significant difference between pre:post/trap data in the Pielach was documented indicating the expected enhancement of the ecological integrity (Table 9, Figure 2). Post:post/trap comparisons were never significant.

**Insert Figure 2 here**
**Insert Table 9 here**

### METRICS AND CONTRIBUTION OF TRAP CATCH DATA

Significant differences between pre and post-project data without trap catch data were found for the FRI (FIA, MULFA) in the Pielach and Melk. An increase of the density of omnivorous species and relative number of tolerant species (Pielach and Melk, EFI), an increase in the density of phytophilic species and a decrease in the relative number of intolerant species (Pielach, EFI) indicated a decrease of the ecological integrity as the EFI generally expects rehabilitation measures to decrease the density of omnivorous species, relative number of tolerant species, density of phytophilic species and increase the relative number of intolerant species (EFI, Tab. 10, see also material & methods). Significant differences between pre and post/trap data reflected an increase in ecological integrity for the number of subdominant species and number of flow guilds (Melk, FIA), the number of type specific species (Melk, MULFA), number of benthic species and number of potamodromous species (Melk, EFI). The density of omnivorous species (Melk), the relative number of intolerant and tolerant species (Pielach and Melk, EFI), as described above, reacted significantly but inversely to their expected behaviour this being interpreted as a decrease of ecological integrity by the EFI. Due the addition of trap data, significant differences between post and post/trap data were found for number of rare species (FIA), number of type specific species (MULFA), number of benthic species, number of rheophilic species, number of potamodromous species and relative number of tolerant species (EFI); the documented increasing values clearly indicate the positive effect of connectivity measures, although, as mentioned above, the EFI inversely interprets the increase of the relative number of tolerant species as a sign for a decreasing ecological integrity.

**Insert Table 10 here**

### MAGNITUDE OF EFFECT

A significant correlation of the ln (effect size) and the distance from the river mouth was found for the EFI in the Melk and for the MULFA index in the Pielach (Fig. 3). In the case of the MULFA, a high negative effect indicates a stronger increase in the ecological integrity being measured with status classes from 1 (=reference condition) to five (=bad condition), however in the case of the EFI a negative effect reflects a decrease in ecological integrity. Significant negative correlations of the ln(effect size) with distance to mouth were found for the FRI (FIA, MULFA) at the river Melk, for the biomass (MULFA) at the river Pielach, and for the number of type specific species (MULFA) at the rivers Melk and Pielach indicating a stronger increase of metric values near the river mouth (Fig. 4).

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## DISCUSSION

The EU-WFD currently represents the driving force for river rehabilitation throughout Europe. As a basis for setting the optimal combination of measures to reach the target of the “good ecological” status of water bodies, a deep understanding of the combined effects of human pressures as well as the effects of each type of measure and their subsequent combinations on the ecological integrity of rivers is crucial. From a catchment point of view the most complicated and urgent problem seems to be the rehabilitation of the continuum as most of European rivers are highly fragmented by weirs and migration obstacles (Dynesius & Nilsson, 1994; Northcote, 1998). The three main questions regarding connectivity and its rehabilitation are: 1) what are the effects of physical barriers, 2) what are the effects of restoring connectivity at the catchment level and 3) what combination of measures is most adequate to achieve good ecological status? Fish indices such as the MuLFA, FIA and EFI have been developed for standardized assessment of the effect of pressures with regard to the EU-WFD based on the assessment of the deviation of the present ecological status from undisturbed river type-specific conditions. However, their potential to evaluate the effects of rehabilitation measures has not been assessed. Most of the European rivers are affected by multiple pressures. In this paper we compared the effect of continuum rehabilitation in a morphologically near-natural river (Pielach) with a channelized river (Melk). A significant increase of the ecological integrity was only documented in the Pielach with the MULFA-index. A small but not significant reaction of the MULFA-index and FIA to connectivity measures was found in the Melk. This is mainly due to the channelization that is still acting as a "press" disturbance in the Melk. The bad morphological situation at the Melk seems primarily to negatively influence the population structure of dominant and subdominant species (FIA) and the density and biomass as well as the number of self-sustaining species (MULFA). Although the number of reproductive guilds (FIA) and the number of guilds in general (MULFA) are still not at reference level in both rivers, the population structure of dominant and subdominant species and the density and biomasses are significantly better at the near-natural Pielach River. Long-term recovery in the Melk is only expected if the morphological conditions will be significantly improved. The EFI showed a decrease in ecological integrity after implementation of the measures mainly because three metrics: density of omnivorous species, relative number of tolerant (both supposed to decrease with decreasing pressure) and relative number of intolerant species (supposed to increase with decreasing pressure) responded to rehabilitation significantly in the opposite manner. The reasons for that could be: that the EFI has been calibrated mainly against water quality pressure gradients (Pont et al., 2006) and opening the continuum enabled immigration of all kind of species including non-sensitive species, being considered to indicate degradation; additionally reproductive effects increasing the density of e.g. omnivorous species have influenced the results (Zitek, unpublished data). Within the present project generally the density based metrics as well as the FRI were reacting mainly to a natural variation of fish densities due to reproductive effects; however the significant positive reaction of metrics like number of accompanying species, number of flow-guilds, number of type specific species, number of benthic species and number of potamodromous species is clearly a result of the re-establishment of the river continuum.

Re-connecting tributaries to the Danube showed significant benefits for both the tributary and main river fish assemblages, a result that is also suggested by other authors (Lelek, 1987). The effect decreased with the distance from the source populations located in the Danube. Some indices (EFI, Melk; MULFA, Pielach) and metrics (FRI, Melk; biomass, Pielach; number of type specific species, Melk and Pielach) showed at clear negative correlation with the distance from the river mouth. This underlies the hypothesis that recovery is a function of availability and distance of source populations (Sheldon & Meffe, 1995; Schlosser, 1998). The importance of tributaries and the availability and distance of source populations should be included in the decision making process for prioritizing connectivity rehabilitation measures. Currently, only few approaches exist for deciding which barrier to restore in multiple-fragmented river systems (O'Hanley & Tomberlin, 2005) although facing the high number of continuum disruptions a hierarchical strategy at catchment level is needed to prioritize rehabilitation measures (Roni et al., 2002). Successful rehabilitation of fish populations generally requires the integration of different scales (Feist et al., 2003), analysis of conditions at the watershed or landscape scale (Allan, 2004) as well as the integration of other human pressures to the river system like water abstraction, hydropeaking or impoundments.

As stream fish are exposed to both natural and anthropogenic disturbances that can alter population distribution and abundance (Ensign et al., 1997), understanding the effects of combined human pressures, the natural fluctuations of fish populations and the recovery processes is crucial for a sound interpretation of the effects of different combinations of rehabilitation measures and a reliable assessment of the ecological integrity. For example, at a given site, factors such as the distance to source populations of potential colonists and "press" disturbances like the occurrence of barriers to movement or channelization are known to preliminarily influence the recovery process. Additionally, life history traits (Ensign et al., 1997) and homing effects (Zitek, unpublished data) might define potential recovery rates of fish populations in lowland rivers. The direction of re-settlement (drift of fish from upstream river sections or re-colonisation from downstream) together with local habitat conditions

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might also significantly influence the temporal pattern of how a fish assemblage recovers from disturbance (Unfer & Schmutz, 1998; Zitek et al., 2004a, b).

A combination of different field sampling methods is supposed to enlarge the species coverage of sampled river systems (Gammon & Simon, 2000). Especially the monitoring of the immediate response of river stretches after re-establishing fish passage at continuum disruptions was found to require detailed observations of the initial re-colonisation process. Fish traps located at fish passes provided the additional information needed to assess the immediate response to continuum rehabilitation. Including trap catch data was found to significantly change the result of indexes as well as single metric values. Many of the immigrating species were only recorded in traps and not at the monitoring sites. In future a further challenging step would be to link the efficiency of fish passes to the overall recovery of upstream and downstream fish populations and assemblages because fish ladders with low efficiency might not be adequate to maintain or restore populations (Oldani & Baigun, 2002).

While within the present project the existing fish indices for assessing the ecological integrity still failed in reflecting short-term response of continuum opening, individual metrics responding to the immigration of new species were able to detect the initial recovery process. This immediate response, mainly caused by upstream migrants, is supposed to be followed by a comprehensive recovery of the fish assemblages which should be reflected by fish indices in the long term, provided that all main pressures have been removed from the river.

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## Tables

Table 1: Main characteristics of the rivers Danube, Melk and Pielach (general and at study site).

| General characteristic | Danube | Pielach | Melk |
|---|---|---|---|
| Total length (km) | 2850 | 67.5 | 35.7 |
| Catchment size ($km^2$) | 801463 | 591 | 295 |
| Characteristic at study site | | | |
| Streamorder | 9 | 4 | 5 |
| Altitude (maA) | 209–196 | 252–205 | 233–206 |
| Gradient (‰) | 0.4 | 2.23 | 1.6 |
| Meanflow ($m^3 s^{-1}$) | ~1900 | ~6.5 | ~3 |
| Flowregime | Moderate-nival | Pluvio-nival | Winter-pluvial |
| Fishregion | Epipotamal | Hyporhithral/Epipotamal | Epipotamal |

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Table: 2: Types of barriers and fish ladders location (distance from mouth), bypassed heights, length, slope and minimum discharge of fish ladders, date of completion and monitoring time frame at the Pielach and Melk (* migration barrier at low flow condition in the Danube).

| River | Code | Migration barrier | Distance from mouth [m] | Bypassed height [m] | Measure | Length [m] | Slope [%] | Minimum discharge [ls-1] | Date of completion | Monitoring time |
|---|---|---|---|---|---|---|---|---|---|---|
| Pielach | P1 | artificial fall* | 0 | 1.5 | nature-like rock-ramp | 25 | 6 | total flow | 01.10.00 | 02.04.-14.07.01, 19.02.-27.06.02 |
| Pielach | P2 | weir | 1600 | 2.8 | bypass channel | 220 | 1.3 | 500 | 15.09.02 | 30.09.02-17.10.02, 05.03.-23.06.03, 11.03.-16-06.04 |
| Pielach | P3 | artificial fall | 5500 | 1.8 | nature-like rock-ramp | 35 | 5.1 | > 700 | 08.07.02 | 05.03.-23.06.03 |
| Pielach | P4 | weir | 8300 | 4 | bypass channel | 280 | 1.4 | 300 | 02.06.03 | 06.06.-26.06.03 |
| Pielach | P5 | weir | 13300 | 2.2 | bypass channel | 296 | 0.7 | 300 | 24.06.03 | - |
| Pielach | P6 | weir | 17500 | 1.6 | bypass channel | 164 | 1.0 | 250-300 | 02.04.02 | 03.04.-07.06.02 |
| Melk | M1 | artificial fall | 250 | 3.4 | nature-like rock-ramp | 89 | 3.8 | total flow | 10.10.02 | 07.03.-26.06.03 |
| Melk | M2 | artificial fall | 7000 | 1 | nature-like rock-ramp | 30 | 3.3 | total flow | 01.10.00 | 29.05.-09.07.01 |
| Melk | M3 | weir | 9500 | 3.5 | pool-and-weir-pass | 110 | 3.2 | 250 | 01.04.03 | 19.04.-22.06.03 |
| Melk | M4 | weir | 12600 | 0.9 | nature-like rock-ramp | 65 | 1.4 | total flow | 12.10.00 | 18.05.-09.07.01 |

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**Table 3: Characteristics of sampling sites at the river Pielach; additional parameters to be filled in the EFI spreadsheet used to calculate the reference fish assemblage of the EFI are: Country (Aut), Ecoregion (9), River region (Danube), Rivername (Pielach), Catchment class (1000 $km^2$), Catchment size (591 $km^2$), Flow regime (Permanent), Geotype (Calcareous), Mean annual air temperature (8.8), Slope (2.2), Sampling Strategy (Whole), Method (Wading), Day/Night (Day), No. of runs (1), Runs separated (Total).**

| Parameter | Stream segment | P1-P2 | | P2-P3 | | P3-P4 | |
|---|---|---|---|---|---|---|---|
| | Pre/Post | Pre | Post | Pre | Post | Pre | Post |
| | Site | 1 | 1a | 2 | 2a | 3 | 3a |
| | Date | 17.11.99 | 24.11.03 | 18.11.99 | 25.11.03 | 18.11.99 | 26.11.03 |
| 1 | Altitude | 201 | 202 | 211 | 211 | 220 | 221 |
| 2 | Distance from source (km) | 67.14 | 66.6 | 63.6 | 63.6 | 60.95 | 59.75 |
| 3 | Distance to mouth (km) | 0.36 | 0.9 | 3.9 | 3.9 | 6.55 | 7.75 |
| 4 | Fished area ($m^2$) | 8068 | 5040 | 3933 | 1155 | 2890 | 5565 |
| 5 | Wetted width (m) | 23 | 20 | 20 | 11 | 17 | 21 |
| 6 | Length (m) | 347 | 252 | 200 | 110 | 170 | 265 |
| 7 | Mean depth | 100 | 35 | 90 | 90 | 90 | 80 |
| 8 | Maximum depth | 180 | 140 | 200 | 150 | 250 | 200 |
| 9 | Water temperature | 8.6 | 7.8 | 8 | 7.6 | 5.8 | 7.1 |
| 10 | Conductivity | 610 | 583 | 589 | 577 | 575 | 629 |
| 11 | Morphology | Nature-like | Nature-like | Nature-like | Nature-like | Nature-like | Nature-like |
| 12 | Residual flow | Partially | Yes | No | No | Yes | Yes |
| 13 | Impoundment | No | No | No | No | No | No |

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**Table 4: Characteristics of sampling sites at the river Melk; additional parameters to be filled in the EFI spreadsheet used to calculate the reference fish assemblage of the EFI are: Country (Aut), Ecoregion (9), River region (Danube), Rivername (Melk), Catchment class (1000 km²), Catchment size (295 km²), Flow regime (Permanent), Geotype (Calcareous), Mean annual air temperature (8.8), Slope (1.6), Sampling Strategy (Whole), Method (Wading), Day/Night (Day), No. of runs (1), Runs separated (Total).**

| Parameter | Stream segment | M1-M2 | | M2-M3 | | M3-M4 | | | | | | upstream M4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre/Post | Pre | Post | Pre | Post | Pre | Pre | Pre | Post | Post | Post | Pre | Post |
| | Site | 1 | 1a | 2 | 2a | 3 | 4 | 5 | 3a | 4a | 5a | 6 | 6a |
| | Date | 17.11.99 | 26.11.03 | 18.11.99 | 26.11.03 | 18.11.99 | 01.12.99 | 01.12.99 | 27.11.03 | 27.11.03 | 27.11.03 | 02.12.99 | 28.11.03 |
| 1 | Altitude | 217 | 217 | 220 | 220 | 224 | 224 | 225 | 224 | 224 | 225 | 227 | 227 |
| 2 | Distance from source (km) | 28.35 | 28.35 | 26.30 | 26.45 | 23.70 | 23.45 | 23.10 | 23.70 | 23.45 | 23.10 | 21.05 | 21.05 |
| 3 | Distance to mouth (km) | 7.35 | 7.35 | 9.4 | 9.25 | 12 | 12.25 | 12.6 | 12 | 12.25 | 12.6 | 14.65 | 14.65 |
| 4 | Fished area (m²) | 2213 | 1995 | 1065 | 3835 | 1200 | 2613 | 2040 | 1750 | 1854 | 800 | 1729 | 3560 |
| 5 | Wetted width (m) | 15 | 21 | 8 | 13 | 8 | 13 | 17 | 10 | 9 | 8 | 11 | 13 |
| 6 | Length (m) | 150 | 95 | 142 | 295 | 150 | 201 | 120 | 175 | 206 | 100 | 153 | 267 |
| 7 | Mean depth | 100 | 100 | 50 | 70 | 40 | 50 | 70 | 50 | 50 | 50 | 90 | 90 |
| 8 | Max. depth | 400 | 200 | 100 | 200 | 75 | 200 | 160 | 90 | 100 | 150 | 250 | 250 |
| 9 | Water temperature | 4.4 | 6.8 | 4.3 | 6.9 | 3.9 | 2.3 | 2.3 | 6.7 | 8.4 | 8.4 | 5.1 | 7.3 |
| 10 | Conductivity | 604 | 575 | 6.5 | 558 | 625 | 619 | 622 | 576 | 561 | 561 | 554 | 551 |
| 11 | Habitat | Channelized | Channelized | Channelized | Channelized | Channelized | Nature-like | Nature-like | Channelized | Nature-like | Nature-like | Re-structured | Re-structured |
| 12 | Residual flow | No | No | Yes | Yes | No | No | No | No | No | No | No | No |
| 13 | Impoundment | No | No | No | Partially | No | No | No | No | No | No | No | No |

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Table 5: Class boundaries for metrics of the MULFA method (Schmutz et al., 2000) developed for this study.

| **Criteria** | **Ecological integrity levels** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1.0** | **1.5** | **2.0** | **2.5** | **3.0** | **3.5** | **4.0** | **4.5** | **5.0** |
| | **high** | | **good** | | **fair** | | **poor** | | **bad** |
| No. of. type specific species missing (%) | 0-15 | 15-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | - | >70 |
| No. of species with self sustaining populations missing (%) | 0-20 | - | 20-35 | 35-50 | 50-60 | 60-70 | 70-80 | - | >80 |
| Fish region changes (absolute numbers) | 0.0-02 | - | 0.2-0.4 | - | 0.4-0.8 | - | 0.8-1.2 | - | >1.2 |
| No. of guilds missing (%) | 0 | - | 0 | - | 0-40 | - | 40-70 | - | >70 |
| Guild composition | relation of dominant guilds, and no.of guilds by expert judgement | | | | | | | | |
| Biomass (density) missing (%) | 0-20 | 20-30 | 30-40 | 30-50 | 50-60 | 60-70 | 70-80 | 80-90 | >90 |
| Population age structure changes | based on absolute numbers of 0+, 1+ and >1+ individuals of dominant and abundant species per sampling site by expert judgement | | | | | | | | |

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**Table 6: List of river type specific species within the study area, results of electric fishing (pre, post) and trap monitoring (trap) per site and total for rivers Pielach and Melk; x=species occurrence; numbers=how often a species was documented per method; species, only documented after implementation of connectivity measures (post, trap) are marked in grey; all river type specific species (n=42) are shown; for explanations of guild abbreviations see legends of tables 7 and 8.**

| River | | Pielach | | | | | | | | | | | | | Melk | | | | | | | | | | | | | | | | | | | | *Pielach & Melk* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River section | | P1-P2 | | | P2-P3 | | | P3-P4 | | | *P1-P4* | | | | M1-M2 | | | M2-M3 | | | M3-M4 | | | | | | | upstream M4 | | | *M1-upstream M4* | | | | *P1-P4 and M1-upstream M4* | | | | |
| Monitoring | | Trap | Pre | Post | Trap | Pre | Post | Trap | Pre | Post | *Pre* | *Post* | *Total* | *Total trap* | Trap | Pre | Post | Trap | Pre | Post | Trap | Pre | Pre | Pre | Post | Post | Post | Trap | Pre | Post | *Pre* | *Post* | *Total* | *Total trap* | *Pre* | *Post* | *Total* | *Total trap* | *Total* |
| Distance from river mouth (km) | | 0.20 | 0.36 | 0.90 | 1.60 | 3.90 | 3.90 | 5.50 | 6.55 | 7.75 | *Electric fishing* | | | | 0.25 | 7.35 | 7.35 | 7.00 | 9.40 | 9.25 | 9.50 | 12.00 | 12.25 | 12.60 | 12.00 | 12.25 | 12.60 | 12.60 | 14.65 | 14.65 | *Electric fishing* | | | | *Electric fishing* | | | | |
| Species name/guild/stretch ID | | P1 | 1 | 1a | P2 | 2 | 2a | P3 | 3 | 3a | | | | | M1 | 1 | 1a | M2 | 2 | 2a | M3 | 3 | 4 | 5 | 3a | 4a | 5a | M4 | 6 | 6a | | | | | | | | | |
| *Abramis ballerus* (L.) | I/R | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | *1* | | | | *1* | *x* |
| *Abramis brama* (L.) | I/E | x | | x | | | | | | | | *1* | *x* | *1* | x | | | | | | | | | | | | | | | | | | | *1* | | *1* | *x* | *2* | *x* |
| *Abramis sapa* (Pallas) | O/R | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | *1* | | | | *1* | *x* |
| *Alburnoides bipunctatus* (Bloch) | R/R | x | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *3* | | x | x | | x | x | | | x | x | | x | | | x | x | *5* | *4* | *x* | | *8* | *7* | *x* | *3* | *x* |
| *Alburnus alburnus* (L.) | I/E | x | | x | x | | | | | | | *1* | *x* | *2* | x | | x | x | | x | x | | | | x | x | x | | | x | | *6* | *x* | *3* | | *7* | *x* | *5* | *x* |
| *Aspius aspius* (L.) | I/R | x | | | | | | | | | | | | *1* | x | x | | x | | x | x | | | | | x | | | | x | *1* | *3* | *x* | *3* | *1* | *3* | *x* | *4* | *x* |
| *Barbatula barbatula* (L.) | R/R | x | x | x | | x | x | | x | x | *3* | *3* | *x* | *1* | | x | x | | x | x | | x | x | x | x | x | x | x | x | x | *6* | *6* | *x* | *1* | *9* | *9* | *x* | *2* | *x* |
| *Barbus barbus* (L.) | R/R | x | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *3* | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | *6* | *6* | *x* | *4* | *9* | *9* | *x* | *7* | *x* |
| *Blicca bjoerkna* (L.) | I/E | x | | | | | | | | | | | | *1* | x | | | | | | | | | | | | | | | | *1* | | *x* | *1* | | | | *2* | *x* |
| *Carassius carassius* (L.) | L/L | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| *Carassius gibelio* (Bloch) | I/L | x | | | | | | | | x | | *1* | *x* | *1* | x | | | | | x | x | | | | | | | | x | | | | | *2* | *1* | *2* | *x* | *3* | *x* |
| *Chondrostoma nasus* (L.) | R/R | x | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *3* | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | *6* | *6* | *x* | *3* | *9* | *9* | *x* | *6* | *x* |
| *Cobitis taenia* (L.) | O/E | | | x | | | | | | | | *1* | *x* | | x | | | | | x | | | | | | | | | | | | *1* | *x* | *1* | | *2* | *x* | *1* | *x* |
| *Cottus gobio* (L.) | R/R | x | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *3* | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | *6* | *5* | *x* | *3* | *9* | *8* | *x* | *6* | *x* |
| *Cyprinus carpio* (L.) | I/L | x | x | x | x | | x | x | | | *1* | *2* | *x* | *3* | x | x | | x | | x | x | | | | x | | | | | | *1* | *2* | *x* | *3* | *2* | *4* | *x* | *6* | *x* |
| *Esox lucius* (L.) | I/L | x | | | | | x | | | | | *1* | *x* | *1* | x | | x | | x | x | | | | x | | | x | | | x | *2* | *4* | *x* | *1* | *2* | *5* | *x* | *2* | *x* |
| *Gobio albipinnatus* (Lukash) | R/R | x | | | | | | | | | | | | *1* | x | | | | | | | | | | | | | | | | | | | *1* | | | | *2* | *x* |
| *Gobio gobio* (L.) | R/R | | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *2* | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | *6* | *6* | *x* | *3* | *9* | *9* | *x* | *5* | *x* |
| *Gymnocephalus baloni* (Holcik & Hensel) | O/L | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | *1* | | | | *1* | *x* |
| *Gymnocephalus cernuus* (L.) | I/E | | | | | | | | | | | | | | x | | x | | | | | | | | | | | | | | | *1* | *x* | *1* | | *1* | *x* | *1* | *x* |
| *Gymnocephalus schraetser* (L.) | O/R | x | | | | | | | | | | | | *1* | x | | | | | | | | | | | | | | | | | | | *1* | | | | *2* | *x* |
| *Hucho hucho* (L.) | R/R | x | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *3* | | | | | x | | x | x | x | x | | x | x | | x | | *5* | *2* | *x* | *1* | *8* | *5* | *x* | *4* | *x* |
| *Lampetra planeri* (Bloch) | R/R | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| *Leuciscus cephalus* (L.) | I/E | x | x | x | x | x | x | x | x | x | *3* | *3* | *x* | *3* | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | *6* | *6* | *x* | *4* | *9* | *9* | *x* | *7* | *x* |
| *Leuciscus idus* (L.) | I/E | x | | | | | | | | | | | | *1* | x | | | | | | | | | | | | | | | | | | | *1* | | | | *2* | *x* |
| *Leuciscus leuciscus* (L.) | I/R | x | x | x | x | x | x | | x | x | *3* | *3* | *x* | *2* | x | x | x | x | x | x | x | | x | x | x | x | x | | x | x | *5* | *6* | *x* | *3* | *8* | *9* | *x* | *5* | *x* |
| *Leuciscus souffia agassizi* (Val.) | R/R | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| *Lota lota* (L.) | I/E | x | x | | | | | | | | *1* | | *x* | *1* | | x | | | | x | | | | | | | | | | | *1* | *1* | *x* | | *2* | *1* | *x* | *1* | *x* |
| *Perca fluviatilis* (L.) | I/E | x | x | x | x | | x | x | | x | *1* | *3* | *x* | *3* | x | x | x | x | | x | | | | | | x | | | | x | *1* | *4* | *x* | *2* | *2* | *7* | *x* | *5* | *x* |
| *Phoxinus phoxinus* (L.) | I/E | x | x | x | | x | x | | x | x | *3* | *3* | *x* | *1* | | x | x | | x | x | | x | x | x | x | x | x | x | x | x | *6* | *6* | *x* | *1* | *9* | *9* | *x* | *2* | *x* |
| *Proterorhinus marmoratus* (Pallas) | I/E | | | | x | | | | | | | | | *1* | x | x | x | | | | | | | | | | | | | | *1* | *1* | *x* | *1* | *1* | *1* | *x* | *2* | *x* |
| *Rhodeus sericeus amarus* (Bloch) | L/L | | | | | | | | | | | | | | | | | | | x | | | | | x | | | | | | | *2* | *x* | | | *2* | *x* | | *x* |
| *Rutilus rutilus* (L.) | I/E | x | | | x | | | | | | | | | *2* | x | | | | x | | x | | x | x | | | | | | | *3* | | *x* | *2* | *3* | | *x* | *4* | *x* |
| *Sabanajewia balcanica* (Karaman) | O/E | | | | | | | | | | | | | | | x | | | x | | | | | | | | | | | | *2* | | *x* | | *2* | | *x* | | *x* |
| *Salmo trutta* forma *fario* (L.) | R/R | x | x | x | x | x | | x | x | | *3* | *1* | *x* | *3* | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | x | *6* | *5* | *x* | *4* | *9* | *6* | *x* | *7* | *x* |
| *Sander lucioperca* (L.) | I/E | x | | | | | | | | | | | | *1* | x | | | | | | | | | | | | | | | | | | | *1* | | | | *2* | *x* |
| *Scardinius erythrophthalmus* (L.) | L/L | x | | x | x | | | | | | | *1* | *x* | *2* | x | | | | x | x | | | | | | | | | x | | *2* | *1* | *x* | *1* | *2* | *2* | *x* | *3* | *x* |
| *Silurus glanis* (L.) | I/E | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | *1* | | | | *1* | *x* |
| *Thymallus thymallus* (L.) | R/R | x | x | x | x | | | x | x | x | *2* | *2* | *x* | *3* | x | x | | x | x | | | x | x | x | | | | x | | | *5* | | *x* | *3* | *7* | *2* | *x* | *6* | *x* |
| *Tinca tinca* (L.) | L/L | x | | | | | | | | | | | | *1* | x | | | x | | | | | | | x | | | x | | x | | *2* | *x* | *3* | | *2* | *x* | *4* | *x* |
| *Vimba vimba* (L.) | O/R | x | | x | | | | | | | | *1* | *x* | *1* | x | | | | | x | x | | | | | | | | | | | *1* | *x* | *2* | | *2* | *x* | *3* | *x* |
| *Zingel zingel* (L.) | O/R | x | x | | | | | | | | *1* | | *x* | *1* | x | x | | | | | | | | | | x | | | | | *1* | *1* | | *1* | *2* | *1* | *x* | *2* | *x* |
| **Total number of guilds/species** | **8** | **29** | **16** | **19** | **16** | **11** | **13** | **11** | **12** | **13** | ***16*** | ***21*** | ***23*** | ***31*** | **31** | **18** | **15** | **12** | **16** | **21** | **14** | **10** | **13** | **14** | **13** | **15** | **11** | **9** | **13** | **14** | ***23*** | ***25*** | ***28*** | ***35*** | ***23*** | ***28*** | ***30*** | ***37*** | ***39*** |

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Table 7: Results of electric fishing (pre, post) and trap monitoring (trap) per site (ind/ha; species in trap: Yes/No) at the river Pielach site characteristics (length, width) with species forming the reference fish assemblages for the MULFA by guild based on Zauner & Eberstaller (2000) (I/R=indifferent/rheoparous, I/E=indifferent/euryoparous, O/R=oligorheophilous/rheoparous, R/R=rheophilous/rheoparous, I/L=indifferent limnoparous, L/L=limnophilous/limnoparous, O/E=oligorheophilous/euryoparous), structure need (n=no, l=low, h=high), natural frequencies (d=dominant, a=abundant and r=rare) and species occurrence (D= immigrating from the Danube for spawning, A=autochthonous population).

| **Basic informations for the assessment methods, reference fish fauna** | | | | | **River section** | **P1-P2** | | | **P2-P3** | | | **P3-P4** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Monitoring** | **Pre** | **Post** | **Trap** | **Pre** | **Post** | **Trap** | **Pre** | **Post** | **Trap** |
| | | | | | **Length of stretch** | **347** | **252** | | **200** | **110** | | **170** | **265** | |
| **MULFA** | | | | | **Widht of stretch** | **23** | **20** | | **20** | **11** | | **17** | **21** | |
| **FRI** | **Guild** | **S** | **A/D** | **F** | **Species name/stretch ID** | **1** | **1a** | **P1** | **2** | **2a** | **P2** | **3** | **3a** | **P3** |
| 6.5 | I/R | n | D | | *Abramis ballerus* (L.) | | | | | | | | | |
| 6.4 | I/E | n | D | | *Abramis brama* (L.) | | 24 | Yes | | | | | | |
| 6.6 | O/R | n | D | | *Abramis sapa* (Pallas) | | | | | | | | | |
| 5.6 | R/R | l | A | d | *Alburnoides bipunctatus* (Bloch) | 56 | 11 | Yes | 87 | 257 | Yes | 158 | 28 | Yes |
| 6.4 | I/E | n | P1 to P4 | r | *Alburnus alburnus* (L.) | | 3 | Yes | | | Yes | | | |
| 6.5 | I/R | n | D | | *Aspius aspius* (L.) | | | Yes | | | | | | |
| 5.5 | R/R | l | A | d | *Barbatula barbatula* (L.) | 97 | 15 | Yes | 6 | 65 | | 54 | 7 | |
| 6.2 | R/R | l | A | d | *Barbus barbus* (L.) | 54 | 55 | Yes | 78 | 102 | Yes | 81 | 149 | Yes |
| 6.7 | I/E | l | D | | *Blicca bjoerkna* (L.) | | | Yes | | | | | | |
| 6.4 | I/L | l | A | r | *Carassius gibelio* (Bloch) | | | Yes | | | | | 2 | |
| 5.9 | R/R | l | A | d | *Chondrostoma nasus* (L.) | 82 | 625 | Yes | 45 | 2208 | Yes | 48 | 274 | Yes |
| 6.3 | O/E | h | A | r | *Cobitis taenia* (L.) | | 3 | | | | | | | |
| 4 | R/R | h | A | a | *Cottus gobio* (L.) | 313 | 48 | Yes | 74 | 54 | Yes | 552 | 5 | Yes |
| 6.5 | I/L | l | A | r | *Cyprinus carpio* (L.) | 2 | 6 | Yes | | 20 | Yes | | | Yes |
| 6.2 | I/L | h | A | a | *Esox lucius* (L.) | | | Yes | | 31 | | | | |
| 6.5 | R/R | l | P1 to P4 | r | *Gobio albipinnatus* (Lukasch) | | | Yes | | | | | | |
| 6 | R/R | l | A | a | *Gobio gobio* (L.) | 58 | 120 | | 7 | 325 | Yes | 14 | 21 | Yes |
| 6.3 | O/R | l | D | | *Gymnocephalus schraetser* (L.) | | | Yes | | | | | | |
| 5.7 | R/R | l | A | a | *Hucho hucho* (L.) | 10 | 9 | Yes | 20 | 54 | Yes | 14 | 9 | Yes |
| 5.1 | R/R | | A | r | *Lampetra planeri* (Bloch) | | | | | | | | | |
| 6 | I/E | h | A | a | *Leuciscus cephalus* (L.) | 179 | 1737 | Yes | 290 | 1078 | Yes | 142 | 145 | Yes |
| 6.4 | I/E | l | D | | *Leuciscus idus* (L.) | | | Yes | | | | | | |
| 6.3 | I/R | l | A | a | *Leuciscus leuciscus* (L.) | 26 | 9 | Yes | | 392 | Yes | 11 | 2 | |
| 5.4 | R/R | l | A | r | *Leuciscus souffia agassizi* (Val.) | | | | | | | | | |
| 5.4 | I/E | h | A | a | *Lota lota* (L.) | 18 | | Yes | | | | | | |
| 6.7 | I/E | n | A | r | *Perca fluviatilis* (L.) | 6 | 58 | Yes | | 31 | Yes | | 2 | Yes |
| 5 | I/E | l | A | d | *Phoxinus phoxinus* (L.) | 311 | 36 | Yes | 92 | 432 | | 354 | 112 | |
| 6.7 | I/E | h | P1 to P4 | r | *Proterorhinus marmoratus* (Pallas) | | | | | | Yes | | | |
| 6.5 | L/L | l | A | r | *Rhodeus sericeus amarus* (Bloch) | | | | | | | | | |
| 6.4 | I/E | n | A | r | *Rutilus rutilus* (L.) | | | Yes | | | Yes | | | |
| 3.8 | R/R | h | A | r | *Salmo trutta* forma *fario* (L.) | 14 | 11 | Yes | 6 | | Yes | 5 | | Yes |
| 6.7 | I/E | l | D | | *Sander lucioperca* (L.) | | | Yes | | | | | | |
| 6.7 | L/L | l | A | r | *Scardinius erythrophthalmus* (L.) | | 15 | Yes | | | Yes | | | |
| 5 | R/R | l | A | a | *Thymallus thymallus* (L.) | 15 | 109 | Yes | | | Yes | 51 | 7 | Yes |
| 6.7 | L/L | l | A | r | *Tinca tinca* (L.) | | | Yes | | | | | | |
| 6.4 | O/R | n | D | | *Vimba vimba* (L.) | | 3 | Yes | | | | | | |
| 6.3 | O/R | l | P1 to P4 | r | *Zingel zingel* (L.) | 41 | | Yes | | | | | | |
| | | | | | **Total [Ind/ha]** | **1307** | **2974** | **-** | **721** | **5048** | **-** | **1483** | **764** | **-** |
| | | | | | **Total biomass [kg/ha]** | **197** | **510** | **-** | **265** | **472** | **-** | **195** | **246** | **-** |
| **RESULTS** | | | | | **Species total per reach and trap** | **16** | **19** | **29** | **10** | **13** | **16** | **12** | **13** | **11** |
| | | | | | **Species total** | | | | | **32** | | | | |
| | | | | | **Species total reference community** | | | | | **37** | | | | |

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Table 8: Results of electric fishing (pre, post) and trap monitoring (trap) per site (ind/ha; species in trap: Yes/No) at the river Melk, site characteristics (length, width) with species forming the reference fish assemblages for the MULFA by guild based on Zauner & Eberstaller (2000) (for further explanations of abbreviations see legend of table 7, except for OL=oligorheophilous/limnoparous)

| Basic informations for the assessment methods, reference fish fauna MULFA | | | | | River section | M1-M2 | | | M2-M3 | | | M3-M4 | | | | | | | upstream M4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Monitoring** | **Pre** | **Post** | **Trap** | **Pre** | **Post** | **Trap** | **Pre** | **Pre** | **Pre** | **Post** | **Post** | **Post** | **Trap** | **Pre** | **Post** | **Trap** |
| | | | | | **Length of stretch** | **150** | **95** | | **142** | **295** | | **150** | **201** | **120** | **175** | **206** | **100** | | **153** | **267** | |
| | | | | | **Widht of stretch** | **15** | **21** | | **8** | **13** | | **8** | **13** | **17** | **10** | **9** | **8** | | **11** | **13** | |
| **FRI** | **Guild** | **S** | **A/D** | **F** | **Species name/site** | **1** | **1a** | **M1** | **2** | **2a** | **M2** | **3** | **4** | **5** | **3a** | **4a** | **5a** | **M3** | **6** | **6a** | **M4** |
| 6.5 | I/R | n | D | | *Abramis ballerus* (L.) | | | Yes | | | | | | | | | | | | | |
| 6.4 | I/E | n | D | | *Abramis brama* (L.) | | | Yes | | | | | | | | | | | | | |
| 6.6 | O/R | n | D | | *Abramis sapa* (Pallas) | | | Yes | | | | | | | | | | | | | |
| 5.6 | R/R | l | A | d | *Alburnoides bipunctatus* (Bloch) | 86 | 244 | | 147 | 4 | | | 421 | 21 | | 389 | | | 13 | 25 | |
| 6.4 | I/E | n | A | a | *Alburnus alburnus* (L.) | | 2770 | Yes | | 1785 | Yes | | | | 7 | 111 | 30 | Yes | | 177 | |
| 6.5 | I/R | n | A | r | *Aspius aspius* (L.) | 16 | | Yes | | 13 | Yes | | | | | 105 | | Yes | | 17 | |
| 5.5 | R/R | l | A | d | *Barbatula barbatula* (L.) | 67 | 60 | | 319 | 60 | | 292 | 146 | 232 | 121 | 553 | 122 | | 187 | 62 | Yes |
| 6.2 | R/R | l | A | d | *Barbus barbus* (L.) | 80 | 8 | Yes | 27 | 176 | Yes | 24 | 210 | 181 | 131 | 474 | 293 | Yes | 578 | 323 | Yes |
| 6.7 | I/E | l | D | | *Blicca bjoerkna* (L.) | | | Yes | | | | | | | | | | | | | |
| 6.5 | L/L | l | A | r | *Carassius carassius* (L.) | | | | | | | | | | | | | | | | |
| 6.4 | I/L | l | A | r | *Carassius gibelio* (Bloch) | | | Yes | | 6 | | | | | | | | Yes | 28 | | |
| 5.9 | R/R | l | A | a | *Chondrostoma nasus* (L.) | 113 | 3405 | Yes | 1173 | 1987 | Yes | 471 | 232 | 789 | 1361 | 516 | 30 | Yes | 53 | 868 | |
| 6.3 | O/E | h | A | a | *Cobitis taenia* (L.) | | | Yes | | 4 | | | | | | | | | | | |
| 4 | R/R | h | A | r | *Cottus gobio* (L.) | 550 | 67 | | 481 | 9 | Yes | 227 | 165 | 32 | 53 | 274 | 15 | Yes | 19 | | Yes |
| 6.5 | I/L | l | A | r | *Cyprinus carpio* (L.) | 21 | | Yes | | 13 | Yes | | | | 7 | | | Yes | | | |
| 6.2 | I/L | h | A | a | *Esox lucius* (L.) | | 8 | Yes | 9 | 47 | | | | 16 | | | 30 | | | 8 | |
| 6.5 | R/R | l | A | r | *Gobio albipinnatus* (Lukasch) | | | Yes | | | | | | | | | | | | | |
| 6 | R/R | l | A | a | *Gobio gobio* (L.) | 359 | 440 | Yes | 1683 | 492 | | 892 | 514 | 742 | 737 | 2800 | 183 | Yes | 592 | 1066 | Yes |
| 6.7 | O/L | l | D | | *Gymnocephalus baloni* (Holcik & Hensel) | | | Yes | | | | | | | | | | | | | |
| 6.5 | I/E | l | D | | *Gymnocephalus cernuus* (L.) | | 16 | Yes | | | | | | | | | | | | | |
| 6.3 | O/R | l | D | | *Gymnocephalus schraetser* (L.) | | | Yes | | | | | | | | | | | | | |
| 5.7 | R/R | l | A | a | *Hucho hucho* (L.) | | | | 64 | | | 24 | 13 | 15 | | 5 | 34 | Yes | 40 | | |
| 5.1 | R/R | | A | a | *Lampetra planeri* (Bloch) | | | | | | | | | | | | | | | | |
| 6 | I/E | h | A | a | *Leuciscus cephalus* (L.) | 112 | 22623 | Yes | 1815 | 909 | Yes | 227 | 648 | 611 | 486 | 5553 | 898 | Yes | 724 | 1656 | Yes |
| 6.4 | I/E | l | A | r | *Leuciscus idus* (L.) | | | Yes | | | | | | | | | | | | | |
| 6.3 | I/R | l | A | a | *Leuciscus leuciscus* (L.) | 6 | 32 | Yes | 128 | 245 | Yes | | 9 | 106 | 34 | 37 | 61 | Yes | 94 | 104 | |
| 5.4 | R/R | l | A | r | *Leuciscus souffia agassizi* (Val.) | | | | | | | | | | | | | | | | |
| 5.4 | I/E | h | A | r | *Lota lota* (L.) | 22 | | | | 6 | | | | | | | | | | | |
| 6.7 | I/E | n | A | r | *Perca fluviatilis* (L.) | 11 | 222 | Yes | | 101 | Yes | | | | | 5 | | | | 3 | |
| 5 | I/E | l | A | d | *Phoxinus phoxinus* (L.) | 112 | 12 | | 1674 | 47 | | 1006 | 336 | 291 | 156 | 574 | 61 | | 919 | 84 | Yes |
| 6.7 | I/E | h | A | a | *Proterorhinus marmoratus* (Pallas) | 6 | 44 | Yes | | | | | | | | | | | | | |
| 6.5 | L/L | l | A | r | *Rhodeus sericeus amarus* (Bloch) | | | | | 157 | | | | | 7 | | | | | | |
| 6.4 | I/E | n | A | a | *Rutilus rutilus* (L.) | | | Yes | 138 | | | | 4 | 23 | | | | Yes | | | |
| 6.3 | O/E | h | A | r | *Sabanajewia balcanica* (Karaman) | 34 | | | 9 | | | | | | | | | | | | |
| 3.8 | R/R | h | A | r | *Salmo trutta* forma *fario* (L.) | 66 | 119 | Yes | 226 | 6 | Yes | 32 | 47 | 57 | 6 | 32 | | Yes | 27 | 11 | Yes |
| 6.7 | I/E | l | D | | *Sander lucioperca* (L.) | | | Yes | | | | | | | | | | | | | |
| 6.7 | L/L | l | A | r | *Scardinius erythrophthalmus* (L.) | | | Yes | 55 | 6 | | | | | | | | | 27 | | |
| 6.7 | I/E | h | D | | *Silurus glanis* (L.) | | | Yes | | | | | | | | | | | | | |
| 5 | R/R | l | A | r | *Thymallus thymallus* (L.) | 6 | | Yes | 9 | | Yes | 32 | 4 | 16 | | | | | | | Yes |
| 6.7 | L/L | l | A | r | *Tinca tinca* (L.) | | | Yes | | | Yes | | | | 21 | | | | | 3 | Yes |
| 6.4 | O/R | n | D | | *Vimba vimba* (L.) | | | Yes | | 6 | | | | | | | | Yes | | | |
| 6.3 | O/R | l | A | r | *Zingel zingel* (L.) | 5 | | Yes | | | | | | | | 5 | | | | | |
| | | | | | **Total [Ind/ha]** | **1693** | **30069** | | **7965** | **6113** | | **3237** | **2755** | **3139** | **3129** | **11432** | **1758** | | **3309** | **4419** | |
| | | | | | **Total biomass [kg/ha]** | **222** | **142** | **-** | **486** | **672** | **-** | **340** | **452** | **941** | **625** | **214** | **161** | **-** | **1187** | **760** | **-** |
| **RESULTS** | | | | | **Species total per reach and trap** | **18** | **15** | **31** | **16** | **21** | **12** | **10** | **13** | **14** | **13** | **15** | **11** | **14** | **13** | **14** | **9** |
| | | | | | **Species total** | | | | | | | | | **39** | | | | | | | |
| | | | | | **Species total reference community** | | | | | | | | | **42** | | | | | | | |

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Table 9: Differences between pre, post and post/trap data for the three indices (EFI, FIA and MULFA) in rivers Pielach and Melk analyzed using the Mann-Whitney-test (**strong significance, *weak significance); due to the low number of sampling sites (n=3) at the river Pielach significances are only given with one decimal place.

| Index | Monitorig | Pielach | Melk |
|---|---|---|---|
| EFI | Pre-Post | 0.1* | 0.041** |
| | Pre-Post/trap | 0.1* | 0.015** |
| | Post-Post/trap | 1.0 | 0.937 |
| FIA | Pre-Post | 0.7 | 0.818 |
| | Pre-Post/trap | 0.4 | 0.937 |
| | Post-Post/trap | 0.4 | 0.589 |
| MULFA | Pre-Post | 0.4 | 0.394 |
| | Pre-Post/trap | 0.1* | 1.000 |
| | Post-Post/trap | 0.7 | 0.310 |

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Table 10: Single metric values [median (minimum-maximum)] for the FIA, MULFA and EFI and significances ($P$) for the differences between pre, post and post/trap using the Mann-Whitney-test (**strong significances and *weak significances are additionally marked with grey colour; Pr-Pre, Po-Post, Po/tr-Post/trap); additionally the type of reaction of the metric is shown (+, as expected; -, contrary to expectation; 0, no significant reaction); biomass is only shown as a metric of the MULFA index, although it is also used as knock-out criterion within the FIA; metrics of the EFI provided by the software but not used for the index calculation are shown in brackets; post/trap information is only given for metrics, where trap catch data were contributing; due to the low number of sampling sites (n=3) for the river Pielach significances are only given with one decimal place.

| Index | Metric | Reaction | Monitoring | Melk | *Test* | *P* | Pielach | *Test* | *P* |
|---|---|---|---|---|---|---|---|---|---|
| FIA | FRI | + | Pre | 5.7 (5.1-5.8) | *Pr-po* | *0.002*** | 5.2 (4.9-5.6) | *Pr-po* | *0.1** |
| | | | Post | 6.0 (5.9-6.1) | | | 5.9 (5.8-5.9) | | |
| | Number of subdominant species reproducing | 0 | Pre | 3.5 (2-6) | *Pr-po* | *0.180* | 5 (3-6) | *Pr-po* | *1.0* |
| | | | Post | 5 (3-6) | *Po-po/tr* | *1.000* | 5 (4-6) | *Po-po/tr* | *0.7* |
| | Number of subdominant species | + | Pre | 5.5 (5-7) | *Pr-po* | *0.394* | 6 (4-7) | *Pr-po* | *0.7* |
| | | | Post | 6.5 (5-7) | *Pr-po/tr* | *0.041*** | 6 (6-7) | *Pr-po/tr* | *0.4* |
| | | | Post/Trap | 7 (6-9) | *Po-po/tr* | *0.132* | 7 (6-8) | *Po-po/tr* | *0.4* |
| | Number of flow-guilds | + | Pre | 4 (3-4) | *Pr-po* | *0.310* | 3 (3-4) | *Pr-po* | *1.0* |
| | | | Post | 4 (3-5) | *Pr-po/tr* | *0.026*** | 3 (3-5) | *Pr-po/tr* | *0.4* |
| | | | Post/Trap | 5 (4-5) | *Po-po/tr* | *0.310* | 5 (3-5) | *Po-po/tr* | *0.7* |
| | Number of reproductive guilds | 0 | Pre | 5 (4-7) | *Pr-po* | *0.937* | 4 (3-5) | *Pr-po* | *0.4* |
| | | | Post | 5 (4-7) | *Pr-po/tr* | *0.699* | 5 (4-5) | *Pr-po/tr* | *0.4* |
| | | | Post/Trap | 5.5 (4-7) | *Po-po/tr* | *0.699* | 5 (4-6) | *Po-po/tr* | *0.7* |
| | Number of dominant species reproducing | 0 | Pre | 3.5 (3-4) | *Pr-po* | *0.485* | 4 (4-5) | *Pr-po* | *1.0* |
| | | | Post | 3 (2-4) | *Po-po/tr* | *1.000* | 4 (4-5) | *Po-po/tr* | *1.0* |
| | Number of dominant species | 0 | Pre | 4 (3-4) | *Pr-po* | *0.699* | 5 (5-5) | *Pr-po* | *1.0* |
| | | | Post | 4 (3-4) | *Pr-po/tr* | *0.699* | 5 (5-5) | *Pr-po/tr* | *1.0* |
| | | | Post/Trap | 4 (3-4) | *Po-po/tr* | *1.000* | 5 (5-5) | *Po-po/tr* | *1.0* |
| | Number of rare species | + | Pre | 4.5 (3-8) | *Pr-po* | *1.000* | 1 (1-3) | *Pr-po* | *1.0* |
| | | | Post | 4.5 (1-7) | *Pr-po/tr* | *0.132* | 1 (1-7) | *Pr-po/tr* | *0.2* |
| | | | Post/Trap | 6.5 (3-20) | *Po-po/tr* | *0.093** | 6 (2-16) | *Po-po/tr* | *0.4* |
| MULFA | Biomass | 0 | Pre | 469 (222-1187) | *Pr-po* | *0.394* | 197 (195-265) | *Pr-po* | *0.2* |
| | | | Post | 419 (142-760) | | | 472 (246-510) | | |
| | Density | 0 | Pre | 3188 (1693-7965) | *Pr-po* | *0.310* | 1307 (721.-1483) | *Pr-po* | *0.4* |
| | | | Post | 5266 (1758-30103) | | | 2974 (764-5048) | | |
| | FRI | + | Pre | 5.6 (5.2-5.8) | *Pr-po* | *0.002*** | 5.2 (4.9-5.6) | *Pr-po* | *0.1** |
| | | | Post | 6.0 (5.9-6.1) | | | 5.9 (5.8-5.9) | | |
| | Number of guilds | 0 | Pre | 4.5 (2-6) | *Pr-po* | *0.818* | 3 (2-5) | *Pr-po* | *0.4* |
| | | | Post | 4.5 (4-6) | *Pr-po/tr* | *0.394* | 4 (4-7) | *Pr-po/tr* | *0.2* |
| | | | Post/Trap | 5 (4-8) | *Po-po/tr* | *0.310* | 5 (4-7) | *Po-po/tr* | *0.7* |
| | Number of self sustaining species | 0 | Pre | 6.5 (6-10) | *Pr-po* | *0.394* | 9 (7-11) | *Pr-po* | *1.0* |
| | | | Post | 8.5 (5-9) | *Po-po/tr* | *1.000* | 9 (8-11) | *Po-po/tr* | *1.0* |
| | Number of type specific species | + | Pre | 13.5 (10-18) | *Pr-po* | *0.699* | 12 (10-16) | *Pr-po* | *0.4* |
| | | | Post | 14.5 (11-20) | *Pr-po/tr* | *0.026*** | 13 (13-19) | *Pr-po/tr* | *0.2* |
| | | | Post/Trap | 17.5 (16-35) | *Po-po/tr* | *0.026*** | 19 (15-31) | *Po-po/tr* | *0.2* |
| EFI | (Density all species) | (0) | Pre | 1415 (696-4789) | *Pr-po* | *0.132* | 567 (198-635) | *Pr-po* | *0.2* |
| | | | Post | 2793 (1413-3447) | *Pr-po/tr* | *0.132* | 1748 (600-3298) | *Pr-po/tr* | *0.2* |
| | | | Post/trap | 2824 (1500-3452) | *Po-po/tr* | *0.589* | 1774 (606-3359) | *Po-po/tr* | *0.7* |
| | Density of insectivorous species | 0 | Pre | 166 (17.-376) | *Pr-po* | *0.180* | 164 (36-253) | *Pr-po* | *0.7* |
| | | | Post | 47 (13-286) | *Pr-po/tr* | *0.310* | 85 (31-225) | *Pr-po/tr* | *0.7* |
| | | | Post/trap | 50 (16-286) | *Po-po/tr* | *0.699* | 87 (32-242) | *Po-po/tr* | *0.7* |
| | Density of omnivorous species | - | Pre | 256 (50-1399) | *Pr-po* | *0.026*** | 74 (69-110) | *Pr-po* | *0.1** |
| | | | Post | 1037 (526-2216) | *Pr-po/tr* | *0.026*** | 961 (119-1139) | *Pr-po/tr* | *0.1** |
| | | | Post/trap | 1046 (537-2256) | *Po-po/tr* | *0.699* | 987 (120-1149) | *Po-po/tr* | *0.7* |
| | Density of phytophilic species | - | Pre | 11 (0-47) | *Pr-po* | *0.937* | 0 (0-1) | *Pr-po* | *0.1** |
| | | | Post | 17 (0-33) | *Pr-po/tr* | *0.180* | 16 (2-26) | *Pr-po/tr* | *0.1** |
| | | | Post/trap | 32 (11-50) | *Po-po/tr* | *0.132* | 22 (4-35) | *Po-po/tr* | *0.7* |
| | (Number of all species) | (+) | Pre | 13 (10-18) | *Pr-po* | *0.394* | 12 (9-18) | *Pr-po* | *0.4* |
| | | | Post | 14.5 (11-23) | *Pr-po/tr* | *0.004*** | 13 (13-20) | *Pr-po/tr* | *0.2* |
| | | | Post/trap | 19.5 (16-37) | *Po-po/tr* | *0.026*** | 20 (16-33) | *Po-po/tr* | *0.2* |
| | Number of benthic species | + | Pre | 5 (4-8) | *Pr-po* | *0.180* | 5 (3-8) | *Pr-po* | *0.4* |
| | | | Post | 6.5 (5-10) | *Pr-po/tr* | *0.004*** | 6 (6-9) | *Pr-po/tr* | *0.4* |
| | | | Post/trap | 9 (6-20) | *Po-po/tr* | *0.065** | 7 (7-16) | *Po-po/tr* | *0.4* |
| | Number of rheophilic species | + | Pre | 11.5 (10-14) | *Pr-po* | *0.310* | 12 (9-15) | *Pr-po* | *1.0* |
| | | | Post | 10.5 (9-13) | *Pr-po/tr* | *0.132* | 11 (10-14) | *Pr-po/tr* | *0.4* |
| | | | Post/trap | 13 (12-21) | *Po-po/tr* | *0.026*** | 13 (13-19) | *Po-po/tr* | *0.4* |
| | Number of long distance migrants | 0 | Pre | 0 (0-0) | *Pr-po* | *1.000* | 0 (0-0) | *Pr-po* | *1.0* |
| | | | Post | 0 (0-0) | *Pr-po/tr* | *1.000* | 0 (0-0) | *Pr-po/tr* | *1.0* |
| | | | Post/trap | 0 (0-0) | *Po-po/tr* | *1.000* | 0 (0-0) | *Po-po/tr* | *1.0* |
| | Number of potamodromous species | + | Pre | 5 (4-6) | *Pr-po* | *0.394* | 5 (5-7) | *Pr-po* | *1.0* |
| | | | Post | 4.5 (3-7) | *Pr-po/tr* | *0.004*** | 5 (4-8) | *Pr-po/tr* | *0.4* |
| | | | Post/trap | 7 (6-9) | *Po-po/tr* | *0.009*** | 6 (6-11) | *Po-po/tr* | *0.4* |
| | Relative density of lithophilic species | 0 | Pre | 81.3 (73.4-84.4) | *Pr-po* | *0.818* | 99.4 (95.1-100) | *Pr-po* | *0.2* |
| | | | Post | 81.1 (57.3-85.8) | *Pr-po/tr* | *0.589* | 92.7 (92.1-96.7) | *Pr-po/tr* | *0.2* |
| | | | Post/trap | 81.0 (57.3-84.2) | *Po-po/tr* | *0.699* | 92.1 (91.5-96.4) | *Po-po/tr* | *0.4* |
| | Relative number of intolerant species | - | Pre | 32.1 (16.7-40) | *Pr-po* | *0.132* | 41.7 (38.9-44.4) | *Pr-po* | *0.1** |
| | | | Post | 20.2 (14.2-33.3) | *Pr-po/tr* | *0.026*** | 25 (23.1-30.8) | *Pr-po/tr* | *0.1** |
| | | | Post/trap | 22.5 (16.2-25) | *Po-po/tr* | *0.818* | 25 (21.2-31.3) | *Po-po/tr* | *1.0* |
| | Relative number of tolerant species | - | Pre | 7.7 (0-11.1) | *Pr-po* | *0.004*** | 0 (0-11.1) | *Pr-po* | *0.1** |
| | | | Post | 13.8 (9.1-23.1) | *Pr-po/tr* | *0.002*** | 15.4 (15.4-20) | *Pr-po/tr* | *0.1** |
| | | | Post/trap | 21.9 (12.5-26.3) | *Po-po/tr* | *0.093** | 20 (18.7-24.2) | *Po-po/tr* | *0.2* |

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**Figure captions**

Figure 1: Study area: location of migratory barriers, sampling sites and fish ladders.
Figure 2: Minimum, maximum and median of the total indices for six stretches to illustrate the differences between pre- post and post/trap monitoring data for the EFI, FIA, and MULFA at the rivers Melk (n=6) and Pielach (n=3).
Figure 3: Significant correlations between Ln(effect size) of the total indices of the EFI and the MULFA and distance from river mouth analysed using the Spearman rank correlation for the Melk (n=6) and river Pielach (n=3); distance in km.
Figure 4: Significant correlations between Ln(effect size) of the single metric values of the FIA and the MULFA and distance from river mouth analysed using the Spearman rank correlation for the Melk (n=6) and river Pielach (n=3); distance in km.

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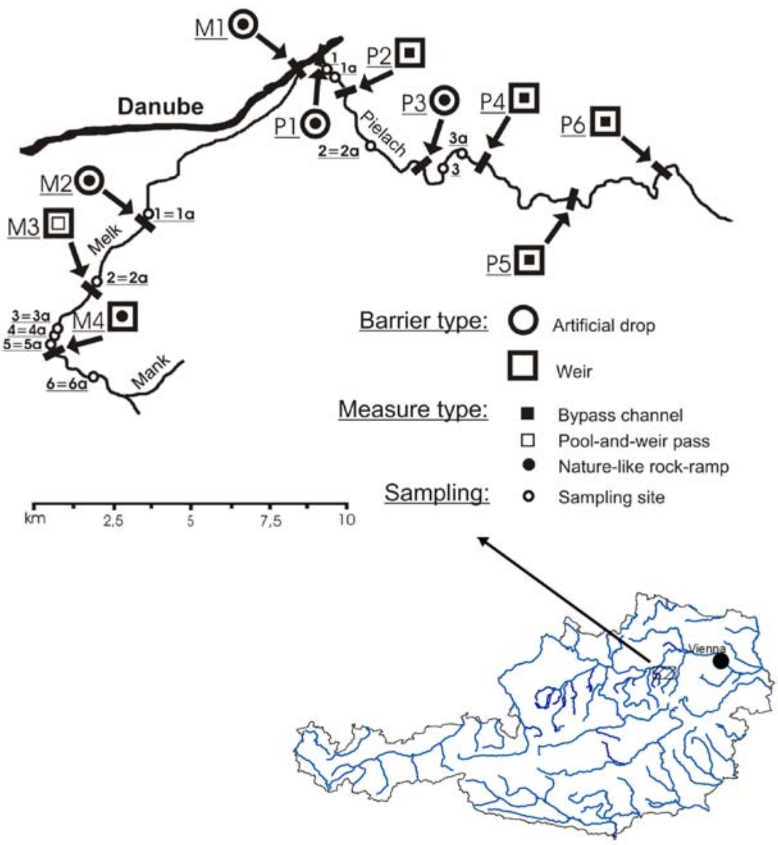
M1
P2
1
1a
Danube
P1
Pielach
P3
P4
P6
2=2a
3a
3
M2
1=1a
M3
Melk
2=2a
P5
3=3a
4=4a
5=5a
M4
6=6a
Mank
Barrier type:
Artificial drop
Weir
Measure type:
Bypass channel
Pool-and-weir pass
Nature-like rock-ramp
Sampling:
Sampling site
km
2,5
5
7,5
10
Vienna

Fig. 1

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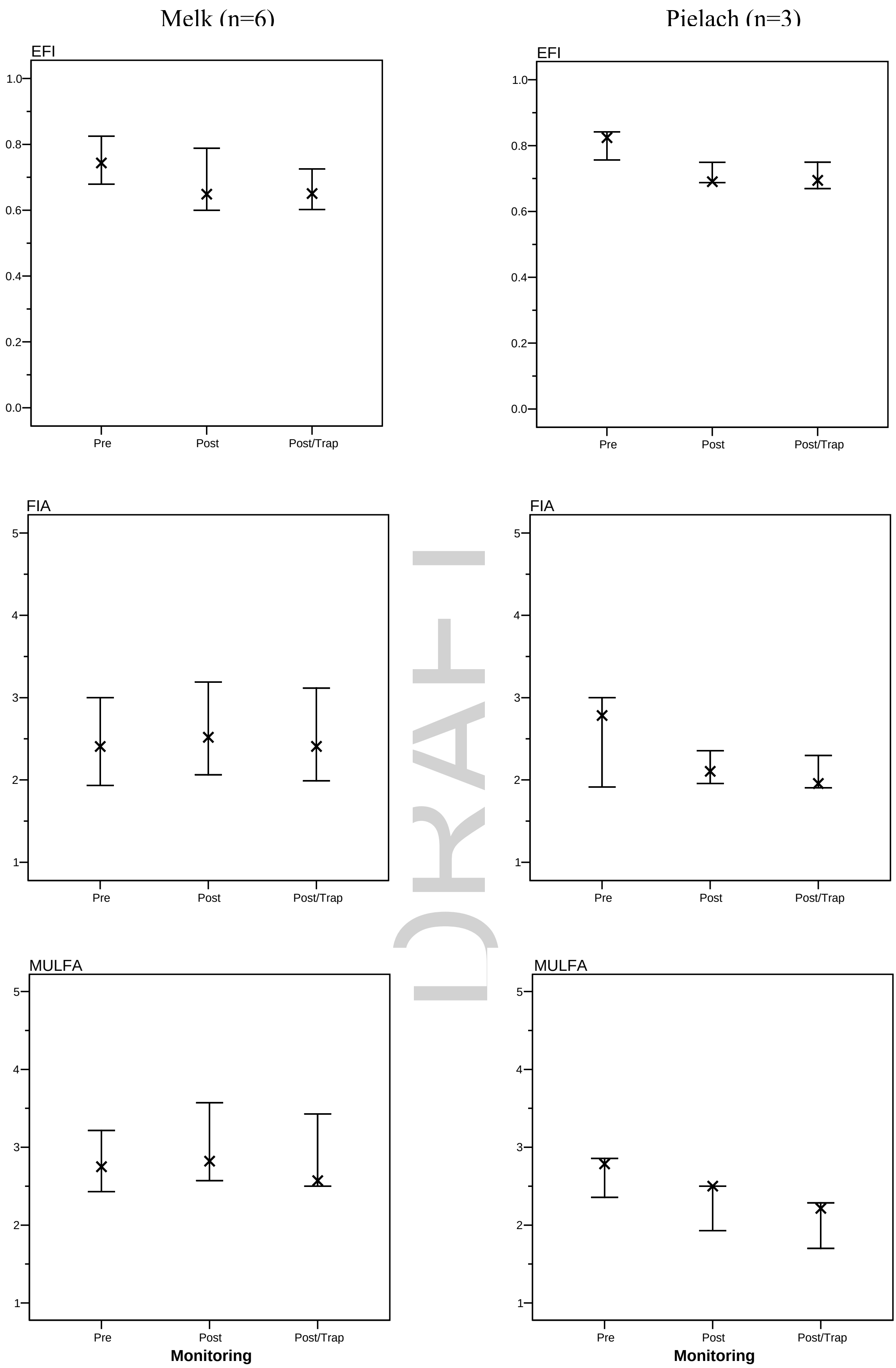

Melk (n=6)
Pielach (n=3)
EFI
1.0
0.8
0.6
0.4
0.2
0.0
Pre
Post
Post/Trap
FIA
MULFA
5
4
3
2
1
Monitoring


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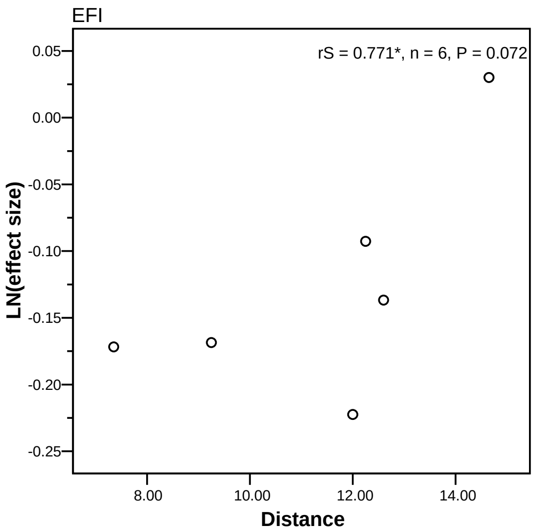
Fig. 2

Melk (n=6)




Pielach (n=3)

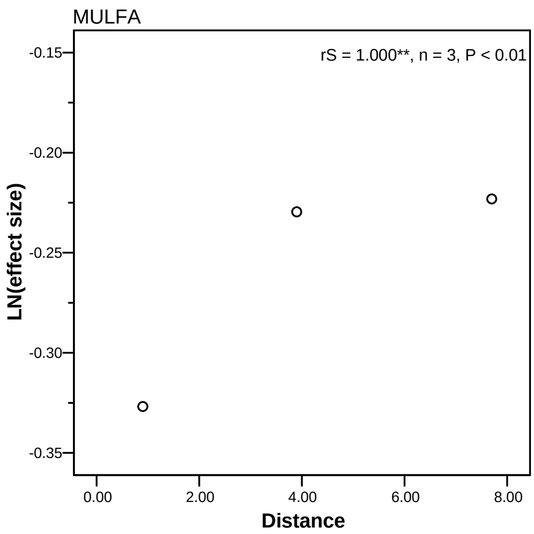



Fig. 3

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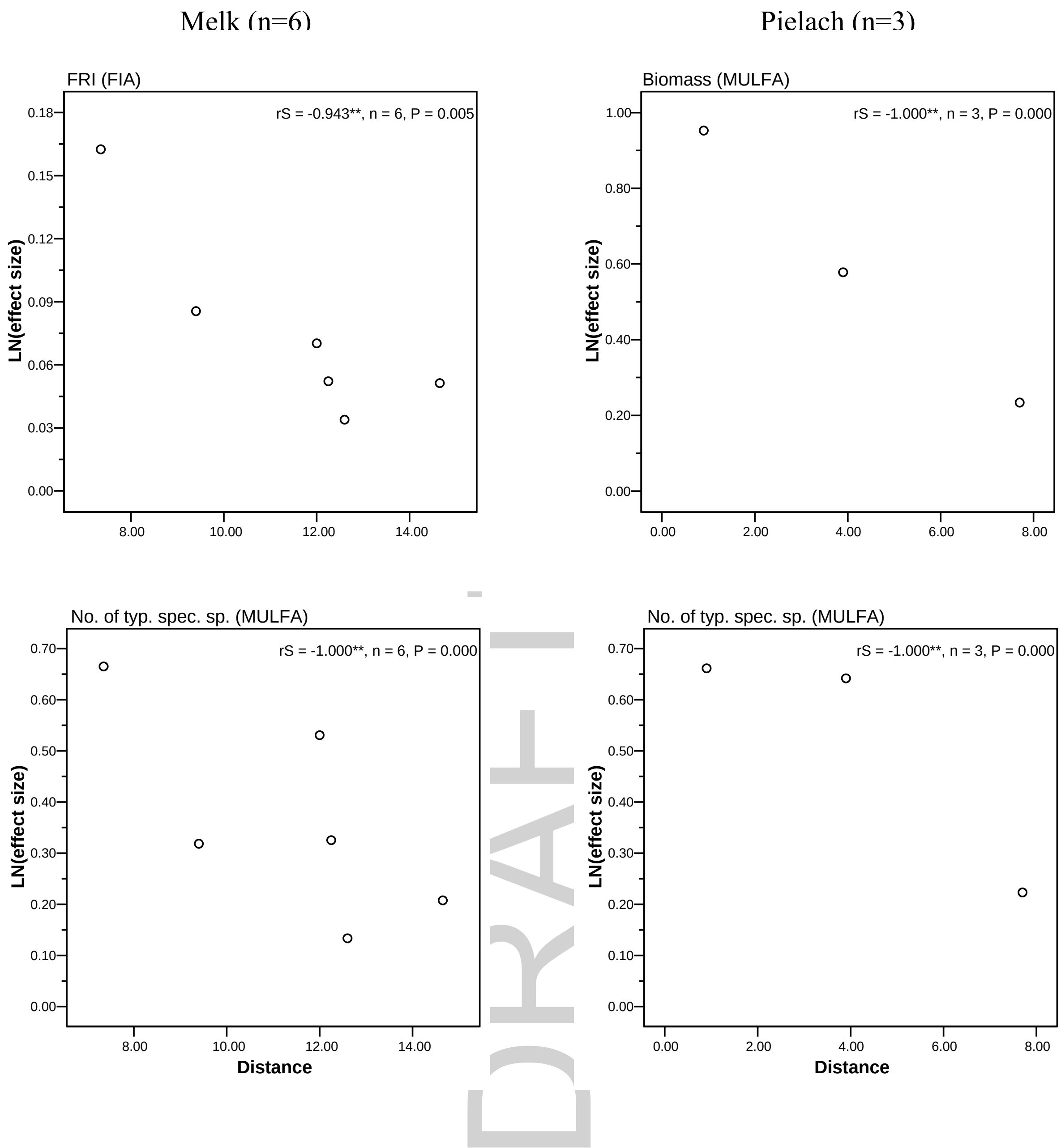


Fig. 4

View publication stats