Migration processes of riverine fish: assessment, patterns of downstream migration & restoration

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Alle Wissenschaft ist letztendlich Kosmologie.

(Sir Karl Popper)

Diese Arbeit widme ich meinem Vater Dietmar Willi Zitek, der mir die Liebe zur Natur geschenkt hat, sowie Bettina und Alwin, die mein Leben mit Sinn und Freude erfüllen!

CONTENTS

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ABSTRACT

Freshwater ecosystems have suffered the most intense intervention of all ecosystems over the past 100 years of human history, with severe negative consequences on fish biodiversity. One of the main human pressures on the aquatic environment is the construction of dams and weirs leading to the loss of fish species and the loss of genetic variability by interrupting the natural migration pathways of fish. Assessing and understanding migration patterns of fish and the importance of river connectivity for conservation and restoration of fish populations are therefore seen as pre-requisites for successful river restoration and management. With regard to this the present thesis focused on three main topics: (1) the development of methods for studying the spatial behaviour of fishes, (2) the assessment of downstream migration patterns of fish larvae and juvenile fishes at different seasons and (3) the development and analysis of river restoration measures with regard to river connectivity.

(1) For studying fish migration in small and middle-sized rivers new methods have been developed and applied to Austrian rivers, especially the automatic drift sampler and a modular and flood resistant dynamic fish weir. Additionally the parasitic fauna of fishes at two rivers in lower Austria has been studied and their potential as natural markers for migration studies is discussed.

(2) The downstream migration of fish larvae was assessed in the Marchfeldkanal (MFK) near Vienna during the spring/summer and autumn/winter period representing one of the most comprehensive drift studies ever conducted within Europe. It was found that nearly all fish species occurring in the MFK drifted as larvae and/or juveniles with clear species-specific differences in densities. A drift index was developed, differentiating the propensity of different fish species to drift under the observed environmental conditions. This classification might form the basis for a future classification of the European fish fauna with regard to their drift behaviour. The phenomenon of the downstream migration of juvenile fishes during the autumn/winter season has been quantitatively described for the first time ever.

(3) The integration of connectivity measures in catchment based river restoration programmes was found to be a pre-requisite for an effective restoration of the river type specific fish fauna. Generally it has been realized, that sustainable river restoration represents a challenging task that has to integrate various ecological (spatial and temporal) and social scales.

Keywords: Fish, migration, methods, downstream, drift, river, restoration, connectivity, continuum, catchment.

ZUSAMMENFASSUNG

Süßwasserökosysteme wurden von allen Ökosystemen in den letzten 100 Jahren vom Menschen am schwerwiegendsten verändert, was sich unter anderem in deutlich ausgeprägten negativen Auswirkungen auf die Fischfauna zeigt. Einer der Hauptgründe für das beobachtete Aussterben von Fischarten und den Verlust der genetischen Vielfalt ist der Bau von Wehren und anderen Querbauwerken, die die natürlichen Wanderungswege der Fische unterbrechen. Das Untersuchen und Verstehen von Wandermustern der Fischfauna und der Bedeutung eines offenen Fließkontinuums für Erhalt und Wiederherstellung von Fischpopulationen stellen daher wichtige Grundbedingungen für die Umsetzung erfolgreicher Flussrestaurierungen und ein erfolgreiches Flussgebiets-Management dar. In Bezug darauf beschäftigt sich die vorliegende Dissertation daher vor allem mit drei Schwerpunktthemen: (1) der Entwicklung von Methoden um das räumliche Verhalten von Fischen zu studieren, (2) der Untersuchung von flussabwärts gerichteten Wanderungen von Fischlarven und Jugendfischen zu verschiedenen Jahreszeiten und (3) der Entwicklung und der Analyse von Fluss-Restaurierungs-Maßnahmen in Bezug auf ein offenes Kontinuum auf unterschiedlichen räumlichen Ebenen. (1) Um die Fischwanderung in kleinen und mittelgroßen Flüssen zu untersuchen, wurden im Rahmen der Dissertation neue Methoden entwickelt und an österreichischen Flüssen angewandt: der automatische Driftsampler und ein modulares und hochwassersicheres dynamisches Fischwehr. Weiters wurde eine vergleichende Studie der Parasitenfauna von Fischen zweier niederösterreichischer Flüsse durchgeführt sowie deren Verwendung als natürliche Markierung für Untersuchung von Fischwanderungen diskutiert. (2) Flussabwärts gerichtete Wanderungen von Fischlarven und Juvenilen wurden während des Frühjahrs/Sommer- und der Herbst/Winter-Zeitraums im Marchfeldkanal (MFK) bei Wien untersucht. Die durchgeführten Driftuntersuchungen repräsentieren eine der umfassendsten Studien zu diesem Thema im europäischen Raum. Es wurde herausgefunden, dass nahezu alle im MFK gefundenen Arten als Larven und/oder Juvenile mit deutlich ausgeprägten artspezifischen Unterschieden driften. Um diese artspezifischen Unterschiede zu quantifizieren, wurde ein Drift-Index entwickelt, der die Neigung der verschiedenen Fischspezies klassifiziert, unter den untersuchten Umgebungsbedingungen zu driften. Dieser Index könnte die Grundlage für eine künftige Klassifizierung der europäischen Fischfauna hinsichtlich ihres Driftverhaltens darstellen. Erstmalig wurde auch das Phänomen der flussabwärts gerichteten Wanderung von Jugendfischen während des Herbst/Winter-Zeitraums untersucht und quantitativ beschrieben. (3) Die Integration von Konnektivitätsmaßnahmen in Einzugsgebiet-orientierte Fluss-Restaurierungs-Programme wurde ebenso als eine wichtige Grundvoraussetzung für nachhaltige das Wiederherstellen einer flusstypspezifischen Fischfauna erkannt, wie die Integration unterschiedlicher ökologischer (räumlicher und zeitlicher) und gesellschaftlicher Ebenen und Prozesse.

Schlüsselwörter: Fisch, Wanderung, Methoden, flussabwärts, Drift, Fluss, Restaurierung, Konnektivität, Durchgängigkeit, Einzugsgebiet.

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). 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 a half of these are associated with obstructions to migration pathways at dams and weirs (Northcote, 1998). Main negative effects of continuum interruptions on riverine fish are the loss of genetic variability (Wolter, 1998; Meldgaard et al., 2003; Habicht et al., 2004; Laroche & Durand, 2004) and the loss of species (Rieman & Dunham, 2000; Joy & Death, 2001; Neraas & Spruell, 2001; Morita & Yamamoto, 2002; Cumming, 2004). Also the dispersal of other species depending on fish migration, e.g. freshwater unionoids, is blocked by the interruption of the connectivity (Watters, 1996).

Migratory behaviour of riverine fishes, and probably of all fishes, result from the separation in space and time of optimal habitats used for growth, survival and reproduction (Northcote, 1984). Each fish species has therefore developed a unique migratory behaviour that corresponds to the existing environmental conditions (Pavlov, 1994). As fish are adapted to the four-dimensionality of the river (Ward, 1989) connectivity has been realized to influence fish distributions of different spatial and temporal scales (Jungwirth, 1998; Schmutz & Jungwirth, 1999; Jungwirth et al., 2000; Schiemer, 2000). The pattern of habitat use is strongly related to the ontogenetic stage of the species (Northcote, 1984), and an appropriate degree of free passage for fish must exist in order to enable access to all habitats required for full life cycles and natural maintenance of stocks (Lucas et al., 1998).

In literature the terms “movement” and “migration” are usually used to describe different types of migratory behaviour of fish. The term movement is more suitable to describe movements within territories and home ranges, while the term migration is used to describe strongly directional movements that result in a change to different, separate habitats or spatial units (Peter, 1998). After Northcote (1978) migrations result in an alteration between two or more separate habitats, occur with regular periodicity and involve a large proportion of the population.

Although a profound knowledge of the ecological requirements of our fish species is a prerequisite for efficient protection and restoration of populations unfortunately we still have a number of species for which little or no information of life history and virtually nothing on migration is available (Kirchhofer & Hefti, 1996; Northcote, 1998). Perhaps this situation partly results from our appreciating that migration or movements in freshwater fishes can occur over relatively short distances and may not be spectacular but is still essential (Northcote, 1998). Different methods for studying use of space through time by fish and their movement/migration/dispersal patterns are therefore needed for understanding population processes as well as performing effective management and conservation actions for restoring fish populations. Following Turchin (1998) generally migration/movement/redistribution methods can be divided into two empirical approaches. The Eulerian approach emphasizes the population and involves recording of large numbers of marked/unmarked individuals in space. In contrast, the Lagrangian approach involves the characterization of the magnitude (spatial extent), speed and directionality of movements of individuals.

It is obvious, that only the integration of results gained by different methods and techniques will help us to better understand the spatial behaviour of fish during their life cycle. Assessing the spatial behaviour fish and quantifying the relevance of movements and migrations for sustaining populations and communities can be seen as key aspects of applied ichthyology.

With regard to the spatial dynamics of riverine populations (Schmutz & Jungwirth, 1999) the movement and migration of adult fish and the drift of fish larvae are thought to be the prime factors determining population distributions (Zitek et al., 2004c).

ASSESSMENT - MS I, II & III

Methods that can be used to study fish migration and movements can also be divided into capture dependent and capture independent techniques. But all techniques and methods for investigating the spatio-temporal behaviour of freshwater fish suffer from intrinsic, environmental and specific limitations (Lucas & Baras, 2000). Therefore, before starting any study on aspects of spatial behaviour of fishes, one should define its objectives most clearly, and adapt existing techniques, alone or in combination, to the environment and the target species of the study.

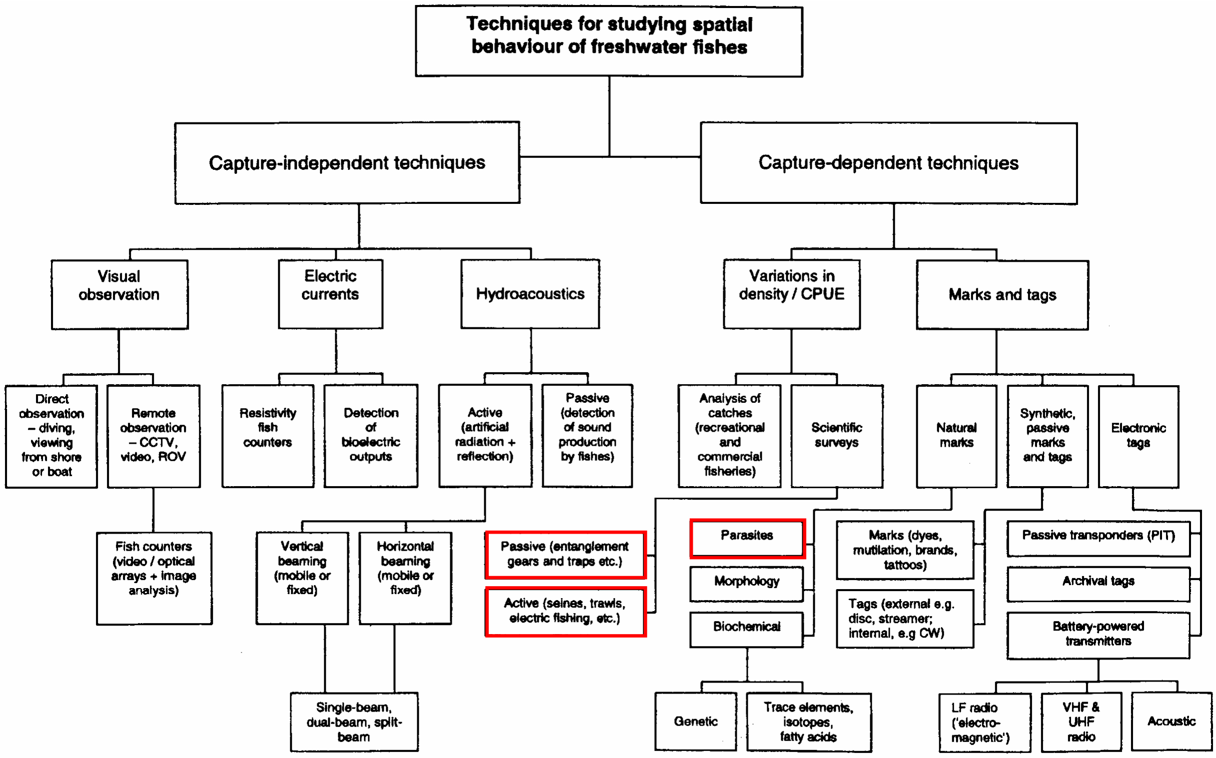

Figure 1: Classification of techniques that might be used to study spatial behaviour of fish in fresh wand brackish water environment after Lucas & Baras (2000); methods that have been applied within this thesis are marked with red rectangles.

Passive methods for studying larval (Schmutz et al., 1997), juvenile (Wiesner et al., 2004) and adult fish migration (Mühlbauer et al., 2003) form therefore an important basis for a quantitative analysis of fish migration. Different marking methods usually accompany passive migration studies to answer more specific questions of behaviour (Schmutz et al., 1998; Zitek, 1999; Unfer et al., 2003). Besides applying the wide range of available marking methods, one can take advantage of natural marks like isotopes (Kennedy et al., 1997; Hobson, 1999; Tresher, 1999; Campana & Thorrold, 2001; Kennedy et al., 2002; Muhlfeld et al., 2005) or parasites (Lucas & Baras, 2000; Jirsa, 2004, 2006) by which differences in water quality might be reflected and thus migration routes could be reconstructed. The role of fish parasites as possible indicators for water quality in general and the effects of environmental stress on parasitic communities has been studied by many authors (Khan and Thulin, 1991; Gelnar et al., 1994, 1995, 1997; MacKenzie et al., 1995; Dusek et al., 1996). Studies describing the use and limitations of parasites as natural markers for migration studies are also available (Lester, 1990; Williams et al., 1992; Mosquera et al., 2003). Analysis of the geographical distributions of parasites is thought to be an excellent source of information about the movement of host fish. Occasionally such analysis can also allow us to discriminate between fish populations, though unequivocal discrimination usually requires methods with a genetic basis. In assessing fish movement, parasites have two advantages over conventional tags: they can more readily detect mass migration and, because the fish only have to be caught once, the data are usually cheaper to obtain. The most important criterion in selecting a parasite to be used as a tag is its longevity in the fish; short-lived parasites give information on short-term movements of the fish, long-lived parasites on more extensive migrations (Lester, 1990).

For the future a combination of methods (electrofishing, trapping, drift investigations, natural or artificial marks) probably most reliably describes the dispersal/movement system, allowing predictive models to be established (Thorrold et al., 2002; Nathan et al., 2003). Here, as in other fields (e.g. human dispersal, Science 291: 1721-1752, 2001.) and with any ecological methodology, multiple independent approaches to a problem enable the elimination of the individual error of methods. Additionally identifying factors that influence fish movement is a key step in predicting how populations respond to environmental change (Albanese et al., 2004).

PATTERNS OF DOWNSTREAM MIGRATION - MS IV, V & VI

Stream drift as a dial- and seasonally related phenomenon is, for water insects and other invertebrates as well as for fish, a part of the colonization cycle of a running water ecosystem (Müller, 1974). The drift phenomenon is part of the life cycle of many fish species (Manteifel et al., 1978; Pavlov et al., 1978; Pavlov, 1994) and plays a crucial role in the life history of far more species than it was previously assumed. Downstream fish migrations are the first migrations in the ontogenesis and therefore the extent and the character of migrations in subsequent life periods depends in many respects in these initial downstream migrations (Pavlov, 1994). These migrations are considered to be an adaptation: they enlarge the feeding grounds, disseminate the species and ultimately increase its abundance (Pavlov, 1994). The best-known migration to compensate early life history downstream migrations is the upstream migration of many fish species for spawning.

In the course of evolution the various fish species have evolved their own specific features of migratory behaviour corresponding to the conditions of their existence (Pavlov et al., 1978; Pavlov, 1994) and to understand this aspect of fish biology it is of great practical importance (Pavlov et al., 1978). The trends of downstream migration of fishes are among the essential conditions for prediction of the consequence of regulation and impoundment of rivers (Nezdoliy, 1984) or the development of methods for preventing fish from entering water intakes at hydropower plants (Pavlov et al., 1978).

As massive transport phenomenon's are influencing fish distribution and moving animals into regions of different habitat quality, consequently a continuous longitudinal sequence of suitable habitats under stochastically changing water level is essential for recruitment (Winkler et al., 1997), and the availability of suitable habitats for early life stages close to spawning places is a prerequisite for effective dispersal and is considered as one of the most important factors for the maintenance of rheophilous fish species like the nase, *Chondrostoma nasus* (L.) (Hofer & Kirchhofer, 1996). For example summer floods often are leading to a complete downstream transport of all larvae ("catastrophic drift") (Hofer & Kirchhofer, 1996; Pokorny, 2000) probably into impounded sections which are considered to be a less valuable habitat for juveniles after their feeding shift in autumn (Hofer & Kirchhofer, 1996); this might be responsible for poor recruitment. Thinning effects due to possible downstream drift of larvae and winter downstream migrations with no possibility of return to upstream spawning places might also be a reason for decline of rheophilous cyprinids like *C. nasus* (Maier, 1997); if young fish survive and grow up to sexual maturity in lower stretches, they will not find adequate spawning areas to reproduce successfully if their upstream migration is blocked.

Drift of fish larvae has been intensively studied since the 1960s (Northcote, 1962; Lindsey & Northcote, 1963). The focus was initially on salmonids, but drift was also recently recognized as an important mechanism in other species (Pavlov, 1994; Vassilev, 1994; Persat & Olivier, 1995; Kostin et al., 1997; Schmutz et al., 1997; Jurajda, 1998; Carter & Reader, 2000; Pokorny, 2000; Pavlov et al., 2001; Reichard et al., 2001; Copp et al., 2002; Pavlov et al., 2002; Reichard et al., 2002b, a; Oesmann, 2003; Reichard & Jurajda, 2004; Reichard et al., 2004; Zitek et al., 2004c, d; Sonny et al., 2006).

Drift dispersal is also considered to play an important role in small-scale metapopulation processes and therefore is to be considered in management concepts which are dealing with self-regulation and self regeneration of riverine fish biocoenosis (Muhar et al., 1995; Jungwirth et al., 2002). Therefore to optimize conservation and restoration strategies for fish stocks it is important to identify the rearing habitats that produce the most successful individuals (Kennedy et al., 1997). Unfortunately for most species, information on "effective" dispersal (dispersal and establishment) sensu Nathan et al. (2003) and distances travelled by larvae during downstream migration (Priegel, 1970; Elliott, 1987; Kennedy & North, 1992) as well as the effect of dispersal patterns on population dynamics is practically unknown.

Usually the phenomenon of downstream migration has been described for early developmental stages of fish (mostly larvae, and early juveniles) after spawning time during spring and summer months showing that the density of drifting larvae is species dependent and seeming to be intimately related with certain periods of ontogeny in fish with being most intensive during early periods of ontogenesis (Pavlov, 1994; Pavlov et al., 2001; Reichard et al., 2002a) leading to clear seasonal drift patterns. Timing of occurrence of the various species in the drift seems to be a function of when they have spawned (Brown & Armstrong, 1985) and through its effect on the seasonality of reproduction water temperature is considered to be the main factor driving the timing of drift (Nezdoliy, 1984; Reichard et al., 2002b). Generally there is no single factor determining the intensity of downstream migration and it changes during a season, and taking into account the significance of diverse factors and their combination, it is emphasized, that the complexes of innate behavioural reactions and of morphological adaptations, which regulate the spatial distribution of young fishes, are the main mechanisms of the seasonal dynamics of downstream migration (Pavlov, 1994).

But downstream migrations are not restricted to the spring/summer period after hatching and to early developmental stages. Wiesner et al. (2004) in a side arm of the Danube found large numbers of juvenile fish migrating downstream during autumn/winter. A total number of about 60000 downstream migrants out of 30 species was estimated. Although fish up to 550mm were recorded, preliminary 0+ fish were found in the samples. Intensive downstream migrations were documented at water temperatures below 12°C; at temperatures around 2°C downstream migration were terminated. Drift peaks were significantly linked with decreasing temperatures being reduced at small temperature increases. Already in the year 1940 the extensive downstream migration of large quantities of fish in winter was mentioned in the “Schweizerische Fischereizeitung” (1940); it was suggested that the downstream migration has to be compensated during the spring/summer period of the next year. After Scheuring (1949a) fish could be transported downstream by high flood events or during periods of lowered water temperatures due to the lower energy budget of fish; the upstream migration in spring is understood as “compensation migration”. The intensive upstream migration of juveniles in autumn documented by a variety of studies (Kucera, 1999; Urbanek, 2001; Prchalova et al., 2004; Zitek, 2005), could be seen as feeding migration or later on as winter refugee seeking migration (Prignon et al., 1998; Lucas & Baras, 2001; Prchalova et al., 2004) probably compensating for the later downstream migration at lower temperatures. In the light of these hypotheses up- and downstream migration in autumn and winter can be seen as searching for suitable habitats for over-wintering. The availability of winter habitats and the connectivity of river ecosystems for up- and downstream migration is therefore assumed to be essential for maintaining viable populations and fish communities.

RESTORATION – MS VII – XII

The discipline of regulated river ecology was formalized at the First International Symposium on Regulated Rivers some 20 years ago (Ward and Stanford, 1979). Since then, hundreds of papers, several books and seven more regulated stream and other symposia with published proceedings have added tremendously to our knowledge of ways that the ecology of rivers and streams responds to dams, abstractions, revetments and the other pervasive human influences mediated by flow regulation. In many respects, the ecology of regulated streams has become a predictive science because specific biophysical responses have been repeatedly observed in rivers worldwide (Stanford & Ward, 2001). River restoration has proceeded from actions ameliorating impacts at the reach scale to serious plans to re-regulate or unregulate entire catchments of large rivers, expressly to enhance natural attributes that have been measurably degraded by regulation and abstraction of flow (Stanford & Ward, 2001).

The term restoration, which in the most formal sense is returning an ecosystem to its original pre-disturbance state (Bradshaw, 1996; Middleton, 1999; Roni et al., 2005), has commonly been used to refer to all types of habitat manipulations including enhancement, improvement, mitigation, habitat creation, and other actions (Fig. 1). These activities are more accurately termed rehabilitation, as most do not truly restore a system and in many areas were the land use is predominantly agricultural, residential, urban or industrial, true restoration is not feasible in the foreseeable future (Stanford et al., 1996).

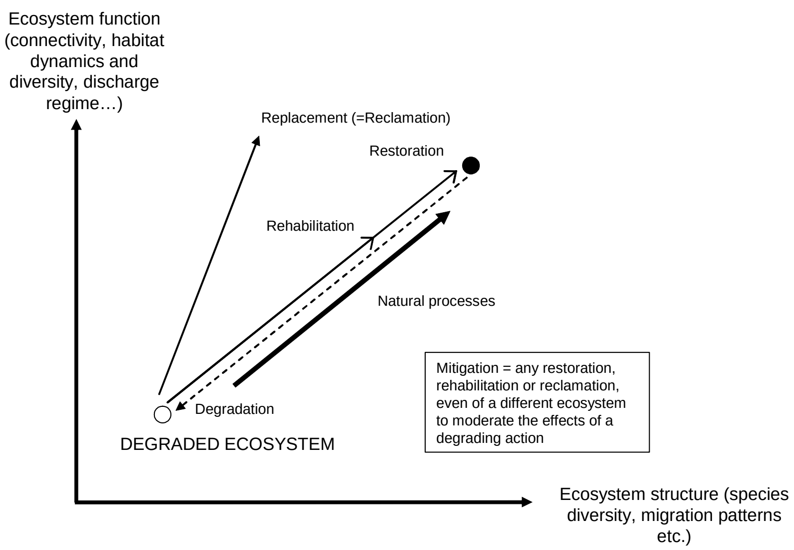

Figure 2: Several different options in remediation work (from Bradshaw, 1996).

In Austria river rehabilitation activities started in the eighties with the establishment of instream structures at a low land river to increase depth and flow heterogeneity (Jungwirth et al., 1993; Jungwirth et al., 1995), known to be significantly related to density, number of fish species and the variance of fish length. At that time legal limitations confined the measures to the low flow bed of he river, but recommendations to orient restoration measures on the original situation of the unmodified river allowing the river to regain its characteristic instream and ecotone structures by dynamic processes corresponding to the type-specific conditions. Later on many river rehabilitations were conducted in Austria`s rivers (Jungwirth et al., 2003) focusing more and more on a river-type specific and dynamic approach (Jungwirth et al., 2002; Jungwirth et al., 2005) but in some cases still allowing only limited river dynamics (Zitek et al., 2004a; Zitek et al., 2004e).

In 2000 the European Union launched a new water legislation, the Water Framework Directive (WFD, http://www.euwfd.com) (WFD, 2000). One of the key objectives of the WFD is to achieve the "good ecological status" of running waters by 2015. The main focus of the WFD is the management of river basins, the natural geographical and hydrological unit. Due to their mobility and adaptation to an open longitudinal and lateral continuum the restoration of longitudinal (and lateral) connectivity for fish on the catchment level is thought to be crucial for reaching the central targets of the WFD.

Migration, particularly in freshwater fishes, has been often regarded as an adaptive phenomenon to increase growth, survival and abundance and being also responsible for the production of freshwater fish (Northcote, 1978). "If fish migration is an adaptation towards abundance, it would explain why the important commercial species are migratory: they are of commercial interest because they are abundant and abundant because they are migratory" (Harden Jones, 1968). Therefore the establishment of fish migration facilities (Ackerbauministerium, 1891) and the interpretation of fish migration monitoring results (Scheuring, 1949b) have a considerably long tradition in Austria with presently again increasing importance (Jungwirth et al., 1998). In recent years various types of buildings have been used to re-establish the river continuum in Austria`s rivers locally (Jungwirth, 1996; Eberstaller & Gumpinger, 1997; Unfer & Zitek, 2000; Zitek et al., 2004b; Zitek, 2005).

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 (Buijse et al., 2002; Schmutz et al., 2002). Unfortunately information how to measure the efficiency of re-establishing the river continuum on a catchment level are rare (Lucas et al., 1998; Zitek & Schmutz, 2004). On the one hand a completely successful fish passage facility for migratory species might be of little value, if habitat to which fish are migrating for spawning, feeding or survival, is either not available or is badly degraded (Northcote, 1998), on the other hand habitat restoration measures might not lead to a full recovery of the type-specific fish fauna as barriers still act as "press disturbances" that may delay or preclude recovery of fish assemblages (Niemi et al., 1990; Detenbeck et al., 1992; Unfer et al., 2004; Zitek et al., 2004a) following different kinds of disturbances (Niemi et al., 1990; Detenbeck et al., 1992; Schachner & Zitek, 2002).

Recent approaches try to develop models for river restoration with regard to the EU-WFD to identifying the most appropriate combination of possible hydraulic and morphological restoration measures (also connectivity measures) for running waters (MIRR-Model-based Instrument for River Restoration, http://mirr.boku.ac.at). For analyzing the present status of the Austrian fish fauna with regard to typical hydromorphological pressures, a database containing information on more than 500 fishing sites was developed. More than 100 relevant criteria characterizing anthropogenic pressures as hydrological alterations (hydropeaking, water abstarction), impoundment, reservoir flushing, channelisation, river bed degradation, continuum interruptions (lateral, longitudinal), land use and water quality changes were pre-defined by an extensive literature search (Zitek, 2006) and assessed using GIS-technology (Poppe & Zitek, 2006). Multivariate analyses of different combinations should allow for a quantification of the contribution of single pressure types to cumulative impacts on different spatial and temporal scales and different types of rivers.

The future of our rivers and their fish populations is unsure, but we are more and more aware, how substantially we have altered our riverine systems. They clearly reflect the pressures that humans create on the environment on different spatial and temporal scales, and therefore act as important indicators for sustainable human behaviour. Realizing that we are only dealing with small fragments of the pristine fish fauna, the EU-WFD represents an important chance for restoring essential parts of our rivers and fish populations. This work has already started and for sure is representing a challenging task for both the next years and the next generations.

LITERATURE

Ackerbauministerium, k. k., Ed. (1891). *Anleitung betreffend der Herstellung von Fischwegen*. Wien, k.k. Hof- und Staatsdruckerei.

Albanese, B., P. L. Angermeier and S. Dorai-Raj (2004). "Ecological correlates of fish movement in a network of Virginia streams." *Canadian Journal of Fisheries and Aquatic Sciences* **61**(6): 857-869.

Anonymus (1940). "Von den Wanderungen der Fische in unseren Flüssen." *Schweiz. Fischerei-Zeitung* **48**(1): 3-5.

Bradshaw, A. D. (1996). "Underlying principles of restoration." *Canadian Journal of Fisheries and Aquatic Sciences* **53**: 3-9.

Brown, A. V. and M. L. Armstrong (1985). "Propensity to drift downstream among various species of fish." *Journal of Freshwater Ecology* **3**: 3-17.

Buijse, A. D., H. Coops, M. Staras, L. H. Jans, G. J. Van Geest, R. E. Grift, B. W. Ibelings, W. Oosterberg and F. C. J. M. Roozen (2002). "Restoration strategies for river floodplains along large lowland rivers in Europe." *Freshwater Biology* **47**(4): 889-907.

Campana, S. E. and S. R. Thorrold (2001). "Otoliths, increments, and elements: keys to a comprehensive understanding of fish populations?" *Canadian Journal of Fisheries & Aquatic Sciences* **58**(1): 30-38.

Carter, K. L. and J. P. Reader (2000). "Patterns of drift and power station entrainment of 0+fish in the River Trent, England." *Fisheries Management & Ecology* **7**(5): 447-464.

Copp, G. H., H. Faulkner, S. Doherty, M. S. Watkins and J. Majecki (2002). "Diel drift behaviour of fish eggs and larvae, in particular barbel, *Barbus barbus* (L.), in an English chalk stream." *Fisheries Management and Ecology* **9**: 95-103.

Cowx, I. G. and M. J. Collares-Pereira (2002). Freshwater fish conservation: options for the future. *Freshwater Fish Conservation - Options for the Future*. M. J. Collares-Pereira, I. G. Cowx and M. M. Coelho, Eds. Oxford, Fishing News Books**:** 443-452.

Cumming, G. S. (2004). "The impact of low-head dams on fish species richness in Wisconsin, USA." *Ecological Applications* **14**(5): 1495–1506.

Delpeuch, B. (2002). Foreword. *Freshwater Fish Conservation - Options for the Future*. M. J. Collares-Pereira, I. G. Cowx and M. M. Coelho, Eds. Oxford, Fishing News Books - Blackwell Science**:** vii-viii.

Detenbeck, N. E., P. W. DeVore, G. J. Niemi and A. Lima (1992). "Recovery of temperate-stream fish communities from disturbance: a review of case studies and synthesis of theory." *Environmental management* **16**: 33-53.

Eberstaller, J. and C. Gumpinger (1997). "Überfallfreies Umgehungsgerinne an der Pielach." *Österreichs Fischerei* **50. Jahrgang, Heft 2/3**: 47 - 51.

Elliott, J. M. (1987). "The distances travelled by downstream-moving trout fry, *Salmo trutta*, in a Lake District stream." *Freshwater Biology* **17**: 491 - 499.

Habicht, C., J. B. Olsen, L. Fair and J. E. Seeb (2004). "Smaller effective population sizes evidenced by loss of microsatellite alleles in tributary-spawning populations of Sockeye Salmon from the Kvichak River, Alaska drainage." *Environmental Biology of Fishes* **69**(1 - 4): 51-62.

Harden Jones, F. R. (1968). *Fish migration*. London, Edward Arnold.

Hobson, K. A. (1999). "Tracing origins and migration of wildlife using stable isotopes: a review." *Oecologia* **120**: 314-326.

Hofer, K. and A. Kirchhofer (1996). Drift, habitat choice and growth of the nase (*Chondostroma nasus*, Cyprinidae) during early life stages. *Conservation of Endangered Freshwater Fish in Europe*. Bern/Switzerland, Birkhäuser Verlag Basel/Switzerland**:** 269 - 278.

Jirsa, F. (2004). Die proto- und mesozoische Parasitenfauna bei *Chondrostoma nasus* L. und *Leuciscus cephalus* L. zweier Habitate in Niederösterreich und die physikalisch-chemische Analyse der Gewässer. Fakultät für Naturwissenschaften und Mathematik der Universität Wien. 144.

Jirsa, F., Zitek, A., Schachner, O. (2006). "First record of Lamproglena pulchella Nordmann 1832 in the Pielach and Melk rivers, Austria." *Journal of Applied Ichthyology* **22**: 404-406.

Joy, M. K. and R. G. Death (2001). "Control of freshwater fish and crayfish community structure in Taranaki, New Zealand: dams, diadromy or habitat structure?" *Freshwater Biology* **46**(3): 417-429.

Jungwirth, M. (1996). "Bypass channels at weirs as appropriate aids for fish migration in rhithral rivers." *Regulated rivers: research & managment* **12**: 483-492.

Jungwirth, M. (1998). River continuum and fish migration - going beyond the longitudinal river corridor in understanding ecological integrity. *Fish Migration and Fish Bypasses*. M. Jungwirth, S. Schmutz and S. Weiss, Eds. Oxford - London - Berlin, Blackwell Sciences Ltd. Fishing News Books**:** 19 - 32.

Jungwirth, M., G. Haidvogel, O. Moog, S. Muhar and S. Schmutz (2003). *Angewandte Fischökologie an Fließgewässern*. UTB. Wien, Facultas.

Jungwirth, M., G. Haidvogl, S. Hohensinner, S. Muhar, S. Schmutz and H. Waidbacher (2005). "Leitbild-specific measures for the rehabilitation of the heavily modified Austrian Danube river." *Archiv für Hydrobiologie Supplement* **155**(1-4): 17-36.

Jungwirth, M., O. Moog and S. Muhar (1993). "Effects of river bed restructuring on fish and benthos of a fifth order stream, Melk, Austria." *Regulated Rivers: Research & Management* **8**: 195-204.

Jungwirth, M., S. Muhar and S. Schmutz (1995). "The effects of recreated instream and ecotone structures on the fish fauna of an epipotamal river." *Hydrobiologia* **303**: 195-206.

Jungwirth, M., S. Muhar and S. Schmutz (2000). "Fundamentals of fish ecological integrity and their relation to the extended serial discontinuity concept." *Hydrobiologia* **422**: 85-97.

Jungwirth, M., S. Muhar and S. Schmutz (2002). "Re-establishing and assessing ecological integrity in riverine landscapes." *Freshwater Biology* **47**: 867-887.

Jungwirth, M., S. Schmutz and S. Weiss, Eds. (1998). *Fish Migration and Fish Bypasses*. Oxford - London - Berlin, Fisching News Books, Blackwell Sciences.

Jurajda, P. (1998). "Drift of larval and juvenile fishes, especially *Rhodeus sericeus* and *Rutilus rutilus*, in the River Morava (Danube basin)." *Archiv für Hydrobiologie* **141**: 231 - 241.

Kennedy, B. P., C. L. Folt, J. D. Blum and C. P. Chamberlain (1997). "Natural isotope markers in salmon." *Nature* **387**: 766.

Kennedy, B. P., A. Klaue, J. D. Blum, C. L. Folt and K. H. Nislow (2002). "Reconstructing the lives of fish using SR isotopes in otoliths." *Canadian Journal of Fisheries and Aquatic Sciences* **59**: 925-929.

Kennedy, T. B. and J. F. North (1992). Drift Behaviour and Distribution of Warner Sucker Larvae (Catostomus warnerensis) and Preliminary Assessment of Stream Habitat Conditions in the Warner Valley, Oregon. Portland. Oregon Department of Fish and Wildlife. 28.

Kirchhofer, A. and D. Hefti (1996). *Conservation of Endangered Freshwater Fish in Europe*. Basel - Boston - Berlin, Birkhäuser Verlag. 341.

Kostin, V. V., A. I. Lupandin and D. S. Pavlov (1997). "Dynamic aspects of juvenile fish distribution in ecological zones of Ivan'kovskoye Reservoir: Relationships with the downstream migration." *Journal of ichthyology* **37**(8): 654.

Kucera, M. (1999). Fischökologische Untersuchung einer Potamalfischaufstiegshilfe im Marchfeldkanal von 1993-98. Institut für Hydrobiologie und Gewässermanagement. Wien, BOKU.

Laroche, J. and J. D. Durand (2004). "Genetic structure of fragmented populations of a threatened endemic percid of the Rhone river: Zingel asper." *Heredity* **92**(4): 329-334.

Lester, R. (1990). "Reappraisal of the use of parasites for fish stock identification." *Australian Journal of Marine and Freshwater Research* **41**(6): 855 - 864.

Lindsey, C. C. and T. G. Northcote (1963). "Life history of redside shiners, *Richardsonius balteatus*, with particular reference to movements In and out of Sixteenmile Lake streams." *Journal of the Fisheries Research Board of Canada* **20**(4): 1001-1030.

Lucas, M. and E. Baras (2001). *Migration of Freshwater Fishes*. Oxford, Blackwell Science. 420.

Lucas, M. C. and E. Baras (2000). "Methods for studying spatial behaviour of freshwater fishes in the natural environment." *Fish and Fisheries* **1**: 283-316.

Lucas, M. C., T. J. Thom, A. Duncan and O. Slavik (1998). Coarse fish migration - occurrence, causes and implications. Bristol. Environment agency. 160.

Maier, K.-J. (1997). "On the Nase, Chondrostoma nasus spawning area situation in Switzerland." *Folia zoologica* **46**(suppl.1): 79-87.

Manteifel, B. P., I. I. Girsa and D. S. Pavlov (1978). On rhythms of fish behaviour. *Rhythmic Activity of Fishes*. J. E. Thorpe, Ed. New York, USA, Academic Press**:** 217-224.

Meldgaard, T., E. E. Nielsen and V. Loeschcke (2003). "Fragmentation by weirs in a riverine system: a study of genetic variation in time and space among populations of European grayling (*Thymallus thymallus*) in a Danish river system." *Conservation Genetics* **4**(6): 735-747.

Middleton, B. (1999). *Wetland restoration, flood Pulsing and disturbance dynamics*. New York, Wiley.

Morita, K. and S. Yamamoto (2002). "Effects of habitat fragmentation by damming on the persistence of stream-dwelling charr populations." *Conservation Biology* **16**(5): 1318-1323.

Mosquera, J., M. de Castro and M. Gómez-Gesteira (2003). "Parasites as Biological Tags of Fish Populations: Advantages and Limitations." *Comments on Theoretical Biology* **8**(1): 69-91.

Muhar, S., S. Schmutz and M. Jungwirth (1995). "River restoration concepts - goals and perspectives." *Hydrobiologia* **303**: 183-194.

Mühlbauer, M., E. Traxler, A. Zitek and S. Schmutz (2003). "Das dynamische Fischwehr - Ein hochwassersicheres Fischwehr zur Untersuchung der Fischwanderung an kleinen bis mittelgrossen Flüssen." *Österreichs Fischerei* **56**(5/6): 136 - 148.

Muhlfeld, C. C., B. Marotz, S. R. Thorrold and J. L. FitzGerald (2005). "Geochemical signatures in scales record stream of origin in westslope cutthroat trout." *Transactions of the American Fisheries Society* **134**(4): 945-959.

Müller (1974). "Stream drift as a chronobiological phenomenon in running water ecosystems." *Annual Review of Ecology and Systematics* **5**: 309-323.

Nathan, R., G. Perry, J. T. Cronin, A. E. Strand and M. Cain (2003). "Methods for estimating long-distance dispersal." *Oikos* **103**: 261-273.

Neraas, L. P. and P. Spruell (2001). "Fragmentation of riverine systems: the genetic effects of dams on bull trout (Salvelinus confluentus) in the Clark Fork River system." *Molecular Ecology* **10**: 1153-1164.

Nezdoliy, V. K. (1984). "Downstream Migration of Young Fishes during the Initial Period of Flow Regulation of the Ili River." *Journal of Ichthyology* **24**(2): 34-46.

Niemi, G. J., P. Devore, N. Detenbeck, D. Taylor, A. Lima, J. Pastor, J. D. Yount and R. J. Naiman (1990). "Overview of case-studies on recovery of aquatic systems from disturbance." *Environmental Management* **14**(5): 571-587.

Northcote, T. G. (1962). "Migratory behaviour of juvenile rainbow trout, *Salmo gairdneri*, in outlet and inlet streams of Loon Lake, British Columbia." *Journal of the Fisheries Research Board of Canada* **19**(2): 201-270.

Northcote, T. G. (1978). Migratory strategies and production in freshwater fishes. *Ecology of Freshwater Fish Production*. S. D. Gerking, Ed. Oxford-London-Edinburgh-Melbourne, Blackwell Scientific Publications**:** 326-359.

Northcote, T. G. (1984). Mechanisms of fish migration in rivers. *Mechanisms of migration in fishes*. J. D. McCleave, G. P. Arnold, J. J. Dodson and W. H. Neil, Eds. New York - London, Plenum Press**:** 317-355.

Northcote, T. G. (1998). Migratory behaviour of fish and its significance to movement trough riverine fish passage facilities. *Fish Migration an Fish Bypasses*. M. Jungwirth, S. Schmutz and S. Weiss, Eds. Oxford - London - Berlin, Blackwell Science Ltd. Fishing News Books**:** 3-18.

Oesmann, S. (2003). "Vertical, lateral and diurnal drift patterns of fish in a large lowland river, the Elbe." *Journal of Applied Icthyology* **19**(5): 284-293.

Pavlov, D. S. (1994). "The downstream migration of young fishes in rivers: mechanisms and distribution." *Folia Zoologica* **43**: 193 - 208.

Pavlov, D. S., A. I. Lupandin and V. V. Kostin, Eds. (2002). *Downstream migration of fish through dams of hydroelectric power plants*. Oak Ridge, Tennesee, Oak Ridge National Laboratory.

Pavlov, D. S., A. I. Lupandin, V. V. Kostin, I. V. Nechaev, P. I. Kirillov and R. V. Sadkovskii (2001). "Downstream migration and behavior of juvenile roach *Rutilus rutilus* (Cyprinidae) from two phenotypic groups." *Journal of Ichthyology* **41**(Supplement 2): 133-179.

Pavlov, D. S., A. M. Pakhorukov, G. N. Kuragina, V. K. Nezdoliy, N. P. Nekrasova, D. A. Brodskiy and A. L. Ersler (1978). "Some features of the downstream migrations of juvenile fish in the Volga and Kuban rivers." *Journal of Ichthyology* **19**: 363-374.

Persat, H. and J. M. Olivier (1995). "The first displacements in the early stages of *Chondrostoma nasus* under experimental conditions." *Folia Zoologica* **44**(Suppl. 1): 43-50.

Peter, A. (1998). Interruption of river continuum by barriers and the consequences for migratory fish. *Fish Migration an Fish Bypasses*. M. Jungwirth, S. Schmutz and S. Weiss, Eds. Oxford - London - Berlin, Blackwell Science Ltd. Fishing News Books**:** 99-112.

Pokorny, B. (2000). Untersuchungen zur Drift und Habitatwahl der frühen Entwicklungsstadien der Nase *Chondrostoma nasus* an der Pielach. Dept. of Hydrobiology, Fisheries and Aquaculture. Vienna, University of Agricultural Sciences.

Poppe, M. and A. Zitek (2006). Development of a strategic instrument for integrated assessment of ecological restoration measures in running waters - AP 1b: Data research: Documentation of data and applied methods. Vienna. Institute of Hydrobiology and Aquatic Ecosystem Management, BOKU.

Prchalova, M., L. Vetesnik and O. Slavik (2004). *Patterns of cyprinid migration through a fish pass*. Fifth international Symposium on Ecohydraulics. Aquatic Habitats: Analysis & Restoration, Madrid. IAHR: 68-74.

Priegel, G. (1970). Reproduction and early life history of the walleye in the Lake Winnebago region. Wisconsin. Department of Natural Resources. 105.

Prignon, C., J. C. Micha and A. p. Gillet (1998). Biological and environmental characteristics of fishpassage at the Tailfer dam on the Meuse River, Belgium. *Fish Migration and Fish Bypasses*. M. Jungwirth, S. Schmutz and S. Weiss, Eds. Oxford - London - Berlin, Blackwell Sciences Ltd. Fishing News Books**:** 69-85.

Reichard, M. and P. Jurajda (2004). " The Effects of Elevated River Discharge on the Downstream Drift of Young-of-the-Year Cyprinid Fishes." *Journal of Freshwater Ecology* **19**(3): 465-471.

Reichard, M., P. Jurajda and M. Ondrackova (2002a). "The effect of light intensity on the drift of young-of-the-year cyprinid fishes." *Journal of Fish Biology* **61**: 1063-1066.

Reichard, M., P. Jurajda and M. Ondrackova (2002b). "Interannual variability in seasonal dynamics and species composition of drifting young-of-the-year fishes in two European lowland rivers." *Journal of Fish Biology* **60**: 87-101.

Reichard, M., P. Jurajda and C. Smith (2004). "Spatial distribution of drifting cyprinid fishes in a shallow lowland river." *Archiv für Hydrobiologie* **159**(3): 395-407.

Reichard, M., P. Jurajda and R. Václavík (2001). "Drift of larvae and juvenile fishes: a comparison between small and large lowland rivers." *Archiv für Hydrobiologie* **135**(Supplement): 373-389.

Rieman, B. E. and J. B. Dunham (2000). "Metapopulations and salmonids: a synthesis of life history patterns and empirical observations." *Ecology Freshwater Fish* **9**(1-2): 51-64.

Roni, P., K. Hanson, T. Beechie, G. Pess, M. Pollock and D. M. Bartley (2005). *Habitat rehabilitation for inland fisheries. Global review of effectiveness and guidance for rehabilitation of freshwater ecosystems*. FAO Fisheries Technical Paper. **484**. Rome, FAO. 116.

Schachner, O. and A. Zitek (2002). *Auffälligkeiten der Sterblichkeit bei Nasen (Chondrostoma nasus L.) zur Laichzeit 2002 in der Melk (NÖ, Österreich)*. Tagung der Deutschen und Österreichischen Sektion der European Association of Fish Pathologists (EAFP), Mondsee/Österreich.

Scheuring, L. (1949a). "Die Wanderung unserer Flußfische." *Österreichs Fischerei* **2**(12): 262-273.

Scheuring, L. (1949b). "Fischpässe, ihre Leistung und Zweckmäßigkeit." *Österreichs Fischerei* **2**: 26-31.

Schiemer, F. (2000). "Fish as indicators for the assessment of the ecological integrity of large rivers." *Hydrobiologia* **422-423**: 271-278.

Schmutz, S., C. Giefing and C. Wiesner (1998). "The efficiency of a nature-like bypass channel for pike-perch (*Stizostedion lucioperca*) in the Marchfeldkanalsystem." *Hydrobiologia* **371/372**: 355-360.

Schmutz, S. and M. Jungwirth (1999). "Fish as indicators of large river connectivity: the Danube and its tributaries." *Archiv für Hydrobiologie, Supplement* **11**(3): 329-348.

Schmutz, S., A. Zitek and C. Dorninger (1997). "A new automatic drift sampler for riverine fish." *Archiv für Hydrobiologie* **139**(4): 449-460.

Schmutz, S., A. Zitek, S. Zobel, M. Jungwirth, N. Knopf, E. Kraus, T. Bauer and T. Kaufmann (2002). Integrated approach for the conservation and restoration of Danube salmon (Hucho hucho L.) populations in Austria. *Freshwater Fish Conservation - Options for the Future*. M. J. Collares-Pereira, I. G. Cowx and M. M. Coelho, Eds. Oxford, Fishing News Books - Blackwell Science**:** 157-173.

Sonny, D., S. Jorry, X. Wattiez and C. Philippart (2006). "Inter-annual and diel patterns of the drift of cyprinid fishes in a small tributary of the Meuse River, Belgium." *Folia Zoologica* **55**(1): 75–85.

Stanford, J. A. and J. V. Ward (2001). "Revisiting the serial discontinuity concept." *Regulated Rivers-Research & Management* **17**(4-5): 303-310.

Thorrold, S. R., G. P. Jones, M. E. Hellberg, R. S. Burton, S. E. Swearer, J. E. Neigel, S. G. Morgan and R. R. Warner (2002). "Quantifying larval retention and connectivity in marine populations with artificial and natural markers." *Bulletin of Marine Science* **70**(1): 291-308.

Tresher, R. E. (1999). "Elemental composition of fish otoliths as a stock delineator in fishes." *Fisheries Research* **43**: 165-204.

Turchin, P. (1998). *Quantitative analyses of movement*. Sinauer.

Unfer, G., C. Frangez and S. Schmutz (2003). *Seasonal Migration Patterns of Nase and Barbel in the Danube and its Tributaries*. Fifth Conference on Fish Telemetry held in Europe, Ustica, Italy.

Unfer, G., C. Wiesner and M. Jungwirth (2004). Fischökologisches Monitoring im Rahmen des LIFE Projekt Auenverbund Obere Drau. Wien. Studie im Auftrag des Amtes der Kärntner Landesregierung.

Unfer, G. and A. Zitek (2000). "Der Vertical-Slot-Fischpass: eine Fischwanderhilfe für räumlich beengte Verhältnisse." *Österreichs Fischerei* **53**: 332-339.

Urbanek, S. (2001). Überprüfung der Funktionsfähigkeit der Fischaufstiegshilfe am Kraftwerk Freudenau - fischökologische Untersuchungen 1999. Institut für Hydrobiologie und Gewässermanagement. Wien, BOKU.

Vassilev, M. (1994). "On the downstream migration of ichthyoplankton along the Bulgarian shore of the Danube river." *Vie et Milieu* **44**(3-4): 273-280.

Ward, J. V. (1989). "The 4-dimensional nature of lotic ecosystems." *Journal of the North American Benthological Society* **8**(1): 2-8.

Watters, G. T. (1996). "Small dams as barriers to freshwater mussels (Bivalvia, Unionoida) and their hosts." *Biological Conservation* **75**(1): 79-85.

WFD (2000). DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy.

Wiesner, C., Jungwirth, M. , S. Schmutz, G. Unfer and A. Zitek (2006). *Importance of connectivity in the Danube river catchment*. International DWA Symposium on Water Resources Management: Free passage for Aquatic Fauna in Rivers and other Water Bodies, 03.-07. April 2006, Berlin. DWA-Themen: 142-150.

Wiesner, C., G. Unfer, A. Zitek and S. Schmutz (2004). *Drift of juvenile freshwater fish in late autumn in a Danube tributary*. Proceedings of the Fifth International Conference on Ecohydraulics - Aquatic Habitats: Analysis and Restoration, 12.-17. 09.2004, Madrid: 117-123.

Williams, H. H., K. MacKenzie and A. M. McCarthy (1992). "Parasites as biological indicators of the population biology, migrations, diet, and phylogenetics of fish." *Reviews in Fish Biology and Fisheries* **2**(2): 144-176.

Winkler, G., H. Keckeis, W. Reckendorfer and F. Schiemer (1997). "Temporal and spatial dynamics of 0+ *Chondrostoma nasus* abundance at the inshore zone of large river." *Folia Zoologica* **46**(Supplement 1): 133 -150.

Wolter, C. (1998). *Population genetic investigation of common bream Abramis brama, silver bream Abramis bjoerkna, roach Rutilus rutilus and rudd Scardinius erythrophthalmus from waters of northeast-German lowlands*. Schriften zu genetischen Ressourcen. **11**. Berlin, IGR. 135.

Zitek, A. (1999). Fischökologische Untersuchung des Marchfeldkanalsystems im zweiten Jahr nach Flutung mit besonderer Berücksichtigung der Drift von Fischlarven. Institute of Hydrobiology and Aquatic Ecosystem Management. Vienna, University of Natural Resources and Applied Life Sciences.

Zitek, A. (2005). Fischökologisches Monitoring der Fischwanderhilfe an der Herrschaftswehr, Raabs a.d. Thaya. Vienna. Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Applied Life Sciences - BOKU. 77.

Zitek, A. (2006). POTENTIAL CRITERIA FOR MODELLING FISH/PRESSURE RELATIONSHIPS IN RUNNING WATERS - A LITERATURE REVIEW. Vienna. Institute of Hydrobiology and Aquatic Ecosystem Management, Department of Water, Atmosphere and Environment, BOKU - University of Natural Resources and Applied Life Sciences. 186.

Zitek, A., D. Fleischanderl, G. Unfer, A. Eisner, N. Baumann, R. Hornich, S. Muhar and M. Jungwirth (2004a). *Ecologically orientated flood control management at a lowland river: Leitbild-orientated measures and their influence on habitat and fish*. Proceedings of the 10th Kongress - INTERPRAEVENT, Riva del Garda, Trient, Italy, 24. - 27.05.04: 12.

Zitek, A. and S. Schmutz (2004). *Efficiency of restoration measures in a fragmented Danube/tributary network*. Proceedings of the fifth international conference on ecohydraulics - aquatic habitats: analysis and restoration (12.-17. 09.04), Madrid.

Zitek, A., S. Schmutz and M. Jungwirth (2004b). Fischökologisches Monitoring an den Flüssen Pielach, Melk und Mank - im Rahmen des Eu-LIFE Projektes "Lebensraum Huchen" - ENDBERICHT. Wien. Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Applied Life Sciences - BOKU. 113.

Zitek, A., S. Schmutz, G. Unfer and A. Ploner (2004c). "Fish drift in a Danube/sidearm-system: I. Site-, species-, and stage-specific drift." *Journal of Fish Biology* **65**: 1319-1338.

Zitek, A., S. Schmutz, G. Unfer and A. Ploner (2004d). "Fish drift in a Danube/sidearm-system: II. Seasonal and diurnal patterns." *Journal of Fish Biology* **65**: 1339-1357.

Zitek, A., G. Unfer, C. Wiesner, D. Fleischanderl and S. Muhar (2004e). Monitoring ökologisch orientierter Hochwasserschutzmaßnahmen an der Sulm/Stmk., Arbeitspaket: Lebensraum & Fischfauna. Wien. Studie im Auftrag des Amts der Steiermärkischen Landesregierung, Graz und des BM für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien.

MANUSCRIPTS (PEER REVIEWED IN BOLD LETTERS)

Manuscript I

Schmutz, S., A. Zitek and C. Dorninger (1997). "A new automatic drift sampler for riverine fish." Archiv für Hydrobiologie 139(4): 449-460.

Manuscript II

Mühlbauer, M., E. Traxler, **A. Zitek** and S. Schmutz (2003). "Das dynamische Fischwehr - Ein hochwassersicheres Fischwehr zur Untersuchung der Fischwanderung an kleinen bis mittelgroßen Flüssen." Österreichs Fischerei 56(5/6): 136-148.

Manuscript III

Jirsa, F., A. Zitek, O. Schachner (2006). "First record of *Lamproglena pulchella* Nordmann 1832 in the Pielach and Melk rivers, Austria." Journal of Applied Ichthyology, 22, 404-406.

Manuscript IV

Zitek, A., S. Schmutz, G. Unfer and A. Ploner (2004a). "Fish drift in a Danube/sidearm-system: I. Site-, species-, and stage-specific drift." Journal of Fish Biology 65: 1319-1338.

Manuscript V

Zitek, A., S. Schmutz, G. Unfer and A. Ploner (2004b). "Fish drift in a Danube/sidearm-system: II. Seasonal and diurnal patterns." Journal of Fish Biology 65: 1339-1357.

Manuscript VI

Wiesner, C., G. Unfer, **A. Zitek** and S. Schmutz (2004). "Drift of juvenile freshwater fish in late autumn in a Danube tributary." Proceedings of the Fifth International Conference on Ecohydraulics - Aquatic Habitats: Analysis and Restoration, 12.-17. 09.2004, Madrid. IAHR: 117-123.

Manuscript VII

Unfer, G. and **A. Zitek** (2000). "Der Vertical-Slot-Fischpass - Eine Fischwanderhilfe für räumlich beengte Verhältnisse." Österreichs Fischerei 53: 332-339.

Manuscript VIII

Schmutz, S., A. Zitek, S. Zobel, M. Jungwirth, N. Knopf, E. Kraus, T. Bauer and T. Kaufmann (2002). "Integrated approach for the conservation and restoration of Danube salmon (*Hucho hucho* L.) populations in Austria". Freshwater Fish Conservation - Options for the Future. M. J. Collares-Pereira, I. G. Cowx and M. M. Coelho, Eds. Oxford, Fishing News Books: 157-173.

Manuscript IX

Schachner, O. and **A. Zitek** (2002). "Auffälligkeiten der Sterblichkeit bei Nasen (*Chondrostoma nasus* L.) zur Laichzeit 2002 in der Melk (NÖ, Österreich)." Tagung der Deutschen und Österreichischen Sektion der European Association of Fish Pathologists (EAFP), Mondsee/Österreich: 6 pp.

Manuscript X

Zitek, A. and S. Schmutz (2004). "Efficiency of restoration measures in a fragmented Danube/tributary network." Proceedings of the Fifth International Conference on Ecohydraulics - Aquatic Habitats: Analysis and Restoration (12.-17. 09.04), Madrid. IAHR: 652-657.

Manuscript XI

Zitek, A., D. Fleischanderl, G. Unfer, A. Eisner, N. Baumann, R. Hornich, S. Muhar and M. Jungwirth (2004). "Ecologically orientated flood control management at a lowland river: Leitbild-orientated measures and their influence on habitat and fish." Proceedings of the 10th Congress - INTERPRAEVENT; Riva del Garda, Trient, Italy, 24. – 27.05.04: 12 pp.

Manuscript XII

Wiesner C., M. Jungwirth, S. Schmutz, G. Unfer and **A. Zitek** (2006). "Importance of Connectivity in the Danube River Catchment." International DWA Symposium on Water Resources Management: Free passage for Aquatic Fauna in Rivers and other Water Bodies, 03.-07. April 2006, Berlin. DWA-Themen: 142-150.