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Succession of fish diversity after reconnecting a large floodplain to the upper Danube River

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ABSTRACT

River floodplains are important for their biodiversity and productivity, yet are considered one of the most threatened ecosystem types. Due to increasing awareness of the ecosystem services provided by floodplains, their restoration and reconnection with the main channels have become core topics in policy, management and science. In one of the last remaining alluvial forests at the upper Danube River, a new secondary floodplain channel was artificially created in 2010 using a nature-orientated construction scheme. The objective of this study was to analyze the colonization and succession of the fish community in the new floodplain river and the adjacent temporarily connected floodplain habitats over a period of four years. Following the restoration-induced changes in habitat morphology and availability of habitat space, a very fast initial colonization was observed, with 46% of the source species pool of the Danube present in the study area after only two months. Colonization by fishes was explained by habitat features such as habitat morphology as well as biological features such as the species inventory of the source habitat and life-history traits. The time span required for developing functional demographic structures could be explained by the degree of specialization in different life stages, with faster population development in species with high ecological plasticity. The high representation of small individuals in multiple fish species indicates the importance of the artificial floodplain channel as habitat for early life stages. Consequently, the new floodplain channel seems to at least partly mitigate the habitat loss in the main river.

1. Introduction

Rivers and their floodplains are characterized by an exceptional richness in biodiversity and productivity (Junk et al., 1989; Ward and Tockner, 2001; Tockner and Stanford, 2002). At the same time, they are considered the most altered and threatened ecosystems of the world (Knutson and Klaas, 1998; Dudgeon et al., 2006; Geist, 2011). As a consequence of the increasing awareness that floodplain ecosystems provide important ecosystem services (Costanza et al., 1997; Feyrer et al., 2006), their restoration and reconnection with the main channel have become core topics in policy, management and science. Commonly applied restoration techniques involve technical modification of the physicochemical characteristics of existing habitats (e.g., the creation of new structures in existing floodplain channels) or the enhancement of longitudinal and lateral connectivity. Floodplain restoration typically intends to produce a great variety of initial habitat stages, which also provide an ideal study case to test general ecological principles of colonization and succession. In particular very early succession states are scarce in natural freshwater habitats and therefore the drivers which determine their ecological functionality and colonization are poorly understood (Milner et al., 2008). To date, the assessment of the success of floodplain restoration is rarely linked to basic ecological theory (Lake et al., 2007; Pander and Geist, 2013).

Life cycle strategies of riverine fish species are strongly dependent on lateral and longitudinal connectivity and on the specific habitat quality in a given area. Therefore the colonization of newly built or restored floodplain habitats with fishes can be an excellent indicator to measure the success of floodplain restoration and to understand the underlying ecological processes on the basis of ecological theory and species autecology.

At the Danube River, the second largest river in Europe with the world's most international river basin, a new permanent floodplain river was created to improve the lateral and longitudinal connectivity of the Danube and to restore the groundwater level fluctuations of the adjacent alluvial forest (Stammel et al., 2012). In addition to the newly constructed river sections, the floodplain

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river also comprises reconnected oxbow habitats. During high water levels, it also floods previously isolated ponds and connects them with the Danube.

The objective of this study was to analyze the colonization and succession of the fish community in the new floodplain river and the changes in existing adjacent habitats over a period of four years. In particular, the relative importance of source populations both in the reconnected Danube as well as in the pre-restored habitats, connectivity to source habitat, life history traits of colonizers, and physicochemical habitat properties of restored habitats was considered to test ecological theory on colonization of freshwater habitats and to deduce management implications.

The following hypotheses were tested:

(i) The artificial floodplain channel serves as substitute habitat for critical life stages of fishes and consequently mitigates the loss of habitat space and quality in the main river.
(ii) Colonization and succession patterns of fishes in the restored floodplain habitats depend on distinct habitat type properties, degree of connectivity and the fish community of the source habitat.
(iii) Colonization time and population development can be predicted based on data of life-history strategies and degree of specialization.

2. Material and methods

2.1. Study area

At the upper Danube River, 68 km north of Munich (Germany), a large-scale floodplain restoration project was realized in the year 2010 within the largest remaining contiguous alluvial forest (Stammel et al., 2012; Fig. 1). As many major European rivers, the Danube was subject to substantial structural changes over centuries (Tockner et al., 2009) for flood protection, hydropower use and reclamation of land. This resulted in channel straightening, embankment, reduced sediment transport, interruption of the river continuum, and disconnection from the floodplain. Due to the anthropogenic pressure, the fish community composition has changed towards increased abundances of potamal species and a decrease of rheophilic specialists. The potential fish ecological region of the Danube within the study area is the epipotamal (Leuner et al., 2013), being dominated by generalist species such as *Alburnus alburnus* L., *Rutilus rutilus* L. and *Squalius cephalus* L. The populations of the historically widespread rheophilic specialists *Barbus barbus* L., *Thymallus thymallus* L. and *Chondrostoma nasus* L. as well as Danube-endemic *Zingel streber* Siebold, *Zingel zingel* L., *Gymnochephalus schraetser* L. and *Gymnochephalus baloni* Holcik and Hensel have strongly declined or are meanwhile entirely absent (Bayerisches Landesamt für Umwelt, 2014).

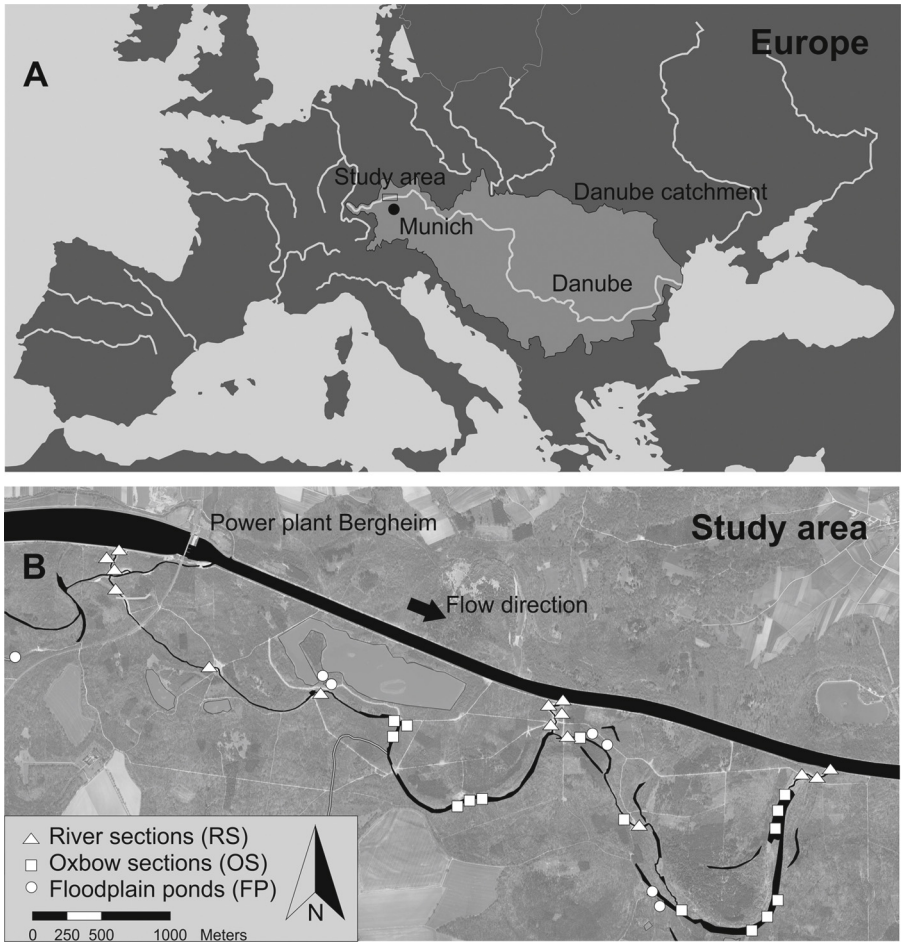

Fig. 1. Location and map of the study area. A = map of Europe with major rivers (white) and the drainage system of the river Danube (highlighted in medium grey). B = map of the study area with the location of all sampling stretches.