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Analysis of soil seed bank patterns in an oxbow system of a disconnected floodplain

André Schwab*, Kathrin Kiehl

Vegetation Ecology & Botany, University of Applied Sciences Osnabrück, Oldenburger Landstr. 24, 49090 Osnabrück, Germany

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ABSTRACT

Soil seed banks have a high potential for vegetation re-establishment in restoration projects. We studied the soil seed bank in an oxbow system of a disconnected floodplain of the Danube River in Southern Germany. The aim of the study was to analyze if floodplain target species were still present in the seed bank after more than 150 years of embankment and disconnection from fluvial dynamics. In this context we investigated seed density, seed bank species richness and species composition in four broad habitat types with and without water-level fluctuations during the time of embankment (permanent water, fluctuating water, reed bed, hardwood floodplain forest). In addition, the similarity between seed bank and above-ground vegetation in these habitat types was studied in order to predict the success of future restoration measures. In total, 124 vascular plant species were determined in the seed bank samples. More than 50 % (66 species) were target species typical for floodplain habitats and 26 of these target species were lost or very rare in the above-ground vegetation. The four habitat types differed significantly in mean seed density and mean species richness. Mean species richness and the number of target species in the seed bank as well as the mean seed density were greatest in the habitats with fluctuating water level whereas mean seed density was much lower in the parts with more or less stable conditions like permanently standing water and hardwood floodplain forest. Sørensen similarity between seed bank and above-ground vegetation was very low in habitats with more or less stable water levels and desirable floodplain target species were very rare or completely absent. Our results indicate that the soil seed bank can be an important seed reservoir for the ecological restoration of floodplain plant communities especially for habitats with unstable environmental conditions during the period of disconnection. Restoration of water level dynamics is important to maintain the seed bank of populations of floodplain target species.

1. Introduction

The ecological restoration of floodplains is a challenge on almost every river affected by humans in the last centuries (Jensen et al., 2006; Woolsey et al., 2007; Feld et al., 2011). Restoration targets aim to regain a functional floodplain as well as to preserve and enhance floodplain biodiversity (Mant et al., 2012; Doi et al., 2013; Mitsch and Gosselink, 2015). In the European Union, the Water Framework Directive and the Habitats Directive make river and floodplain restoration obligatory to reach a predefined "favorable ecological status" (European Union, 2000, 2004).

Due to small scale relief changes and their influence on hydrological regime natural floodplains of large rivers are characterized by different habitat types, which are important for many specialized plant and animal species (Ward et al., 1999, Mitsch and Gosselink, 2015). Plant communities in these habitats vary according to the gradient of natural river dynamics caused by fluctuating water levels and mechanical disturbance (Tockner et al., 1999; Ward et al., 2002). Today, the connection between rivers and floodplains is lacking in many anthropogenically transformed rivers and floodplain communities are degraded with strong negative effects on biodiversity (Gumiero et al., 2013). To stop this development fluvial dynamics can be restored by re-connecting rivers with their floodplains (Ward et al., 1999; Amoros, 2001; Bunn and Arthington, 2002; Nilsson and Svedmark, 2002). In such restoration projects, however, it is often not clear if restoration success depends only on the applied restoration measures or also on the initial conditions

* Corresponding author.
E-mail addresses: schwab.a@gmx.de (A. Schwab), k.kiehl@hs-osnabrueck.de (K. Kiehl).

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concerning abiotic factors, pre-restoration plant communities and soil seed banks.

Soil seed banks are repositories from past and present vegetation and have great potential in restoration projects to enable the re-establishment of plant communities (e.g. Grime, 1979; Bakker et al., 1996; Baskin and Baskin, 1998; Liu et al., 2009; Lu et al., 2010). While Goodson et al. (2001) pointed out the general lack of knowledge concerning the role of soil seed banks in riparian systems, some recent studies have analyzed the seed banks of riparian habitats in relation to the burial depth (O'Donnell et al., 2014), under the influence of non-native tree species (Skowronek et al., 2014) and according to flow regulation (Greet et al., 2013). In France, Abernethy and Willby (1999) investigated the composition and density of propagule banks in aquatic habitats which changed along a gradient of disturbance. These authors found that species richness and seed density of the seed bank decreased with decreasing disturbance and that seed bank similarity to the above-ground vegetation is higher in regularly disturbed than in stable habitats. Little is known, however, if and how long floodplain species, which are adapted to regular disturbance, can survive in the soil seed bank of disconnected floodplains without regular flooding. To our knowledge no study exists, which compares soil seed banks under fluctuating and stable conditions for aquatic as well as for terrestrial and semi-terrestrial habitats in a disconnected floodplain.

The river Danube is one of the largest rivers in Europe, with only a few natural or near-natural floodplain areas. In Germany, a large scale restoration project planned to re-connect the old oxbows of a Danube floodplain forest with the river and to enhance fluvial dynamics more than 150 years after embankment (Stammel et al., 2012). Before restoration, this area included habitat types with rather stable conditions, such as terrestrial hardwood floodplain forest or old deep backwaters with permanently standing water but also habitat types with fluctuating environmental conditions such as temporary backwaters with fluctuating water levels or reed beds (Margraf, 2004; Lang et al., 2011). The aim of our study was to investigate the soil seed bank of these major habitat types to answer the following questions:

1. Are target species typical for floodplains still present in the seed bank more than 150 years after embankment and disconnection from fluvial dynamics?
2. Are there differences in seed bank species richness and species composition between habitat types differing in initial conditions like water regime (area, depth, duration and timing) and due to influence of the construction works?
3. How similar is the species composition of the soil seed bank and the above-ground vegetation in different habitat types of a disconnected floodplain?

2. Materials and methods

2.1. Study area

The study area, a floodplain forest of 1200 ha is located on the Danube River between Neuburg (48°43′49.0" N, 11°11′19.6" E) and Ingolstadt (48°45′59.5" N, 11°25′32.7"E), Southern Germany (Fig. 1) at elevations between 368 m and 378 m a.s.l. Average annual rainfall is 700–750 mm and mean annual temperature 8.8 °C (1990–2012, Deutscher Wetterdienst, Karlshuld).

Important changes of this part of the river Danube started around 1820 with river straightening, embankment and incising of the river bed. Around 1970 two hydropower dams in Bergheim and Ingolstadt were constructed (Stammel et al., 2012). Due to the altered connection between river and floodplain, which resulted in altered hydrology, large areas of the floodplain with former channels and oxbows degenerated to terrestrial forest (Margraf, 2004; Lang et al., 2011). Only a few backwaters with more or less stable water level by 1–2.5 m depth remained. Areas with frequently fluctuating water levels were rare in the floodplain and water level changes were mostly due to ground- or rainwater influence. Recent larger floods of the Danube River (HQ 10), which covered a bigger part of the study area, only occurred in 1999 and 2005. Restoration planning started in the early 1990s aiming to restore hydrological dynamics within the floodplain (Stammel et al., 2012). We focus our study area on these parts, which are affected by the two main measures (Fig. 1): A new floodplain water course with dynamic

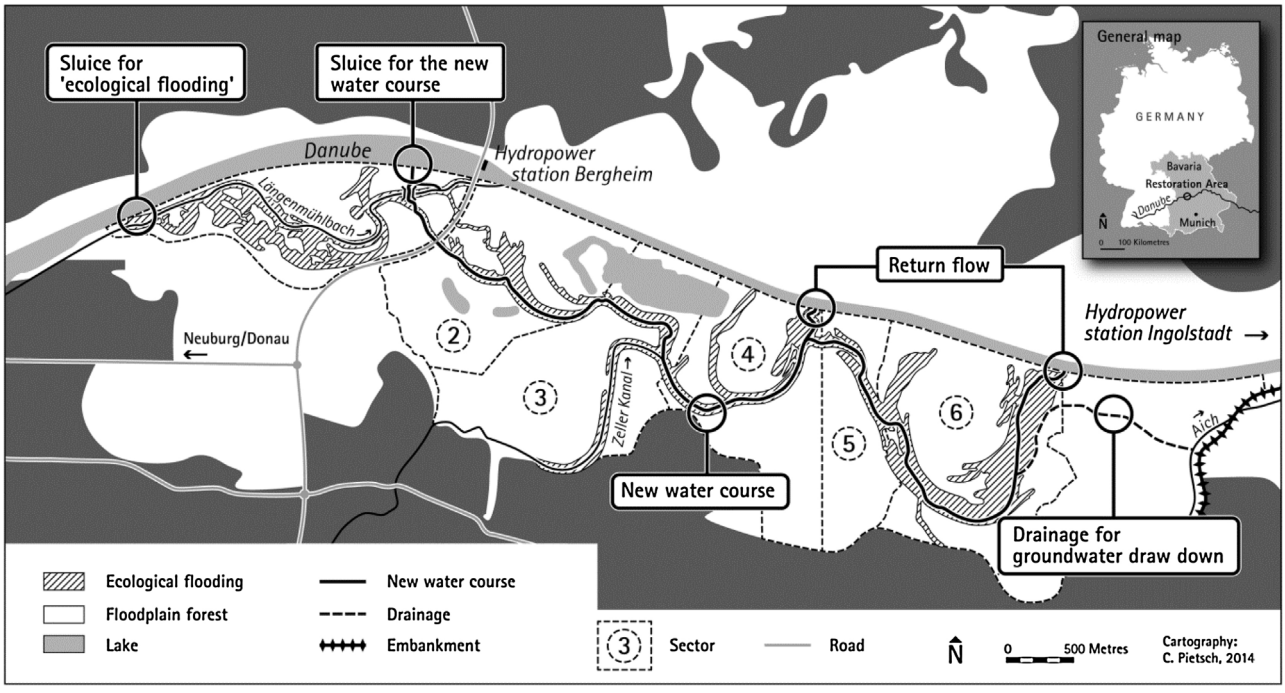

Fig. 1. Study area and restoration measures; sector: division of the study area depending on the water regime before start of the restoration (Table 1, Lang et al., 2013).