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How restoration measures can affect biogeochemical cycles in protected floodplain areas along the Danube River

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Abstract

Floodplain ecosystems have a strategic role in biodiversity aspects in intensely used catchments and can provide multiple functions and services of importance for human well-being. Especially floodplains in the vicinity of urban areas can be areas of conflicting interests, as it is the case in floodplains in the Danube Nationalpark downstream Vienna. The alteration of riverine landscapes has led to increasing efforts in water management, also concerning rehabilitation and restoration activities, especially in areas of high nature value. The Lobau within the city limits of Vienna for example has undergone severe changes by mainly altered ground- and surface water connectivity and urban development in the last 20 to 100 years which result in various alterations including changes in biogeochemical cycling. In order to estimate the effects of different management options related to conservation and restoration and compare the situation in restored and degraded floodplain systems, nutrient dynamics as key ecosystem properties and functions are analysed. We demonstrate that principles of hydromorphological dynamics control potential greenhouse gas emissions and the nutrient status in the water column and sediment compartments and these can be used as proxies to assess environmental changes in floodplain systems. Changes in hydromorphology as introduced by restoration measures may stimulate nitrogen turnover and can even reduce greenhouse gas emission of nitrous oxide compared to degraded floodplain systems. The results clearly show that increasing hydrological connectivity can impact various ecosystem properties and ecosystem services and these effects have to be considered in a sustainable management approach of highly valuable areas, such as protected areas and national parks.

The example of the Nationalpark Donau-Auen showcase the importance to focus research efforts on remaining intact ecosystems and present the positive impacts of continuous research efforts for improved understanding of river-floodplain systems in general and the value of specific insights for local management decisions.

Keywords

river restoration, large river, nitrogen, nutrient, Nationalpark

Introduction

Floodplains are providing a multitude of ecosystem service, which are of key importance for river systems, acting as biogeochemical hot spots of nutrient cycling and carbon processing. As central sites of nutrient transformation, floodplains can prevent river and even coastal eutrophication (RICHARDSON 2004) and the accumulation of toxic compounds such as heavy metals in their sediments also contribute to these purification effect. In terms of carbon cycling, floodplains play a major role in the recycling and removal of soluble organic carbon released from terrestrial ecosystems (BATTIN et al. 2008).

River regulation severely impacts the ecology and morphology of the river system, including the adjacent floodplains. The majority of floodplains have been lost and with them the associated ecosystem services they provide. These anthropogenic effects can drastically change the structure and function of microbial communities, and also affecting the control and cycling of carbon and nitrogen in rivers (HEIN et al. 2004). Depending on the composition and their activity, these biological units can increase the nutrient spiraling, especially that of nitrogen. Areas of high nutrient cycling activity are found in regions and subsystems coupled with high hydraulic retention - for example, in riparian zones, wetlands, and floodplains. The speed and efficiency of carbon and nitrogen cycles are, along with the composition of the present microbial community, significantly shaped by three principles: the hydro-morphological conditions (e.g. the hydrologic network of streams), the frequency and duration of sediment-river water contact, and hydrological extremes such as high- or low-water phases.

Interventions such as an altered flow regime, or a modification of the river landscape structure, or the interaction between landscape elements leads to changes in the biogeochemical processes, as well as causing a temporal shift of metabolic processes and therefore has a larger impact on nutrient transport and retention.

The presented research summarizes results on the effects of changed surface water exchange on whole ecosystem processes in selected floodplain areas of the Nationalpark Donau-Auen, one of the last remnants of riverine floodplains along the Upper Danube.

Key questions have been how a change in connectivity impact nutrient cycling, expecting a biogeochemical activation following restoration measures. The research was performed in the national park area as these areas one of the last to study the effects under less constrained environmental conditions and furthermore, the results can be used to optimize future measures in this very sensitive stretch.

The article provides a summary of results and more details, especially technical information, can be found in the references cited.

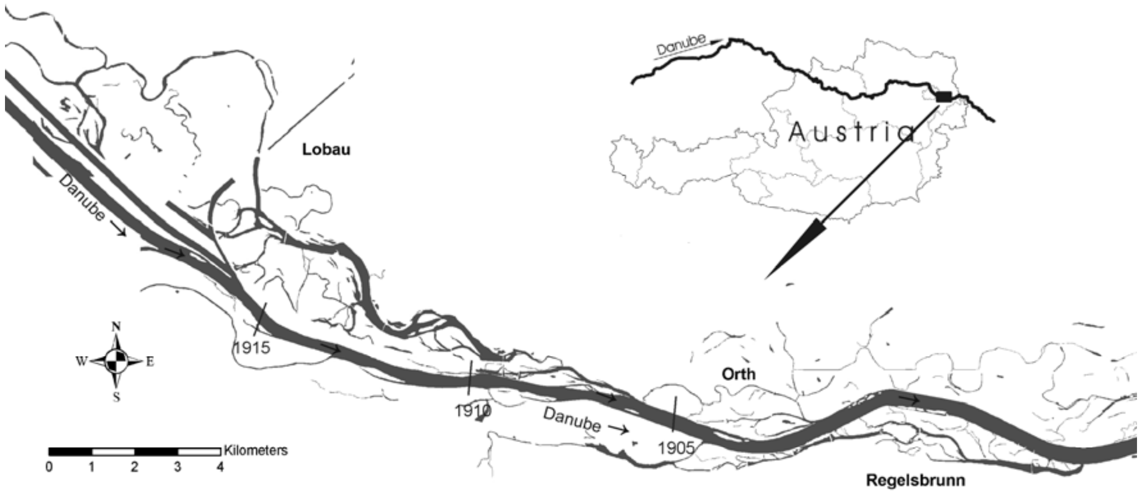

Figure 1: Selected floodplain areas along the Danube River east of Vienna. Insert: location in Austria.

Study Site

The two floodplains, Lobau and Orth, are within the boundaries of the Alluvial Zone National Park, located downstream of the city of Vienna, Austria (Fig. 1). In this area, the Danube River is a 9th order river with a drainage basin of 104 000 km^2. The flow regime has an alpine character with variable and stochastic patterns (regulated low discharge = 915 m^3s^{-1}, mean discharge = 1930 m^3s^{-1}, annual flood discharge = 5300m^3s^{-1}, 30 year max. flood discharge = 9340 m^3s^{-1}). Following the major regulation scheme in 1875, the Danube River was confined between flood protection dams, thus the main channel was disconnected from the adjacent floodplains.

The Lobau floodplain covers an area of approximately 23 km^2. As no significant restoration measures have been undertaken within the Lobau floodplain, it is not integrated within riverine flow and in this study, considered as an altered and degraded floodplain based on the altered surface water exchange. Aside from ground-surface water exchange and a controlled small water intake, the primary water exchange with the main channel takes place through an artificial 5m wide breach in the flood levee in the Lobau's south-eastern end (HEIN et al. 2006).

In contrast, the reconnected and restored floodplain Orth, located downstream of the Lobau floodplain covering approximately 5.5 km^2, is characterized by very diverse flow conditions following restoration measures to increase the surface water exchange. Some side arms in this system have through-flow conditions just above riverine summer mean flow (2230 m^3s^{-1}), while others are connected only at much higher flow conditions. These changes provide the basis to analyse the effects of frequent periods of flow in the floodplain (HEIN et al. 2004).

Results and discussion

The results are summarized in the references listed in the reference section. These results confirm that an increase of surface water connection with the Danube River improved nitrogen removal capacities in the adjacent floodplains (WELTI et al. 2012 a, b, c). Yet, it is not the hydrological connections alone that control denitrification processes occurring in the floodplains – the specific morphology of the site within the floodplain determines the available carbon sources and creates the optimum conditions for denitrification. In controlled laboratory experiments, we demonstrated that denitrification is controlled not only by the supply of nitrate, but also by the available dissolved organic carbon sources found in the water column. River water, although containing less dissolved organic carbon, has a higher carbon quality during certain time periods, which provided the necessary substrate for denitrification. Denitrification rates were shown to increase in areas where the Danube River regularly flooded. Based on the results of the hydrology and ecology, a model was developed to spot potential areas of denitrification during different discharge conditions and during flooding events TRITTHART et al. 2011, WELTI et al. 2012c).

On the other hand, laboratory experiments clearly showed that the phosphor dynamics in sediments are affected by changes in wetting and drying cycles of riparian zones. A more pronounced phosphorus release from sediments can be observed after complete drying of sediments and following frequent dry/wet cycles. The results are presented in SCHÖNBRUNNER et al. (2012). The implication of changes in phosphorus dynamics are discussed in BONDAR-KUNZE et al. (2009).

The most important finding of this research is the role of restored floodplains on overall biogeochemical cycling and major factors influencing N cycling and N_2O versus N_2 emission and the release of phosphorus. We have shown that restoration, by increasing the frequency of inundation will improve biogeochemical cycling efficiency and reduce N_2O emissions from denitrification compared to decoupled systems. Overall, the research improved understanding of the function of different subsystems within a riverine landscape as well as the role of overall transformation capacity, and biogeochemical interplay within floodplain systems and highlighted the importance to restore ecosystem processes such as biogeochemical cycles for a sustainable development of protected areas. The results can be used for the design of future restoration measures addressing nutrient retention aspects.

Furthermore, the new insights can improve the understanding how complex fluvial landscape react on different measures and what overall changes can be expected, also in line with multiple utilization patterns (SANON et al. 2012). In line with some general topics of the conference, the research presented here points to the important role of Nationalpark areas for continuous research programmes such as LTER programmes to understand changes over long term periods including restoration activities and provide science based information for future management decisions.

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