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# The importance of heterogeneous shoreline habitats for ecosystem functions in large regulated rivers

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## Keywords

Danube, shoreline habitats, organic carbon cycling, river restoration

## Summary

River systems have long been viewed as drainage pipes simply transporting terrestrial matter to the oceans, but are actually active players in the global carbon cycle and a key ecosystem property. Large amounts of organic carbon and nutrients are not only stored in river sediments, but are also degraded, transformed and mineralized due to microbial activity in the water column and sediments (BATTIN 2009). Especially for regulated rivers and water ways with altered main channel habitats, riparian habitats and shoreline structures are considered to be bioactive zones, so called 'hot spots', for biological activities (e.g. HEIN et al. 2005).

In the last century the Danube, like most large rivers of highly urbanized and developed regions (see e.g. PETTS et al. 1989; DYNESIUS & NILSSON 1994; WARD 1998), has been morphologically modified to a large extent for flood protection, navigation and hydropower production. The Danube reach downstream of Vienna is one of the last remaining free flowing sections of the Upper Danube. It is surrounded by the largest still existing floodplain landscape in central Europe- a designated Natura 2000, Ramsar and Nationalpark area. While still exhibiting its high ecological value, this former highly dynamic river ecosystem was hydrologically decoupled to a large extent due to radical and far-reaching river engineering measures. Channelization and straightening of the fluvial corridor has increased the flow of surface water and minimized contact time and space between the active channel and it´s riparian subsystems as bioactive zones. Therefore, especially during mean and low water levels, instead of extended floodplains and heterogeneous river banks, artificial shoreline habitats, such as groyne fields or restored side arms, are the only remaining structures within the riverine landscape with a potential of performing some important functions in the carbon and nutrient cycle.

Ecologically orientated planning and management of biological active areas, thus require an understanding of the relationship between their structures and functions (VERHOEVEN et al. 2006). However, until recently the restoration focus was mainly on morphological structures rather than on processes and functions (FRIBERG et al. 2016). Therefore, in this study we investigated the carbon dynamics of different artificial and altered shoreline habitats assuming, that morphological structures and hydrological patterns frame sediment dynamics, which in turn control the carbon cycling in these habitats. We also expected that based on these environmental conditions some habitats will show an intense cycling and thus, could be identified as key habitats for carbon cycling in regulated rivers. Therefore, we compared six different shoreline habitats in March and April 2015 at water levels below riverine mean water level as to the turnover and degradation of organic matter in the water column and sediments (e.g. DOC concentration, benthic respiration, extracellular enzymatic activity). A groyne field, a secondary flow channel and a restored side arm, all relatively dynamic and well connected to the main channel during the period of this study, were sampled in the free flowing reach of the Danube. The other three habitats are artificial shoreline habitats within the impounded section of the Danube in Vienna, built as compensation measures in the course of the construction of the hydroelectric power plant Freudenau. One of these sites is only connected to the Danube via pipe culverts, one has several lateral connections upstream and downstream and the third one is a shallow habitat with a single downstream connection to the main channel (Fig. 1 showing 5 of 6 habitats).

Our results show that the less dynamic and more isolated shoreline habitats were the ones where more fine sediment accumulation occurred. The mean share of fine sediment to total sediment varied from 13 to 92%, and was of mostly mineral origin, with organic contents ranging from 0.6 to 5.4 %. The accumulation of fine sediment and organic content was highly correlated though.

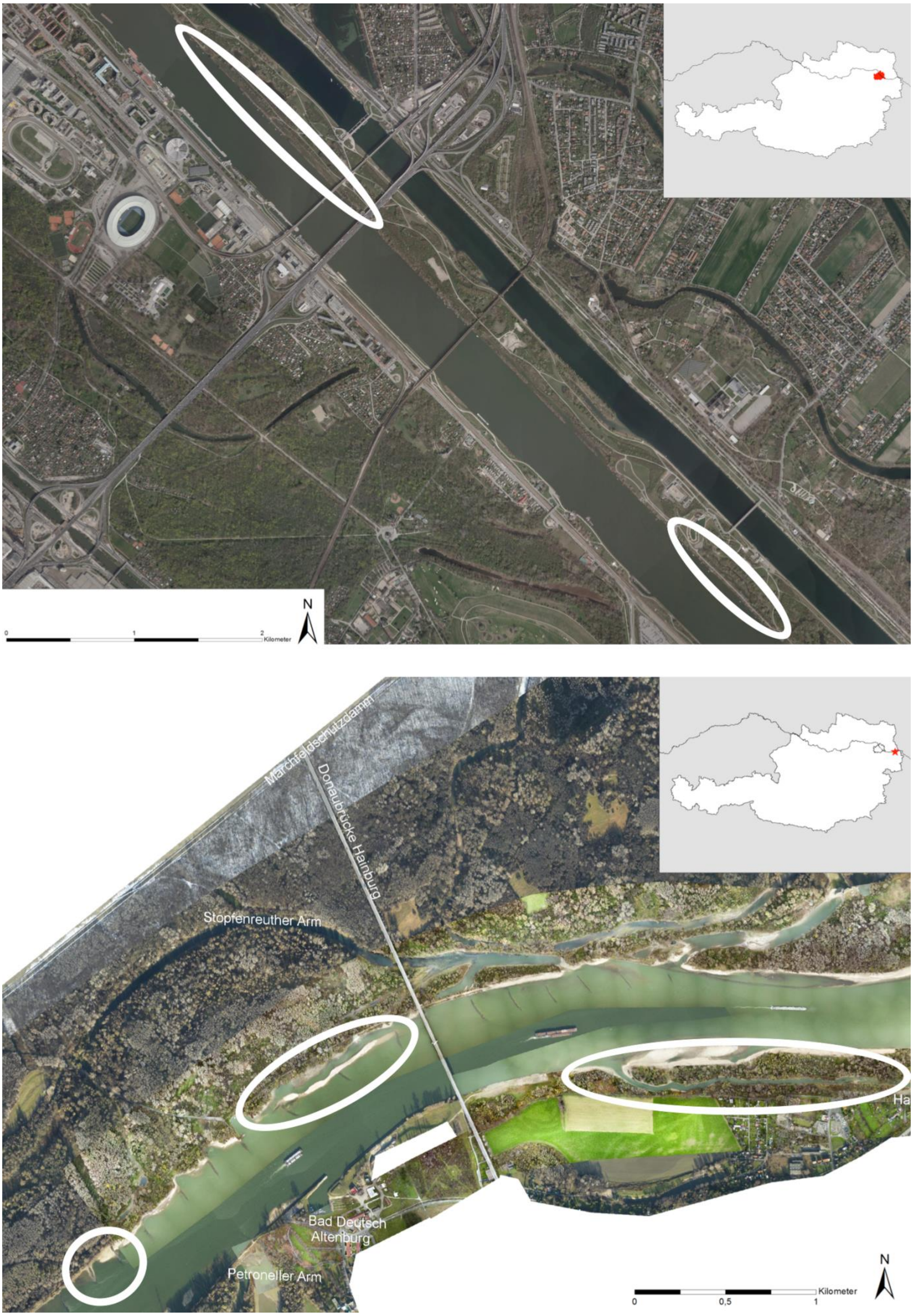


Figure 1: © ArcGIS (ESRI World Topo Map), via Donau

This has a massive influence on biological processes and the ecosystem functioning of these habitats, because sediment properties turned out to be the main factor influencing microbial activity and carbon turnover. Benthic respiration, extracellular enzymatic activity and the amount of DOC in the sediments for example increased significantly with the share of fine sediment. Similar respiration rates as to the ones from the isolated habitats were found in fine sediment dominated rivers like the Elbe River, while the values of the more dynamic habitats were comparable to gravel bed streams and rivers with high amounts of allochthonous organic material (FISCHER & WILCZEK 2006). If the overall river dynamics cannot be restored - as in impoundments - the character of shoreline habitats of gravel bed rivers may differ drastically from pristine conditions. However, these shallow and isolated habitats might be able to partly compensate for the lack of adjacent floodplains in terms of storage and turnover of organic carbon, at least on a small scale. The results for the dynamic habitats in the free flowing section on the other hand approach more riverine type conditions, with the secondary flow channel showing a significantly higher response in microbial activities in the sediments than the groyne field and the reconnected side arm.

In summary, different shoreline habitat types in large, regulated rivers- from shallow, isolated to dynamic and connected ones- offer a wide range of processes and functions regarding the carbon cycling. In highly transformed rivers with limited possibilities to achieve pristine conditions due to flood protection, navigation and hydropower production, these artificial shoreline habitats can contribute to an improved ecosystem functioning and ecosystem service provision.

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