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# The development of abandoned side-channels: ecological implications and future perspectives

**Walter Reckendorfer[1,2], Marlen Böttiger[3], Andrea Funk[1,2] & Thomas Hein[1,2]**

[1]WasserCluster Lunz, Austria
[2]Institute of Hydrobiology & Aquatic Ecosystem Management, Department of Water, Atmosphere & Environment, BOKU - University of Natural Resources & Life Sciences Vienna, Austria
[3]University of Vienna, Department of Limnology, Austria

## Abstract

River–floodplain habitats have been strongly affected by damming and river regulation, which have initiated long-term trends towards terrestrialization and fragmentation. We studied the terrestrialization processes in the Donau-Auen National Park over the last 80 years by means of airborne images. The aggradation of side-arms is an ongoing process. The main parameters affecting the terrestrialization process are river bed degradation, the connectivity to the main river and the size and shape of the water bodies. As smaller water bodies silt up faster than larger ones, the process of terrestrialization speeds up. From a nature conservation point of view, inhabitants of small temporary water bodies such as amphibians and molluscs are particularly affected. First results of river engineering projects to re-connect abandoned side-channels show that the trend may be impeded. But for a sustainable solution of the problem the stop of river bed degradation is indispensable.

## Keywords

Terrestrialization, river management, river engineering, isolated, connectivity, Lobau, wetland

## Introduction

Land use changes in the catchment and water engineering measures such as channelization and impoundments have led to severe impairment of river-floodplain-systems (PETTS et al. 1989). The Donau-Auen in Vienna (Lobau) were not spared from these developments. Originally, this river landscape was in a dynamic equilibrium, i.e. a balance between erosion of existing and aggradations of new floodplain terrain existed (e.g. HOHENSINNER et al. 2008).

As a result of the Danube regulation in the late 19th century and a chain of imoundements upstream, the dynamic equilibrium now is disturbed, and aggradation of the floodplain and siltation of its water bodies prevail (HOHENSINNER et al. 2008, KLASZ et al. 2013).

About 10 years ago first restoration measures with the aim to reduce the sediment load in the Lobau (controllable weir, HEIN et al. 2006) have been implemented and it's a key question to predict effects of restoration measures on hydromorphological processes. Of great importance in this context is which factors affect the siltation rates in the various water bodies. Certainly the sedimentation during floods (RECKENDORFER & HEIN 2006) plays a significant role. Other potential factors are the conditions in the river itself (degradation of the river bed, RECKENDORFER et al 2005), as well as changes in the groundwater table in the "Marchfeld", where it came to significant reductions in the water table in the 1970s.

Within the project "Gewässervernetzung (Neue) Donau - Lobau (Nationalpark Donau-Auen)" these issues have been analysed in detail to answer open questions related to the silting of the Lobau. We used a multi temporal landscape analysis with high temporal resolution based on visual interpretation of aerial photographs from 1938 to 2005 to visualize and quantify the large-scale changes in the landscape. These changes reflect the processes which are acting now within the area and allow assessing their impact on the landscape and on threatened species and habitats. The morphological changes in the river-floodplain system were analysed with respect to the above mentioned controlling factors (sediment, bed degradation, groundwater levels, ...). The geostatistical analysis of the data led to a prediction model for the further development of the Lobau and its habitats for threatened species (FFH).

## Methods

The study area is located below Vienna on the left bank or the Danube (river km 1918-1908). The region, with a size of about 30 km², is bordered by the "Marchfeldschutzdamm" in the south and the Schönauer Rückstaudamm in the north. Fifty-two water bodies (sections) were delineated based on transverse check dams, points of intersection, fjords (natural high points) and changes in morphology. Aerial photographs and digital orthophotos from 1938 to 2005 were analysed. The aerial photographs from 1938, 1960, 1968, 1973, 1973, 1980 and 1986 were rectified and georeferenced. From the years 1992, 1996, 1997, 1999, 2000, 2004 and 2005 orthophotos were available. Aquatic and semi aquatic areas were delineated. Areas were classified as aquatic or semi-aquatic when they were either free of vegetation, or had typical riparian vegetation (sedges, reeds, cattails). This procedure ensured that the analysis was independent of the actual water level at the time of recording. Between two consecutive time-periods the rate of sedimentation was calculated as:

$S = [-1 + ((F2/F1) (1 / J))] * 100$
F1: aquatic and semi-aquatic area at time 1 (= starting time of the observation period)
F2: aquatic and semi-aquatic area at time 2 (= end point of the observation period)
J: difference in years between the starting and ending time

Positive sedimentation rates occur when there are gains in water areas, and negative numbers when water areas disappear.

The relationship between the rate of sedimentation and the hydrological and morphological parameters was analyzed using a linear model (forward selection of variables).

The following predictor variables were used:

- Water levels of the Danube
- Water levels in the Lobau area
- Ground water levels in the Marchfeld area

Based on these hydrological data and a digital elevation model of the Lobau the following hydromorphological parameters were estimated or calculated for each homogeneous section using a geographic information system (ArcGIS, ESRI):

- Surrogate parameters for connectivity:
    - Distance to the Schönauer Schlitz (m) - the distance a body of water inflow to the Schönauer Schlitz in meters;
    - Connection (m) - height at which a water body is connected to the Danube;
    - Connection rate (%) - relative frequency of access to the Danube
    - Water level (m) - Water level at the gauge Fischamend (km 1908);
- Surrogate parameters for the impact of dam seepage:
    - Distance from the Danube (m) - the distance a body of water to the Danube and New Danube in meters;
    - Distance to flood control dam (m) - the distance a body of water to the flood control dam in meters;
- Surrogate parameter for energy input and autumnal leavefall: Direct sunlight (hours per day);
- Surrogate parameter for the permanence of a body of water: Frequency of water coverage (%);
- Surrogate parameter for the shape of a body of water:
    - Mean Shape Index; higher values indicate a more complex form;
    - Fractal dimension; the fractal dimension varies between 1 for compact, simple shapes and 2 for complex shapes (McGarigal & Marks 1994);

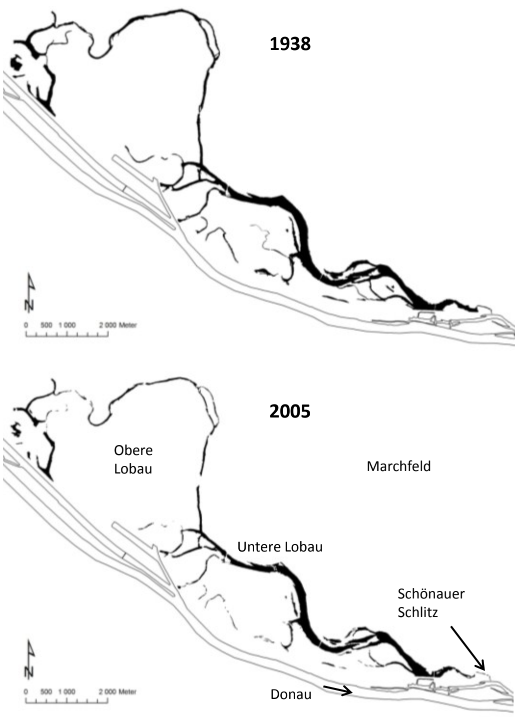


Figure 1: Development of aquatic and semiaquatic areas in the Lobau Floodplain between 1938 and 2005.

## Results

Over the period of 66 years, a significant reduction of the aquatic and semi-aquatic areas by 30 % is evident (P <0.05, Figure 1).

If the Obere and Untere Lobau are considered separately, a higher sedimentation in the Obere Lobau is apparent. This is due to the fact that the siltation of small water is much faster than that of larger ones (Figure 2) and the waters bodies in the Obere Lobau are significantly smaller. Another factor affecting the siltation is the shape of a water body: Complex, narrow waters dry up faster than wide or compact ones.

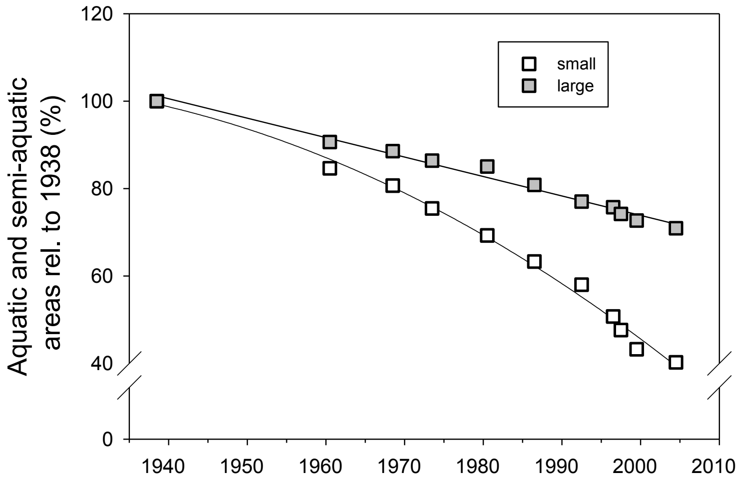


Figure 2 Development of the aquatic and semi-aquatic areas during the study period (1938 - 2005) separately for small and large water bodies

The average sedimentation rates ranged from 0.2 to 3.5% per year. Between 1996 and 1997 the sedimentation rate was particularly high (Figure 3). There was a significant trend with an acceleration of the sedimentation rates in the last decades (r = 0.66, p = 0.038).

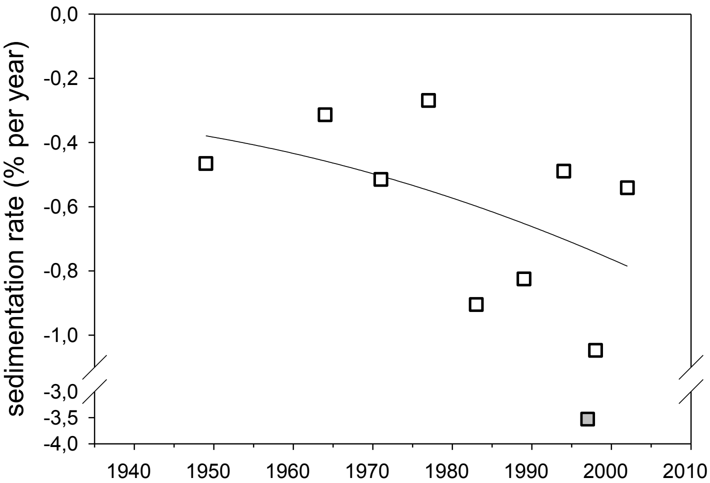


Figure 3 Development of sedimentation rates; the sedimentation rate between 1997 and 1998 (marked in gray) was not considered for the regression shown.

A general linear model explained 29 % of the variability in the sedimentation rates. The siltation of water bodies is promoted by a small size, an elongated or complex shape, the river bed degradation in the Danube, and a frequent downstream connection.

## Discussion

The present study demonstrates a strong sedimentation of backwaters in the study area and underlines previous findings of SCHRATT-EHRENDORFER & ROTTER (1999), DISTER (1994) and AMOROS (1991) who also described significant terrestrialisation in isolated floodplains. SCHRATT-EHRENDORFER & ROTTER (1999) calculated a loss of more than 40 hectares of water bodies and wetlands in 50 years for the total Lobau area. Our data showed a loss of 93 ha in 56 years, including 66 ha in the Untere Lobau and 27 acres in the Obere Lobau. All authors refer to a close correlation between the extent of siltation and the connection to the main stem of the parent river. In waters with decreased hydrological dynamics, fine sediment accumulation is favoured, a frequent upstream connection leads to reduced sedimentation (RECKENDORFER & STEEL 2004). A downstream connection, however, has the opposite effect: Frequently connected waters often receive a high input of suspended solids from the river. In contrast, isolated waters, without connection to the main stem or in large distance to the river receive less suspended solids since the sediment load decreases with increasing distance to the river (RECKENDORFER et al. 2013).

Small oxbow show particularly high sedimentation rates. This can be explained by a relatively higher allochthonous nutrient and sediment input associated with a small size and shallow depth. The river bed degradation in the Danube of about 2-3 cm / year (since 1938 about 1-1.5 meters; RECKENDORFER et al. 2005, KLASZ et al. 2009) also had negative impacts in the studied floodplain. Due to artificial bed load addition by the "Verbund Hydro Power AG" this trend is now stopped and no longer relevant for the future development.

As smaller water bodies silt up faster than larger ones, the process of terrestrialization speeds up. From a nature conservation point of view, inhabitants of small temporary water bodies such as amphibians and molluscs are particularly affected (FUNK et al. 2012). First results of river engineering projects to re-connect abandoned side-channels show that the trend may be impeded. But for a sustainable solution of the problem the stop of river bed degradation is indispensable.

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## Contact

Walter Reckendorfer
walter.reckendorfer@wkl.ac.at

WasserCluster Lunz
Dr. Carl Kupelwieser Promenade 5
3293 Lunz am See
Austria

Institute of Hydrobiology & Aquatic Ecosystem Management
Department of Water, Atmosphere & Environment
BOKU - University of Natural Resources & Life Sciences Vienna
Max Emanuel-Str. 17
1180 Vienna
Austria