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Development of an integrated modeling tool to assess the nutrient dynamics and trophic status of a decoupled floodplain along the Danube River in Austria

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Abstract

The Lower Lobau, a floodplain of the River Danube southeast of Vienna, today represents a back-flooded groundwater-fed lake system, mainly decoupled from the main stem of the river.Ongoing terrestrialisation processes have led to a reflection on restoration measures aiming at the improvement of thelateral connectivity of the Lower Lobau. Potential measures plan to increase the hydrological dynamics and are expected to have far-reaching consequences on ecosystem processes and properties. In line with these expectations, the measures are supposed to have a major impact on the cycling of matter and the sediment balance.Therefore, a dynamic water quality model is adapted to cover the trophic development of surface water quality for different management options. WASP 7 (Water Quality Analysis Program, DiToro et al. 1983, Ambrose et al. 1988) is a 2- dimensional compartment-modeling program including water column and the uppersediment layer.Based on hydrological data the model computes the limnochemical conditions, nutrients and algaeunder varying hydrological and seasonal conditions in hourly time steps.Based on this coupled model approach we expect a high potential to predict the effects of the planned measures on the trophic development in different habitats andto locate hotspots of ecosystemmetabolism.

Keywords

primary production, nutrient cycling, modeling, floodplain restoration

Introduction

In functionally intact river-floodplain systems lateral exchange processes are essential for the biogeochemical cycling (Thorp et al. 2006), which is the basis for primary production and other fundamental ecosystem properties (Junk & Wantzen 2004). Regulation and damming have led to fragmentation and disrupted structure and function of most European rivers (Ward 1998, Friedl & Wuest 2002).These human alterations have led to reduced hydrological connectivity and in consequence to changes in biogeochemical cycling and productivity patterns (Hein et al. 2004), which has also been observed in floodplains of the Danube (Welti et al. 2012, Preiner et al. 2008). One of the floodplains in this region, the Lower Lobauis characterized by the continuing loss of aquatic and semi-aquatic habitats during the last decades (Hein et al. 2006, Reckendorfer et al. 2005, Schiemer 1999). Despite degradation, the areas ecological value is still high (Alluvial Zone National Park, Natura 2000, NP, RamsarConvention area).

Table 1.Areas with different hydrological connectivity with the main channel of the River Danube and their percentage on total surface-water areas.

Connectivity	Area (m²)	% of total area
> 100 d a^{-1}	719480	43,8
< 100 d a^{-1}	602764	36,7
floods	321193	19,5

Considering the trend in the hydromorphological development since the major river regulation in the 19th century, restoration efforts in the Lower Lobauare essentialto improve the ecological conditions (Sanon et al. 2012). Though, the realization is difficult because of multiple different partly conflicting use forms, like drinking water supply for the city of Vienna, recreation and ecologyof the area.

Addressing major aspects of expected changes, a comprehensive modeling framework is developed to generate reliable prediction of the effects of potential restoration measures on the surface- and groundwater hydrology, water quality and ecological parameters.

Main objective of the presented studyisthe application of a generally accepted and for this case study adapted water quality model (WASP 7.5) to accessthe spatial development of the phytoplankton biomass and main nutrients for different potential restoration measures and varyinghydrological situations. Aim is to detect, whether internal nutrient sources or external sources from the Danube River are mainly controlling the nutrient dynamics and the trophic development in different floodplain sections and how this is changed by different restoration measures.

In this paper the general problem, the restoration setting and the modeling approach are presented.

Study site

The Lower Lobau is a large floodplain area (1,040 ha) at the eastern border of Vienna, where the Danube is a 9th order river and drains a 104,000 km². The annual flow is characterized by an alpine regime with highly variable and stochastic patterns and a mean discharge of 1,950 $m^3\ s^{-1}$.
The historically braided river section has been strongly altered by regulation schemes conducted in the late 19th century, cutting of the side-arm systems from the main channel. The Lower Lobau is part of the semi-natural reach of the River Danube between Vienna and Bratislava which represents one of the last remnants of river-floodplain systems (SCHIEMER 1999) in Europe and has been designated as a National Park ("Alluvial Zone National Park") in 1996.

Hydrological conditions

The water body of the Lower Lobau is devided into distinct basins (Figure 1), connected only at its downstream endto the main channel and thus is characterized by a backflooded flooding pattern. The hydrological conditions in the basins are determined by the water level of the river. Surface water connection in the downstream parts of the Lobau is established at a point of 0.5 m above mean water level, which happens on about 137 days per year. The higher the water level, the more basins are connected. Some basins are only connected during floods.Potential restoration measures are aimed to establish an upstream surface-water connection between main channel and side-arm for more than 300 days per year.

Restoration measures

Two different restoration measuresto increase the upstream connectivity are considered. First, a controlled reconnection with low discharge (4.5 m^3s^{-1}) will be constructed(2012 – 2013) to decrease the hydrological retention time and establish transport phases in large sections of the Lower Lobau. Second,a reconnection with discharges up to 80 m^3s^{-1}, depending on the water level of the Danube, is discussed.

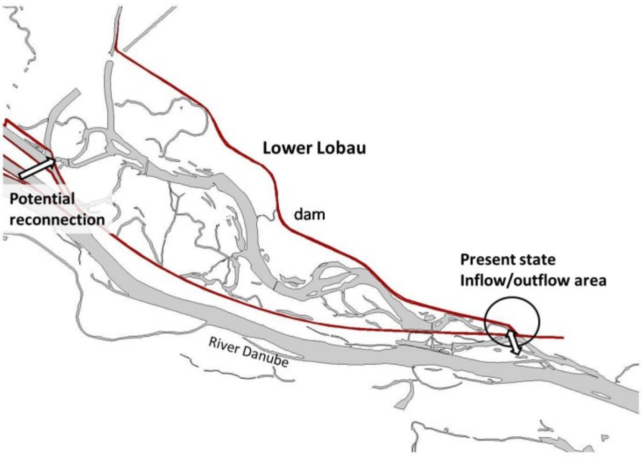

Figure 1: Map of the study area Lower Lobau.

Methods

Model description

The Water Quality Analysis Simulation Programm (WASP 7.5, 2011) is an enhancement of the original WASP (DITORO et al. 1983, AMBROSE et al. 1988). WASP is a dynamic compartment-modeling program for aquatic systems, where the time varying processes of primary production, nutrient cycling and the degradation of organic matter are represented. WASP will be linked with a hydrodynamic model developed for the Lobau area and is based onsmall compartments of the basins, so called segments, which are differentiated by their hydromorphology and their macrophyte coverage. Empirical data out of a frequent monitoring program (ZORNIG et al. 2010, ZORNIG et al. 2012) and two flood events are used to define boundary conditions (Danube limnochemical conditions) and initial conditions of the segments. Of high importance for the water quality modeling is the inclusion of the underlying sediment layer and the major processes on the water/sediment-boundary layer like degradation of organic material and phosphorus release (oxic and anoxic).

Table 2: Macrophyte coverage (reed, floating leaf plants) depending on water depth.

Depth (m)	Makrophytes	Mean makrophyte coverage (%)	Max. makrophyte coverage (%)
< 0.5	reed	37	98
	floating leaf plants	24	88
0.5 - 2	reed	9	94
	floating leaf plants	35	93
> 2	reed	3	16
	floating leaf plants	7	21

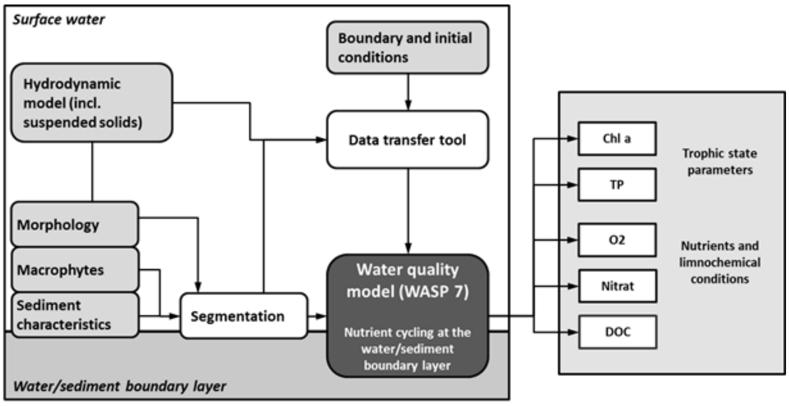

Figure 2: Model framework for water-quality modeling in the Lower Lobau.

<u>Segment characterisation</u>

The project area was differentiated in 400 surface water segments, 310 primary flooding zones, usually dry areas rewetted during floods and 76 bottom sediment segments. The mean area of the surface-water segments is 4,100 m², where the smallest are about 100 m² and the largest are about 37,000 m².In 62 % of the aquatic area the depth is less than 0.5 meters at mean water level, only 13 % are deeper than 2 meters. At the present state, approximately 45 % of the surface-water area is frequently connected to the main channel of the river (> 100 days per year), 20 % are connected at most during floods. Macrophytesare frequent in the whole project area. The lower the connectivity, the higher is the share of floating-leaf plants. In segments with a depth up to 2 m, ratios of floating-leaf plant cover up to 93 % was calculated. Segments deeper than 2 m are showing significantly lower macrophyte coverage. Reeds are frequent in segments up to 0.5 m depth showing maximum coverage ratios (98 %) in isolated water bodies.

<u>Modeling approach</u>

Alterations of limnochemical parameters (Figure 2) are calculated by the model in time-steps of 1 h for each segment.Based on the hydrological exchange, computed by the linked hydrodynamic model and the actual loads of matter (nutrients, phytoplankton biomass, dissolved organic matter, etc.), the exchange with adjoining segments is, calculated(Figure 3). Furthermore segment-internal processes calculated by state-of-the-art algorithms, foraquatic primary production, respiration, phosphorus and nitrogen cycling and the degradation of organic mattermodify the concentrations of the modeled parameters.

Different hydrological conditions like flood events and periods of mean or low water level for the present state of the Lower Lobau and the potential reconnection measures, will be modeled.

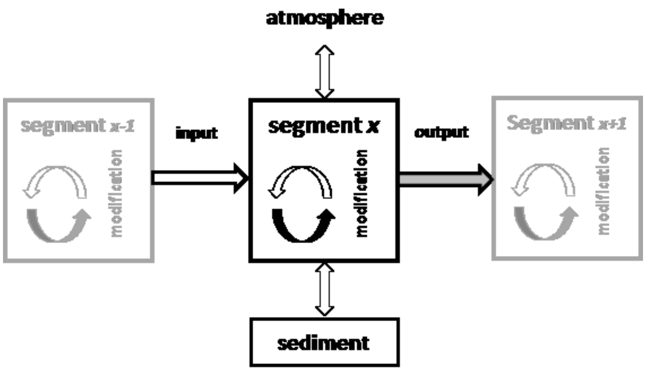

Figure 3: Schematic presentation of the calculationcontextwithin and between modelsegments.

References

AMBROSE, R.B. et al. 1988. WASP4, A Hydrodynamic and Water Quality Model—Model Theory, User'sManual, and Programmer's Guide. U.S. Environmental Protection Agency, Athens, GA. EPA/600/3-87-039.

DI TORO, D.M., FITZPATRICK, J.J. & R.V. THOMANN 1981, rev. 1983. Water Quality Analysis Simulation Program (WASP) and Model Verification Program (MVP) - Documentation. Hydroscience, Inc., Westwood, NY, for U.S. EPA, Duluth, MN, Contract No. 68-01-3872.

FRIEDL, G. & A. WUEST 2002.Disrupting biogeochemical cycles – consequences of damming. Aquatic Sciences, 64, 55–65.

HEIN, T., BARANYI, C., RECKENDORFER, W., F. SCHIEMER 2004.The impact of surface water exchange on the hydrochemistry and particulate matter dynamics in floodplains along the River Danube, Austria. Science of the Total Environment, 328, 207-218

HEIN, T., BLASCHKE, A. P., HAIDVOGL, G., HOHENSINNER, S., KUCERA-HIRZINGER, V., MUHAR, S., PREINER, S., REITER, K., SCHUH, B., WEIGELHOFER, G., & I. ZSUFFA 2006. Optimised management strategies for the Biosphere reserve Lobau, Austria - based on a multicriteria decision support system: using ecohydrological model approaches. Ecohydrology and Hydrobiology, 6, 25-36; ISSN 1642-3593

JUNK, W.J. & K.M. WANTZEN 2004. The flood pulse concept: new aspects, approaches, and applications –an update. Proceedings of the Second International Symposiumon the Management of Large Rivers for Fisheries,Vol. 2 (Eds R.L. Welcomme & T. Petr), pp. 117–149.FAO, Bangkok.

PREINER, S., DROZDOWSKI, I., SCHAGERL, M., SCHIEMER, F., HEIN, T. 2008. The significance of side-arm connectivity for carbon dynamics of the River Danube, Austria. Freshwater Biol. 2008; 53(2): 238-252.

RECKENDORFER, W., SCHMALFUß, R., BAUMGARTNER, C., HABERSACK, H., HOHENSINNER, S., JUNGWIRTH, M. & F. SCHIEMER 2005.The Integrated River Engineering Project for the free-flowing Danube in the Austrian Alluvial Zone National Park: framework conditions, decision process and solutions. Archiv für Hydrobiologie, Large Rivers Supplement, 155/1-4, 613-630.

SANON, S., HEIN, T., DOUVEN, W., WINKLER, P. 2012. Quantifying ecosystem service trade-offs: The caseof an urban floodplain in Vienna, Austria. J. Environ Manage. 2012; 111: 159-172.

SCHIEMER, F. 1999. Conservation of biodiversity in floodplain rivers. Large Rivers 11(3): 423-438.

THORP, J.H., THOMS, M.C. & M.D. DELONG 2006. The riverine ecosystem synthesis: biocomplexity in river networks across space and time. River Research and Applications 22(2):123-147.

WARD, J.V. 1998. Riverine landscapes: biodiversity patterns,disturbance regimes, and aquatic conservation.Biological Conservation, 83, 269–278.

WELTI, N., BONDAR-KUNZE, E., SINGER, G., TRITTHART, M., ZECHMEISTER-BOLTERSTERN, S., HEIN, T. & G. PINAY 2012. "Large-scale controls on potential respiration and denitrification of riverine floodplains." Environmental Engineering, 42, 73-84.

ZORNIG, H., GOERNET, B., RIEDLER, P., DONABAUM, K. & S. PREINER 2010. Monitoring Untere Lobau 2010 – Bericht Hydrochemie und Phytoplankton der Oberflächengewässer, Hydrochemie und Hygiene des Grundwassers. Im Auftrag der Stadt Wien, MA 45.

ZORNIG, H., RIEDLER, P., PALL, K., MAYR, E. 2012. Monitoring Untere Lobau 2012 – Bericht Hydrochemie und Phytoplankton der Oberflächengewässer, Hydrochemie und Hygiene des Grundwassers. Im Auftrag der Stadt Wien, MA 45.

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