Chapter 25
Danube Floodplain Lobau

Stefan Preiner, Gabriele Weigelhofer, Andrea Funk, Severin Hohensinner, Walter Reckendorfer, Friedrich Schiemer, and Thomas Hein

Along the Upper Danube, almost all former floodplain areas have been lost due to river regulation, large-scale land-use changes, and terrestrialization processes. In the Lobau floodplain near the City of Vienna, ongoing terrestrialization leads to a dramatic loss of aquatic and semiaquatic habitats. Although the ecological values of the remaining floodplain area, such as high productivity and high biodiversity, are widely acknowledged, the implementation of restoration measures is difficult. In urban environments such as the Lobau, planning and decision-making for floodplain restoration inevitably involves trade-offs, uncertainties, and conflicting objectives and value judgments. Beyond ecological values, the main socioeconomic aspects are flood control, drinking water supply for Vienna, and recreation.

The aim of this chapter is to present the current ecological situation and the major development tendencies of the Lobau floodplain and to show the effects of potential management measures on the ecological situation.

S. Preiner (✉) · G. Weigelhofer · A. Funk · T. Hein
Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences, Vienna, Austria

WasserCluster Lunz Biological Station GmbH, Lunz am See, Austria
e-mail: stefan.preiner@boku.ac.at; gabriele.weigelhofer@boku.ac.at; andrea.funk@boku.ac.at; thomas.hein@boku.ac.at

S. Hohensinner
Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences, Vienna, Austria
e-mail: severin.hohensinner@boku.ac.at

W. Reckendorfer
VERBUND Hydro Power GmbH, Vienna, Austria
e-mail: walter.reckendorfer@verbund.com

F. Schiemer
Department of Limnology and Oceanography, University of Vienna, Vienna, Austria
e-mail: friedrich.schiemer@univie.ac.at

© The Author(s) 2018

S. Schmutz, J. Sendzimir (eds.), *Riverine Ecosystem Management*, Aquatic Ecology Series 8, https://doi.org/10.1007/978-3-319-73250-3_25

25.1 Introduction

Floodplains are among the most productive habitats in the world and play a major role in the dynamics and the ecological integrity of riverine landscapes (Tockner et al. 2002). Due to the variety of different habitats, floodplains are key landscape elements for biogeochemical processing and hotspots for biodiversity (McClain et al. 2003; Tockner et al. 2010; Weigelhofer et al. 2015). Furthermore, floodplains provide a broad range of ecological and socioeconomic goods and services, including flood retention, groundwater recharge, and aesthetic and recreational values (Hein et al. 2006; Sanon et al. 2012; Rebelo et al. 2013).

However, river regulation, flow control, and large-scale land-use changes have altered nearly all central European riverine landscapes and have reduced the ecological and economic integrity of floodplains drastically. More than 68% of the floodplains of the Danube River have already been lost, with the highest reductions, e.g., up to 90%, of the former floodplain areas in the Upper Danube region (Tockner et al. 2009; Hein et al. 2016). The consequences of these changes are an increase in catastrophic flooding of urban areas, a reduction of in-river retention of nutrients, the loss of physical habitat diversity, and a correspondingly high percentage of endangered riverine species (ICPDR 2009; Hein et al. 2016). As a result, the Danube River Basin is among the most pressured large rivers in the world (Tockner et al. 2009).

Although strongly impacted by regulation measures, the free-flowing section of the Danube between Vienna and Bratislava is one of the last remnants of fluvial landscapes in the Upper Danube and in central Europe. It provides habitat for a diverse fauna and flora and was designated as a national park in 1996 (Reckendorfer et al. 2005). Within this stretch, the urban Lobau floodplain is located, which is a 2020 ha large floodplain area in the most western part of the national park right at the eastern border of the City of Vienna (Fig. 25.1).

During the major river engineering phase for the Danube between 1870 and 1885, this former dynamic floodplain has been disconnected from the main channel by the construction of a flood protection levee. Lateral embankments along the main river channel have severely altered the geomorphic and hydrological dynamics and have impeded the natural sequence of erosion and sedimentation (Hein et al. 2006; Hohensinner et al. 2008). Nowadays, the floodplain can be separated into two subareas that differ considerably in their ecological integrity due to differences in the degree of lateral hydrological connectivity with the main channel and the intensity of human use. The upstream section of the floodplain, the “Upper Lobau,” has been completely disconnected from flood events and is integrated into the settlement area of the City of Vienna, thus severely impacted by human activities. The downstream section, called “Lower Lobau,” is still included in the flood regime of the River Danube by a downstream opening and is kept as floodplain forest with water bodies of varying degrees of ecological integrity.

During recent decades, the vertical erosion in the main riverbed (incision) and the ongoing aggradation in the floodplain have further decoupled the wetland area from the main river channel, both hydrologically and ecologically (Reckendorfer et al. 2013b).

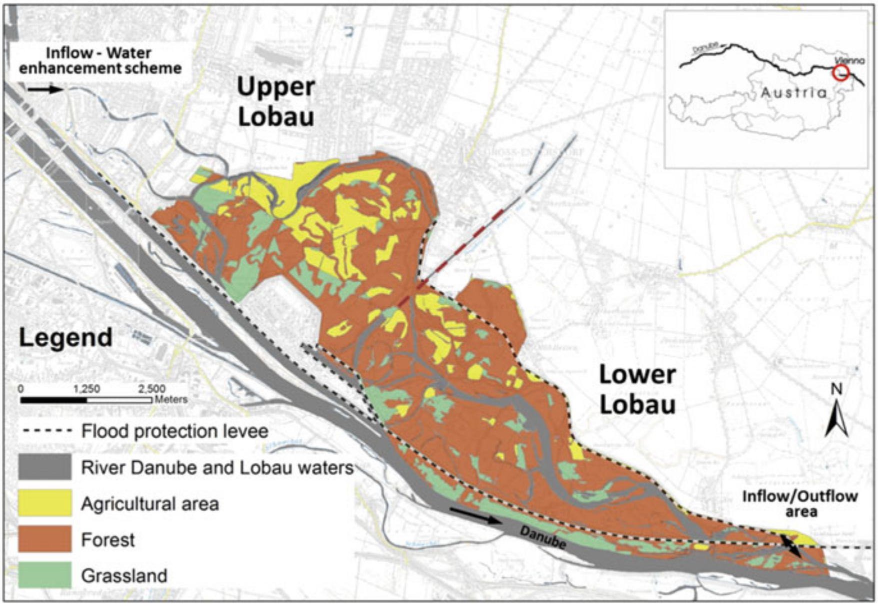

Fig. 25.1 Study area Lobau. Arrows indicate current inflow and outflow areas in the Lower Lobau and the inflow of the water enhancement scheme in the Upper Lobau

The consequences of this development are an ongoing decrease of the lateral hydrological connectivity, the loss of semiaquatic areas in the floodplain, a decreasing biodiversity, and the loss of typical river-floodplain species. Without any management activities, most aquatic and semiaquatic habitats are expected to disappear within the next decades (Schiemer et al. 1999; Hohensinner et al. 2008), with far-reaching ecological and socioeconomic consequences. The improvement of the current status of residual Danube floodplains through a basin-wide application of restoration measures is also one of the key water management issues identified in the Danube River Basin Management Plan (ICPDR 2009).

This chapter presents the current ecological situation of the urban Lobau floodplain, major development tendencies, the effects of management measures to improve the ecological situation, and constraints due to the intense human utilization.

25.2 Study Area

The Upper Lobau comprises an area of about 540 ha. It has been completely and permanently disconnected from the main channel even during floods (Fig. 25.1), thus oscillating hydrologically with the river only in response to groundwater fluctuations (Funk et al. 2009; Weigelhofer et al. 2011). The 12-km-long main side arm is separated into large, shallow, lake-like basins by check dams with culverts that prevent water losses to the river and secure the current water levels in the floodplain. Due to the prevailing lentic conditions, extended reed and macrophyte communities have developed in the backwaters. Before the implementation of management measures, the individual water bodies showed distinct differences in both water chemistry and trophic state, featuring highly eutrophic conditions in some backwaters. The Upper Lobau is situated within the settlement areas of the City of Vienna and is used intensively as a recreation area for hiking, cycling, and bathing.

In contrast to the Upper Lobau, the Lower Lobau (1480 ha, Fig. 25.1) is connected with the River Danube at least temporarily via back-flooding (Reckendorfer et al. 2013b). In the current situation, water from the Danube River enters the Lower Lobau during high water levels through a small opening in the main levee located at the downstream end (Schönauer Schlitz, Fig. 25.1) and drains during receding riverine water levels. With increasing Danube water levels, larger areas are inundated, including also terrestrial habitats. The connectivity of the various floodplain water bodies ranges from 140 days per year in the downstream parts of the main side arm adjacent to the inflow to less than 2 days per year in isolated ponds in the upstream parts of the Lower Lobau (Reckendorfer et al. 2006).

Sedimentation and terrestrialization processes prevail in the Lower Lobau due to decreasing surface and groundwater levels, siltation of sediments during floods, eutrophication, and the lack of erosion and export of fine sediments and nutrients to the river. Currently, terrestrialization accounts for 0.2–3.5% loss of aquatic habitats per year in the Lower Lobau. Most affected are shallow, semiaquatic habitats and isolated backwaters (Reckendorfer et al. 2013a).

Despite the hydrological deficits, the Lower Lobau still harbors a diverse and complex mosaic of aquatic, semiaquatic, and terrestrial habitats, resulting in a high biodiversity. Therefore, the Lower Lobau is an integral part of the "Nationalpark Donau-Auen" since 1996 and was designated a Natura 2000 area by the EU. Beyond the ecological value, the Lower Lobau plays a central role in the landscape water balance. It retains floodwater, recharges groundwater, and provides further socioeconomic values, such as recreation (Rebelo et al. 2013). In addition, the Lower Lobau serves as an important drinking water reservoir for the City of Vienna. In extraordinary situations, such as drought or maintenance activities, the floodplain can provide drinking water for up to about 25% of Vienna's inhabitants.

25.3 Management and Restoration Approaches

A systematic evaluation of existing floodplain areas and an assessment of their restoration potential form the basis for specific management activities (Schwarz 2010). Among various possible measures, the lateral hydrological connection with the main channel plays a central role in floodplain restoration (Henry et al. 2002). It leads to the exchange of water, material, and species among the various floodplain water bodies and initiates the rejuvenation of floodplain habitats, thus maintaining a high biodiversity. The rehabilitation of the lateral hydrological connectivity is also a key issue for the further development of the Lobau to mitigate the continuous decoupling of floodplain habitats from the hydrological regime of the Danube.

However, the development of adequate management measures, which can compensate for historic and ongoing human impacts, is a subtle matter in urban floodplains, such as the Lobau. Sustainable management of urban floodplains needs to integrate the partly competing, socioeconomic aspects and requirements (Knoflacher and Gigler 2004) and to counteract further large-scale changes in the hydrological regime of the main river due to river regulation measures, impoundments, and climate changes. Consequently, different approaches for the Upper and Lower Lobau were developed in a step-by-step procedure, corresponding to the divergent development of these two areas (Weigelhofer et al. 2013). Due to the strong socioeconomic restrictions resulting from use as settlement and recreation area, a water enhancement scheme was implemented in the Upper Lobau as a first step that provided a subtle and strictly regulated water enrichment in this part of the floodplain. In the Lower Lobau, the absence of nearby settlements allows for an increased hydrological connection with the Danube. However, the high nature conservation value of this area requires careful planning. Thus, as a second step, several options for reconnection were developed for the Lower Lobau under consideration of existing ecological and socioeconomic demands and based on the experiences from the Upper Lobau. Hydro-ecological models were used to investigate and evaluate possible effects of these management options on the various floodplain habitats and functions.

25.3.1 Upper Lobau

In the Upper Lobau, a water enhancement scheme was initiated in the late 1990s to maintain minimum water levels in the backwaters during the vegetation season (Imhof et al. 1992), restore the surface water connection along the chain of backwater pools, ensure the enrichment of groundwater within the area, and discharge nutrients from the area's highly eutrophic water bodies (Imhof et al. 1992; Schiemer 1995; Weigelhofer et al. 2011).

The measure is a strictly controlled surface water supply to the Upper Lobau using predominantly nutrient-poor, bank filtrate water of the Danube discharged via the New Danube flood relief channel, an artificial side arm of the Danube (Funk et al. 2009). Water enhancement is limited to the vegetation season from March to October in order to allow the floodplain to dry up during winter (Funk et al. 2009). Additionally, the discharge is restricted to a maximum of 1.5 $m^3\ s^{-1}$ and is shut down during flooding periods to conform to water quality criteria (Weigelhofer et al. 2011). As a result, the mean discharge amounted to only 0.25 $m^3\ s^{-1}$ supplied to the Upper Lobau between 2001 and 2008 (Weigelhofer et al. 2011).

Despite the low discharges, the implementation of the water enhancement scheme resulted in stabilized high surface and subsurface water levels, sustaining the presence of the backwaters. The increased water exchange also stabilized the trophic conditions of the backwaters and reduced extreme trophic conditions by improving the supply of dissolved oxygen to the sediment surface. It also increased water exchange through dense macrophyte stocks as well as the resulting filtration of nutrients and algae (Bondar-Kunze et al. 2009; Weigelhofer et al. 2011).

In addition, the water enhancement scheme significantly increased local habitat diversity by creating temporary flowing conditions in narrow parts of the channel (Funk et al. 2009). This enabled a shift in the mollusk and dragonfly communities in these areas toward higher abundances of rheophilic species. Due to the restricted extent of the water exchange, however, the enhancement scheme has shown no effects on the fish community so far, especially regarding the recolonization of the main side arm by rare Danube species or rheophilic specialists.

25.3.2 Lower Lobau

Management options proposed for the Lower Lobau range from the conservation of the present status to rehabilitation toward pristine conditions of parts of the floodplain. The measures aim to rehabilitate rare aquatic and semiaquatic habitats, restore the ecological functioning of floodplain areas, and conserve the existing fauna, flora, and designated habitats based on European regulations (Council of the European Communities 1992; NP Donau-Auen 2009; Hein et al. 2016). Thus, ecological aims comprise both the rehabilitation of rheophilic floodplain habitats and the protection of newly established lentic and semiaquatic species. Among the most important socioeconomic demands in the Lower Lobau are an integrated flood protection scheme for the City of Vienna, based on the EU Floods Directive (Council of the European Communities 2007), and the guarantee of the current drinking water supply.

The identification of adequate management measures was based on several approaches: (1) the historical analyses of the floodplain development from the unregulated to the current state (Hohensinner et al. 2008; Baart et al. 2013), (2) long-term monitoring of hydrological and ecological properties of floodplain water bodies from 2005 to 2014 (Reckendorfer et al. 2013b; Weigelhofer et al. 2015), (3) the development of hydrological and ecological models predicting the further development of the floodplain under different hydrologic scenarios (Baart et al. 2010, 2013; Funk et al. 2013), and (4) a multi-criteria decision study about the effects of a wide range of management scenarios on the various ecological and socioeconomic demands (Hein et al. 2006; Sanon et al. 2012). The following sections show the main procedures and the results of the different approaches.

Historic Development of the Lower Lobau

In 1817, before the onset of the Danube regulation, the total water area in the Danube section of the Lower Lobau covered approximately 11.9 km^2, about 37% of which were formed by side arms and backwaters (Graf et al. 2013). The majority of the secondary water bodies were hydrologically dynamic side arms, with more than 66% belonging to the Eupotamon B habitat (Graf et al. 2013; typology of aquatic habitats according to Hohensinner et al. 2011, based on Amoros 2001). These lotic side arms were branched by vegetated islands and gravel bars. About 20% of the backwaters were classified as Parapotamon A (highly dynamic, connected above mean water level), while periodically connected (Parapotamon B) and isolated backwaters (Plesio-/Palaeopotamon) comprised about 14% of the total water area (excluding the area of the Danube main channel). As a consequence of river regulation, the total water area was reduced to about 4.2 km^2 at mean water level. Dynamic floodplain water bodies were displaced by plesio-/paleopotamal water bodies, accounting for up to 77% of the water area in 2011, while 9% were assigned to Parapotamon B. Only recently, due to the restoration of the most downstream part of the Lobau by lowering of the levee, Parapotamon A backwaters have reoccurred and currently add up to 14% (Graf et al. 2013). As a consequence of channel incision and deposition of sediments in the floodplain, the groundwater tables have declined from 1.9 m in 1849 to 3 m in 2003 at mean water level (Hohensinner et al. 2008). Furthermore, the habitat turnover rates and, accordingly, habitat rejuvenation have decreased dramatically between the pre-regulation and the post-regulation phase (Baart et al. 2013).

The changes in the availability of aquatic habitats significantly affected the macrophyte communities in the Lower Lobau (Baart et al. 2013). The total number of species increased slightly from 108 species before the regulation to 116 species around 2000. Furthermore, the composition of the macrophyte communities changed. Hydrophytes, which are typical for shallow eutrophic, lentic water bodies such as *Nymphoides peltata* and *Nymphaea alba*, were able to spread in the main side arm after the regulation. Additionally, oligotraphent species, such as Charophyceae, were able to colonize paleopotamal water bodies supplied by nutrient-poor groundwater. By contrast, many eu-/parapotamal species, such as pioneer plants, as well as marsh plants have disappeared.

The loss of aquatic and semiaquatic water bodies also decreased the available habitat and abundance of aquatic and amphibian species in the Lower Lobau.

Hydro-chemical Status Quo of the Lower Lobau

In general, the water bodies of the Lower Lobau show significantly lower concentrations of suspended solids and nutrients than the River Danube (Table 25.1, Hein et al. 1999). Thus, hydrological connectivity with the Danube determines the hydro-chemical character of the respective water bodies. Along the main side arm, a distinct hydro-chemical gradient has been established in both the water column and the sediments (Reckendorfer et al. 2013b). With increasing distance to the inflow, the concentrations of geochemical parameters (e.g., conductivity, alkalinity) increase, while the amounts of total suspended solids and dissolved nutrients decrease (Table 25.1). The fine sediment layer is significantly higher in water bodies near the inflow than in more distant parts of the main side arm, yielding a maximum thickness of up to 270 cm close to the first check dam compared to a maximum of 50 cm in distant parts. The organic content of the sediments shows the reverse pattern, with increased concentrations in the upstream parts of the Lower Lobau. During floods, the inflowing river water imports

Table 25.1 Mean concentrations of nutrients (N–NH_4, N–NO_3, P–PO_4, P-tot), chlorophyll-a, and suspended matter (total suspended solids, organic content) of different parts of the Lower Lobau, the Upper Lobau, as well as the Danube and the New Danube (an artificial flood relief channel of the Danube) as potential water sources for reconnection

Parameter		Lower Lobau downstream parts	Upstream parts	Isolated
N–NH_4	μg L^{-1}	36.3 ± 163.5 (n = 234)	26 ± 101.1 (n =406)	92.3 ± 454.9 (n = 744)
N–NO3	μg L^{-1}	543.3 ± 617.8 (n = 234)	202.1 ± 333.4 (n = 406)	287 ± 384.6 (n = 744)
P–PO_4	μg L^{-1}	6 ± 9.3 (n = 234)	1.2 ± 3.2 (n = 406)	15 ± 42.1 (n = 744)
P-tot	μg L^{-1}	44.5 ± 34.5 (n = 234)	16.1 ± 9.5 (n = 406)	49.7 ± 81.6 (n = 744)
Chlorophyll a	μg L^{-1}	17 ± 17 (n = 506)	5.7 ± 6.8 (n = 745)	14.5 ± 51.4 (n = 1706)
Total suspended solids	mg L^{-1}	27.1 ± 69.3 (n = 233)	3.4 ± 4.3 (n = 404)	3.8 ± 7.8 (n = 766)
Organic suspended solids	%	28.8 ± 16.3 (n = 233)	63.6 ± 20.7 (n = 403)	80.7 ± 17.5 (n = 764)
		Upper Lobau	New Danube	Danube
N–NH_4	μg L^{-1}	30.8 ± 25.6 (n = 63)	21.2 ± 13.4 (n = 112)	51.2 ± 229.9 (n = 73)
N–NO_3	μg L^{-1}	193 ± 368.4 (n = 63)	981.1 ± 548 (n = 98)	1537.2 ± 472.5 (n = 73)
P–PO_4	μg L^{-1}	0.5 ± 0.6 (n = 63)	2 ± 4.3 (n = 98)	18.2 ± 11.2 (n = 73)
P-tot	μg L^{-1}	12 ± 4.7 (n = 63)	14.6 ± 7.2 (n = 98)	60.5 ± 54 (n = 73)
Chlorophyll a	μg L^{-1}	4.2 ± 2.4 (n = 102)	7.8 ± 10.3 (n = 28)	10.2 ± 10.8 (n = 161)
Total suspended solids	mg L^{-1}	1.8 ± 1.2 (n = 79)	3 ± 2.5 (n = 112)	58.9 ± 119.4 (n = 83)
Organic suspended solids	%	87.1 ± 14.8 (n = 79)	58.2 ± 20.7 (n = 89)	15.7 ± 11 (n = 83)

Data obtained from a monthly long-term monitoring of hydrological and ecological properties of the Upper and the Lower Lobau from 2005 to 2014

nutrients from the Danube, thus leading to a hydro-chemical homogenization of the water bodies in the main side arm (Weigelhofer et al. 2015). The nutrient inputs also stimulate primary production, resulting in chlorophyll-a peaks in the connected parts of the main side arm after floods (Schiemer et al. 2006).

Isolated water bodies (Plesio-/Palaeopotamon) in the upstream part of the Lower Lobau have developed their own independent hydro-chemical characteristics (Table 25.1). In general, fine sediment layers are highest there, yielding also the highest organic matter and phosphorus concentrations of all water bodies in the Lobau (Reckendorfer et al. 2013b). Due to their low connectivity, isolated backwaters may partly dry out during periods of low precipitation in summer and winter. The repeated drying and rewetting of the sediments may result in the release of huge amounts of phosphorus from the sediments to the water column (Schoenbrunner et al. 2012), momentarily boosting phytoplankton and zooplankton production in these backwaters (Weigelhofer et al. 2013). Thus, isolated backwaters are usually characterized by high nutrient concentrations, occasional high peaks of phytoplankton biomass, and changes in the nutrient cycles (Welti et al. 2012).

In its present state, 50% of the water area is characterized by shallow mean depths of less than 1 m, and more than 75% of the water area shows maximum water velocities less than 0.1 $m\,s^{-1}$ (Baart et al. 2010). These conditions favor the establishment of species-rich, macrophyte communities. The highest macrophyte biomass and species richness can be currently found in deeper water bodies of the main side arm (Baart et al. 2010; Reckendorfer et al. 2013b).

Potential Development of the Lower Lobau Under Different Management Scenarios

In order to find an optimal ecologic solution for the Lower Lobau, various hydrological management options have been evaluated regarding their effects on the probable development of the floodplain compared to development without management measures. Here, we present the two most relevant management options to highlight the effects of different degrees of connection of the Lower Lobau with the Danube on the development of the floodplain's ecological state and functions, as well as on habitats. Option 1 ("controlled water supply") includes a limited water supply from the New Danube at the upstream part of the main side arm, comparable to the already existing water enhancement scheme in the Upper Lobau (Table 25.2, Fig. 25.2). Due to restricted water exchange, this option represents a conservative approach. Option 2 ("partial reconnection") includes an uncontrolled reconnection at the upstream part of the main side arm. Though limited in maximum discharge, it represents an approach to restore basic floodplain functions.

Table 25.2 Description of selected potential management options for the Lower Lobau

	Measures	Objectives
Controlled water supply	Water supply with nutrient- and sediment-poor water from the "new Danube" with maximum discharge of 5 m^3/s	Controlled surface water supply, control of trophic state of the system Conserve selected aquatic habitats
Partial reconnection	Uncontrolled upstream connection with the Danube with maximum discharge of 120 m^3/s Morphological adaptions of the affected main side arm necessary	Increase in hydrological dynamics, increase of nutrient inputs from the Danube, increase of ecological integrity of the floodplain

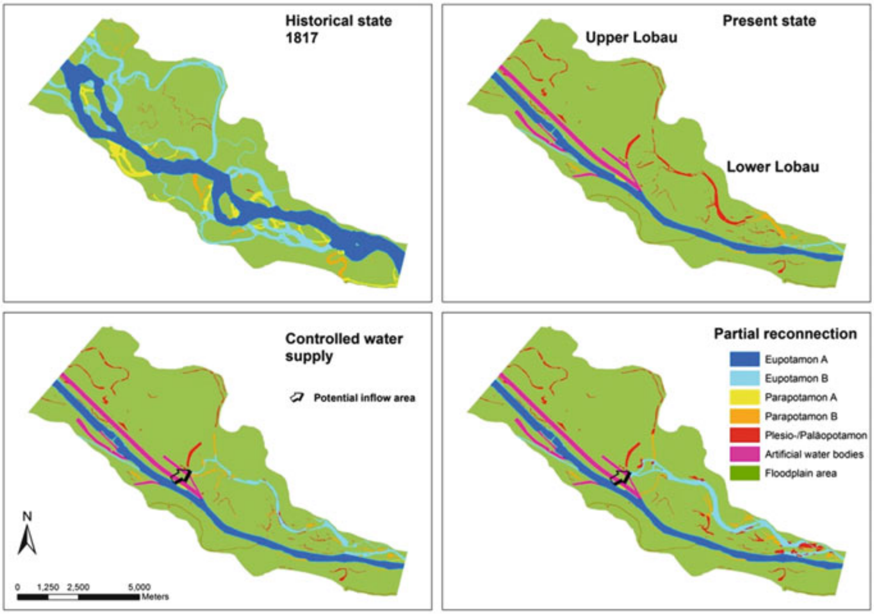

Fig. 25.2 Distribution of aquatic habitats in the Lobau for the historical situation 1817, the present state, and two management options "controlled water supply" and "partial reconnection." Potential inflow areas are marked by arrows

25.4 Methods and Results

The effects of the different management options on the development of the floodplain were assessed via detailed state-of-the-art hydrological and ecological predictive models, which were based on the results of the hydrological and ecological long-term monitoring of the Lower Lobau. In the following section, the most important results are shortly described.

Detailed descriptions of the model structure and setup can be found in Hein et al. (2006), Baart et al. (2010), and Funk et al. (2013).

For the management option "controlled water supply," the hydrological changes are predicted to be small, and lotic water bodies are only created in narrow passages (Fig. 25.2). Nevertheless, the water enhancement scheme will result in a steady transport of water through the system and in a slight increase of the water table and the water areas in ways similar to the development in the Upper Lobau.

By reconnecting the Lobau to the main river channel (management option "partial reconnection"), paleopotamal water bodies will decrease significantly in size, and, at the same time, lotic water bodies will reestablish. The area of habitat types Eupotamon B and Parapotamon A will be increased, and the rejuvenation ability of the floodplain will be enhanced, at least in some areas.

Table 25.3 Modeled values of indicator parameters for the management scenarios "present state," "controlled water supply," and "partial reconnection"

Indicator	Present state	Controlled water supply	Partial reconnection
Total area of connected water bodies (ha)	54.4	99.7	166.6
Share of highly productive water bodies (15 < Chl-a < 30 μg L^{-1}) (ha)	13.2	17.2	33.6
Potential areas for submerged macrophytes (ha)	96.3	100.9	114.4
Potential areas for emerged macrophytes (ha)	81.7	86.7	122.7
Total macrophyte species number	12.3	12.5	13

From the study "OptimaLobau—Optimised management of riverine landscapes based on a multi-criteria decision support system," Austrian Ministry of Science, ProVision 133–113

The management option "controlled water supply" will result in changes of nutrient concentrations and primary production patterns (Weigelhofer et al. 2011) due to the input of nutrient poor water from the New Danube channel and its steady transport through the system. Concurrently, changes in nutrients and primary production will be small in the upper part of the Lower Lobau (Table 25.1). In the lower parts of the Lower Lobau, the enhancement of connectivity will decrease the concentrations, especially after floods; the subsequent chlorophyll-a peak will clearly be reduced.

For the "partial reconnection" option, model results are different, because the main channel of the Danube will be the water source, and much higher amounts of water will be imported, leading to increased nutrient concentrations in the water columns of the whole side arm system. As a result, primary production will be much higher than at present and also higher than in the main channel of the Danube, because of better light availability. Side ditches and currently isolated ponds will be connected to the side arm, increasing the overall area of connected water bodies (Table 25.3) and also the share of highly productive water bodies.

Macrophyte species composition in floodplain areas is indicative of the degree of hydrological dynamics, and restoration measures are, thus, expected to result in alterations in the macrophyte composition (Reckendorfer et al. 2005). Both a controlled water supply and a reconnection will increase the potential habitats for emerged and submerged macrophytes by increasing the total surface water area (Table 25.3). Macrophytes will especially profit from the increase in shallow water areas (Baart et al. 2010, 2013).

In the "partial reconnection" option, the reversal of paleopotamal to parapotamal water bodies will lead to the reemergence of pioneer species and species tolerant to higher flow velocities (Baart et al. 2013). Otherwise, vegetation communities of oligo- and mesotrophic habitats, such as Characeae, which are currently quite abundant in paleopotamal areas of the Lobau, will decline dramatically. While the total number of macrophyte species will barely change, there will be a huge decrease of species-rich areas with paleopotamal character compared to the present state.

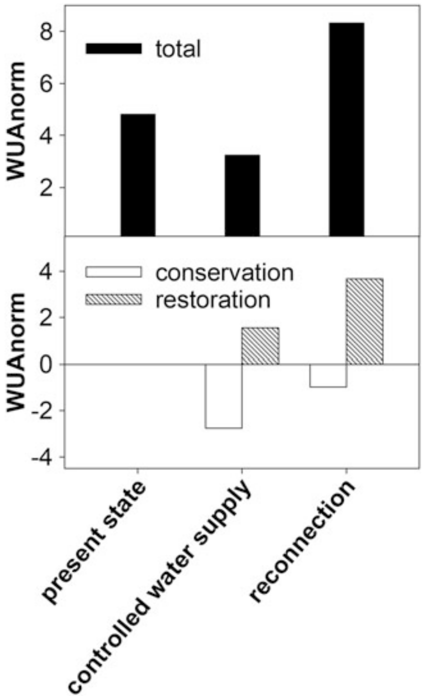

Fig. 25.3 Total sum of the normalized weighted usable area (WUA), a measure of the available habitat area, per management option over all selected, protected indicator species (European pond turtle, five species of amphibians, six species of fish, and one invertebrate species). Conservation/ restoration potential compared to the present state (modified after Funk et al. 2013)

Regarding faunal indicator species, Funk et al. (2013) showed a reduction of available habitat area for selected species (WUA, weighted usable area after Bovee, 1986, Fig. 25.3) for the management option "controlled water supply" due to a decrease of permanent and temporary stagnant habitats. These are important for stagnophilic species, such as amphibians, while at the same time the potential for the creation of lotic habitats for rheophilic species remains low.

For the management option "partial reconnection," the developed model calculated an increase of the useable area. Habitats of stagnophilic species, such as *Emys orbicularis* or amphibian species, are conserved or even fostered due to increased water tables in the area. Due to partial reconnection, potential habitats for rheophilic species (e.g., the fish species *Vimba vimba*, *Romanogobio albipinnatus*, or *Aspius aspius*) are created. Funk et al. (2013) concluded that additionally to the preservation of most of the habitats of the present community, sufficient habitats for rheophilic species will be created by that management option.

Basic Assessment of Trade-Offs Among Ecosystem Functions and Services in the Lower Lobau

In a feasibility study, several potential management measures were developed and assessed for their effects on different ecosystem properties and relevant ecosystem services (Sanon et al. 2012). Multi-criteria decision analysis (MCDA) was applied to support floodplain managers to identify best-compromise solutions for areas of conflicting interests by highlighting possible trade-offs among the various ecological and socioeconomic demands. In order to guarantee a clear demarcation of possible

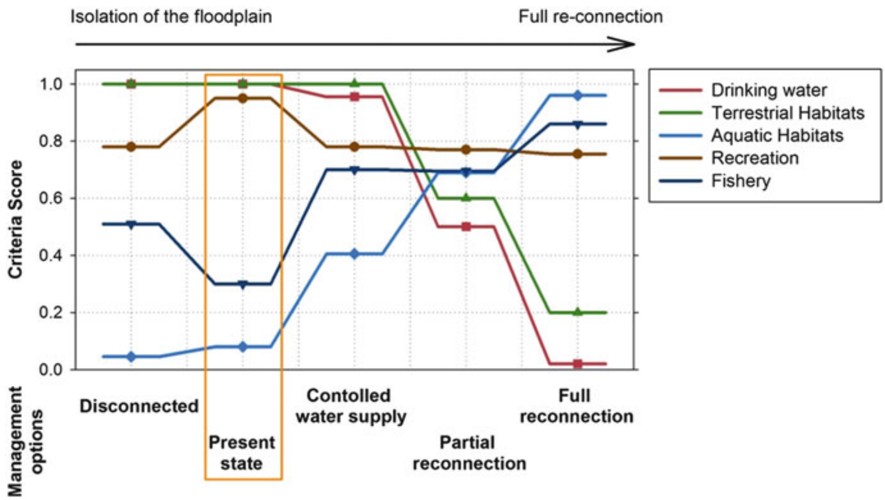

Fig. 25.4 Impacts of different management options on the potential drinking water production, the ecological conditions of terrestrial and aquatic habitats, recreation, and fishery. The x-axis represents hydrological options with increasing connectivity. Present state is circumscribed by the orange rectangle (Sanon et al. 2012 modified)

trade-offs, different hydrologic management scenarios were combined with future-use scenarios with either predominantly ecological or socioeconomic focus. The effects of these hypothetical management options were evaluated through state-of-the-art multi-criteria decision analysis (Sanon et al. 2012).

The results showed that the largest trade-offs occurred between the ecological aims and the aspects related to drinking water supply. An increased connection with the Danube will improve the hydrological and ecological status of the floodplain water bodies considerably through increases in the available aquatic area and the establishment of lotic conditions and will also enable other socioeconomic demands, such as fishery and recreation, within the restrictions given by the national park regulations. In addition, terrestrial habitats will benefit from the more frequent flood inundation that enables the establishment of typical floodplain vegetation. However, an increased hydrological connectivity will probably reduce the groundwater residence time in the area that may impair the potential for drinking water production (Fig. 25.4).

25.5 Conclusions

In the Upper Lobau restoration efforts are limited to a strongly controlled water enhancement scheme. However, it significantly changes nutrient dynamics and primary production patterns of the floodplain water bodies and increases habitat diversity and improves conditions for rheotolerant species at least locally. In summary, the water enhancement scheme in the Upper Lobau demonstrates that controlled management schemes can be successful in urban areas, where it is not possible to reconnect directly to the river main channel, and, therefore, to rehabilitate the natural hydrological regime.

In the Lower Lobau, basic processes, such as nutrient cycling and aquatic primary production, can be managed effectively with a controlled water supply. However, the restoration of typical habitats of dynamic floodplains and the resettlement of rheophilic species need greater efforts to steer toward pre-regulation conditions. Such significant investments are required to regain dynamic water level changes, including floods, and, thus, support natural floodplain rejuvenation. Although the Lower Lobau is not located within a settlement area, restoration is limited by current ecosystem services (including secondary habitat development for rare species, drinking water supply, and recreational uses) that are in conflict with ecological restoration efforts aiming to initiate basic hydromorphological processes that operated during pre-regulation conditions.

References

Amoros C (2001) The concept of habitat diversity between and within ecosystems applied to river side-arm restoration (abstract). Environ Manag 28:805–817

Baart I, Gschöpf C, Blaschke AP, Preiner S, Hein T (2010) Prediction of potential macrophyte development in response to restoration measures in an urban riverine wetland. Aquat Bot 93:153–162

Baart I, Hohensinner S, Zsuffa I, Hein T (2013) Supporting analysis of floodplain restoration options by historical analysis. Environ Sci Policy 34:92–102

Bondar-Kunze E, Preiner S, Schiemer F, Weigelhofer G, Hein T (2009) Effect of enhanced water exchange on ecosystem functions in backwaters of an urban floodplain. Aquat Sci Res Across Bound 71:437–447

Bovee KD (1986) Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Biol Rep 86:235. US Fish and Wildlife Service

Council of the European Communities (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Off J Eur Communities L206:7–50

Council of the European Communities (2007) Council directive 2007/60/EC of 23 October 2007 on the assessment and management of flood risks. Off J Eur Communities L288:27–34

Funk A, Reckendorfer W, Kucera-Hirzinger V, Raab R, Schiemer F (2009) Aquatic diversity in a former floodplain: remediation in an urban context. Ecol Eng 35:1476–1484

Funk A, Gschoepf C, Blaschke AP, Weigelhofer G, Reckendorfer W (2013) Ecological niche models for the evaluation of management options in an urban floodplain—conservation vs. restoration purposes. Environ Sci Pol 34:1–13

Graf W, Chovanec A, Hohensinner S, Leitner P, Schmidt-Kloiber A, Stubauer I, Waringer J, Ofenboeck G (2013) Macrozoobenthos as an indicator group for the assessment of major rivers incorporating riparian ecological aspects. Österreichische Wasser- und Abfallwirtschaft 65:386–399

Hein T, Heiler G, Pennetzdorfer D, Riedler P, Schagerl M, Schiemer F (1999) The Danube restoration project: functional aspects and planktonic productivity in the floodplain system. Regul Rivers Res Manage 15:259–270

Hein T, Blaschke AP, Haidvogl G, Hohensinner S, Kucera-Hirzinger V, Preiner S, Reiter K, Schuh B, Weigelhofer G, Zsuffa I (2006) Optimised management strategies for the biosphere reserve Lobau, Austria- based on a multi criteria decision support system. Int J Ecohydrol Hydrobiol 6:25–36

Hein T, Schwarz U, Habersack H, Nichersu I, Preiner S, Willby N, Weigelhofer G (2016) Current status and restoration options for floodplains along the Danube River. Sci Total Environ 543:778–790. https://doi.org/10.1016/j.scitotenv.2015.09.073

Henry CP, Amoros C, Roset N (2002) Restoration ecology of riverine wetlands: a 5-year post-operation survey on the Rhone River, France. Ecol Eng 18:543–554

Hohensinner S, Herrnegger M, Blaschke AP, Habereder C, Haidvogl G, Hein T, Jungwirth M, Wei M (2008) Type-specific reference conditions of fluvial landscapes: a search in the past by 3D-reconstruction. Catena 75:200–215

Hohensinner S, Jungwirth M, Muhar S, Schmutz S (2011) Spatio-temporal habitat dynamics in a changing Danube River landscape 1812–2006. River Res Appl 27:939–955

ICPDR—International Commission for the Protection of the Danube River (2009) Danube river basin management plan (DRBMP) according to EU Water Framwork Directive (WFD)

Imhof G, Schiemer F, Janauer A (1992) Dotation Lobau—Begleitendes ökologisches Versuchsprogramm. Artificial Water Enrichment for Lobau—Ecological Test Programme. Österr WasserWirtschaft 44(11–12):289–299

Knoflacher M, Gigler U (2004) A conceptual model about the application of adaptive management for sustainable development. In: Pahl-Wostl C, Schmidt S, Jakeman T (eds) iEMSs 2004 International Congress: "Complexity and integrated resources management". International Environmental Modelling and Software Society, Osnabrueck

McClain ME, Boyer EW, Dent CL, Gergel SE, Grimm NB, Groffman PM, Hart SC, Harvey JW, Johnston CA, Mayorga E, McDowell WH, Pinay G (2003) Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems. Ecosystems 6:301–312

NP Donau-Auen (2009) NP Donau-Auen management plan

Rebelo LM, Johnston R, Hein T, Weigelhofer G, D'Haeyer T, Kone B, Cools J (2013) Challenges to the integration of wetlands into IWRM: the case of the inner Niger Delta (Mali) and the Lobau floodplain (Austria). Environ Sci Policy 34:58–68

Reckendorfer W., R.Schmalfuss, C.Baumgartner, Habersack H., Hohensinner S., Jungwirth M., & Schiemer F. (2005) The integrated river engineering project for the free-flowing Danube in the Austrian alluvial zone national park: framework conditions, decisions process and solutions. Arch Hydrobiol,

Reckendorfer W, Baranyi C, Funk A, Schiemer F (2006) Floodplain restoration by reinforcing hydrological connectivity: expected effects on aquatic mollusc communities. J Appl Ecol 43:474–484

Reckendorfer W, Boettinger M, Funk A, Hein T (2013a) Die Entwicklung der Donau-Auen bei Wien—Ursachen, Auswirkungen und naturschutzfachliche Folgen. Geogr Augustana 13:45–53

Reckendorfer W, Funk A, Gschöpf C, Hein T, Schiemer F (2013b) Aquatic ecosystem functions of an isolated floodplain and their implications for flood retention and management. J Appl Ecol 50:119–128

Sanon S, Hein T, Douven W, Winkler P (2012) Quantifying ecosystem service trade-offs: the case of an urban floodplain in Vienna, Austria. J Environ Manag 111:159–172

Schiemer F (1995) Revitalisierungsmaßnahmen für Augewässer - Möglichkeiten und Grenzen. ArchHydrobiolSuppl 101:383–398

Schiemer F, Baumgartner C, Tockner K (1999) The Danube restoration project: conceptual framework, monitoring program and predictions on hydrologically controlled changes. Reg Rivers Research & Management 15:231–244

Schiemer F, Hein T, Peduzzi P (2006) Hydrological control of system characteristics of floodplain lakes. Ecohydrol Hydrobiol 6:7–18

Schoenbrunner IM, Preiner S, Hein T (2012) Impact of drying and re-flooding of sediment on phosphorus dynamics of river-floodplain systems. Sci Total Environ 432:329–337

Schwarz U (2010) Assessment of the restoration potential along the Danube and main tributaries. For WWF International Danube-Carpathian Programme, Vienna, 58 p

Tockner K, Malard F, Uehlinger U, Ward JV (2002) Nutrients and organic matter in a glacial river-floodplain system (Val Roseg, Switzerland). Limnol Oceanogr 47:266–277

Tockner K, Uehlinger U, Robinson CT (2009) Rivers of Europe. Elsevier

Tockner K, Pusch M, Borchardt D, Lorang MS (2010) Multiple stressors in coupled river-floodplain ecosystems. Freshw Biol 55:135–151

Weigelhofer G, Hein T, Kucera-Hirzinger V, Zornig H, Schiemer F (2011) Hydrological improvement of a former floodplain in an urban area: potential and limits. Ecol Eng 37:1507–1514

Weigelhofer G, Reckendorfer W, Funk A, Hein T (2013) Auenrevitalisierung - Potential und Grenzen am Beispiel der Lobau, Nationalpark Donauauen. Österreichische Wasser- und Abfallwirtschaft2 65:400–407

Weigelhofer G, Preiner S, Funk A, Bondar-Kunze E, Hein T (2015) The hydrochemical response of small and shallow floodplain water bodies to temporary surface water connections with the main river. Freshw Biol 60:781–793

Welti N, Bondar-Kunze E, Tritthart M, Pinay G, Hein T (2012) Nitrogen dynamics in complex Danube River floodplain systems: effects of restoration. River Syst 20:71–85

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.