LARGE RIVER RESTORATION: CONCEPTS & EXPERIENCES FROM THE DANUBE

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Abstract: Over the past 10 years a sound conceptual basis has been developed for understanding functional processes and biodiversity patterns of large rivers. It is well understood that the key factors are the flood-controlled geomorphologic processes which create the characteristic patch dynamics, spatial heterogeneity, the mosaic structure of densely packed ecotones and patterns of successions over a range of scales. The ecological significance of a dynamic habitat equilibrium in floodplains, as expressed in disturbance and succession theory, is a continuous rejuvenescence process. In turn, these provide the habitat diversity and the specific habitat conditions for characteristic floodplain species and result in high levels of local species richness, habitat diversity and between-habitat differences.

Keywords: change of natural dynamics, identifying appropriate conservation and restoration objectives, restoration of water dynamics, environmental policy

Anthropogenic alterations in the catchment, pollution, river regulation and damming have effected almost all large river ecosystems in Europe and North America. The most destructive impacts are due to river engineering which has disrupted ecological integrity with regard to the longitudinal continuity, the lateral interactions with the bordering riparian zones, and the structure of the in-stream channel. This has led to deficiencies in functional processes, in the diversity of habitats and characteristic biota and has reduced the "ecological services" of river systems. In order to restore the ecological integrity, restoration has become an important issue during the past 20 years.

The experiences in restoration programmes in this paper refer to a sequence of guiding mitigation programmes in the free- flowing section of the Austrian Danube between Vienna and Bratislava which have been carried out or are in the phase of implementation.

The present conditions are determined by a major regulation scheme starting in the 19th century. It represented a major engineering feat at its time, however did not take ecological aspects into consideration. The main engineering approach was to change the braided course into a single, straightened channel, stabilized by riverside embankments and ripraps. The former arms of the braided system were cut off. Weirs had to be built in order to retain the water level in the floodplain. The riverside embankments reduced the hydrological interaction with the floodplain and large levees completely cut off parts of the former floodplains from erosive, scouring flood flow.

The immediate effects were:

- a loss of riverine inshore habitats, which had strong impacts on inshore retention characteristics and on habitat value for rheophilic organisms, e.g. as nurseries for riverine fish
- a reduction of the lateral floodplain extent
- reduced hydrological connectivity both of groundwater exchange and open surface water connections between river and floodplains

- strongly reduced geomorphic processes in the floodplain and complete change of cut and fill
- a concentration of the erosive forces on the main channel bed.

These effects initiated:

- a deepening of the channel
- a lowered groundwater table
- isolation of backwaters
- sediment accumulation and terrestrialization in the isolated water bodies
- and in sum an ongoing fragmentation and disintegration of river and floodplains.

The reduction of ecological integrity due to engineering is expressed in a considerable loss of biodiversity and floodplain functions.

Different stakeholders are - for various reasons –interested in mitigation programmes. An overall concept for the improvement of the whole 45 km stretch between Vienna and Bratislava has been worked out by a team of ecologists, hydrologists and engineers compromising between the interests of navigation and ecology. The main focus is to stop the deepening of the channel and to improve the nature of the inshore structure and the lateral integration of river and floodplain. These are, from a conservation point of view, the most important aspects.
The stretch consists of segments (Fig. 1) differing strongly with regard to
a) the deviation from original (reference) conditions
b) reversibility towards the original conditions
c) existing connectivity and technical potential for improvement.

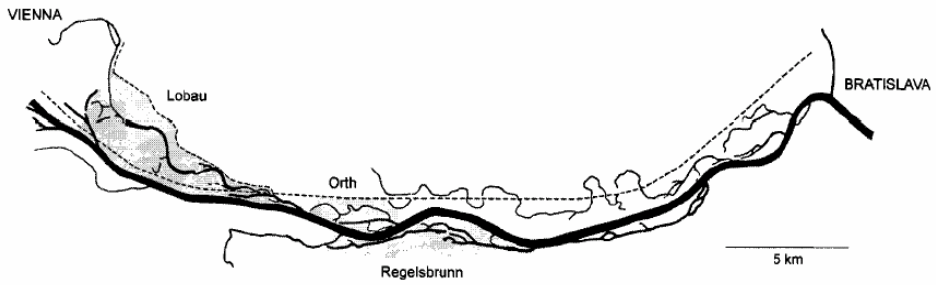

Figure 1. The Danube and its floodplains from Vienna to Bratislava. The broken line shows the existing flood protection levees. Different segments have been identified for individual restoration programmes, e.g. Regelsbrunn, Orth and Lobau

The various river stretches range for example from strongly disconnected former floodplain areas within the municipality of Vienna (Lobau) where over the last 120 years strong terrestrialisation processes have taken place and for which the potential of ecological restoration is strongly constrained by requirements of flood control and drinking water supply of Vienna. On the other end of the scale are segments with a

continued more dynamic integration between the regulated river and its floodplain although even in such cases the continuous habitat change in direction of a loss of aquatic habitats and an increase of terrestrial habitats has been dramatic.
These segments can be considered as units for which individual restoration schemes have to be developed. This offers the opportunity to develop and improve restoration programs step by step and develop restoration strategies and skills. It represents a large scale experimentation field in landscape ecology, where the master factor – hydrology and flow diversion is controlled and the dependent variables – various ecological properties, limnological processes, biodiversity pattern, geomorphology, etc. – are the dependent variables. The planning and monitoring of these restoration programmes provide a unique opportunity to execute large scale experiments in river ecology. The experiences gained allow to draw guidelines for future conservation management.
Restoration in the sense of a return of an ecosystem to conditions prior to human interferences is rarely a realistic goal. However in defining the realistic goals - the ecological targets, their end-points and long-term sustainability and in the evaluation of alternative management measures it is irrevocable to refer to the original conditions as reference standards. These reference standards, the original landscape pattern as the dynamic equilibrium of fluvial processes, defined by hydrology, bed-load transport and geomorphology, have to be derived from historical maps and descriptions and analytical procedures using undisturbed reference sites. In applying reference standards in the definition of targets and the evaluation of management alternatives, it is of paramount importance to follow the hierarchy of cause - effect relationships (see Fig. 2): Key factors within a specific topographic and geological setting are hydrology and bedload transport. The resulting geomorphic dynamics lead to a dynamic equilibrium of habitat composition and connectivity which finally is the arena where the ecological processes and the characteristic biotic diversity is dependent upon.

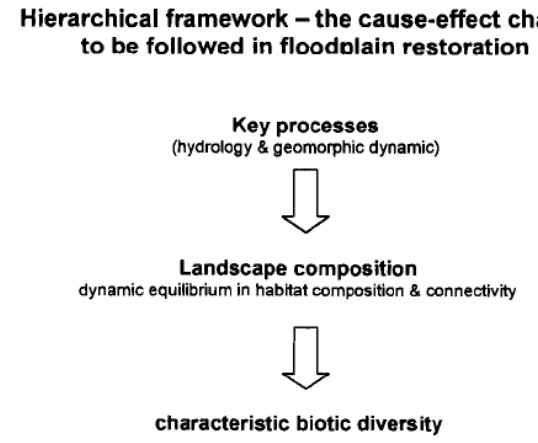

Figure 2. Hierarchical framework to be followed in the application of reference standards

This hierarchical framework resolves the controversy between a system vs. a species centred approach. Different groups of bioindicators from plants to mammals- have to be

integrated. In managing "riverscapes" the key factors hydrology and bed-load transport form the screw which have to be used ("let the river work principle"). In order to attain a dynamic habitat equilibrium with appropriate functions, hydrology and bedload transport have to reach and maintain a dynamic geomorphic equilibrium resulting in a characteristic habitat pattern. Such endpoints should be sustainable without further management.

The need for prognostic eco-hydrological parameters

The formulation of restoration programmes is in a learning phase considering the limited international experience so far made. This necessitates long-term monitoring of pre- and post-restoration conditions in order to resolve questions on feasibility, time scales, sustainability, and to document and analyse the various stages of recovery. An important goal in this respect is the formulation of appropriate eco-hydrological parameters. From the limnological perspective in the formulation of the goals of restoration programmes the following aspects have to be distinguished:

1. limnological processes linking to the integration between the river and its floodplain
2. the biodiversity and the representation of various ecological guilds, from stagnotopic to rheotopic with respect to connectivity
3. the extent of channel transport processes and geomorphic processes within the floodplains with respect to habitat dynamics
4. exchange processes between the groundwater and the river.

For all those aspects different ecohydrological parameters have to be formulated and their significance calibrated on a bioindication of effects.

Conclusions

From our experiences it is apparent that the development of management criteria has to be based on insight into the ecological functioning and also the knowledge of short- and long-term effects of the various forms of human utilisation and engineering.

The goal of restoration is to retain and regain the functions of the rivers and their riparian zones in respect to

- the water budget of the whole landscape,
- their value for natural purification processes,
- the significance of wetlands as focal points - as hotpots - of biodiversity and
- the significance of riparian wetlands as a resource for human recreation.

In the formulation of the management strategy for a particular wetland area several questions have to be addressed and constraints identified especially with regard to

a) the reversibility, i.e. to which extent under the present day constraints is it possible to turn back the clock in the direction of the original conditions prior to river regulation and damming
b) the ecological target conditions ("reference standard")
c) long-term sustainability with regard to a dynamic equilibrium of hydrology and fluvial geomorphic processes.