ISSN 2070-1292

danube news

Bulletin of the International Association for Danube Research (IAD)
Informationsblatt der Internationalen Arbeitsgemeinschaft Donauforschung (IAD)

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Modeling tools for water management

Editorial

Dear Reader

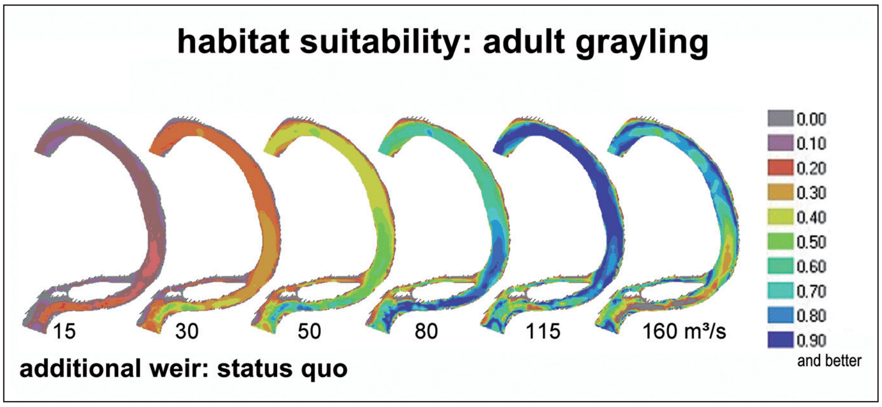

Figure 1. An example of ecohydraulic modeling, River Rhine, showing spatial distribution of habitat suitability for adult grayling (Thymallus thymallus) in relation to various discharge scenarios (15–160 m^3/s) and additional weir operation (status quo). The applied model CASiMiR with its "fuzzy logic" approach is a typical example of how to link river hydrology and morphology with fish requirements. By using realistic scenarios, predictions of ecological quality can be made. (Reference: Bloesch J, Schneider M & Ortlepp J (2005): An application of physical habitat modelling to quantify ecological flow for the Rheinau hydropower plant, River Rhine. Arch. Hydrobiol. Suppl. 158/1–2 – Large Rivers 16/1–2, 305–328)

Water and river basin management are based on the understanding of complex aquatic ecosystems and respective models. A model is an abstraction of reality. But what is behind this abstraction? Science has developed various concepts of models such as the physical model (for example in experimental hydrology), the dynamic and stochastic model (as used for random natural processes), the deterministic model (based on probability theory), the regression model (based on mathematical relationships), and conceptual models (linking different functions). Any of these models help to understand the function of complex aquatic ecosystems such as lake metabolism, dynamic river processes or food-web interactions. However, although models became technically more sophisticated (for example, hydrological 1D models were developed into 2D and 3D models), modeling means to simplify and, hence, a model clearly is not reality. We always need to keep this fact in mind when considering our faith and expectations in models.

Accuracy and uncertainty matters when we cope with models. This is evident when dealing with weather forecast (short-term prediction), climate change and global warming (long-term prediction), or flood risk assessment (alarm system). Any model must be calibrated against measured data to prove its usefulness. This process is not easy since measured data have a various degree of precision. Therefore, any model needs to consider the accuracy and range of error. Further, the scale in space and time is of crucial importance. The larger and complex the system, the longer the time period, the less accurate is the model output. An inherent problem of modeling is the many parameters changing by time and complex parameter interference. If the calibrated model can well describe the reality, then it has the strength to make predictions into future developments. Hence, a future status of an ecosystem may be predicted under given scenarios or under estimated trends that are extrapolated under certain assumptions of parameter change from historical or present developments.

This issue of Danube News provides a selection of models dealing with basic processes in the Danube River Basin. Hydrology is the driving force of floods, bed-load transport and river morphology, and ultimately the conditioner of biota and their habitats. However, there is also a feedback of the biota by influencing hydrological processes. The articles stress that not only scaling is of utmost importance, but also the quality of input data and monitoring of the model output. The predictive potential of these models can help water managers and decision makers to seek for truly "sustainable" measures in using and protecting the Danube River. IAD can make an important contribution to such applied research.

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Ecohydrology for engineering harmony between environment and society

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Introduction

The dynamics of the water cycle in a river basin depends on climate, geomorphology, plant cover, freshwater ecosystems typology and modifications by agriculture, urbanization, industrial development and hydro-technical infrastructure.

Water management till the end of the 20th century was dominated by a mechanistic approach focused on the elimination of threats such as floods and droughts, and provision of water to societal needs. The biological structure of ecosystems around 1900 was mostly used as indicator of ecological status (Kolkwitz & Marsson 1908). Declining water quality at the global scale and increasing progress in the predictive potential of ecology and limnology provided the background for the development of integrative sustainability science, i.e., ecohydrology (EH). The basic question of EH is: what is the hierarchy of factors regulating the dynamics of hydrological—biological interactions? And further, could its application be used to solve societal problems with reference to Integrated Water Resources Management (IWRM) in the frame of the EU Water Framework Directive (WFD 2000)?

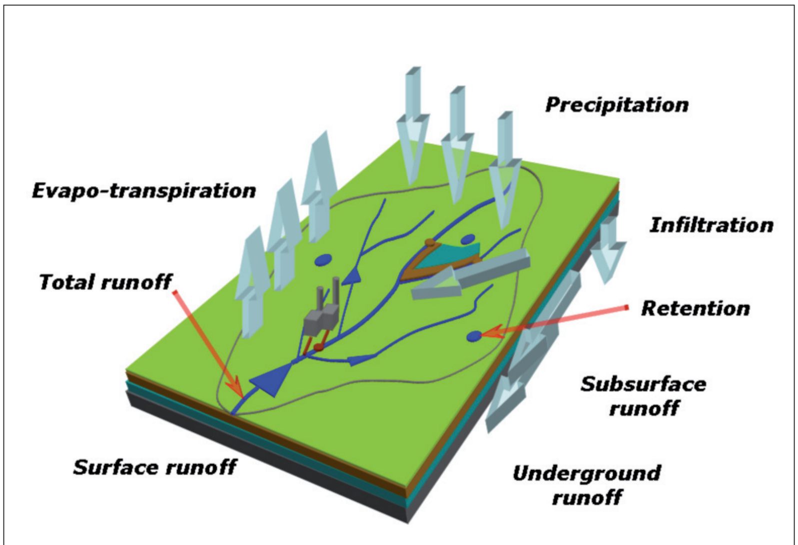
Ecohydrology – evolution of a paradigm

EH is a transdisciplinary science which has been developed in the framework of the International Hydrological Programme of UNESCO (IHP V—VII). As a sub-discipline of sustainability science it is focused on biological aspects of the hydrological cycle. It provides not only scientific understanding of the hydrology/biota interplay, but also systemic framework how to use ecosystem properties as a new tool for IWRM, complementary to already applied hydrotechnical solutions. The novel element of this approach to restore degradation of aquatic ecosystems is to combine protection and regulation of ecosystem performance from a landscape to a molecular scale. Biocenotic processes are shaped by hydrology and, vice versa, biocenotic structure and interactions shape hydrological processes (Zalewski 2000, 2006). In terms of evolution, terrestrial and aquatic organisms have adopted to water quantity and quality dynamics in the catchment.

The recent integration of environmental sciences toward problem solving is based on the concept of ecological engineering formulated by Mitsch (1993). This changed the way of thinking about relations between humanity and the biosphere. The increasing global environmental degradation suggested that ecosystem properties have to be considered as a new management tool toward reversing degradation. This approach was expanded to the catchment scale by the concept of ecohydrology (e.g., Zalewski 2000; Harper et al. 2008). The evolving paradigm was the change from interdisciplinarity to transdisciplinarity by harmonizing societal goals with ecosystem potential. Due to the complexity of applied knowledge the development of mathematical models for decision support systems should be a useful tool to test alternative scenarios and implement EH methodology for sustainable water use, ecosystems and societies.

Such a transdisciplinary approach, which integrates different disciplines of environmental sciences toward societal goals and aspirations taking into account cultural heritage (Berton & Bacchi 1997), creates a new opportunity to achieve sustainable development. The future of the biogeosphere will be dependent not only on the development of technologies but also on harmonization of technologies with the potential of the environment.

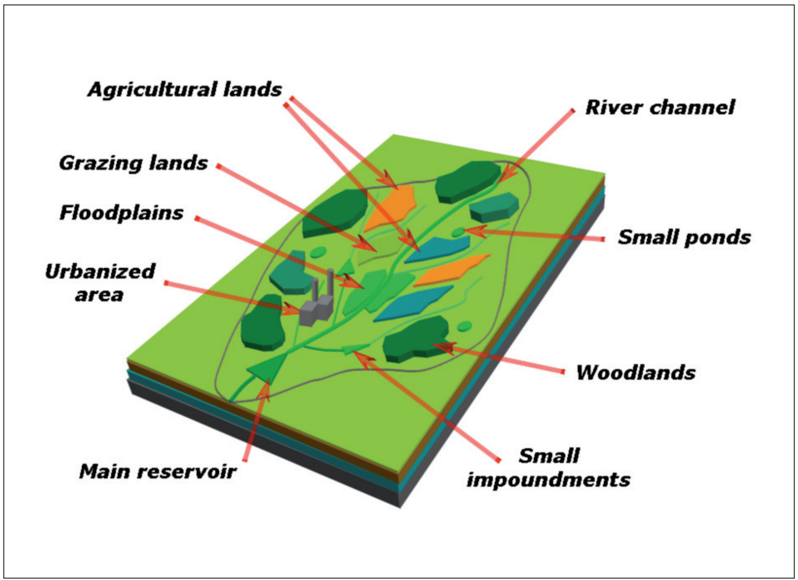
Figure 1. First EH Principle – Hydrology. Quantification of the hydrological cycle from the viewpoint of socio-economy and spatial-temporal dynamics vs. various forms of human impacts



Ecohydrology – the terrestrial and aquatic dimension

The scientific catchment approach and its implementation for IWRM encompass an atmospheric/terrestrial and an aquatic phase of the hydrological cycle. In both, diverse biota appear as moderators of water dynamics. In the terrestrial phase (EHT), vegetation moderates water quantity and quality, and the major question is how land-cover changes influence the hydrological cycle. In the aquatic phase (EHA), complicated biotic interactions affect water quality and related symptoms of eutrophication (e.g., toxic algal blooms).

Figure 2. Second EH Principle – Ecology. The distribution analysis of various types of biocenoses and its potential to enhance resilience and absorbing capacity for human impact (GIS)



The reduction of point source pollution is dependent on technology, monitoring and law enforcement. However, the impact reduction of diffuse pollution without lowering food production is dependent, first of all, on understanding the hierarchical complexity of ecological processes in the river basin. Of utmost importance is the interplay between water and biocenosis – both in the terrestrial and aquatic phases of the hydrological meso-cycle.

Both EHT and EHA require multidisciplinary and interdisciplinary cooperation of basic scientific disciplines (e.g. Baird & Wilby 1999; Zalewski 2000). A key component of this paradigm is the aspect of "problem solving". Hence, ecosystem properties serve as management tools for sustainable development by respecting the quantitative side of the hydrological cycle. Supporting tools are remote sensing, GIS techniques and mathematical modelling (Jørgensen 2002).

Ecohydrology – the novel aspects of systemic solutions for environmental sciences

Aquatic ecosystems are complex entities studied in a multidisciplinary approach by considering the hierarchy of various regulatory environmental factors. However, their regulation needs an additional reference point, society, which combines with natural science into an integrative transdisciplinary science and management.

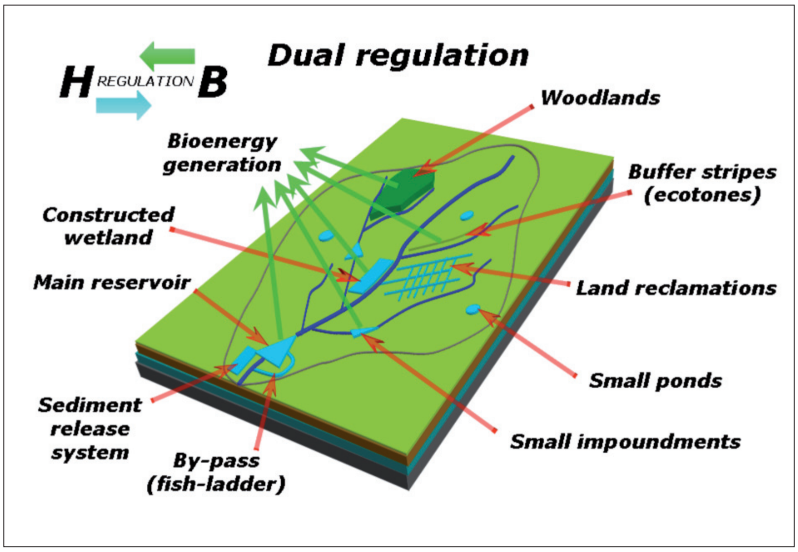
EH provided three new aspects to environmental sciences and their implementation: (1) The use of ecosystem properties as new management tools complementary and harmonized with hydro-technical solutions; (2) The necessity to enhance the ecosystem's carrying capacity toward UN Millennium Development Goals by using the interplay between hydrology and biota. The analysis of dynamic oscillations of the ecosystem, productivity and succession reflected by nutrients/pollutants absorbing capacity vs. human impacts should be the key for process regulation; (3) The use of "dual regulation" to improve water resources, biodiversity and ecosystem services for society (expressed as carrying capacity).

Principles of ecohydrology as a framework for scientific investigation and problem-solving implementation

The hydrological principle — The quantification and integration of hydrological and biological processes at the basin scale is based on the assumption that abiotic factors are of primary importance and become stable and predictable when biotic interactions start to manifest themselves *(Figure 1).* The quantification covers the patterns of hydrological pulses along the river continuum and monitoring of point and non-point source pollution to regulate processes toward sustainable water use and ecosystem protection.

The ecological principle — The ecological principle is based on the assumption that under intensive global changes it is not enough to protect ecosystems against increasing human population, energy consumption and aspirations *(Figure 2).* It is necessary to regulate ecosystem structure and processes toward increasing the "carrying capacity" (water quality, restoration of biodiversity, ecosystem services for society, resilience of river ecosystem). Understanding the role of vegetation in water cycling processes is of crucial importance (Vorosmarty & Sahagian 2000).

Figure 3. Third EH Principle – Dual regulation. Using biota to control hydrological processes and, vice versa, using hydrology to regulate biota



The ecotechnological principle —The use of ecosystem properties as management tool is based on the first and second principles of EH and related to ecological engineering *(Figure 3).* This principle features three steps of implementation:

(1) "Dual regulation" – biota by hydrology and, vice versa, hydrology by shaping biota or controlling interactions.
(2) Integration at the basin scale of various types of biological and hydrological regulations toward achieving synergy to improve water quality, biodiversity and freshwater resources.
(3) Harmonization of ecohydrological measures with necessary hydrotechnical solutions (dams, irrigation systems, sewage treatment plants, etc).

Achievements and limits of ecohydrology

Pollution is one of the key issues and greatest challenges of ecohydrology. An implicit but major goal of EH is to reduce input to, and regulate excess nutrient and pollutant load in aquatic systems by considering important pools like soils, sediments, vascular plant biomass, and conversion of matter by organisms. However, EH methods are less efficient and have a lower potential when the carrying capacity of the ecosystem is exceeded, e.g., in the case of hypertrophy (Zalewski 2000). Ecological biotechnology used in the framework of EH is becoming the fundamental tool for successful implementation of Integrated Water Resources Management.

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Applying meso-scale habitat modeling to waterway management

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Introduction

Riverine ecosystems and their habitats are inherently complex and contain many relationships between biotic and abiotic components. Habitat models can be an appropriate instrument to study the ecological functions of these systems. They allow for the quantitative and qualitative assessment of habitat conditions for resident indicator species such as fish.

In the past, habitat modeling has focused primarily on ecological impacts at the local scale using short (hundreds of meters) investigation reaches. In recent years, there was a growing need for tools allowing for an integrated analysis at larger scales. To satisfy this demand MesoCASiMiR (Schneider et al. 2006; Eisner et al. 2007), as meso-scale habitat model was developed at the University of Stuttgart. It acts conceptually as a decision support system at a scale of larger river segments, or even river catchments and is an extension of the micro-scale, fuzzy-logic model CASiMiR (Jorde 1996; Schneider 2001; Wieprecht et al. 2008).

Fish habitat modeling in waterways requires a focus on factors which may differ substantially from those of natural rivers. Special attention must be given to the bank and overbank areas. Main navigation channels are usually less important for fish due to their poor morphology and frequent disturbances by passing ships. Habitat modeling is a promising approach when improving the ecological integrity of waterway banks. However, current model concepts must be extended to conform to the specific conditions and requirements of large waterways.

Two-staged model concept

MOFIR (**Mo**del for **Fi**sh **R**esponse) is a fish habitat model developed as complement of the platform INFORM designed by the German Federal Institute of Hydrology (BfG 2003). It provides a decision-support-system for hydraulic engineers and biologists to be utilized in the early planning and design stages of a project. Fish have been chosen as indicator species for riverine ecosystems since they are highly sensitive to both structural and hydraulic changes. Additionally, measures and alterations in and around river banks account for the largest and most severe impacts to fish habitats. MOFIR, based on the original CASiMiR model system which combines habitat requirements of fish with abiotic conditions, provides quantitative information of habitat quality and availability to support environmental impact assessment.

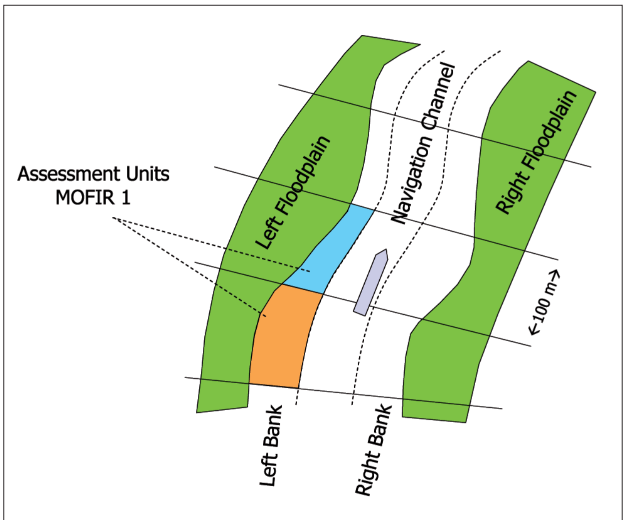
MOFIR incorporates two separate versions, each having its own focus of application. MOFIR 1 has been tailored for those working in the water and navigation management sector to provide a first critical look at potential ecological impacts of design options. The program must rely on a limited set of model parameters which do not require complicated or time-intensive data retrieval methods. The more detailed version MOFIR 2, on the other hand, must be able to carry out thorough, site-specific analyses. The model base is designed to enable an accurate prognosis through user-defined analysis. MOFIR 2 can make use of an expanded set of input data and parameters.

Riparian zones, connections between main channel and floodplains as well as tributaries are of particular importance as fish habitats, whereas the main channel itself often has little or no value due to poor morphologic conditions, high turbidity and frequent disturbances by passing ships. For these reasons, the development of MOFIR is focused on the bank and floodplain areas only. Motivated by the cross section data available for German waterways the smallest assessment unit length in MOFIR 1 is set to a default value of 100 m and the left and right floodplains are accounted for separately *(Figure 1).* In MOFIR 2 the smallest assessment unit depends on the available grid resolution of the digital elevation model (usually a few m²).

MOFIR 1

Hydraulic conditions near banks and in riparian zones are often complex due to heterogeneous morphology or engineering measures such as groynes, parallel hydraulic structures, excavations or restoration efforts. Since MOFIR 1 is equipped with a one-dimensional hydrodynamic model only, it should be used to gain an overview of potential impacts of planned changes.

Figure 1. Assessment Units in the MOFIR 1 Program



To account for the fundamental impacts of various measures on fish species, MOFIR 1 deals with ecological groups, rather than focusing on specific fish species and their life stages. The following ecological groups are considered:

- Group A: Juvenile fish and hatchlings *(Group reacts sensitively to changes to the shallow bank areas)*
- Group B: Limnophilic fish *(Group is sensitive to hydraulic changes on the scale of groyne fields, and pool areas)*
- Group C: Rheophilic fish and gravel spawners *(Group is sensitive to changes in local hydraulic conditions as well as to the substrate composition)*
- Group D: Gap residents, e.g. Eel *(Group is sensitive to changes in the coverage properties)*

Beside water quality, fish are also strongly affected by local hydraulics and morphology. Flow velocity and water depth may be taken directly from an integrated hydraulic model (1D) using cross section data usually available for navigable rivers. The other key parameters for habitat modelling using MOFIR 1 are substratum and coverage. These input parameters can be transferred from existing databases and supplemented by local experts. Through these key parameters, it is possible to quantify a basic habitat suitability of a 100 m reach for fish. The model also allows for the inclusion and interpretation of aerial photographs (orthophotos) with regard to fish habitat-relevant structures such as groynes, different bay types, side channels, steep or flat banks.

Habitat suitability ordered in five classes is derived in a first step by the section-wise evaluation of expert-rules including the key parameters. In a second step the structural parameters are assessed by another rule-set. Thus, for each ecological group the identification of suitable or unsuitable habitat areas can be determined.

For scenarios of future technical measures the model data base is different. Since, e.g., there are no orthophotos available for planning alternatives an additional set of rules predicting the effects of management measures on certain model parameters was established. Whereas parameters such as mean water depth and flow velocity can be derived by hydraulic calculations on the basis of a new bathymetry defined for one measure, other parameters like flow diversity cannot be derived directly. At this point the rule-system comes into play. E.g., it is predicted that the construction of a groyne will create a cross-sectional structure, and consequently the flow diversity and depth variability will be "high". With further fuzzy-logic processing habitat suitability is derived (Wieprecht et al. 2008).

MOFIR 2

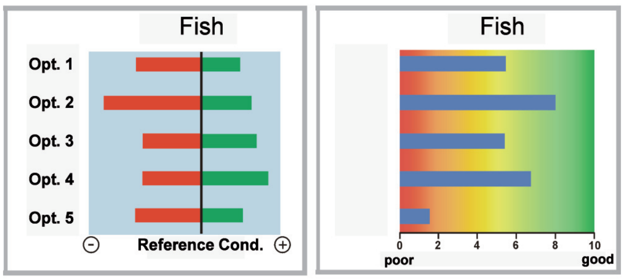
MOFIR 2 is designed for more detailed investigations. By the intersection with a digital terrain model a high level of accuracy and resolution (few m² per cell) for the river bank areas can be provided when assessing fish habitats. Instead of ecological groups, in MOFIR 2 specific species and life-stages are considered. The high resolution of the model enables the input of detailed data on water depth and velocity as well as direct incorporation of structures such as shallow zones, groynes, bays, etc. The rule systems of MOFIR 2 are based on the fuzzy-logic approach of the habitat model CASiMiR (Schneider 2001). Using the results of a two-dimensional hydraulic model, habitat conditions for a wide range of flow rates can be assessed. The habitat model assigns a habitat suitability index to each cell ranging from 0 to 1 (SI = 0: not suitable; SI = 1.0: highly suitable).

Model evaluation

MOFIR evaluation is performed by comparison with a reference status. In contrast to other reference-based approaches this reference status is not the one prior to human impacts but the current status. Thus, the evaluation delivers quantitative information on the degree of amelioration or deterioration in comparison to the existing situation.

Using the habitat suitability index a Weighted Usable Area (WUA) as equivalent of habitat availability is determined. The WUAs for each design scenario are compared with the one for the reference condition. *Figure 2* shows an exemplary result of an evaluation. The horizontal bars reflect the various planning alternatives and their consequences. Green bars extending to the right of the vertical line represent the total of areas with improved habitats, red bars show the sum of areas with decreased habitat suitability. Areas with a large change of suitability receive a higher weight to emphasize heavily affected river parts. The same applies to reaches/grid cells with a high suitability index (SI> 0.7) indicating good habitat quality. The model results for a planned design option will be depicted as a change of state in relation to the reference condition and displayed in a bar chart format *(Figure 2, left).* In addition to the presentation of negative and positive impacts, an ecological assessment of the design options based only on the negative impact is performed on a scale from 0 to 10. The value 0 is given to the variant with the largest negative change, the variant with the lowest negative change is assigned 10. The values of the other variants are interpolated linearly *(Figure 2, right).*

Figure 2. Example of the evaluation result showing a comparison of design options **left:** *Chart representing the changes of status, red bar as equivalent of areas with decreased habitat quality, green bars as equivalent of areas with increased habitat suitability, weighing of areas with large change and areas with high habitat suitability index (SI>0.7) is included*
right: *Chart depicting the overall ecological impact assessment based on the negative impacts in terms of loss in habitat suitability*



Since calculations are performed for each species or ecological group separately, the interim results can be traced back to the fish's ecological function (e.g. habitat suitability for juveniles). By weighting results of certain ecological groups, such as e.g. gap residents, development objectives can be incorporated in the evaluation. Results for the species or groups are summarized to a combined result "fish" (e.g. by averaging). This end result can then be included into a large scale assessment using the INFORM platform, and compared to other modules (Wieprecht et al. 2008).

Conclusions

The presented MOFIR models extend basic fish habitat modeling principles from non-navigable rivers to waterways by respecting bank structures, wave action and fish requirements. This tool may be applied for Environmental Impact Assessment (EIA) on actual navigation projects in the "Green Corridor" of the Danube River. As such, it can help to implement the EU Water Framework Directive in the framework of the Danube River Basin Management Plan. Due to a two-staged model concept mitigation measures and their impact on fish habitats can be considered in the early planning and design stages (MOFIR 1) as well as analyzed in more detail (MOFIR 2). Since the model concept allows for the integration of existing data into the modeling framework, MOFIR may be applied without additional time-expensive data collection.

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Modeling river bed morphology with special reference to the bottlenecks in the Green Danube Corridor

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Introduction – Progress in developing a new integrated planning process

Previous issues of "Danube News" addressed the problem that ongoing or planned projects in the Danube River may affect its hydromorphology and, hence, the ecological conditions in the river and its landscape (e.g. Bloesch 2007). Schabuss & Schiemer (2007) deal with possible threats through navigation and point to the bottleneck sections of the Danube where river engineering measures should ensure navigation in times of low water levels. These bottlenecks, however, are also highly valued "hotspots of diversity" (Kutzenberger & Nichersu 2007). Schabuss and Schiemer further argue that the "latest innovations both in navigation infrastructure and river engineering as well as in life sciences must be considered and applied" to find ecologically acceptable solutions.

An essential step forward in developing a planning process that considers such arguments can be seen in the "Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin" prepared by ICPDR. This document introduces a new integrated planning philosophy and advocates for developing a joint approach that is designed to meet both the needs of Inland Waterway Transport (IWT) and ecological integrity. It further contains recommendations for planning principles and criteria for river engineering to obtain sustainable development. In the context of river morphology, the following two principles should be considered: the principle of "working with nature" and the principle to implement measures in an adaptive form. This implies that measures should be implemented – wherever possible – "according to given natural river-morphological processes ...".

Studies on river morphology including comprehensive in situ observations and measurements must be performed to provide the basis for the planning process. For example, monitoring and modeling are an essential part of the "Integrated River Engineering Project on the Danube to the East of Vienna (IREP) to get a sound understanding of the morphological processes (Habersack et al. 2008).

Understanding morphological processes in the river – a prerequisite for the planning process

Morphological dynamics is the result of a complex interplay of sediment input to, and local sediment transport in, a river reach and varies considerably at different temporal and spatial scales. Rivers develop characteristic features of planform, channel pattern, gradient, type of bed material etc. depending on how this interplay works under the specific geomorphologic and hydrologic conditions. This allows to classify river courses as straight, braided, meandering, anastomosed, etc., which helps to assess the principal processes determining the changes and variations of the morphological structures of a river section.

Applied to the Danube, the natural river landscapes with floodplains of the Upper Danube are braided and anabranched river sections (Hohensinner et al. 2008). Both river planform and floodplain connections were, however, heavily altered mostly by channelization. Now these river sections exhibit straight or slightly sinuous channels with alternate bars.

Quite different is the picture of the Lower Danube. The river with its varying widths, its tendency to build multiple branches and islands, with its much lower gradient and much finer bed material, can be classified as an anastomosed river. The wide channel sections are prone to frequent in-channel bar and island formation by sand and silt deposition. Permanent variations in extent, location, and height of these bed forms contribute to an ecologically highly valued variety of flow and water depth. However, they also cause frequent changes in location and depths of the navigation fairway. Sections with "over-width" (very wide channel sections) are also prone to permanent bank erosion which can amount to several meters per year (Phare 2000).

Many processes at different scales contribute to the occurrence and development of various bed and riverine structures and variations in sediment transport. To characterize a river reach in detail, cross-section profiles, bed forms (type, location, length, and height), longitudinal profile and gradient are to be studied by considering information on sediments (bed load and suspended load, grain sizes and gradation). From recurrent bathymetric surveys river bed changes in space and time, and the dynamics of bed forms, bars, scours and fords can be deduced. *Figure 1* shows the result of such an analysis and the consequences of the big flood in August 2002 for an 8 km long section of the Austrian Danube. The two upper maps (02-1 and 02-2) show various bar sections (brown-yellow bar and deep-blue scour cross-section parts) and ford sections between the bars. From the third map (meas) the areas of deposition or erosion can be identified.

Further, detailed studies of river engineering (groynes etc.) at five fords in the Austrian Danube east of Vienna were performed by DonauConsult (2004). Ideally, an analysis of the current state of the river is completed by historical data. Such information is now available, e.g., for two river-flood-

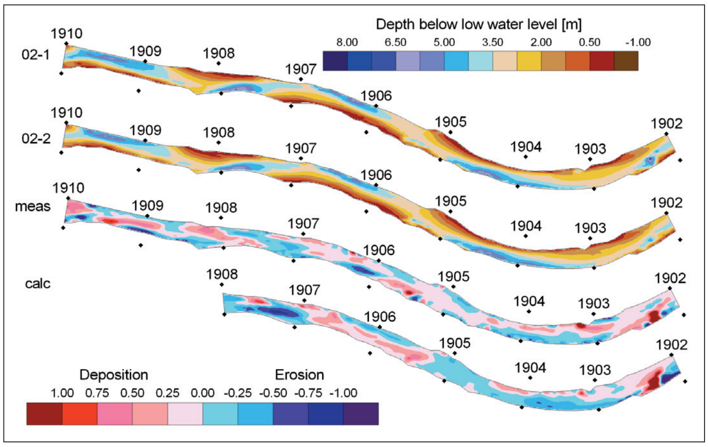

Figure 1. Morphological changes of an 8 km long reach of the Austrian Danube east of Vienna during the flood episode 2002: water depths (below the reference low water level) according bathymetric surveys before (02-1) and after (02-2) the flood; bars and fords are characterized by brown-yellow colour, deep-blue colour shows the pools; observed (meas) and calculated (calc) river bed changes (areas of deposition or erosion) between the two surveys (Fischer-Antze 2005)

plain systems of the Austrian Danube (Hohensinner et al. 2008). Data reconstructed from historical maps of the river landscapes – in this case maps of 1812 for the Machland area and 1849 for the Lobau area – were used to quantify characteristic features such as the water-covered areas and the bank lengths of the "Active Zones". Comparison with corresponding results for the current situation highlights the tremendous changes in hydrological surface connectivity due to the channelization in the 19th and 20th century and helps to identify the basis of sustainable and effective river restoration concepts.

Modev (2005) described the characteristics of six selected bottlenecks in the Bulgarian part of the Green Danube Corridor (Somovit, Malka Barzina, Milka, Batin, Mishka, Popina), based on bathymetric and hydraulic data and water levels. The morphological features – location and development of bars, islands and banks – provided a classification in five groups that may help to assess river engineering measures in accordance with the morphological regime in these river sections.

Comparing old river maps was also a starting point to gain insight into the morphological changes over time at a reference section of the Lower Danube (Behr et al. 2000). To make the surveys performed in the two countries Bulgaria and Romania comparable, a special procedure based on local coordinate transformations was developed to transfer the maps based on different coordinate and height systems to produce the gridded difference maps (Phare 2000). The results showed a strong movement of river bed in the given time.

All these studies showed that such analyses of river bed morphology are necessary to understand the occurrence, formation and alteration of the morphological features of a river and are, therefore, also a prerequisite to modeling.

Modeling river bed morphology – examples from the Danube River Basin

Models are usually classified as 1D-, 2D-, and 3D-models depending on the number of dimensions incorporated in the model. Viewed from the aspect of enabling to capture the 3-dimensional features of a river bed, 3D-models would be ideally suited for morphological studies. There are, however, some obstacles against a wide spread use of such models as their application is associated with long computational times and the need of detailed observational data for calibration. Current state-of-the-art is the application of 2D-models. Allowing to describe the flow processes in the longitudinal and in the transversal dimension, they can be applied to model channel-floodplain interactions and flow and transport variations in channels with non-uniform shape. 1D-models have been so far the backbone of many studies which were designed to simulate sediment balances in long river-reaches and over longer time scales.

Before 2000, mainly empirical approaches based on channel parameter, cross-section-flow relationships, and sediment balance estimates were applied in the Danube River due to the fact that river bed surveys were not available (Phare 2000). An exception are a few applications of 1D- and 2D-hydrodynamic models to study suspended sediment transport, river bed changes, and modifications of the Danube upstream of Nagymaros (Hungary), in a Serbian river section (rkm 1333-1317), and in the backwater zones of Iron Gate I dam. Other studies using hydrodynamic models were devoted to describe flow patterns, velocity and shear stress distributions as a basis to conclude on river engineering measures.

The progress in model development and computer techniques has led to a new level of hydrodynamic models. In the Bavarian Danube the flow and morphological evolution in the Straubing-Vilshofen reach was investigated by several authors. Well documented is the application of the 2D-model FAST2D to study the morphological changes under extreme hydraulic conditions in typical flood situations in the river section between rkm 2282 and rkm 2265 (Minh Duc et al. 2005). In the Austrian Danube Fischer-Antze (2005) employed the 3D SSIIM-model (Olsen 2002) to simulate river bed changes during the flood episode of August 2002 *(Figure 1)*. The lowermost map ("calc" in *Figure 1)* shows the calculated bed changes (in m erosion or deposition, respectively) in comparison to the observed ones ("meas"). Reasonable accuracy in representing the relevant morphological features has been achieved.

Related to the ongoing studies in the frame of the IREP-project mentioned above a new 3D-model (Rsim-3D, Tritthart 2005) has been designed to model the interactions between the channel and the groyne fields in the 40 km long Danube River section downstream of Vienna (Tritthart et al. 2009). The model is part of the strong efforts to provide the means for the continuous monitoring and modeling activities planned to accompany and assess the various engineering and ecological measures employed in the course of the project (Habersack et al. 2008).

Another study on the Hungarian Danube deals with the application of the 3D SSIIM-model to simulate the flow and sediment transport processes in a 6 km long river section with several groynes downstream of Mohács where a sequence of an over-widened and a shallow channel section causes frequent navigational difficulties (Rákóczi et al. 2008).

Outlook and conclusions

The examples given above may point towards the future direction of modeling river bed morphology to support an integrated planning process. The models used in these studies allowed to capture flow and transport phenomena such as secondary currents, non-uniform sediment transport, and sorting and armouring processes. They were applied to study dune and bar movements, the exchange processes between the river channel and groyne fields, and the impact of structures on river morphology, features that may be of paramount importance when the morphological situation of the bottleneck sections of the Lower Danube shall be analysed and modeled.

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An integrated model approach for sustainable floodplain management: the case study of the urban floodplain Lobau

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Introduction

Floodplains are highly endangered ecosystems as shown for the Danube River Basin, where about 80% of the pristine floodplain areas are lost (WWF 1999). The remaining areas show a distinct decline of ecosystem functions and services. In face of the increasing ecological and socio-economic constraints on river floodplain systems, sustainable management strategies are urgently needed. However, conflicts among the various societal demands and utilizations tighten the potential for good solutions. An additional challenge is the often limited understanding of these complex systems, especially as regards the interaction between different natural and anthropogenic driving forces. With respect to a sustainable development of the ecosystem, management approaches must be based on predictive geomorphological, hydrological and ecological models as well as on the comparison with reference conditions or guiding images which give an insight into the complex interactions of the different compartments. Especially in urban areas, ecological objectives have to integrate the many-fold, often conflicting social and economic demands and involve local and regional stakeholders in a participatory process to raise public support for the proposed strategies (Hargrove et al. 2005).

From a methodological point of view, the integration of the various ecological and socio-economic aspects of urban floodplain management often confronts managers and scientists with the problem of the incomparability of quantitative and qualitative data. Together with contradicting objectives this may hamper the comparison and evaluation of different management strategies. A sustainable management approach for urban floodplains, hence, needs an evaluation method which has the power to overcome these problems (Faucheux et al. 1998).

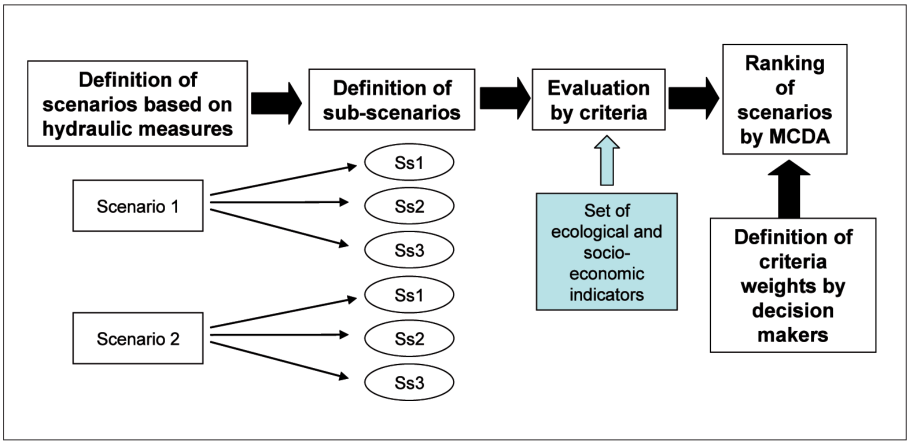


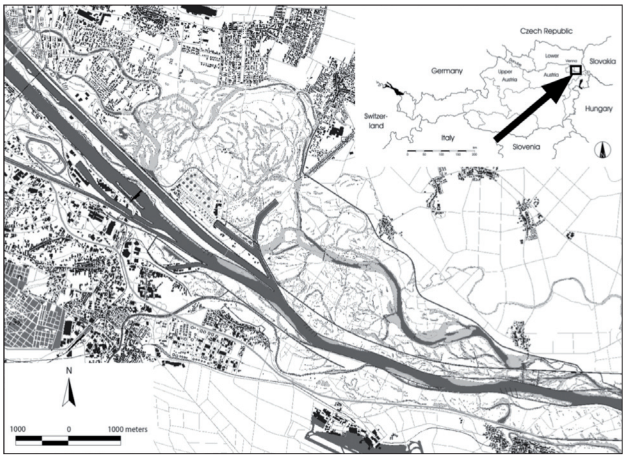
Figure 2. Work flow scheme, showing the interdisciplinary co-operation in the Lobau Project. Ss 1–3 = Sub-scenarios 1–3 (modified after Weigelhofer et al. 2006)

Here we present the outcomes of an interdisciplinary approach for identifying potential solutions for the sustainable management of an urban floodplain in the frame of the project “Optima Lobau”. Because of the multi-objective nature of floodplain management, we used an integrated model framework and a Decision Support System (DSS) based on a multi-criteria decision aid (MCDA) method. This approach is mainly based on the comprehension of the physical and biological processes and on the identification of drivers and factors for degradation.

Case study: urban floodplain Lobau

The Lobau is situated along the left bank of the Danube River at the eastern border of the city of Vienna *(Figure 1).* During the major regulation of the Danube in the 19th century, this former dynamic floodplain was disconnected from the main channel by the construction of a flood protection dam (Hein et al. 2006). Today, the Lobau represents a groundwater-fed and back-flooded lake system where sedimentation and terrestrialisation processes prevail. River engineering has not only led to a reduction of most of the basic ecosystem functions, but also to a drastic shift in the structure and composition of habitat types and vegetation cover. The reduced hydrological dynamics favors the establishment of rare but atypical species of dry meadows. Nevertheless, due to a still existing complex mosaic of aquatic, semi-aquatic and terrestrial habitats, the Lobau features an extraordinary high biodiversity. The floodplain has been designated as UNESCO Men and Biosphere Reserve, Ramsar site and Natura2000 area and constitutes a part of the Alluvial Zone National Park.

Figure 1. Project area Lobau at the eastern border of Vienna, Austria (after Hein et al. 2008)



Because of its proximity to Vienna, societal demands, including flood protection, drinking water supply (5 groundwater wells) and recreation (more than 600,000 visitors per year) play a considerable role in floodplain management. Land- and water-use like forestry, agriculture and sports fishery are currently regulated by the National Park Authority, but still need to be considered and harmonised in future management schemes.

Scientific approach and results

The MCDA approach in this project is based on the creation of scenarios and changed hydrological exchange conditions which describe possible future conditions of the floodplain as hydrological responses to different hydraulic measures (Weigelhofer et al. 2006). Main scenarios were differentiated into sub-scenarios as to the effects of the maximum development of one dominating ecological and socio-economic demand *(Figure 2).* In a participative, transdisciplinary process, the following driving forces were identified for the Lobau: fishery, eco-farming, recreation, drinking water supply, and the maximum potential for ecosystem development (rehabilitation of functional processes and conservation of habitats). Restrictions due to laws and legal regulations as well as the ecological potential of the landscape for various utilizations determined the framework of the different sub-scenarios. For the assessment of the sub-scenarios, various ecological and socio-economic indicators were developed by linking hydrological, ecological and socio-economic models.

To assess the effects of the potential changes, 75 indicators were selected from the following fields: aquatic ecosystem quality, terrestrial ecosystem quality, drinking water use, potential for recreation, potential for sport fishing and potential for organic farming. The details for the set up of the models and the data used can be found in Hein et al. (2006) and in the final report. The results for each indicator and each scenario were integrated in the MCDA using the PROMETHEE outranking technique. The basic matrix for the MCDA was a 31 scenarios x 75 indicators table. The calculation of the MCDA was performed for the unweighted indicator matrix as well as for several weighted matrices based on preferences from the different stakeholder groups.

Summarizing the results of the MCDA, the comparison of the different rankings clearly showed that the status-quo is not the preferred status for most of the involved stakeholders. The hydro-ecological and social modelling yielded measures involving a partial reconnection of the area that have the power to improve ecosystem conditions and equilibrate different ecological and socio-economic demands by keeping gains and losses in a balance. By contrast, a full reintegration of the area into the riverine flow regime will lead to a decrease of all human orientated utilizations, like e.g. recreation or the drinking water supply, while the impacts on endangered species in secondary developed lentic habitats remain unclear. Thus, a partial and controlled re-connection of the floodplain with the river constitutes the "best compromise solution", which also lies within the preferences of all involved stakeholders.

Future aspects and strategies for urban floodplain management

The developed approach linked research tasks with management strategies in a more explicit way and provided a scientific sound basis for further planning steps in the management of the Lobau area. So far, the potential directions for future strategies have been identified and the trade-offs between social and ecological demands, like e.g. requirements of increased ecosystem quality vs. the security of the drinking water supply, are presented.

The Lobau project covers the analysis of the status quo, including information gaps for further research (e.g. the need of a more advanced sedimentation model), a detailed description of drivers and demands in the area, and a historic analysis of potential reference conditions (compare to Hohensinner et al. 2005). The presented research, thus, constitutes the basis for a proposed planning process and provides a scientific sound background for the next steps in design and implementation of measures *(Figure 3).* The MCDA turned out to be an useful tool to assess operational guiding images, reveal trade-offs among different indicator fields which may constrain the latitude of solutions, and offer compromise solutions with a high potential for an integrated sustainable development of this urban floodplain ecosystem. Based on these results, potential measures for floodplain restoration are developed in a cooperative process of stakeholders and scientists.

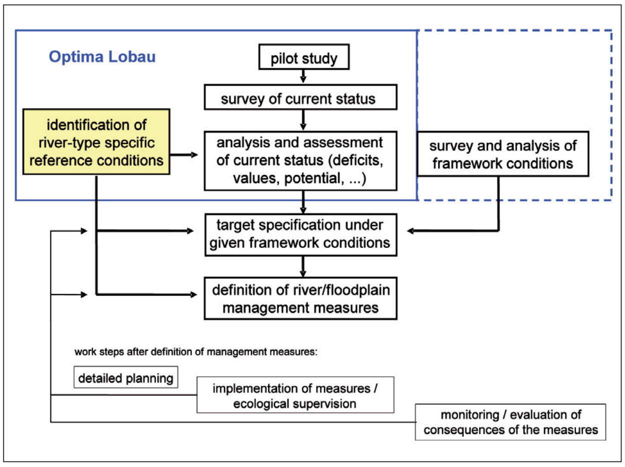


Figure 3. Scheme showing the role of the research project Optima Lobau in a planning process (modified after Muhar et al. 2003)

Acknowledgement

The study was conducted in line with the proVision-project "Optimized management strategies for the Floodplain Lobau, Austria – based on a multi criteria decision support system". We are thankful for the great teamwork of Iris Baart, Christine Habereder, Gertrud Haidvogl, Severin Hohensinner, Stefan Preiner and Gregori Stanzer. This work was partly funded by the Austrian Ministry of Science (ProVision 133-113), the Federal Ministry of Agriculture, Forestry, Environment and Water Management, the Federal Ministry of Transport, Innovation and Technology, Municipal Authorities of Vienna, the provincial government of Lower Austria and the Nationalpark Authority.

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Predictive modeling of biodiversity – a case study of a second order Carpathian River

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Introduction

Biodiversity is important to quantify the degree of internal regulation (homeostasis) and the carrying capacity of lotic ecosystems. Mathematical models can be used to reveal biodiversity-biotope relations and to predict the evolution of these systems.

We present a case study of the Cibin River, a second order tributary of the Danube in Transylvania, in the centre of Romania. Cibin River originates in the glacial lakes of the Cindrel Mountains (1920 m a.s.l.) in the Carpathians, has a length of 82 km and a catchment of 2210 km^2 (Posea et al. 1982). The river features various biotopes and is subject to many human impacts such as hydro-technical works, pollution sources, overexcavation of river bed gravel, and exploitation of riparian land (Curtean-Bănăduc & Bănăduc 2001). Scientific data exist since 1851 (Curtean-Bănăduc 2005).

Methods

During 1999–2004, quantitative samples of benthic macro-invertebrates were taken monthly, in the period March–November, at nine stations. In addition, biotope characteristics were evaluated (slope, substrate type, mean water flow, and physico-chemical parameters: temperature, pH, mineralization of organic matter (RF), total hardness (TH), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD-Mn), Cl^-, SO_4^{2-}, NO_3^-, total N, PO_4^{3-}, total P, Pb, Zn, Cu, Cd, and Mn). The sampling stations were chosen according to the valley morphology, the confluence of main tributaries, and type and degree of human impacts.

At each station, numerous samplings at different sites and substrates were carried out to cover the diversity of habitats. A total number of 1404 quantitative samples were analyzed.

Correlation and regression analysis were used to show the variation in diversity of benthic macro-invertebrates (expressed through biodiversity indices of Margalef – MA, Menhinick – ME, Simpson – SIM, Shannon-Wiener – H and equitability – €) related to the variation in biotope indicators.

Results and discussion

In Cibin River, 107 macro-invertebrate species belonging to 67 genera, 39 families, 16 orders, 10 classes and 6 phyla were identified. Caddis flies (Trichoptera), stoneflies (Plecoptera), mayflies (Ephemeroptera) and dragonflies (Odonata) were more abundant in the mountainous river sector, where the water has a high flow velocity, stony substrates predominate, and pollution is insignificant. Midges (Chironomidae) and worms (Oligochaeta) showed higher species numbers in the middle and lower course of the river, where the slope and flow velocity are low and the trophic supply (water richer in organic substances) is favorable for these organisms.

Macro-invertebrate diversity is highest in the mountainous sector of the river, where human impact is insignificant, and decreases downstream in parallel with increasing human impact. The minimum is found downstream of the input by the effluent of Sibiu's waste water treatment plant *(Figure 1).* In the mountainous section stenovalent rheophilic and oxyphilic species prevail, but the number of individuals of each species is low due to low trophic supply and relatively unstable physical environment (high water velocity, frequent floods). In the middle and lower river sections, the structure of benthic macro-invertebrate communities is determined by the type and degree of pollution. However, these communities are characterized by a stability (structural constancy) which is higher than that found in the mountains (Curtean-Bănăduc 2004).

The comparison of our data with historical records (Bielz 1851, 1867; Mayr 1853; Kis 1971; Plattner 1963; Schneider 1973; Botoşăneanu & Schneider 1978) showed that in Cibin River 19 macro-invertebrate species have disappeared and 13 species have a reduced distribution along the river. The majority of these stenovalent species has low resistance to environmental changes induced by human impact. These temporal dynamics reflect the degradation of natural river habitats by hydro-technical works (Gura Râului Dam, river

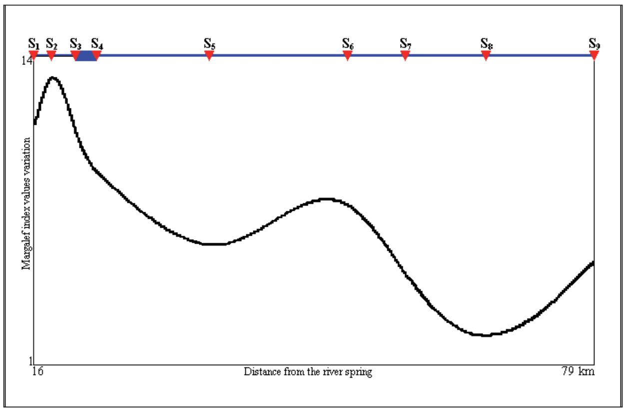

Figure 1. Variations of the Margalef-index MA along Cibin River (S_1 – S_9 sampling stations). Interpolation between stations by cubic function. High values of MA express high diversity. Macro-invertebrate diversity is highest in the mountainous sector of the river (S_1 – S_3), where human impact is insignificant, and decreases downstream in parallel with increasing human impact. The minimum is found downstream of the input by the effluent of Sibiu's waste water treatment plant (S_8)

canalization, marshes and floodplain drainage, cutting off meanders, river bank reshaping and embanking, tributary deviations, etc.), and pollution.

Regression analysis showed significant statistical relations between the diversity of benthic macro-invertebrates and the following biotope parameters: slope, dissolved oxygen, biochemical oxygen demand, organic matter, total hardness, chloride and sulphate concentration, and degree of mineralization. Some examples are given below (in the equations r^2 signifies the determination coefficient, S.D. is the standard deviation and q the level of significance):

$\ln(MA) = 2.523 – 0.053 \ln(BOD_5) \ln(DO) \ln(COD\text{-}Mn)$;
$r^2=0.799$; S.D.±0.247; $q<0.001$

$\ln(H) = 1.526 - 0.029 \ln(BOD_5) \ln(COD\text{-}Mn) \ln(DO)$;
$r^2=0.897$; S.D.±0.09; $q<0.001$

$\ln(SIM)=-2.712 + 0.056 \ln(BOD_5) \ln(COD\text{-}Mn) \ln(DO)$;
$r^2=0.788$; S.D.±0.269; $q<0.001$

$\ln(ME)=0.639 – 0.150 \ln(TH) \ln(RF)$;
$r^2=0.795$; S.D.±0.391; $q<0.005$

Conclusions

The predictive potential of regression analysis can be used by changing the independent variables (e.g., parameters of habitat quality) in various scenarios of river management. The output of such models is a prognostic variation in biodiversity (as a measure of homeostasis) of benthic macroinvertebrates with a known range of error. Hence, the model may deliver a set of modifications of some biotope parameters that can be used to establish a sound programme for sustainable river basin management. It must be stressed that such statistical and empirical models can hardly be transposed from one system to another and cannot be generalized without a sound calibration. These methods are time and resource-consuming, involving a highly skilled team of professionals.

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The use of models in flood risk management of the Lower Danube

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Introduction

Long-term strategic planning to achieve the objectives of the Water Framework Directive and the effective implementation of flood prevention, protection and mitigation need a sound scientific basis. The complexity of natural hydrological processes determines the principles, methods and analysis used for their study.

For example, establishing and reassessing the flood defence lines of settlements in the Lower Danube Plain and developing an integrated analysis of the hydromorphological, ecological, and economic conditions means to map, in a first step, the hydro-geomorphological units such as floodplains and agricultural polders.

Mapping has been neglected in the last 25 years. Therefore, a digital terrain model (DTM) was created which can design the defense strategy against flooding and base spatial planning (Kraus & Pfeifer 1998). With the DTM, floodplain dynamics and land use can be correlated, and indicators and indices of landscape can be characterized. Maps make the results clearly visible to the public, stakeholders and politicians.

Methods of mapping and modeling

Since the area of the Lower Danube Plain is crowded with channels and dams, the DTM needs at least nine topographical points to model a dam in three dimensions (2 pts for its base, 4 pts for the berm, 3 pts for its top). Hence, four points per square meter with a precision in altitude of ±5 cm are necessary when considering a dam with a base-width of 20 m. LIDAR (Light Detection and Ranging) is the only method that can ensure these requirements. The light detection is based on echo/laser pulse backscattering, i.e., measures the time used by the beam from leaving the sender in a round-trip plane to reaching the targeted scanned object, e.g., the land surface with hills, trees, houses, etc. We used a laser scanner with an accuracy of 5 cm (Riegl LMS-Q560) located on a plane (Partenavia P3) with two engines (Ly-

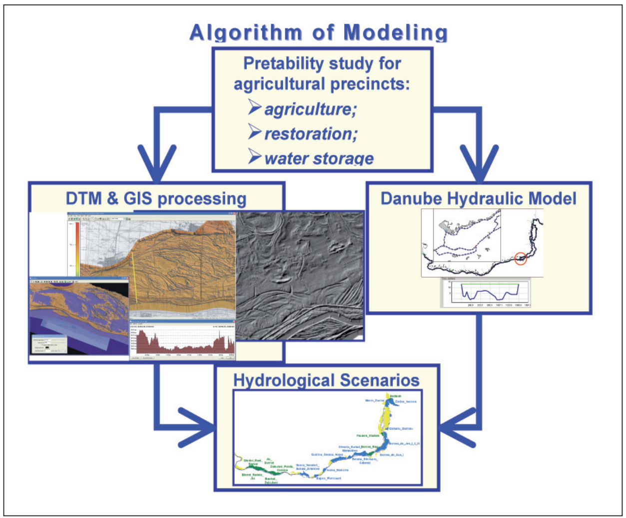


Figure 1. Scheme for using models in decision making. The first step of mapping the floodplains is followed by parallel DTM/GIS and hydraulic modeling that provides the basis for hydrological scenarios

coming 180CV) providing a flight altitude between 450 and 500 m. The scanned width is a land strip of 520 m, with 20% overlap between the parallel strips, and the flying speed is 45 m/s. LIDAR points were calculated by the software GraphNav, with simultaneous observations using GPS reference stations at ground, and calculations to collate the range of GPS and IMU (inertial measurement unit) by the laser sequential INERTIAL EXPLORER program (Hofmann-Wellenhof et al. 1992). This procedure allows coordinates with the required accuracy to show a good quality 3D picture. The method combined with a flight photogrammetry for viewing both normal color and infrared ranges supports mathematical models with applications in ecology and decision analysis.

DTM modeling is suited to simulate complex hydromorphological dynamics. It provides information on the restoration potential as well as natural and anthropogenic changes. DTM supports the adopted hydraulic model by designing various flood scenarios respecting water level and flow and by determining various stages of a flood alarm system.

The hydraulic model (software Sobek_Rural produced by the Institute of Hydraulics Delft, Netherlands in collaboration with the Institute for Water Management and Treatment of Interiors Waste, Riza Netherlands, SOBEK 2000) is one-dimensional and encompasses five distinct modules for modeling natural processes. These include permanent and temporary flow, sediment transport, river morphology, water quality, hydraulic scenarios for water management, hydro-engineering (dredging, dams, canals), controlled flooding and navigation. Model input parameters are cross sections over the total length of the Lower Danube, data series (daily values of levels and flows) from hydrometric stations, and channel roughness (Manning and Chezy formulas, Arcement & Schneider 2004).

Model application

Dykes along almost the entire Lower Danube Plain have affected the hydro-geomorphological function of the river, the socio-economic and natural capital, and the local and regional climate (Romania 2006). Global climate change further accentuates the problem. Hence, reassessment of economic activities in the polders of the Lower Danube Plain with a scientific, coherent foundation of sustainable development will provide alternative technical solutions. To restore the socio-ecologic balance in the Lower Danube Plain complex measures within the damaged and abandoned agricultural enclosures are necessary. These are identified by a multi-criteria model of socio-economic analysis. The following three aspects are important for spatial planning issues:

(1) Systems should be considered as a whole identity (according to the concept of River Basin Management). Otherwise, a water manager intervening directly only in a part of the system will not consider the consequences in other parts of the system.
(2) Human and natural systems are dynamic and, hence, constantly evolving, but never in balance. Therefore, small interventions of water managers involved in changing the system may trigger, at a certain critical point, consequences of great importance.
(3) River systems need space due to the natural flow pulse. Hence, the consequences of planning policy depend on the spatial design.

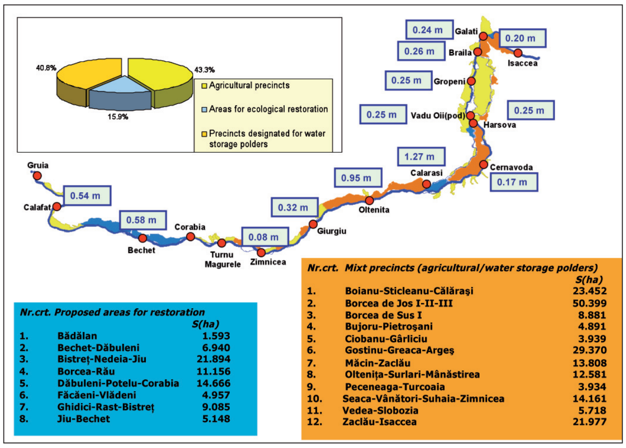
The applied method supplements the physical analysis through an evaluation of the socio-ecologic quality and ecosystem functions: productivity, habitat for species of plants and animals, regulation and control of biodiversity and links and exchange between two or more ecosystems. The purpose of this analysis is to elucidate the dynamics of functional and structural variables and to

- determine the indicators that define the structure, composition and operational components of the Natural Capital and Socio-Economic System
- perform an impact assessment (EIA) and environmental risk assessment (ERA)
- identify the tendency of structural and functional changes
- evaluate the causes of occurred changes.

Three flood scenarios were calculated with the hydraulic model to reduce maximum water levels by

- flooding not dammed agricultural enclosures as natural retention areas
- using water tanks for water storage in agricultural enclosures
- applying a mixed solution through water storage in some enclosures and flooding in others (restoration).

A combination of the three models described *(Figure 1:* multi criteria model of socio-economic analysis; digital terrain model (DTM); hydraulic model) helps to implement a strategic program for sustainable development and reassessment of the flood defense lines of settlements. The priorities are to develop the concept for flood defense of settlements by determining the capping level of new defending lines, to manage flooding of agricultural enclosures by storing water during periods of maximum Danube water levels, and to eval-



Nr.crt.	Proposed areas for restoration	S(ha)
1.	Bădălan	1.593
2.	Bechet-Dăbuleni	6.940
3.	Bistreț-Nedeia-Jiu	21.894
4.	Borcea-Rău	11.156
5.	Dăbuleni-Potelu-Corabia	14.666
6.	Făcăeni-Vlădeni	4.957
7.	Ghidici-Rast-Bistreț	9.085
8.	Jiu-Bechet	5.148

Nr.crt.	Mixt precincts (agricultural/water storage polders)	S(ha)
1.	Boianu-Sticleanu-Călăraşi	23.452
2.	Borcea de Jos I-II-III	50.399
3.	Borcea de Sus I	8.881
4.	Bujoru-Pietroşani	4.891
5.	Ciobanu-Gârliciu	3.939
6.	Gostinu-Greaca-Argeş	29.370
7.	Măcin-Zaclău	13.808
8.	Oltenița-Surlari-Mânăstirea	12.581
9.	Peceneaga-Turcoaia	3.934
10.	Seaca-Vânători-Suhaia-Zimnicea	14.161
11.	Vedea-Slobozia	5.718
12.	Zaclău-Isaccea	21.977

Figure 2. *Example of a mixed scenario (restoration, blue areas, and water storage, brown areas) to decrease high water levels of the Danube River. The meter values indicate the difference between actual reference water levels and predicted water levels*

uate agricultural enclosures for their reintegration into the natural water cycle and the creation of natural wetlands.

Based on available data and hydraulic scenarios, the landuse in the Lower Danube Plain encompassing in total 445,000 ha of presently impounded agricultural land could be quantified. 43% are suitable for agriculture; 41% are retention areas and can be used for mixed activities; 16% are suitable for restoration to create wetlands. This ensures a socio-economic sustainable development in the Lower Danube Plain *(Figure 2).* Wetland restoration is sustainable and conserves the integrity of ecosystems (van Breen 2002).

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In brief Information – New books

Kriska G, Tittizer Th.: ***Wirbellose Tiere in den Binnengewässern Zentraleuropas – Ein Bestimmungsbuch.*** *(Review by Jürg Bloesch: Stauffacherstrasse 159, CH-8004 Zürich, Switzerland, e-mail: bloesch@eawag.ch)*

A new identification key for aquatic invertebrates in freshwaters of Central Europe has been published. In the preface, the second author poses the critical question if such a new key is necessary, provided that numerous professional taxonomy books and popular illustrated identification books already exist. He himself provides the answer and stresses the positive sides of this book: it combines the two identification concepts and focuses on six eco-regions covering also the Danube River (Western and Central Mountains, Central and Hungarian Plains, Dinaric Western Balkans and Carpathians); it comprises 21 selected main groups of aquatic invertebrates with a general and a specific part; it provides simplified dichotomous identification keys supported by excellent colored photos and computerized drawings. Lists of photos, popular and scientific names of species, and expert expressions round off the book.

The book addresses to teachers and students of Universities and High Schools as well as interested people. The users will appreciate the attached CD containing demonstrations and exercises for further studies on aquatic organisms. For those willing to deepen their knowledge specific hints to group specific identification keys and literature would have been of advantage. (Weissdorn-Verlag Jena, 2009, 377 Seiten, 235 Abbildungen, 515 Farbfotos, Übungs-CD. ISBN-No. 978-3-936055-58-0. Price 34.90 Euros); an Hungarian version is also published, an English translation of the book is planned. The book (in German) can be ordered directly at Weissdorn-Verlag Jena, Wöllnitzer Str.53, D-07749 Jena, Germany (e-mail: weissdorn-verlag@t-online.de).

Rivers of Europe. *Edited by Klement Tockner, Christopher T. Robinson & Urs Uehlinger (Review by Georg Janauer: University of Vienna, Department of Freshwater Ecology, Althanstrasse 14, Vienna, Austria, e-mail: georg.janauer@univie.ac.at)*

I am most enthusiastic about this book and highly appreciate the enormous effort the editors, and the authors of the different chapters, have put into this most comprehensive piece of scientific literature. The extensive, yet detailed coverage of such a wide geographic area, from Iceland and the British Isles to the rivers in Russia, the Kaukasus and in Turkey, and from the Mediterranean countries to the rivers in Europe's "Northern Slope" is unsurpassed at present. Excellent haptic appearance competes positively with the very clearly structured contents, including highly informative overview maps, a table on river characteristics, and instructive diagrams and pictures of habitats and river sections. I especially enjoyed sub-chapters for all rivers and tributaries on biodiversity and human impact as well as on conservation and management, which rate this book as up-to-date with respect to urgent environmental problems of our time. Regarding the Danube River, my own prime research topic, I was quite delighted to see this subject most carefully worked out, including many interesting details and presenting a remarkable overview on that large river; Klement Tockner did certainly not forget about his personal study object a few years in the past. This book is a must regarding further reading for my students. (Academic Press as an imprint of Elsevier, London. First Edition 2009, 700 pp. ISBN-13: 978-0-12-369449-2. Price 146.– Euros).

ISSN 2070-1292

danube news

Bulletin of the International Association for Danube Research (IAD)
Informationsblatt der Internationalen Arbeitsgemeinschaft Donauforschung (IAD)

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Hydrological catchment of the River Danube

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Layout:
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Tel. 0041 (0)44 440 11 50

Printing:
FUTURA – Petrovaradin, Serbia