Integrating riparian wetlands into river basin management – towards an ecohydrological approach

BEÁTA PATAKI[1], GÉZA JOLÁNKAI[1], ISTVÁN ZSUFFA[2] & HERTA CZÉDLI[1]

1 University of Debrecen, Department of Civil Engineering, Otemető str. 2-4, H-4028 Debrecen, Hungary
patakibea.unideb@gmail.com
2 VITUKI Mendei str. 3, H-1173 Budapest, Hungary

Abstract In recent decades, ecologists and water managers have recognized that the riparian wetlands, besides their ecological value and potential, provide numerous – in certain cases badly abused or overused – ecosystem services, even at the river basin level. However, at present, despite numerous guidelines and directives, there is practically no scientifically supported management of endangered riparian wetlands at the local or basin scale. Wetlands should be a coherent part of integrated river basin management to ensure their conservation, sustainable use and also their positive impacts on the river and river basin. However, complex and flexible long-term wetland management plans, which could be integrated into the river basin management plans, are not available. Thus a united ecologically and hydrologically appropriate method is missing. The paper describes the role of the ecohydrological approach and summarizes the state of the art, issues and potential responses with the example of the Hungarian Danube Basin.

Key words ecohydrology; riparian wetlands; integrated river basin management; Hungarian Danube Basin

INTRODUCTION

Before river regulation works, the use and management of riparian wetlands was part of the everyday life and livelihood of the inhabitants living on the floodplains of large rivers in Europe. People learned to live together with the living river and its continuously changing floodplain, and took advantage of the goods provided by the system of wetlands, water and land.

However, after this "close-to-nature" period, in fact from the moment we can speak of water management, the large rivers of Europe gradually lost their natural character as a consequence of different river management measures. The remaining floodplains with their isolated oxbow lakes have lost their former importance. At the same time, the intensification of land uses, such us agriculture, forest management, urbanization, etc., have led to the modification of the river basins. These processes are still going on.

In recent decades ecologists and water managers recognized that, besides their ecological values, riparian wetlands also provide numerous – in certain cases badly abused or overused – "ecosystem services" (MEA, 2005). These locally well-known, ecologically and economically valuable services (e.g. regulation of floods and nutrient retention, provision of drinking and irrigation water, as well as cultural services, and especially habitat services) can be important at the river basin level too.

In the last few years, not only has the recognition of wetlands' values and services been enhanced, but also the need for their integration into river basin management. While adapting to the integrated river basin management approach, as also requested by the Water Framework Directive (WFD) of the European Union, one has to take into consideration that not only spatially or economically large-scale measures could alter the river basin, but also the superposition of numerous small-scale interventions, e.g. restoration of wetlands.

Ecohydrology (Zalewski *et al*., 1997), a new paradigm for river basin management, addresses two aspects: firstly, it provides new "know how" for freshwater ecosystem restoration and management and empirical knowledge on how to use ecosystem properties as a complementary tool to civil engineering and hydro-technical solutions; secondly, it formulates a systems approach to use transdisciplinary science for integrated river basin management (IWRM) (Zalewski, 2007). Therefore it is a useful tool that can support wetland management through understanding and evaluating the underlying environmental processes and, in addition, it is also capable of catalysing the integration of wetlands into river basin management.

This paper explores the potential of applying the ecohydrological approach in the integration of wetlands into river basin management using the example of the Hungarian part of the Danube River Basin.

WHY ECOHYDROLOGY?

In the face of increasing pressure on freshwater resources, there remains an urgent need for new practical tools to achieve their sustainable management. Traditional water management does not consider the use of ecosystem processes as a potential management tool (Zalewski *et al*., 2006). Ecohydrology "*is a transdisciplinary science, which uses understanding of relationships between hydrological and biological processes at the catchment scale by "dual regulation" for improvement of water quality, biodiversity and ecosystem services for society. Regulation of hydrology and hydraulics belong also to the main ecohydrological tools, as actually trigger the rest of the processes*" (Zalewski, 2000; UNEP, 2004).

The theory of ecohydrology is based upon the assumption that sustainable water resources management can be achieved by:

- re-establishing and making use of the resilience and resistance of ecosystems (Harper *et al*., 2008);
- restoring and maintaining the evolutionarily-established processes of water and nutrient circulation and energy flows at a catchment's scale (UNEP, 2004; Jelev & Jelev, 2012);
- enhancing the carrying capacity (robustness) of ecosystems against human impact (UNEP, 2004; Jelev & Jelev, 2012);
- using ecosystem properties as water management tools (UNEP, 2004; Jelev & Jelev, 2012).

Ecohydrology as a framework has the potential to support the integrated management of wetlands and river basins in two ways:

1. ecohydological concepts link the wetland and river basin levels in the management cycle;
2. the ecohydrological toolbox provides background for applied research that supports planning on both wetland and basin scales (e.g. determining and analysing the interactions between environmental processes or ecosystem services, as well as assessing impacts at different scales of the river basin) and provides a set of technical solutions (e.g. ecological engineering measures) for the implementation of integrated plans.

STATE OF THE ART

Wetland management in Hungary

Besides the exploitation of ecosystem services, wetland management practices in Hungary and in the Danube River Basin are mostly confined to conservation and rehabilitation measures aiming to maintain/achieve a desired status at the wetland scale. Wetland conservation on a local level is an end-in-itself issue, which is very important, but completely disregards other river basin level goals.

Most of the Hungarian wetlands are under the international protection of Natura 2000 and/or Ramsar. Unfortunately, the implementation of the governing principles of the Habitat Directive and Ramsar Convention is not always sufficient in practice. The existing Nature Conservation Management Plan of an area with wetland includes, in line with the national legislation, basic management issues only. It is more a plan for maintenance and not for management: it aims at solving the actual problems only, without preventing the upcoming ones. Nevertheless, these plans are still important from the point of view of wetland conservation, as they do recognize the significance of the relationship between ecology and hydrology, especially on the two "large" floodplains of the Hungarian Danube: Szigetköz and Gemenc. However, the current wetland management planning is based on information from the present and past, and fully disregards the changes expected in future hydromorphological and climatic conditions. These changes will likely have huge, mainly negative, impacts on the wetlands, as has been proven by the vulnerability analysis carried out with regard to the Gemenc wetland (Pataki *et al*., 2012).

Wetland restoration programmes in general are not funded from the national budget of Hungary. Only casual, standalone international (EU, World Bank) and national projects provide financial background for developing and implementing new management strategies, though these sources are usually not sufficient to cover the expense of the necessary follow-up activities. Thus, there is no feedback, especially not in case of small-scale investments. This practice also hampers the integration of scientific results (e.g. interrelations and processes revealed by a given research project) into the relevant wetland-, country- and basin-scale management plans.

River basin management in Hungary

Although Hungary only became a member of the European Union in 2004, the country has complied with the requirements of the EU WFD since its introduction in 2000. The outline of Hungary's River Basin Management Plan (RBMP) was published on 22 December 2008 and presented the concept of the programme of measures addressing the significant water management issues at the country level (KvvM, 2010). Hungary's RBMP was incorporated into the Danube River Basin Management Plan elaborated by the International Commission for the Protection of the Danube River (ICPDR).

Integrated wetland and river basin management in Hungary and on the Danube River Basin

In practice this approach is not been implemented in Hungary and on the Danube River Basin. Floodplain restoration activities take place, but not all wetland functions and the catchment context are taken into account (BOKU, 2007).

The ICPDR's basin-wide vision is that floodplains/wetlands across the entire Danube River Basin District (DRBD) should be restored and re-connected to the main river channel. The integrated function of these riverine systems ensures the development of self-sustaining aquatic populations, flood protection and reduction of pollution in the entire DRBD (UNECE, 2011).

In spite of the recommendations of the WFD's Common Implementation Strategy (CIS) on wetlands, the river basin management plans for the relevant planning sub-units of Hungary, which provide the background of national and river basin management plans, hardly deal with the restoration and reconnection of riparian wetlands. However, the Danube River Basin Management Plan of the ICPDR, the implementation of which is obligatory for Hungary, has a chapter on the restoration and reconnection of large riparian wetlands along the Danube River. Figure 1 illustrates the floodplains potentially to be reconnected in Phase 1 (till 2015) of the DRBMP (ICPDR, 2009). According to the DRBMP, five wetlands of 62 300 ha extent are planned to be reconnected out of the total of 612 745 ha identified for potential reconnection; two of the five – Szigetköz and Gemenc floodplains – belong to Hungary.

At the same time, little is known about the relative effectiveness of most restoration practices in meeting ecological goals (Jolánkai *et al*., 2002; Palmer *et al*., 2006) in general, as there is no follow-up monitoring, especially of ecohydrological processes. The DRBMP states that: *it is difficult at this stage to indicate what the exact effect of such measures would be at the basin-wide scale*.

The EU WFD and the EU Strategy for the Danube River aim at utilizing the riparian wetlands mainly for supporting the achivement of good ecological status of the main river. However, the Ramsar Convention as well as the Habitat Directive promote the protection and wise-use of the wetlands themselves. It is obvious that the combination of these strategies has the potential to provide a good basis for the integration of wetlands into RBM. Unfortunately, this approach does not appear in the current river basin management plans developed for the River Basin Districts in Hungary.

BASIC INTERACTIONS AND THE ECOHYDROLOGICAL CONCEPT BEHIND

It is well known that the ecosystem of a river is less diverse, its water quality is worse and the flood risk is higher without riparian wetlands, while riparian wetlands would cease their ecosystem services or even disappear in the long run without the feeding by the main river. The impacts originating from the entire river basin – defined in two dimensions: technological and environmental

Fig. 1 Potential floodplains to be reconnected in the Phase 1 (to 2015) of the DRBMP (ICPDR, 2009).

(Zalewski, 2006) – on the river proper are very high, but could be significantly lessened when making use of all existing wetlands by re-establishing, through the appropriate handling of in- and outflows of the wetlands, their resistance and resilience.

Detailed knowledge of the interactions, impacts and ecosystem services of the different components and scale of a river basin, and the underlying, interlocking ecological-biological-chemical-physical-morphological-hydrological-hydraulic processes, are of primary importance. Table 1 shows both directions of impact between the two main levels of the spatial scale, namely the wetland and its river basin, in the case of Gemenc, floodplain of the Danube in Hungary.

Table 1 Top-down and bottom-up impacts between Gemenc floodplain and the Danube River Basin.

River Basin => Wetland	Wetland-scale impacts			
Basin-scale interventions	Alluvial and aquatic habitats	Provision of fish for humans	Traditional livelihoods	recreation, ecotourism
Flood control dikes	– –	– –	– –	
River regulation	– –	– –	– –	–
Pollution	.	–	–	–
Wetland => River basin	Basin-scale impacts			
Wetland-scale restoration measures	Aquatic fauna of the river: *WFD*	migratory birds: *Bird Directive*	Water quality of the river: *WFD, Drinking Water Directive*	Flood safety: *Flood Directive*
Restoration and reconnection of oxbow lakes	++	+	+	+
Restoration of side channels	++		+	+
Removal of summer dikes				+
Restoration of natural alluvial forests		++		

The most important relationships at spatial scale, we conclude, are:

- the river and the river basin profit notably from the riparian wetlands due to their functions and ecosystem services if the wetlands are in a good ecological state;
- the ecosystem health and ecosystem services of riparian wetlands highly depend on the river attributes and the impacts from their direct watershed and the entire river basin;
- river basin-scale interventions (also policies/strategies) have significant impacts on the river itself and therefore on its riparian wetlands too;
- wetland-scale restoration measures have positive impact on basin-scale functions given that these measures are not constrained to a limited number of riparian wetlands.

These inter-relations and even hidden links between the spatial levels can be clearly recognized by applying the concept of ecohydrology. Knowing the system of linkages and interactions, properly selected ecohydrological tools, e.g. monitoring or combined hydrological and ecological models, can support the assessment and quantification of the tightness and relevance of different links.

THE POTENTIAL ROLE OF ECOHYDROLOGY IN THE MANAGEMENT CYCLE

The Ramsar Convention recognizes the critical linkage between wetlands, water and river basin management (Rebelo *et al*., 2012). Whilst several countries have achieved good results in integrating wetland management and water resources management at the local, site or sub-basin level, successful upscaling of these approaches to the basin level has generally proved difficult, though not impossible (RAMSAR, 2010). This is the case on the Danube River Basin, as indicated above.

The relevant national and international policies, directives and concepts for the wetland and river basin management have their own, partly overlapping management cycles. The integration of all the important "road maps" combined with the approach of ecohydrology leads to a comprehensive management approach for the integration of wetland into the river basin management.

To support the intergration of wetland management into river basin management, a Conceptual Framework has been developed by the EU FP7 WETwin Project (Johnston *et al*., 2013) (Fig. 2). The framework nests adaptive management of the wetland within the adaptive management cycle of the

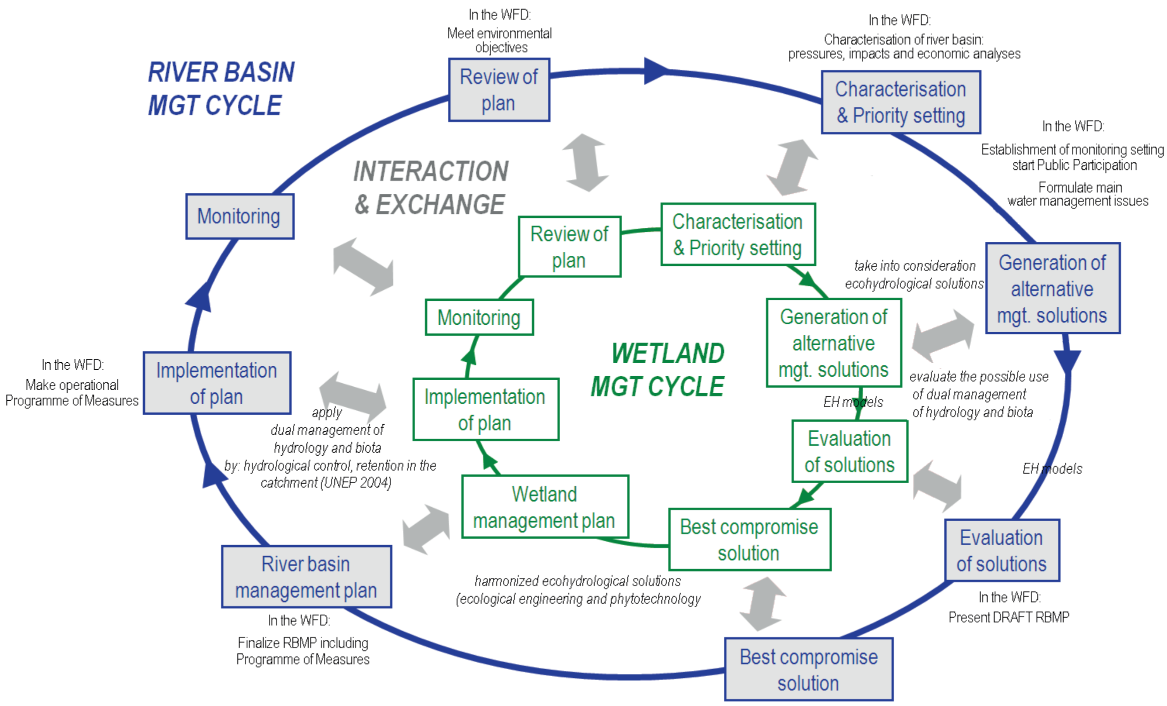

Fig. 2 Ecohydrological approach in the integrated wetland and river basin management, based on the Ramsar Critical Path (RAMSAR 2010), updated by the WETwin Project (Johnston *et al*., 2013) and modified by B. Pataki.

river basin, with on-going feedback between the two. An actual merge or transfer of responsibilities is not envisaged, since wetlands continue to have their own dynamics, and need to be managed at a different scale and have different challenges from river basins (Johnston *et al*., 2013).

Figure 2 also indicates the potential places for practical implementation of the ecohydrological concept and tools. The ecohydological concept in the management cycle serves to link the wetland and river basin levels as it provides a basis for common approaches during the top-down and bottom-up scaling. There are two main types of tool in the ecohydrological toolbox that can be applied in the management cycles. Technical tools (e.g. conceptual and mathematical models) can support the planning and decision-making in parallel on the wetland- and river basin-scale, as they help to measure/assess/model the underlying processes. Monitoring of environmental – ecohydrological – processes is a key issue in the planning and implementation of plans at both levels. Ecological engineering measures can be important tools for the implementation of an integrated wetland and river basin management plan by site-specific hydro-technical solutions.

PRACTICAL RECCOMENDATIONS

Reasons for the disappointing lack of implementation are given in Table 2, with possible solutions.

Table 2 Reasons for lack of implementation and possible solutions.

Reason of failure at river basin scale	Ideas for solving the problem
No system of riparian wetlands of larger (medium) size river basins were subjected to experiments	Projects on medium size river basins, 1000–3000 km^2 drainage basin, with several wetlands and carry out measurements for several years on all wetlands (hopefully in the frame of the actual DRBMP)
Experiments frequently left out extreme periods, especially flash floods, that would provide most of the useful results	Have a local partner or an adaptive research group, which cares for taking measurements at such extreme conditions (automatic samplers may in certain case help)
Approved very good results and techniques of many projects have never been used after the project, usually due to lack of follow up	Ensure appropriate funding for follow up activities and the integration of results into national wetland management or river basin management plans
In the case of well-developed strategies harmonized by local water and environmental authorities (stakeholders and policy makers), none or very few were implemented	Ensure appropriate funding and monitoring for implementing the strategies
Lack of appropriate monitoring and the nearly complete lack of objective oriented field measurements	The well-known Europe-wide decrease of monitoring programmes and substitution of field measurements by modelling should be halted. It should be recognized that calibration and verification of all proven existing models would need much and continuing measurement. The human time spectrum and environmental processes are not synchronized, e.g. most governments' decisions are short-term (1 to 4–5 years) whereas environmental processes operate on a time spectrum ranging from very short (seconds) to very long periods (decade/century) (FAO, 2002) Example: According to the planned reconnection of floodplains in Phase 1 of the DRBMP, the impact of this large-scale measure has to be monitored not only to be able to review the plans (both wetland and river basin management plans) and prepare the next generation of RBMP, but also to trace the linkages, the impact of changes and the dynamic interactions
River basin wide strategies when known and well developed will not be implemented due to conflicting upstream–downstream water user interests, especially in transnational basins	International legislation, i.e. river basin conventions and agreements must ensure the enforceability of the actions of such strategies (e.g. elimination of the small print amendments/footnotes that allow escaping from water release or withholding obligation and also the obligation of the polluter-pays-principle
Lack of appropriately calibrated and verified planning tools for river-basin wetland management	Ensure continuing measurement and follow-up activities, which needs much more money to spend on real work, instead of on talking and writing about such work

CONCLUSION

We can conclude that riparian wetlands form a very important and coherent part of the river basin, with numerous very strong linkages and inter-relations between the different management levels. The quantitative and qualitative analyses of the ecohydrological processes and the role of riparian wetlands in river basin management are timely and crucial. Thus, bottom-up and top-down approaches combined with the "dual-regulation" ecohydrology concept in wetland and river basin management are needed to cope with these multi-issues.

We can also conclude that the ecohydrology approach exists in a sometimes hidden, indirect manner both in wetland management and in the Danube River Basin Management. But, to obtain a common and better understanding of processes and to strenghten the linkage between wetlands, the river and the river basin, direct use of the framework of ecohydrology, and even commonly accepted ecohydrological tools, are crucial.

To our knowledge the major targets of ecohydrology are well proven and achieved only as part of small-scale experiments in a large number of projects. The target of helping riparian wetland (and other) ecosystems by providing sufficient flows of water of appropriate quality by eco-engineering methods, thus inducing the resilience of ecosystems and upgrading them, which will provide better water quality and quantity management plus ecosystem services for the downstream recipients and river basin, have probably not been implemented anywhere as yet. The main problem is that the inclusion of all wetlands in river basin management is missing, and also the re-establishment of those that have already disappeared.

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