REFORM

REstoring rivers FOR effective catchment Management

International Conference on River and Stream Restoration

Novel Approaches to Assess and Rehabilitate Modified Rivers

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Key notes

A Global View on Future Major Water Engineering Projects

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Human activities have altered how the world functions. During the past decades, we have globally, fundamentally, in the long-term, and in most cases irreversibly modified all spheres of earth. This new epoch, often referred to as the Anthropocene, is just in its early stages. Indeed, there is general agreement that the transformation of our globe takes speed, with consequences that we can hardly imagine but that may threaten our own survival. This goes along with the general idea that major infrastructure projects are a sign of technological progress and believed to stimulate economic development and to improve living conditions for humans. In the present essay, a representative inventory of future major engineering projects, either planned or under construction in aquatic systems worldwide, shows that the rapid transformations of the Anthropocene are particularly evident in the freshwater domain. Worldwide examples of very large dams, major interbasin water-transfer and navigation projects, as well as large-scale restoration schemes underline the dimensions of and the challenges associated with future megaprojects that will change our freshwater environment. Opportunities to mitigate the consequences of megaprojects based on the lessons learnt from projects in other infrastructure sectors range from ecological engineering to smart water investments that are adjusted to the respective national social, economic and environmental conditions.

Hydromorphology - Vegetation Interactions along River Corridors: A Conceptual Framework

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Vegetation combines with hydromorphological (hydrological and fluvial) processes of water flow and sediment mobilisation-transport-deposition to drive channel and floodplain form, complexity and dynamics. This paper proposes a conceptual framework within which such interactions can be conceptualised within different river corridor environmental settings. It incorporates five spatially and temporally dynamic river corridor zones whose relative spatial extent and character vary widely between biogeographical regions and also between and within catchments. Complex biotic-abiotic interactions occur within each zone leading to characteristic landforms and micro-topography in unmanaged river corridors. These zones often become spatially restricted, modified or completely destroyed by human actions, leading to major reductions in river corridor complexity and natural function.

Anticipating future trajectories of floodplain rivers and human systems in river restoration

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The central focus of river restoration inescapably must be the river. Restoration is the design of a more ecologically sound and liveable future. River managers sometimes attempt to serve social needs and create relatively static river ecosystems, designing the channel, floodplain, and riparian plant communities to remain unchanging. In contrast, river restoration can be viewed as a river--- dynamic and changing---reflecting the structure and processes along the river network. One of the greatest challenges in river restoration is anticipating the future. Human populations, land uses, and climate inevitably change. Past practices alter hydrology and sediment transport, altering successional processes in riparian vegetation, and ultimately creating a new river. In this example, trajectories of past and future change in the Willamette River basin have been quantified and incorporated in the restoration of the floodplain river. The channel has been simplified—63% of islands, 56% of side channels, and 22% of active channel area has been lost since 1850. Floodplain forests have been reduced to 10% of their historical area and only 40% of their length. Flood control reservoirs have reduced sediment delivery by 60%. Richness and abundance of native fish communities decrease along the mainstem river. Human population is projected to double in less than 50 years. Regional agencies, communities, and non-governmental partners collectively have developed a conceptual framework of interactions that shape the river ecosystem and created an explicit spatial framework for 1) design and selection of restoration efforts and 2) monitoring and assessment of future trajectories in the geomorphology, vegetation, water quality, aquatic communities, and human communities. Partners are creating a regional network of communities and restoration practitioners to 1) restore a geomorphically dynamic river, 2) facilitate ecological recovery, 3) meet social expectations, and 4) anticipate the future of the river and its human communities.

Hydromorphic change and biotic response challenge efficient river rehabilitation

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Recently hydromorphological degradation has been identified as major impact on the ecology of European rivers. However, different pressure types often occur together in rivers and act simultaneously on important processes and variables. This complicates the clear diagnosis of hydromorphological deficits, and the causality of biotic response; both hamper the design of effective rehabilitation measures. A conceptual meta-analysis is presented that aims to identify the most relevant hydromorphological processes and variables controlling ecological degradation and restoration as well as the principal mechanisms and effects to which stream biota respond.

A fuzzy cognitive mapping approach based on 730 scientific peer-reviewed case studies was used to deal with the complex interactions of hydromorphology, vegetation, water chemistry, and thermal regime. Water flow dynamics appeared as most important hydromorphological process of all simultaneously interacting pressures. Other relevant processes identified, such as vegetation encroachment and sediment entrainment, are closely linked to water flowing.

Correspondingly, the biotic link to hydromorphology refers in particular to stream power, sediment transport and sediment sorting. On one hand, high stream power non-specifically limits the habitat use by taxa depending on their resistance or swimming performance. On the other hand stream power maintains sediment transport and sorting and especially the provision of coarse gravels. Lithophilic species that essentially depend on such substrates provide specific indicators for hydro-morphological degradation, rehabilitation, and integrity.

Therefore, the ecological requirements of aquatic plants, benthic macroinvertebrates and fish have been analysed with regard to substrate preferences, resistance to friction forces and stream power and swimming performance. The total quantifiable data that it was possible to obtain on species response to hydromorphological changes is rather limited. Of about 500 described aquatic macrophyte species, more than 20,000 freshwater macroinvertebrates, and about 550 lamprey and fish species, quantitative data on gravel size requirements were found for 10, 56, and 28 taxa, respectively, on flow velocity thresholds for 75, 78, and all fish taxa, the latter derived from regression functions based on total length of fish. Significant knowledge gaps became obvious regarding the habitat requirements of riverine species.

Key considerations for measuring river restoration success: lessons from Western North America

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Despite the fact that scientists have been calling for better evaluation of restoration for more than 75 years, adequate information on the success river restoration techniques is still needed. This is due to both technological and social challenges to monitoring restoration responses including: the scale of restoration and its response, the ability to control timing of restoration and management actions, and adequate monitoring and sampling designs. Several monitoring programs to evaluate restoration in the United States, costing tens of millions of dollars, highlight these challenges. Evaluation of reach-scale response to restoration has suffered from similar problems with numerous successes and failures in United States and Europe. Here I outline the key steps to evaluate river restoration success and provide examples of effective approaches to evaluate actions programmatically. Surprisingly, many monitoring and evaluation programs still fail because they do not address key steps in the monitoring design process including: identifying goals, hypothesis, response scale, appropriate monitoring and sampling design, sample size, monitoring implementation, and analysis and reporting of results. Both reach and watershed scale evaluations of restoration require extensive coordination and identification of cost-effective metrics for measuring success. The larger the restoration and monitoring program, the more critical coordination and identification of key metrics becomes. Cost-effective approaches for collecting habitat data have been developed, but are still needed for biota and examining system productivity. A recently implemented program to evaluate restoration in the Columbia River basin provides an example of a successful programmatic approach to evaluating river restoration at multiple scales.

Between a rock and a hard place: ecological responses to degraded hydromorphology in rivers

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Degraded hydromorphology are one the most extensive impacts on river ecosystems in Europe today. Centuries of modification by man to ensure drainage, flood protection, navigation and hydropower has completely altered habitat area, channel form and processes in rivers and floodplains almost everywhere. In parallel, these systems were impacted by a number of other very deteriorating stressors, primarily sewage influx and land-use intensification. As a result of this sum of stressors, the ecological status of rivers was very impaired and they are still globally among the ecosystems that have seen the greatest loss of biodiversity. While the effects of stressors such as low oxygen levels on the river biota are well documented and has been instrumental in reducing sewage loads, specific methods to assess the impact of degraded hydromorphology on ecological status are relatively uncommon. A large scale analysis of existing data sets across Europe showed in general weak relationships between identity-based ecological indicators and measures of hydromorphological quality. However, relationships were dependent of sampling methods and to some degree scaled with organism size, with fish showing most promise. These relationships were further improved when using species traits (also using macrophytes) that are more closely linked to the habitat template, including hydromorphology. When using controlled experiments at small scales the impacts of hydromorphology and fine sediments become more clear-cut also for macroinvertebrates. Moreover, previous detailed field studies have shown that habitats that are assessed as being similar can differ markedly with regard to biota and that suitable habitats might not be colonized due to dispersal limitations. These findings suggest that scales of sampling are a core issue in assessing the influence of degraded hydromorphology and that methods using species traits of large(r) organisms are likely to be the most sensitive. However, the focus on in-stream biota that is routinely monitored ignores that many of the pronounced effects of degraded hydromorphology relates to the riparian zones and the wider floodplain. Especially riparian zones are important as they influence in-stream processes as well as providing a very diverse habitat for both aquatic and terrestrial organisms. Overall, findings suggest that direct measurements of hydromorphological processes and riparian vegetation are likely to be better in assessing hydromorphological degradation than in-stream biota.

Gaps and possible ways forward for river restoration

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What does good status hydro-morphology look like - some possible concepts and principles?

Across Europe, we have set ourselves the goals of protecting rivers at good status and restoring those that are worse than good back to good wherever feasible and proportionate. To achieve these goals, we need a clear understanding of what good means – including the hydro-morphological conditions required for good: As regulators, we need to know what matters for good so that we can judge whether development projects will compromise our goals. As river restorers, we need to know what success looks like. Good status requires there to be only a "slight" change in the abundance and diversity of wildlife in river water bodies compared with what would be expected under near natural hydro-morphological conditions: Rivers at good status are places where water plants and animals are still thriving – in terms of their abundance and diversity. Whether they thrive will be some function of whether the right habitats are present; how much of those habitats are present (the space for thriving); the connectivity between habitats; and the quality of the habitats. Experts from the different countries and the European Commission have been working together on a Common Implementation Strategy for river basin management. That work has had increasing emphasis on hydro-morphology over the last few years. However, it has not yet generated a common understanding on good hydro-morphology. This presentation will consider principles for establishing what good hydro-morphology might look like at a river water body scale.

Why ecological assessments matter and why we haven't yet got them – a non-scientist perspective?

The objectives we are required to achieve are ecological. Restoration work can be expensive. We need ecological assessments to help show the investment is both needed and that it has been effective. One of the big achievements of the last decade or so has been the step change in many countries' ability to assess the ecological impact of pollution, in particular nutrient enrichment, and to do so in comparable ways. We know this because of an EU-wide exercise to compare biological assessment systems, called inter-calibration. It is far less clear that many countries have developed an equivalent level of competence in assessing the ecological impacts of hydro-morphological change. This presentation will argue that we need to re-think the problem; focus initially on systems that can pick up severe impacts rather more subtle impacts. To do this we need to start with an understanding of the hydro-morphological change – and this means bringing together biological and hydro-morphological expertise.

Where can we achieve good status and some thoughts on the components of a national restoration delivery framework?

Rivers have been modified to help deliver a wide range of important societal benefits, including flood defence, drainage of productive farmland, drinking water supply and hydroelectricity generation. We cannot achieve good status everywhere without significant impacts on these important benefits. Work in the Common Implementation Strategy shows there has been considerable progress in the development of national strategies for improving rivers affected by water abstraction and impoundment for uses such as hydroelectricity generation and water supply. This includes identifying relevant mitigation; setting constraints on what can be achieved - for example in terms of national limits on the reduction in hydroelectricity generation; and prioritising improvements in order to maximise environmental benefits within the constraints. This presentation will argue that to achieve our goals for rivers, we also need to develop national strategies for the many rivers that are squeezed, and hemmed in, by surrounding urban and rural land uses. Such a strategy has to decide how it balances land use priorities with river restoration – how the land use settings of our rivers can, and will inevitably, shape what can be achieved.

The Economic Value of Restoration based on the Ecosystem Services Approach

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The term “scarce” is often used to describe the limited quantity of water resources. The optimal allocation of scarce resources is the core of environmental economics. The arsenal of economic techniques provides the solution to such problems. More specifically, economists attempt to model human behaviour taking into account the functioning of ecosystems in order to achieve a status that ensures sustainability (environmental, societal, economic). Apart from economic modelling, economic valuation aims at eliciting people´s preferences in relation to a good. Under either economic modelling or valuation, the necessity of interdisciplinary approaches arises, given the complex nature of the environment. It is obvious that policy designing requires the combination of many different fields of science in order to analyse the complexity of the environment and human behaviour. Therefore, biologists, chemists, ecologists, sociologists, engineers and economists must work together in order to design policies that are socially, economically and environmentally optimal. The literature shows a trend towards this state, however many fields of environmental management are still need to follow a holistic approach. As an example, it could be mentioned the fact that although there is a vast number of restoration projects worldwide, only some of them achieve sufficient integration of natural and social sciences.

The socio-economic benefits of river restoration

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River restoration provides a wide array of hydrological, ecological and socio-economic benefits. Many of these benefits are so-called public goods and services provided by restored or natural river systems, and can only be estimated in monetary terms using non-market valuation techniques. A limited number of such non-market valuation studies exists, which are summarized and synthesized in a structured way in the meta-analysis in this paper. Meta-analysis is a method of synthesizing the results of multiple studies that examine the same phenomenon, in this case the estimated non-market benefits associated with river restoration, through the identification of a common effect, which is then 'explained' using regression techniques in a meta-regression model (Stanley, 2001). In this paper we conduct a meta-analysis to identify and quantify the key determinants of the economic value of river restoration projects around the world. Based on the specifications of previous meta-analyses of wetland values and on theoretical expectations we define four groups of explanatory variables that represent different determinants of variation in the nonmarket values found in the literature, namely the characteristics of the ecosystem services provided by river restoration, the characteristics of the river and location where the restoration took place, the socio-economic characteristics of the population of ecosystem service beneficiaries, and the characteristics of the valuation methodology.

"The Missing Links in River Restoration – Towards a Network-Based Approach"

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River restoration has long followed the "Field of Dreams" model of "build it and they will come" – assuming that, if the environmental or habitat template is in place, the biota will simply map onto it, with no consideration of how communities actually assemble in nature. In reality, this is a highly non-random process that is not captured by simple diffusive source-sink dynamics of propagules, in which species act as isolated units that simply bolt together to produce identikit communities. Community dynamics are driven by interactions within the food web – the "missing links" that are ignored in restoration ecology – which act as powerful biotic filters on the emergent community. River restoration science currently has little grasp of these key fundamental processes, which is inevitably compromising our ability to understand, predict and manage restoration effectively. We need to move beyond the traditional obsession of viewing biodiversity in its narrow definition of species richness (or proxy measures such as functional traits) to a more explicit consideration of trophic diversity, and how food webs assemble and collapse in response to environmental change. By viewing the community as a network of interacting individuals we can glimpse the multiple organisational levels that lie beyond the limited species-centric view, improving our ability to restore the functional attributes of ecosystems that provide us with key processes and services. The food web therefore provides a useful new framework for understanding how services are distributed and interconnected, and unveils the links between the ecological and socioeconomic drivers and responses involved in restoration.

Measuring restoration success

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Despite the rapid increase in river restoration projects, there is a paucity of information about the effectiveness of these restoration efforts because often they are not fully evaluated in terms of success or reasons for success or failure. A review of concepts to measure the success of river restoration found that despite large economic investments in what has been called the “restoration economy”, many practitioners do not follow a systematic approach for planning restoration projects. As a result, many restoration efforts fail or fall short of their objectives, if objectives have been explicitly formulated. This largely arises because a fundamental lack of understanding of the planning, design and implementation stage of rehabilitation schemes.

The aims of restoration activities in Europe are influenced by a plethora of EU Directives and national government policies that have conflicting targets. Current river restoration tends to encounter obstacles as a result of societal demands, particularly through a select number of ecosystem services, such as provisioning and regulating services like flood protection, hydropower, navigation and agriculture. Recent developments have resulted in directives such as Floods Directive (FD (2007/60/EC)) and Renewable Energy Directive (RED (2009/28/EC)), these are directives and legislation that are potentially at conflict with the Water Framework Directive (WFD (2000/60/EC)), but are necessary to support river management from the social and economic perspectives. As a consequence, managers are required to change the way European inland waters are conserved.

Here we discuss common problems or reasons for failure and the potential for restoring river ecosystems to optimise benefits accrued for biodiversity and ecosystem services, whilst considering climate change effects on the ability to deliver these outcomes. A planning framework is proposed that systematically guides practitioners through two main planning stages of river restoration 1) catchment scale & 2) project cycle. The framework identifies a number of tools and guidelines for best practice to measure performance and determine appropriate targets for river restoration, some of which have been developed in REFORM.

Contrasting the roles of section length and instream habitat enhancement for river restoration success: a field study on 20 European restoration projects

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Restoration of river hydromorphology often has limited detected effects on river biota. One frequently discussed reason is that the restored river length is insufficient to allow populations to develop and give the room for geomorphologic processes to occur.
In a pan-European study, we investigated ten pairs of restored river sections of which one was a large project involving a long, intensively restored river section and one was representing a smaller restoration effort. The restoration effect was quantified by comparing each restored river section to an upstream non-restored section. We sampled the following response variables: habitat composition in the river and its floodplain (e.g. gravel bars and instream habitats), three aquatic organism groups (aquatic macrophytes, benthic invertebrates and fish), two floodplain-inhabiting organism groups (floodplain vegetation, ground beetles), as well as food web composition and land-water interactions reflected by stable isotopes (δ13C and δ15N signatures of resources and organisms).
For each response variable, we compared the difference in dissimilarity (Bray-Curtis index) of the restored and nearby non-restored section between the larger and the smaller restoration projects. In a second step, we re-grouped the pairs and compared restored sections with large changes in substrate composition to those with small changes.
When comparing all restored to all non-restored sections, ground beetles were most strongly responding to restoration, followed by fish, floodplain vegetation, benthic invertebrates and aquatic macrophytes. Aquatic habitats and stable isotope signatures responded less strongly.
When grouping the restored sections by project size, there was no significant difference in the response to restoration between the projects targeting long and short river sections with regard to any of the measured response variables except nitrogen isotopic composition. In contrast, grouping the restored sections by substrate composition, the responses of fish, benthic invertebrates, aquatic macrophytes, floodplain vegetation and nitrogen isotopic composition were greater in sections with larger changes in substrate composition as compared to those with smaller changes.
The effects of hydromorphological restoration measures on aquatic and floodplain biota strongly depend on the creation of habitat for aquatic organisms, which were limited or not present prior to restoration. These positive effects on habitats are not necessarily related to the restored river length.

Improving river restoration policy: a few discussion points following 10 to 20 years of actions

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Reaching a “good ecological status” of rivers is a challenging issue for the EU state members in charge of implementing the Water Framework Directive. In this domain, acting on hydromorphological drivers is one way which is known as restoring rivers. After almost 10 to 20 years of actions in this domain, a few feedbacks can be discussed for improving policy. Especially, very basic questions can be reconsidered with the new lights of these feedbacks.

Why should we restore rivers? Definition of river restoration evolved over the last two decades and a conceptual and social debate is still needed to reconsider objectives. The second question which is also in discussion is “where?”, where restoring rivers? There is a clear need to improve network understanding to establish a top down strategy to define priorities, improve planning design and target actions. “How restoring rivers” is another critical question. Should we primarily act on forms or on processes? Assessing the sensitivity of rivers to change is a clear challenge to evaluate the sustainability and efficiency of potential restoration actions and has also consequences in term of diagnosis. “How” is also related to gaining experiences and knowledge for implementing these new measures. Monitoring efforts combined with modeling are critical for assessing restoration success and then designing successful measures.

REFORM: scientific progress and tools for water management

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Many European rivers are regulated to support flood protection, navigation, freshwater supply or hydropower production. It is insufficiently known what the ecological side effects of these modifications in hydrology and morphology are and to what extent the side effects can be effectively reversed or mitigated. REFORM (EC FP7 Grant 282656) is a 4-year integrated research project (2011 – 2015) that has addressed the challenges to reach the hydromorphological and ecological objectives for rivers as required by the European Water Framework Directive (www.reformrivers.eu). The project is executed by 26 partners from 15 European countries and has cooperated amongst others with LIFE+ RESTORE, the European Centre for River Restoration (ECRR) and the working groups of the WFD Common Implementation Strategy (e.g. CIS ECOSTAT and CIS PoM). REFORM has developed and improved instruments and guidelines that enlarge the success and cost-effectiveness of restoration and mitigation measures. In addition, numerous assessment tools to monitor the biological responses to hydromorphological changes have been evaluated resulting in clear recommendations on how to improve precision and sensitivity. During this international conference “Novel Approaches to Assess and Rehabilitate Modified Rivers” over 30 keynote, oral and poster contributions present specific results of REFORM. This final contribution presents the major scientific conclusions and recommendations of REFORM and how the large amount of scientific information is summarised and adapted in such a form that it can be used for water management.

Linking science to practice: tools to assess river status and guide rehabilitation to optimize river basin management

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How are we knowing our rivers? What toolkits, building upon which foundations, do we use to assess river character, behaviour, condition, limiting factors, pressures, evolutionary traits, and likely futures? Perhaps more importantly, how do we frame these understandings alongside local knowledges to inform river restoration? The REFORM project has made many advances in developing an integrating platform for such endeavours. Importantly, the integrative hydrogeomorphic template that has been produced is cross-scalar (hierarchical), process-based, and is readily adapted to the wide array of conditions across Europe (and beyond). Framing catchment-based approaches in their regional context provides an important basis to work with change, supporting meaningful transferability of understandings from one situation to another. In this way, emphasis is placed upon cumulative effects, rather than endeavouring to address issues in isolation.

Stakeholder (end user) deliberations fashion the development and use of information that shapes how we are managing our rivers. Effective management extends well beyond mere transfer or translation of scientific tools into practice. Rather, a process of negotiation is most readily facilitated through adaptive practices that apply flexible (non-prescriptive), readily usable, and appropriately tested (and validated) toolkits. Local circumstances, key values, and policy framings determine which approaches gain primacy. Thankfully, there is general agreement on the core principles upon which most hydrogeomorphic river classification toolkits build, such that ‘differences’ are generally relatively superficial. However, these differences may have significant real-world consequences. Critically, decisions made in these deliberations influence how emerging technologies and automated procedures underpin monitoring and modelling applications, in turn fashioning how we are making the world. There is an inherent politics in the ways in which we respect difference, ensuring that we do not set out to ‘make rivers the same’ (Tadaki et al., 2014)? In considering such matters, and their material implications, what are the rights of the river itself?

Oral presentations - Tuesday June 30

SESSION I. ASSESSMENT AND REHABILITATION OF HYDROMORPHOLOGICAL PROCESSES IN RIVERS

Development of a classification system of geomorphic units aimed at characterizing physical habitats and stream morphology

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In this presentation we briefly illustrate a system for the classification and survey of geomorphic units (*GUS*, Geomorphic Units survey and classification System) aimed at characterizing physical habitats and stream morphology. The method is suitable to integrate the hydromorphological assessment at the reach scale (e.g. the Morphological Quality Index, *MQI*), and therefore to better establish links between hydromorphological conditions at the reach scale, characteristic geomorphic units and related biological conditions. The method is embedded into a multi-scale, hierarchical framework which has been developed within the context of the REFORM project.
Three scales of the geomorphic units are considered (i.e. Macro-units, Units, Sub-units), and organized in three spatial domains (i.e. Instream, Marginal, and Floodplain). Different levels of characterization can be applied, depending on the aims of the survey: Broad, Base, and Detailed level. At each level, different specific information is collected: from the simple census of units and their number, to the measurement of units size and the survey of specific unit characteristics (e.g. sediment, hydrology, vegetation). The method is applied by combining remote sensing analysis and field survey, according to the spatial scale and the level of description. It is applicable to most of fluvial conditions (e.g. from small streams to large rivers), and has been designed to be flexible and adaptable (i.e. including mandatory and/or optional sections) on the basis of specific objectives (e.g. reach characterization, assessment, monitoring) and available data (e.g. image resolution).

Reach Scale Floodplain Reconnection and Restoration: Achieving the Objectives of the Columbia River BiOp

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The M2 (Middle Methow) Floodplain Reconnection and Restoration Project is located within the Methow River between Winthrop and Twisp, Washington, encompassing the recent, historic floodplain and included side channels, wetlands, and disconnected aquatic habitats. Phase I implementation was completed in 2013 and 2014, and preliminary monitoring results have shown over a 100% increase in ESA-listed juvenile fish use within the reach.

Two segments of the river were targeted for Phase I implementation based on the presence of available floodplain, side channels, alcoves, and disconnected habitats. Although the two sites appeared similar in planform and shared many objectives; increasing connectivity and complexity of existing side channels, improving riparian conditions, and enhancing floodplain connectivity, they were quite different in process: one channel was contracting and went dry during the summer low flow period, while the other was expanding and countermeasures had been taken to impede avulsion. Therefore, the design analyses evaluated differing critical parameters when determining an appropriate, sustainable design.

Collectively, the sites enhanced habitat along more than 3,500 feet of mainstem and 3,000 feet of side channel, removed 900 feet of levee, placed more than 2,000 pieces of large woody material (including more than 30 ELJs), reconnected several acres of off-channel wetlands, and planted numerous riparian species. Levees previously contained the 10-year flow event and removal has resulted in floodplain connectivity at the 2-year return period. New culverts through an existing roadway reconnected valuable alcove and wetland habitat, and ESA-listed juvenile salmonids have flocked to these habitats during spring run-off flows.

Sediment is not a problem

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Every year almost 2 % of worldwide reservoir volume is lost due to sedimentation. This loss is not even compensated by the actual new build of dams, in many cases making reservoirs not sustainable. By 2050, more than 25 % of all reservoirs will be inoperable due to sedimentation. At the same time, due to climate change there is an increased need for additional water storage. Thus sedimentation becomes a major problem for those who do not take sedimentation into account at an early stage or ignore sedimentation effects too long.

Sedimentation is not only an issue within a reservoir. The other side of sedimentation is missing sediment downstream, leading to massive erosion. The German River Rhine alone faces a sediment deficit of 2.5 million tons per year due to sediment retention in its tributaries reservoirs. Even massive and extremely costly addition of “artificial” sediment does not catch up with annual significant bed erosion.

Conventional approaches to deal with the problem are either simply giving up a valuable reservoir one day, perform strongly questionable flushing or to do costly dredging and landfill, if at all applicable. To distract sediment from the streaming river or to abruptly silt up river reaches cause other problems and lead to further cost and environmental impacts.

But in recent years, a competitive and environmental friendly technique of continuous sediment transfer has been developed and also successfully implemented in practice. Sediment transfer is restored in a near nature way, at the same time providing maximum cost efficiency. Ecological benefits evolved in short time and reservoir storage capacity is restored and maintained. By not taking sediment as a problem but as a natural condition to deal with, a sustainable and advantageous solution can be gained with great success.

Application of the Morphological Quality Index (MQI) to European case studies

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The Morphological Quality Index (*MQI*) and Morphological Quality Index for monitoring (*MQIm*) are two related tools originally developed in Italy and then adapted to be applied in other European countries in the context of the REFORM (REstoring rivers FOR effective catchment Management) project. The MQI is designed to assess the overall morphological conditions of a stream reach, whereas the MQIm is a specific tool for monitoring changes of morphological conditions (enhancement or deterioration).
The two indices have been applied to eight case studies which included restoration measures, selected within different biogeographical regions of Europe with the main objectives of: (1) testing and improving the new versions of the indices which aim at better representing those alterations and channel morphologies which were under-represented in the original version of the MQI and MQIm, but which can occur throughout Europe, and (2) analyzing the hydromorphological response to various restoration measures.
Different channel morphologies are represented by the selected case studies including straight, sinuous, meandering, wandering and anabranching types. For each river the MQI and the MQIm were calculated at two selected reaches, representing a degraded and a restored section. In the case of restored reaches, the indices were also applied to the pre-restoration conditions.
Results showed that in most cases the restoration measures improved the morphological quality of the reach. The response was likely dependent on channel morphology, with meandering and high energy sinuous reaches being more sensitive to the restoration measures.

SESSION II. ACHIEVEMENTS BY RESTORATION AND MITIGATION PRACTICES

The effect of river restoration on fish, macroinvertebrates and aquatic macrophytes: a meta-analysis

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An increasing number of rivers have been restored over the past decades and several studies investigated the effect on biota. The published monitoring results have already been summarized in narrative reviews but there are few quantitative reviews and a comprehensive meta-analysis on different organism groups and factors influencing restoration effect is missing. We compiled monitoring results and information on catchment, river and project characteristics from peer-reviewed literature and unpublished databases to (i) quantify the effect of restoration measures on fish, macroinvertebrates and macrophytes, and (ii) identify predictors which influence restoration effect.

Results indicated positive effects of restoration on all three organism groups investigated, especially of widening projects on macrophyte richness/diversity, instream measures on fish and macroinvertebrates, and higher effects on abundance/biomass compared to richness/diversity. However, variability was high, stressing the need for adaptive management approaches. Restoration effect was most strongly affected by agricultural land use, river width and project age. Effects were smaller but generally still positive in agricultural catchments. Project age was the most important factor but had different and non-linear effects on restoration outcome for different organism groups, stressing the need for long-time monitoring to better understand the trajectories of change caused by restoration measures and to identify sustainable measures.

The meta-analysis was restricted to metrics commonly reported in literature and future studies would greatly benefit from authorities and scientists reporting original monitoring data, which would allow to use functional metrics to investigate the effect of restoration measures and to infer causal relationships.

The introduction of large woody debris to improve biodiversity in a modified navigable river stretch of the Dutch Rhine

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Dutch River ecosystems lost much of their ecological values due to human impact. In order to
improve biodiversity and water quality, these regulated rivers now are to be renaturalised to a feasible extent. In impounded river stretches, potentially effective measures are scarce. A major missing element is large woody debris (LWD), which is removed to facilitate water flow and navigation. LWD is an important habitat structure for both fish and macro-invertebrates in free flowing rivers. But does it also improve biodiversity in an impounded river stretch, without hampering navigation and flood-control?
To answer this question Rijkswaterstaat started a pilot study in 2014 by introducing LWD (large trees) in the Nederrijn-Lek. We investigated the impact on fish and macro-invertebrates by various sampling methods. On shallow locations, especially near the branches, high concentrations of juvenile fish were found. The groyne fields were dominated by the alien species. Around the trees the fish community is composed more evenly, and mainly consists of native species, whereby biodiversity is higher.
For macro-invertebrates high numbers of characteristic riverine species were found on the LWD, such as caddisflies (Trichoptera) and Chironomidae (Diptera), which are missing on the studied rip-rap in the river. The results indicate that the first phase of colonization is prosperous.
If future monitoring results remain positive and the fixation methods prove to be adequate, the measure will be exported to faster flowing parts of rivers with even more intensive navigation. Here we expect even better results due to the interaction with morphodynamic processes.

Ecological aspects of fluvial processes recovery at Becva River

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Flood-induced renaturalization of Becva River segments was studied applying multidisciplinary approach. Ecological linkages among channel units and stream biota (macroinvertebrates, phytobenthos, fish) were identified. Specific macroinvertebrate taxa and community characteristics were found for four types of river habitats (channel units). Based on position in the channel and using hydraulic thresholds there were distinguished riffles and pools in central part of main channel, marginal zone of main channel and lateral arms/pools. Differentiation of stream biota between central-channel and lateral habitats was related to degree of their isolation (connectivity of side arms). Macroinvertebrate trophic strategies and substrate preferences reflected importance of substrate specificity in lateral habitats.

Partial recovery of channel forming processes, increased bank zone heterogeneity, temporal occurence of large woody debris in the channel and formation of lateral channels/pools characterized renaturalization process of Becva River at studied segments.

Study results contribute to knowledge of hydromorphological processes in gravel bed river, development of biological indicators responding to physical changes of channel, ecological processes in relation to seasonal and discharge-related dynamics of fluvial system. Study outputs can support planning of river restoration by development the efficient monitoring strategies (sampling design – habitats, seasons; indicators; survey methods), hydraulic modelling and analyzing biological response to instream changes.

Challenges in floodplain and river restoration in the Elbe catchment -case study "Lebendige Luppe" - revitalization project in Leipzig's urban floodplain forest

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In the Elbe catchment already many projects for floodplain and river restoration have started, but only a few have been realized. One of the larger projects in Central Germany is the restoration project "Lebendige Luppe" started in 2012. The objective is the revitalization of more than 20 km of a former river course in Leipzig's northern floodplain ecosystems, with one of the largest floodplain forests in Germany. One of the main objectives is to improve floodplain dynamics to increase the quality of the habitats for plants and animals, and to maintain and increase its ecosystem functions and services for people. Unexpected events like the flooding events in January 2011 and in June 2013 inundated the study area and showed the potential of the former river dynamics in the project area.

The presentation will give a short overview of floodplain restoration projects in the German Elbe catchment and presenting more in detail the project "Lebendige Luppe" with its planning challenges in a strongly modified hydrological river and floodplain network in an urban context.

To measure the effects of the river and floodplain restoration a scientific monitoring design was established and indicators for restoration success were identified. First results of the field campaigns for hydrology, soil and biodiversity in 2013 and 2014 will be presented, which are describing the current status of the main ecological features of the area.

SESSION III. BENEFITS OF RIVER REHABILITATION AND SYNERGIES WITH OTHER USES (FLOOD PROTECTION, NAVIGATION, AGRICULTURE, HYDROPOWER)

Strategic river management for considerations in the power and water management sector in Styria/Austria

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Between 1995 and 2015 large-scale river restoration projects have been initiated along the river Mur in Styria, Austria. Most projects were situated at reaches with already existing nature protection sites, aiming at further ecological improvement and long-term protection of the characteristic river landscape. The restoration measures enabled the reconstruction of lost habitats, the reactivation of flooding areas, the stabilization of the bed-load balance as well as the growth of public awareness. All projects were co-financed by the EU-funding programs LIFE, Interegg II-IIIa and ETZ SI-AT.
After 2015 EU-funded nature conservation programs along Styrian rivers will be questioned due to contradictions between river restoration and promotion of renewable energy. Further growth of the renewable energy sector is a political goal in the EU. In Austria this will be striven for primarily by means of hydropower expansion. This development may contradict the goal of improving the rivers' ecological status as set in the Habitats- and Water Framework Directive.
To overcome the conflict between hydropower expansion and nature protection, management plans were established in a consensual process between energy providers and river experts. The objective is the designation of river stretches for specific use. Thereby hydropower development is prevented from environmentally sensitive sections, while in other sections hydropower use is enabled under certain preconditions. The classification of river stretches laid the foundations for Styria to comply with the mandatory energy targets for the expansion of hydropower as a renewable energy source, while improving the ecological status and creating opportunities to improve river habitats.

A qualitative Cross-Impact Balance analysis of the hydrological impacts of Land Use change on channel morphology and the provision of stream channel services

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For REFORM, IRSTEA has developed a Cross-Impact Balance (CIB) analysis hypermatrix, in ScenarioWizard 4.11, for land use planners and stream restoration stakeholders to use as a tool to anticipate the potential impacts of drainage area hydrology changes on stream channel morphology, ecological function, and services provision.

The need to attain or preserve good ecological status under the WFD will tend to increase the planning importance of the hydrogeomorphologic effects of land use change and will be exacerbated by expanding populations, population redistribution, and climate change. Land use planners do not always take into account the long-term impacts of land cover and associated hydrology changes on the loss of or need for stream channel services.

The long-term impacts of land use change and the need for new or the potential loss of watershed hydrogeomorphological functions are not always part of the initial analysis of a land use change proposal. Current land use development is often opportunistic and may start with expensive and time consuming land acquisition, engineering design, permitting application, financial, and legal efforts. This is true even within existing zoning and land development regulations and, where accommodating zoning and land development regulations do not exist, may lead to rezoning or regulation changes. Once significant time and money have been spent, it is often difficult for planners and enforcement agents to stop or reverse the course of land use change. The results may be costly to the taxpayer and the environment in the short and long-term.

Stream restoration projects are often designed and implemented on relatively short reaches, usually in the context of current land use hydrology. Future changes in land use and the associated hydrology may reset stream channel geomorphologic evolution with unintended consequences on already existing restoration projects or may result in the need for future restoration. Channel restorations can be very expensive in the short-term and the costs of failure can be expensive in the long-term.

Before a great deal of money and time is spent or lost, an initial, qualitative impact analysis may be useful to municipal planners, regulatory agencies, investors, restoration designers, and other watershed stakeholders to get a more global view of the short and long-term impacts and the potential benefits and/or costs of land use change.

Hydrogeomorphology is a complex subject and may intimidate elected officials, citizen planners, and watershed stakeholders. There are many variables to consider, quantitative and qualitative. We have developed the CIB analysis hypermatrix to make initial analysis relatively accessible without the need for engineers or scientists. However, the use of the matrix and its future development would certainly be improved by additional expert judgment.

Integrated Evaluation to support River Restoration: A simple, but effective decision making framework applied to the Chiese River (Italy)

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There is a tendency to consider multiple aspects related to River Restoration (RR) projects, including their environmental services. Several attempts are being gathered where such services are assessed in economic terms. When not aggregated, however, they remain uncorrelated and unverifiable statements; while when aggregated through economic analysis, questionable hypothesis are generally introduced. Moreover, the approach is not suited to address the explicit interests of relevant stakeholders and their interest conflicts which are perhaps the driving force of real decision making. As a result, we have weaker arguments to support RR projects and less restoration is obtained. A significant step forward can be done provided we succeed to demonstrate, through a priori and a posteriori evaluation, that advantages offset the (inevitable) drawbacks.
I propose an approach articulated on three levels that spontaneously stems from the evolution of the traditional approach to flood risk management and fulfills a number of key requirements; namely: i) recognizing the multiobjective nature of the decision making problem; ii) linking the effects to the stated objectives (which implies a serious issue of measuring and clear criteria for monitoring after implementation); iii) supporting a negotiation process to manage interest conflicts amongst stakeholders; iv) being simple, understandable by the layman and applicable; v) integrating the main approaches adopted to support evaluation: EIA, CBA and MCA.
Results and conclusions from a relevant case study on a 80 km stretch of the Chiese river (Italy) are discussed where some river setting alternatives are systematically compared leading to interesting policy indications.

Using Hydroscapes to maximize the benefits of riparian corridor restoration for multiple river ecosystem services

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Riparian corridors play a major role in determining river ecosystem functioning as they control bank erosion and river morphology, they generate habitat heterogeneity within the channel, banks and floodplain, they influence nutrient and organic matter inputs, they buffer against sharp changes in water temperature and they constitute an important habitat for many riverine species. However, the assessment of riparian corridor conservation status has rarely been achieved continuously for entire river networks and linked to the provisioning of different river ecosystem services. This prevents the elaboration of catchment restoration planning that maximizes the provision of multiple ecosystem services. In this study we have assemblage a large spatial scale (120.000km^2) database from northern Spain which incorporates different riverine ecosystem components. We delineated and characterized Hydroscapes for all the major river networks included in the study domain and produced a continuous conservation status riparian corridor assessment. This diagnosis was then used to prioritize river reaches for riparian restoration which maximized bank erosion protection, water temperature control, nitrate runoff and enhanced floodplain habitats.

SESSION IV. ASSESSMENT AND REHABILITATION OF HYDROMORPHOLOGICAL PROCESSES IN RIVERS

Exploring spatial scales of geomorphical features driving macroinvertebrate communities (Duero Basin, NW Spain)

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Spatial scaling has been largely used in fields such as hydrology and geomorphology. The understanding of the scales at which fluvial processes are more important driving physical habitat features has become an issue in recent research (REFORM, WP2) and becomes crucial to assess the effects of human pressures and impacts on fluvial ecosystems. However, the relationship between the biological communities and the fluvial spatial scales is still partially understood despite its significance in biodiversity conservation.

The aim of this work is to determine the spatial scale at which the macroinvertebrate community is more representative. 75 sites along 23 rivers were sampled in the four seasons of the year 1981, and macroinvertebrate specimens were identified mostly at the species level. The sampling period corresponds to one when the studied rivers were relatively slightly altered, i.e., in many cases were dammed but not affected by other significant geomorphic impacts that have occurred during the following periods (e.g. channelization, dredging, natural riparian vegetation removal).

Statistical analyses (ANOVA, CA) to assess the significance of spatial scales (catchment, landscape unit and segment scale) driving different taxonomic levels of macroinvertebrates (group, family, genus and species) have been carried out, using the data of the most representative taxa (>180) of the 300 samples. The results are discussed within the geomorphological and biological context and linked to the use of macroinvertebrates as bioindicators in river monitoring and management.

Recolonisation and succession of benthic invertebrate assemblages in restored former sewage channels

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Field studies on stream restoration are often flawed by uncertainties whether benthic invertebrates recorded have colonised the sections after restoration or if they have been present before. We investigated restored streams in an urban area in western Germany, which have formerly been open sewers and were not inhabited by benthic invertebrates. The restored sites differ in age of restoration. We sampled seven restored sites connected to near natural upstream sections, and six unconnected restored sites. Additionally, we sampled 22 near natural sites in the surrounding of 5 km as potential recolonisation sources. All taxa recorded were categorised into five dispersal classes reflecting dispersal capabilities and ecological specialisation. Assemblages of restored sites were characterised by lower taxa numbers and abundances of hololimnic taxa, of poorly dispersing winged species, and by higher taxa numbers and abundances of strongly dispersing generalists. NMS and ANOSIM showed clear differences in assemblages between source and restored sites and “connected” and “unconnected” sites. Integrating the age of restoration, we observed a succession from pioneer assemblages to more mature communities resembling those of the near natural sites.

Assessing the effect of a catchment-scale restoration project in Wallonia (Belgium)

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In the context of fulfilling the Water Framework Directive requirements, the LIFE+ project *Walphy* allowed experimental restoration projects to be undertaken on two medium-size catchments of the Meuse basin in Wallonia (Belgium) between 2009 and 2014.
Before undertaking sustainable rehabilitation measures, a multi-scale assessment of hydromorphological conditions (catchment, stream and site) was conducted. It was based on a variety of variables characterizing the river system and its geomorphic processes (e.g. sediment transport), along with human-induced disturbances (e.g. barriers to river continuity).
The Bocq catchment has been subject to a large-scale restoration project through the removal or modification of 20 barriers (mainly old weirs), reconnecting the Bocq with the Meuse. In addition, 2.6 km of straightened courses were improved by restoring meanders or diversifying habitats through a wide range of rehabilitation techniques.
The success of the restoration projects was evaluated on the basis of a multi-disciplinary monitoring. We compared hydromorphological parameters and biological diversity of benthic invertebrates, fish and macrophytes. 2-3 years post-rehabilitation, hydromorphology was significantly improved. Depending on the rehabilitation measures, the restoration effects observed for invertebrates and fish differ. Weir removal and restored meanders have resulted in the most positive effects, while habitat diversification has led to more contrasted results, depending on the level of ambition. The geomorphological monitoring has focused on the effectiveness of spawning gravel rehabilitation and the effect of barriers on sediment transport. Topographic surveys and the use of pebble tracers have highlighted a natural bedload transport following a weir removal.

The Hydromorphological Evaluation Tool

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River engineering structures such as bank protection or bed sills act as constraints on river morphology and limit morphodynamic processes. Accordingly, the deviations of a river's morphology from a natural reference condition were attributed to the degree of artificiality in the observed river section and river restoration works mainly aimed at reducing artificial constrains within the river reach. Less attention was drawn to alterations of the sediment continuum between sediment production in the river's catchment and downstream river reaches. However, especially in gravel bed rivers, the sediment supply from upstream is strongly reflected by morphodynamics such as bar formation or reworking of the river bed. Any alteration of the quantity of sediment supply (i.e. sediment discharge) or sediment quality (e.g. grain size) may affect the morphological appearance of a reach and determine its deviation from an undisturbed condition.

The decision tree for the evaluation of sediment regime accounts for sediment supply and sediment transfer as preconditions for sustainable morphodynamics in river reaches. At the reach scale, artificiality and the sediment budget are assessed. In contrast to existing evaluation methods for assessing hydromorphological state, no reference condition is needed for determining hydro-morphological alterations. Here, with re-established sediment supply and reduced artificiality, a river reach is expected to develop the morphodynamics that approaches an undisturbed condition.

Application to the Drau River showed that the alteration of sediment supply strongly affected the evaluation result of a restored reach, indicating remaining potential for re-establishment of morphodynamics through catchment-wide restoration plans.

SESSION V. DISCERNING THE IMPACT OF HYDROMORPHOLOGICAL MODIFICATION FROM OTHER STRESSORS

Mechanistic models can help to disentangle effects of different stressors on the macroinvertebrate community in streams

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Mechanistic models facilitate the synthesis of existing quantitative knowledge about ecological processes that are relevant for ecosystem management. They provide the possibility to integrate different sources of information and to propagate their uncertainty to model predictions.

We developed the mechanistic model Streambugs for the community composition of macroinvertebrates in streams. Macroinvertebrates are susceptible to different kinds of stressors like hydromorphological impairments, input of organic matter, pesticides from point and non-point sources, and temperature changes. The exposure to these stressors varies over space and time. Therefore, it is a challenge to assess the relative importance of stressors and propose effective mitigation options. For river management it is important to anticipate potential effects of different management actions on ecological endpoints. This is even more challenging than predicting potential effects on physico-chemical properties of the ecosystem.

To contribute to the solution of this problem, we combine knowledge from food web ecology, the metabolic theory of ecology, and ecological stoichiometry with the use of functional trait and ecotoxicological databases in the model Streambugs. The model describes the coexistence of macroinvertebrate taxa in streams dependent on different environmental conditions. With this model, we can assess functional as well as structural aspects of river ecosystems and test hypotheses about the influence of different stressors. We will demonstrate the predictive capacity of the model with two case-studies from the Swiss Plateau, the Glatt catchment and the Reform case study Thur/Töss.

Streambed microhabitat heterogeneity as a determinant of macroinvertebrate population development

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In streams hydromorphological degradation often results in a decreased streambed microhabitat heterogeneity, negatively affecting its inhabitants through interfering with, for example, resource acquisition or refuge use. To quantify these effects, it was experimentally tested if caddisfly emergence success and fitness were affected by the spatial arrangement of resource patches under different flow regimes. Larvae of *Sericostoma personatum*, *Lepidostoma basale*, *Micropterna sequax* and *Potamophylax rotundipennis* were reared together in indoor artificial recirculating channels in which leaf patches were offered on a sand bed in three spatial arrangements (fully aggregated, fragmented into three smaller isolated patches, checkerboard pattern of six small patches) under different flow regimes (constant 5 $cm.s^{-1}$ or 25 $cm.s^{-1}$ and alternating between both current velocities). The number of emerging caddisflies was counted, and for each adult fitness correlates in the form of total mass, mass of the abdomen en forewing length were measured. Microhabitat heterogeneity had clear effects on the caddisflies, but its direction and magnitude were species- and sex-specific and differed between the individual fitness correlates. Nevertheless, in three out of four species the most patchy habitat configuration yielded the highest emergence success. Flow regime was particularly important to *M. sequax*. The wide range of effects of microhabitat heterogeneity found in the experiment indicates that patchiness of the streambed is an important driver of community patterns in running waters. As a consequence, changes in substrate composition or spatial arrangement of patches due to natural or anthropogenic disturbances could have considerable effects on macroinvertebrate populations.

Managing the impact of fine sediment on river ecosystems

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Sediment plays a pivotal role in determining the physical, chemical and biological integrity of aquatic ecosystems. However, human activities have increased loads of fine sediment to such an extent that it has been suggested that fine sediment is one of the most widespread and detrimental forms of aquatic pollution. Given the key role of sediment in determining water quality, and the spatial scale over which mitigation must be implemented to achieve reductions in inputs, a sound evidence base is critical to understanding the impact of fine sediment on biota. Enhanced sediment inputs impact adversely upon aquatic ecosystems both by degrading habitat condition and by directly impairing biota. Furthermore, the biological impact of fine sediment is likely to be a consequence of a combination of the source of fine sediment and both the amount and rate of delivery and retention, as well as the susceptibility of the resident community to any impact.

Here we report the results of an investigation into the impact of fine sediment on aquatic invertebrates involving community analysis based on large-scale field survey (covering England and Wales) and field scale experimental manipulations in experimental channels. The objective of the work was to develop and test an empirical index relating invertebrates to pressure from fine sediment that can be coupled to a landscape scale modelling framework to explore the impact of land-use management interventions at the national scale.

Changing e-flows resulting from land use change and altered groundwater conditions in the Regge Catchment, the Netherlands

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In addition to climate and hydromorphology, in many catchments groundwater has a large effect on surface waters and their ecological functions (Hendriks et al., 2014). In this study the causes of changing ecological flows in the Regge catchment were assessed for the period 1956-2003, using data series of river discharge, climate and groundwater in combination with an historical assessment of land use changes. Data series analyses consisted of calculation of flow parameters, standard indexes of precipitation and evaporation, impulse-response modelling of groundwater data, and statistical trend testing of all data series.

Results showed that flow dynamics decreased over the measurement period, first resulting from a decrease of peak flows (1956-1980) and later due to an increase of low flows (1990-2003). Climatic variables (P and ET) did not show significant changes, while changes in groundwater levels were significant and corresponded to the changes in flow parameters. It was concluded that the changes groundwater level, e-flow parameters, and flow variability in the Regge catchment were probably strongly affected by the large scale anthropogenic changes to the catchment (land use and alteration to the streams). Although no direct causal relation could be proved, the significant changes in groundwater level (increase) and low flows (increase) during the period 1990-2003, could be linked to re-naturalization projects that took place in the catchment since the 1990's.

SESSION VI. HOW TO IMPROVE THE (COST-) EFFECTIVENESS OF RIVER REHABILITATION?

Reporting and Predicting Costs of River Restoration Projects

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Cost-effectiveness analysis (CEA) could be a highly useful instrument for advising the selection of river restoration measures at project level. It enables decision-makers and stakeholders to compare restoration measures ex ante in order to assess which alternatives are financially viable. However, incomplete cost assessments often hamper the evaluation process. In order to support managers in identifying and estimating relevant project costs, this paper discusses the various cost categories related to hydromorphological restoration and develops a cost typology which can serve as a basis for comprehensive cost assessments. Furthermore, the potentials of CEA in the planning and design of river restoration projects are examined. International best-practice examples are presented to show that CEA can play a central role in the process of selecting restoration measures and in determining the appropriate size of the budget and volume of the project. Finally, a set of guidelines is presented which support decision-makers and planners in identifying cost-effective river restoration measures at project level. This conference paper summarises the findings from an analysis on the role of cost assessments in river restoration projects that was carried out as part of Deliverable 5.2 of the FP7 REFORM project.

The economics of river restoration: Experiences throughout Europe in understanding effects, Costs, and Benefits

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More information is needed to help river basin managers to understand the costs and benefits of river restoration to effectively support the drafting of programme of measures for the implementation of the EU Water Framework Directive. This conference paper summarises the findings from a review of the literature on the effects, costs, and benefits of river restoration options throughout Europe that was completed as part of Deliverable 1.4 of the FP7 REFORM project. The paper begins by characterizing commonly implemented river restoration measures in Europe and continues by reviewing available information about their typical effects, costs and ultimately, economic benefits. Finally, the paper aims to highlight from an interdisciplinary perspective relevant lessons learned for water management.

Evaluating the environmental costs of flow regulation: a dynamic water pricing approach

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Flow regulation and water abstraction alter rivers worldwide and cause serious damage to fluvial ecosystems. Environmental flows have been proposed as a basic mitigation measure but they represent an important challenge in water resources management, not only for the agreement in discharge values, but also for evaluating their ecological costs that water users should pay for the recovery of environmental costs.

The objective of this work is to develop a methodology to assess the marginal environmental costs of flow regulation. The approach is based on the principle of '"polluter pays' that is included in the Directive 2004/35. We applied this principle to flow regulators considering that the amount to be paid should be proportional to the intensity, duration and frequency of the resulting regulated flows. The proposed methodology represents an alternative and flexible approach that promotes a self-mechanism to optimize impact mitigation and cost/efficiency of flow regulation

The proposed methodology includes three separated steps: (i) estimating the natural hydrological variability of the flow regime of a river through studying the hydrologic conditions before regulation, (ii) assessing the hydrologic alteration of the river by current dam operation, and (iii) calculating marginal environmental costs of regulated flows.

The developed methodology has been applied to different case studies. The results have been analyzed in relation to water uses, reservoir traits and regulation intensity. Differences with environmental flows adopted in River Basin Management Plans are discussed. The methodology represents an efficient tool to achieve the goal of guarantying the full cost recovery addressed by the Water Framework Directive.

Oral presentations – Wednesday July 1

SESSION VII. a. ASSESSMENT AND REHABILITATION OF HYDROMORPHOLOGICAL PROCESSES IN RIVERS – b. LINKING SCIENCE TO PRACTICE: TOOLS TO ASSESS RIVER STATUS AND GUIDE REHABILITATION TO OPTIMIZE RIVER BASIN MANAGEMENT

Applying process-based hydromorphological assessment to the identification of fine sediment pressures and impacts in a lowland agricultural catchment

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Fine sediment is a widespread pressure affecting rivers across Europe, particularly those in agricultural or urban settings. Changes to the quantity and quality of fine sediment entering rivers means that what was once a purely natural component of river systems now impacts significantly the ecology and hydromorphology of waterbodies. Methods to identify sediment sources, pathways and impacts are needed to develop a fuller understanding of sediment transport processes in order to develop sustainable management solutions. In this study, the hierarchical hydromorphological assessment framework developed in the REFORM project was applied to a lowland gravel-bed river affected by excess fine sediment. The framework was used to uncover the possible sources and timing of fine sediment delivery to the river channel and its impact on channel geomorphology over the last 100 years. A catchment-scale analysis of land cover and agricultural land use identifies intensive cereal and livestock production in the second half of the 20th century as the likely sources of excess fine sediment. It also suggests that the absence of significant riparian vegetation cover facilitated the delivery of fine sediment to the river network. A reach-scale analysis of channel planform using historical maps notes decreases in channel widths and increases in reach sinuosity over this time period. Field observations suggest that riparian and aquatic vegetation are central to this progressive adjustment through the trapping and stabilisation of fine sediment in bars, benches and islands. The study demonstrates how a process-based framework can help diagnose fine sediment pressures and identify management solutions.

Distinct patterns of interactions between vegetation and river morphology

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Modelling vegetation and morphodynamics is often one-way traffic that either takes into account the effect of vegetation on morphodynamics or vice versa. The few models that do incorporate an interaction have until now represented vegetation in a simplistic manner, mostly as cylinders causing hydraulic resistance that do not change over time. We coupled a morphodynamic model to a dynamic vegetation model to test the hypothesis that dynamic vegetation creates more realistic patterns in vegetation and fluvial morphology as opposed to the 'old fashioned' static vegetation. Vegetation can colonize, grow, die and interact with the flow. We compare a reference scenario without vegetation to a scenario with static vegetation and an innovative dynamic vegetation scenario. Results show that the dynamic vegetation scenario has a decreased lateral migration of meander bends and maintains its active meandering behaviour as opposed to the scenarios without vegetation and with static vegetation. Also the patterns in vegetation and fluvial morphology and the vegetation age distribution mostly resemble the natural situation when compared to aerial photos of the study area. Furthermore, a sensitivity analysis in which several vegetation types have been tested, reveal strong negative correlations between on the one hand dynamic vegetation cover and on the other hand the median bed level, sediment transport rate and sinuosity. This demonstrates that dynamic vegetation processes as opposed to static vegetation predicts more natural patterns and dynamics in vegetation and fluvial morphology. Furthermore, we quantitatively show the interacting role of vegetation in shaping river patterns.

Torrent restorations in the flysch mid-mountain environment: The case study of the Kněhyně Torrent, Czech Republic

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The occurrence of channel-reach morphologies (e.g., bedrock channels, step-pools, anabranching channels) in mountainous landscape is driven by several internal and external time- and space-variable factors. Especially, the identification of the sediment supply potential related to transport capacity is crucial for later stream management in torrential mountain channels. The contribution deals with theoretical aspects of stream restorations of this part of fluvial net with emphasis on the flysch Western Carpathians on the example of restored anabranching channel-reach of the Kněhyně Torrent. This channel-reach was partly renaturalized by the 100y flood event in 1997, when the single riprap-regulated channel was transformed into anabranching pattern with relatively large gravel deposits. Stabilization elements were added into the channel to preserve that morphology during the restoration project realized in 2003-2004. The field geomorphological mapping shows, that longitudinal disconnectivity in the form of check-dams exists in the stream longitudinal profile and recent potential sediment sources are limited at the watershed scale. These facts make difficult the sustainable preservation of the transport-limited conditions in the Kněhyně. We suppose, that the original anabranching pattern noticed by the 2nd Military survey (half of the 19th century) was resulted from the higher sediment supply caused by different land-use of mountain region and the important role was played by the sediment delivery driven by debris flows under suitable climatic conditions during the LIA. The role of potential sediment supply estimations, bedload transport modelling and dendrogeomorphological approach is discussed in order to better asses relationship between the sediment supply, transport capacity and resulted channel-reach morphology.

Towards a more comprehensive assessment of river ecological conditions: application of a dragonfly-based index in Northern Italy

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Recent studies showed that the bioindicators commonly used to evaluate the ecological conditions of rivers (i.e. diatoms, aquatic macrophytes, benthic macroinvertebrates and fish) detect alterations of water quality, but are not particularly sensitive to hydromorphological degradation. In addition, their application is limited to flowing channels, thus not taking into account other aquatic and terrestrial habitats of the river corridor. In this study we correlated the assessments obtained from three bioindicators (i.e. dragonflies, diatoms and benthic macroinvertebrates) and the Morphological Quality Index (MQI) in seventeen lowland river reaches in northern Italy. The selected reaches are characterized by a wide range of morphological degradation.
Dragonflies provide information about the ecological integrity and habitat heterogeneity of both the aquatic breeding sites and the surrounding terrestrial areas, due to their amphibious life cycle and because their ecological requirements are well known. Starting from a dragonfly-based assessment system proposed in Austria, we developed a multimetric index, the Odonate Quality Index (OQI), which assesses the conditions of the whole river corridor, as also secondary channels and ponds in the floodplain are sampled. OQI and MQI turned out to be highly correlated, while no significant relationships were found between MQI and the indices that are based on diatoms (i.e. ICMi) and macroinvertebrates (i.e. STAR_ICMi). These results underline that dragonflies are good indicators of the ecological integrity of river corridors at reach scale, also reflecting morphological quality, and that the OQI provides information on the ecological condition of rivers not covered by the other bioindicators.

A Multi-scale framework for modelling River basin sediment connectivity

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Fluvial sediment connectivity is a central driver behind fluvial processes. Here, connectivity refers to a cascade of sediment transport processes through the basin, from initial mobilization, to intermediate storage or remobilization, and final deposition, which link various sediment sources and sinks over a wide range of spatio-temporal scales. Human activities alter sediment connectivity, and result in negative externalities in form of altered fluvial processes, and related ecosystem services.

So far, the ability to model the sediment cascade connectivity over the relevant spatio-temporal at the basin scale is highly limited due to scarcity of significant data and a limited conceptual understanding of basin-scale processes, which can be translate into effective modelling framework.

Here, we propose a novel, graph-theoretic, process-based model to traces sediment transport along multiple transport pathways from each sediment source. It considers competition for transport capacity between sediment pathways that locally leads to sediment deposition or remobilization.

Based on the model, we identify most relevant spatio-temporal patterns of sediment connectivity for a larger river basin (55'000 km2) in Vietnam. First, the model allows identifying which parts of the river basin are (dis)connected on various spatio temporal scales. The analysis is spatially explicit and identifies magnitude and timing of sources and sinks locations and associated grain size distribution throughout the entire basin river network. From this information, aggregated indices of sediment connectivity are derived that allows to localize and quantify anthropic impacts on sediment connectivity, e.g. due to the construction of reservoirs, and to plan and prioritize effective mitigation measures.

SESSION VIII. ACHIEVEMENTS BY RESTORATION AND MITIGATION PRACTICES

The dam removal in the Sélune River (France): a long-term interdisciplinary program from the particle to the watershed scale

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Dam removal constitutes a major action to restore connectivity in rivers. However, compared to the number of such operations conducted, their risks/benefits balance remains poorly documented. A 16-year scientific program has been initiated to monitor the removal of two dams in the Sélune River (France, flowing into the Bay of Mont Saint-Michel, UNESCO's world heritage site), and planned in 2019. The ultimate aim of the project is to characterize the nature and the dynamic of ecological changes due to dam removal, and to identify the underlying mechanisms. Involving 20 labs from complementary research fields, the scale of studies conducted in this program ranges from the particle to the watershed. Several studies are currently running according to four interconnected tasks. The first task relates on aquatic biota and intends to characterize the evolution of diadromous and resident fish, invertebrates, crayfish, and vegetal communities after dam removal. It aims to evaluate the changes in water quality, identify successful evolutionary strategies for diadromous fishes, and highlight fundamental changes in the functioning of freshwater ecosystem after the ocean-river reconnection. The second task focuses on physical river dynamics and aims at characterizing changes in physico-chemical, fine sediments and water fluxes, and resulting impact on geomorphology and aquatic habitats. The third task deals with landscape ecology and intends to monitor changes of riparian vegetation and interactions with agricultural landscape. Finally, the fourth task relies on social geography and aims to study the appropriation process of dam removal by inhabitants of the valley and to evaluate the success criteria of this large-scale restoration program.

Woody debris increases and stabilizes macrofauna communities in stream construction works

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Stream restoration and rehabilitation to increase biological water quality has become a priority task for authorities to comply the European Water Framework Directive. In the past, most streams have been normalized resulting in an uniform flow rate which is unfavorable for macrofauna survival. One of the methods to increase water flow velocity is to fix woody debris into the stream bed. Woody debris will lead to increased habitat heterogeneity by causing variable water flow velocity. Theory predicts that increased habitat heterogeneity increases and stabilizes associated macrofauna diversity. In the “Snelle Loop”, a stream in the South of the Netherlands, a dam was removed and replaced with 10 patches of woody debris to increase water level and slow down flow rate over a course 1,2 kilometer. Hydrodynamics, water quality and macrofauna communities were measured twice a year for three years. The removal of the dam caused a water level decrease of 50 cm, the introduction of 10 woody debris constructions compensated the removal of the dam. The input of woody debris resulted in increased habitat heterogeneity and increased macrofauna diversity. Surprisingly, already within a year after appliance of the woody debris, macrofauna species indicative for healthy streams were already sampled. During the following sampling periods the same and even more species specific for healthy stream ecosystems were found. For example the red list species *Goera pilosa* was found half a year after the dam was replaced by woody debris. Macrofauna diversity seems to be higher near patches with grind as substrate and high habitat heterogeneity. Results from this study show that woody debris can be a successful cost-efficient natural replacement of dams and can increase habitat heterogeneity and stabilizes macrofauna abundances.

Effects of hydromorphological stream restoration measures on stream and riparian zone plant diversity

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Abstract Streams and their riparian zones provide typical examples of naturally species-rich, dynamic habitats. Under natural conditions, spatial and temporal variation in flooding disturbance coincide with a strong hydrological gradient from the channel to the uplands, generating a heterogeneous environment with corresponding high plant and animal diversity. Yet, streams and their riparian zones are highly vulnerable freshwater systems which are increasingly threatened across the world by anthropogenic modifications, such as damming and channelization, as well as by projected increases in climate-induced droughts and flash floods. Severe losses of diversity along streams and their riparian zones, and the lack of ecological improvement after costly restoration programmes, call for detailed and mechanistic understanding of the regulation of species distributions and biodiversity in relation to the dynamic interactions of water flow, erosion and sedimentation. We present the results of a series of innovative hydromorphological stream restoration measures in The Netherlands, aimed at re-constructing the naturally dynamic and heterogeneous stream-riparian gradient of lowland sandy-substrate streams. These measures include re-meandering, channel excavation, narrowing of the stream profile and re-creation of a v-shaped stream valley with gently sloping riparian zones. We evaluate the achievements following these restoration measures in terms of vegetation rehabilitation and plant diversity and report on the mechanisms that contributed to successes. More specifically, we evaluate whether restoration of stream hydromorphology is sufficient, considering other abiotic limitations (water and soil quality) and biotic limitations (availability of nearby source populations to allow colonization of the restored sites).

The response of hydrophyte growth forms and plant strategies to river restoration

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Evaluating ecological responses to restoration is important for assessing the success of river restorations. We evaluated the response (effect size) of species richness and diversity of aquatic macrophyte (hydrophyte, in-stream aquatic plant) growth forms and strategies (Grime's CSR strategies; C competitive, S stress tolerant, R ruderal) in 10 small- and 10 large-scale river restoration projects in nine European countries. Species richness and diversity of elodeids (submerged without floating leaves) increased, whereas the proportion of C strategies decreased at small scale-scale restoration sites with mainly widening as the main restoration measure. Flow restoration positively affected effect size of nymphaeids (floating-leaved). Catchment properties explained the effect size of the proportion of C strategies in the plant communities. Our results highlight the importance of river and catchment properties when evaluating river restoration projects. We suggest hydrophyte growth forms and plant strategies as suitable response variables to assess the success of river restoration projects.

Helophytes are efficient indicators of river restoration success

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River banks in Europe are often artificially altered for river regulation purposes, contributing to general river degradation. In the course of river restoration, removal of bank reinforcements and thereby widening the banks is often conducted to improve lateral connectivity between riverbed and flooded area. In order to enhance the rate of evaluation following river restoration and thus increase restoration success overall, we aim to find more cost-efficient ways of its assessment. So far, helophytes as plants growing on the edge of waterbodies have only rarely been considered as indicators for restoration success, but we assumed that their diversity strongly responds to restoration. We expected helophyte diversity to depend on environmental factors (i.e. slope, discharge and bed substrate) and to reflect alterations in hydromorphological parameters (i.e. channel geometry and connectivity). Therefore, we gathered data on macrophytes and environmental variables in 20 restored river sections across Europe. Samplings and surveys in both restored and adjacent degraded reaches of each river allowed for the evaluation of restoration success. Median richness (+104%) and median Shannon diversity index (+39%) of helophytes were higher in the restored compared to the degraded reaches. Both variables were correlated with hydromorphological parameters affected by restoration. Consequently, we encourage water managers to consider helophytes as efficient indicators of river restoration success, because recording their diversity is easy and cost-efficient.

SESSION IX.EUROPEAN CENTRE FOR RIVER RESTORATION

European Centre for River Restoration and River Restoration through the years!

BART FOKKENS
Chairman and co-founder of the ECRR

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The European Centre for River Restoration is a Greater European Network with 15 national centres and river restoration organisations as members or partners and has about 800 organisational and individual subscribers of the newsletter and other products of the ECRR. The ECRR disseminates river restoration information, supports the development of best practices of river restoration and connects therefore people and organisations working on river restoration.
The ECCR was initiated in 1996, established in 1999 as a loose network and became an association in 2014. The ECRR worked together in close collaboration with the RESTORE project, which ran between 2010 and 2013. Some of the key outputs of the this project are the RiverWiki, a Laymans report, setting out future directions and the guide, Rivers by Design, for planners. The ECCR organised over the years 6 European / International River Restoration Conferences of which the last two featuring the awarding of the first and second IRF European Riverprize.
The presentation will describe the development of the ECRR in relation to the results of implemented river restoration and river basin management initiatives, addressing various themes as urban resilience, sustainable land use and ecological & economical benefits, confirming the significant progress made in shifting from the science & ecology focus on the local level towards integrated, cross-sectoral policy and planning practices over regions and basins.
Demonstrated value of a focused exchange of knowledge and experiences between involved sectors encourages river restoration practitioners to expand the practical application of innovative approaches and instruments in contributing to holistic considerations of maintaining natural river processes, by aligning sustainable socio-economic development planning through considerations for the multiple benefits from ecosystem services & natural values.
The impacts from known, underestimated as well as new, unexpected pressures on rivers and aquatic ecosystems remain significant. Addressing these impacts with sustainable integrated river basin management approaches requires the strengthening of cross-cutting planning and implementation, between countries & basins, sectors & themes, policy & legislation, stakeholders and the public.
Successful integrated river basin management, as valued by citizens depends on the proper reflection of societal choices on sustainable socio-economic development into a realistic and practical planning and implementation framework as the EU Water Framework and other Environment Directives, based on public participation and stakeholder involvement.

RESTORE's multiple benefits for river restoration and the ECRR

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The relevance of river restoration to achieve river management goals and solutions has become increasingly apparent in recent years and become increasingly reflected in policy at European and national level. On the ground there is an ever increasing frequency of projects and initiatives. However, the gap between innovation, best practice, meaningful landscape scale implementation and impacts remains significant. The RESTORE LIFE+ project was a key communications initiative that sought to try and address this across Europe, supporting key networks and actors such as the ECRR and its National Centers. The presentation will reflect on the successes and speculate on the direction that similar initiatives and actors such as the ECRR need to move in the years to come.

Increased river restoration needs societal and political choices based on leadership, courage, cooperation, public participation, (sector) stakeholder involvement. Successful integrated river basin management including basin restoration, as valued by citizens while addressing the pressures, depends on the proper reflection of societal and political choices on sustainable socio-economic development into a realistic and practical planning and implementation framework, based on public participation and stakeholder involvement. Win-win solutions, linking economic gain with adaptation & mitigation of impacts need to be considered, taking uncertainties regarding socio-economic development and climate change into account.

Discussion on integration issues of River Restoration implementation

The facilitated discussion will be on opportunities for innovative Integrated River Basin Management provided by emerging policy initiatives, with specific focus on using approaches like Green Infrastructure, Natural Water Retention, and Contemporary River Corridor Management, but also by the results of the REFORM project outputs and outcomes.

The two ECRR presentations show the extensive work done in recent decades towards developing best practice approaches for river restoration, towards restoring the ecological state of rivers and their biodiversity. With specifically water quality having been significantly improved, attention is shifting towards addressing hydro-morphological pressures and issues of re-installing lateral and longitudinal connectivity. Practical applications commonly rely on pilot projects in small and large rivers targeted for subsequent upscaling, using qualitative and quantitative survey, modelling and monitoring tools. Other actual themes include urban resilience, sustainable land use and hydropower, as well as the integrated consideration for ecological and economic benefits.

Increasingly due attention is paid to balancing ecological and socio-economic needs and the application of accepted principles such as ecosystem services, sustainable & precautionary planning and decision making, and stakeholder involvement at all relevant levels, including transboundary concerns. Endorsed relevant EU Directives – the WFD, FD, HBD, Natura-2000, RES-E, and others – provide the enabling environment for embedding the overarching principles into policy development and implementation. This strengthens common understanding, and creates the enabling environment for targeted action on addressing ecological concerns in sustainable development planning.

Meanwhile, significant challenges remain. While improvements are observed, the status of many rivers in Europe is still critical. Although there is an increased awareness and knowledge on the factual and future consequences of past impacts on water from development activities, European wide assessments show that agreed Programmes of Measures to 2015 were insufficiently ambitious; both in defining actions needed, in coordinating actions among Directives, and in factual addressing identified pressures towards an improved ecological status of the aquatic environment. Meanwhile, the envisioned expansion of hydro power is a threat for the ecological status of Europe's pristine rivers, if the guidance on maintaining continuity and environmental flows is not urgently developed and efficiently implemented. Also the forecasted increase in pressures on water resources from population growth, economic development, climate change and others strengthen the need for a paradigm shift towards proactive, integrated, adaptive planning, decision making and action at the appropriate scale, based on inclusive public participation and broad stakeholder involvement, comprehensive hazard & risk assessments, and continuous monitoring.

The discussion will be on what reaching more and better on-the-ground success requires and how the results of the REFORM project could contribute to this success.

SESSION X. a. DISCERNING THE IMPACT OF HYDROMORPHOLOGICAL MODIFICATION FROM OTHER STRESSORS – b. LINKING SCIENCE TO PRACTICE: TOOLS TO ASSESS RIVER STATUS AND GUIDE REHABILITATION TO OPTIMIZE RIVER BASIN MANAGEMENT

Stream and riparian plant community responses to increased flooding

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An increased flooding risk from European streams and rivers has been projected to change riparian plant community composition and species richness, but the extent and direction of the expected shift remain uncertain. We conducted both a meta-analysis and field experiments to synthesise experimental evidence and assess the effects of increased flooding on riparian plant and seedling survival, biomass and species composition. We evaluated which plant traits are of key importance for the response of riparian species to flooding. We identified and analysed papers with quantitative experimental results on flooding treatments and corresponding control situations. Moreover, we conducted a flooding experiment along five North-Western European riparian gradients. Our meta-analysis clearly demonstrated how longer duration of flooding, greater depth of flooding and, particularly, their combination reduce seedling survival of most riparian species. Plant height above the water level, ability to elongate shoots and plasticity in root porosity were decisive for adult plant survival and growth. Our literature survey confirmed that the projected increase in the duration and depth of flooding periods is sufficient to result in species shifts. Nutrient, climatic and hydrological status of the catchment determine the direction of change; species richness was generally reduced at flooded sites in nutrient-rich catchments and at sites that previously experienced relatively stable hydrographs, while it increased at sites in desert and semi-arid climate regions. Our field experiment revealed that a six-week flooding period can already lead to a reduction in riparian species richness.

Diatoms as indicators of fine sediment stress

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Excessive mobilisation and delivery of fine sediments to water bodies has detrimental impacts on those biotic elements used for waterbody status classification. Typically changes in the diatom assemblage (as either phytobenthos or phytoplankton) are used to assess the extent of stress from eutrophication. As increased delivery of fine sediment has the potential to impact diatom assemblages in many ways, it is not surprising that indices based on benthic diatom assemblage structure have been proposed. These comprise simply of the relative abundance of motile species. This measure is based on the fact that many raphid species are capable of migrating through deposited sediment to avoid its negative impacts. However, the use of such an index has yet to be fully tested.

Here we used various techniques to explore how diatoms, and indices based on diatoms (related to both eutrophication and siltation), respond to a gradient of percentage cover of fine sediment. We also explored how two traits, motility and nutrient affinity, were associated with the gradient of fine sediment. We conclude that the relationship between motility and deposited fine sediment is not sufficiently strong to be used reliably as an indicator of fine sediment stress.

Disentangling stressors in boreal rivers: diffuse pollution overrules channel alteration in degrading river assemblages

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River ecosystems are degraded by multiple anthropogenic stressors. Hence, to improve the ecological status effectively, water managers need to know which stressors are most harmful to the biota. We disentangled the importance of two pervasive stressors, hydromorphological alteration and diffuse pollution, on the structure and status of diatom, macrophyte, and macroinvertebrate communities in Finnish rivers. We first grouped our 97 study sites based on their deviation from reference conditions for both hydromorphological alteration due to channel dredging and nutrient status due to diffuse pollution to four pressure levels: (i) least impacted sites, (ii) sites with only hydromorphological degradation, (iii) sites with only diffuse pollution, and (iv) sites with both pressures present. We then conducted Principal Component Analysis on pressure data which indicated clear stressor gradients and distinct grouping by the pressure levels. The community structure of all three biological groups responded significantly to diffuse pollution. However, PERMANOVA detected no response to the altered hydromorphology. The status of the communities was evaluated by observed-to-expected number of those taxa specific to national reference conditions (EQR) which showed negative response of diatoms and macroinvertebrates to diffuse pollution, but no response to hydromorphological degradation. Our results emphasize the importance of tackling diffuse pollution and associated stresses due to land use to improve ecological status of rivers. Mitigation of land use pressures over in-stream habitat improvement should thus be emphasized in river basin management plans.

Combine with: Multiple interacting hydromorphological stressors and their impact on fish population in alpine regions

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One of the most proximate causes of fish species decline is habitat alteration as a result of systematic river channelization. Although one or two principal causes of decline can be identified for each fish species, the decline is typically the result of multiple, cumulative, long-term effects. A detailed analysis of the processes of degradation based on detailed surveys of several sites in the ecoregion of the Alps and the Central Highlands was embedded in the Reform-project. Descriptions of measures and pressures based on human impacts were compiled for seven study sites. The focus was on mechanistic understanding of the biological response to hydromorphological degradation over a time period of more than 100 years, including altered sediment dynamics. Hydrological, morphological and biological analyses were performed for all study sites. In addition, the datasets are also linked with a conceptual fish model to explain changes in the composition of fish communities. Analyses of hydrological information, morphological aspects in terms of modelling results and fish databases show the clear degradation and therefore loss of habitat and it`s variability due to multiple pressures caused by human impacts.

Morphology revisited; an ecologist's view on morphology

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The question dealt with in this contribution is "How did and do we ecologists see or should see streams?". Stream morphology can be approached in different ways. A number of former WFD morphological assessment methods are built on visibility. What we can see, score in the field on a form, was considered relevant. This is dealing with morphology from a human's eye point of view. Morphologists take another perspective and studied for a long time all kind of processes that range from processes a geological time scale toward local erosion-sedimentation processes. Leopold & Wolman (1957), Schumm (1981) and Church (2006) developed an integrated view on stream morphological processes and identified parameters, like channel slope, bank full discharge (Q), sediment load and size, flow, stream power 9see Lewin and Brewer, 2001), width : depth, and bed load and total load that together classified stream shape.

With the implementation of the Water Framework Directive water managers accelerated their activities to restore streams. In the Netherlands the ambition included re-meandering of streams and creating nature friendly banks for the period 2007-2027 over an estimated length of >8000 km and a financial cost of about 929 million euro (PBL, 2008). In practice until now re-meandering was mainly based on historical maps from the late 18 hundreds and nature friendly banks were restricted to small strips of bank area. Europe wide hydromorphology seemed to become popular as we counted about 132 hydromorphology based assessment systems (physical habitat assessment 72, morphological assessment 23, fish longitudinal continuity assessment 20, riparian habitat assessment 14, hydrological assessment 10). The methods together cover the whole stream valley but why so many and what are the commonalities.

For an ecologist the stream is approached at a relatively small scale. Stretch and habitat were for a long time the main domain. Especially, macro-invertebrates species showed individual preferences for substrate types, like gravel, sand, and coarse and fine organic material (e.g. Tolkamp 1980). Later on, more extensive analyses showed that only a restricted number of taxa, about 23%, had a significant preference but also occurs in other habitats. Which means that substrate or habitat type is not the only key for macroinvertebrate distribution.

Still, meandering is generally linked to habitat/substrate diversity and restoration strongly focussed on that. A recent study on meandering of low gradient (slope <1 m/km), sandy (median grain size <250 µm), lowland streams in the Netherlands showed that meandering is a temporal phenomenon and only occurs in the first period after meander initiation (Eekhout, 2014). Such initial meandering starts with local bank erosion, is followed by meander migration and increase of channel sinuosity and quite soon stabilised by riparian vegetation. This results in a stable sinuous planform (local to stretch) over a longer time scale. The main conclusion was that meandering is induced by exogenous influences (weak banks (seepage), clay or peat layers, trees and that

Dutch streams do not (really) physically meander. Our own detailed habitat study on macro-invertebrates in lowland streams showed that stream stretch was a more explanatory variable than habitat.
We asked ourselves whether habitat configuration would not be more important than habitat itself and better fitted to earlier results. So, we tested if habitat configuration was related to fitness in adult stream caddisflies as case. Three out of four species appeared to significantly sustain this hypothesis. Also Rice et al. (2006) and Lancaster et al. (2006) showed that macroinvertebrates move around over the stream bed and make optimal use of 3-D structures. These 3-D structures provide resilience.
In conclusion, the human eye does catch the organisms strategy. Therefore, ecologists should focus on much more larger scales of stretch and landscape, and take habitat configuration and 3-D habitat structural complexity into account. Further studies are needed that contribute to a better understanding of habitat fragmentation and habitat edge effects on species distribution and on the other on species dispersal capacity.
Management can improve stream ecology by easy to implement measures that enhance structural complexity and configuration such as the introduction of coarse organic material (CPOM) and by adaptive maintenance of the aquatic vegetation.

SESSION XI. ACHIEVEMENTS BY RESTORATION AND MITIGATION PRACTICES

Flow restoration of the Durance River: implementation and monitoring of targeted water releases to reduce clogging and improve river function

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The Durance River is a highly regulated, gravel bed river with a naturally high fine sediment load in southern France. EDF operates eight dams along the regulated main stream channel (218 km from the Serre-Ponçon Dam to the confluence with the Rhône River), that divert water to16 hydroelectric power plants via a canal. Flow regulation has contributed to fine sediment accumulation (clogging) in the Durance River. In addition to a recent increase in minimum flows and in an effort to restore river function for fishes and invertebrates, EDF has implemented targeted water releases at four out of eight dams to simulate floods and reduce clogging. The timing of these releases is defined for each dam based on the reproduction period of target fish species. A comprehensive long-term monitoring program has been implemented. During the release, TDS, O2, T, H, Conductivity are measured continuously. Before and after each release, clogging (superficial/interstitial) is measured and macroinvertebrate communities are sampled. Fish (communities and target species) are sampled at least annually. Coupled with these monitoring efforts is a detailed study of biofilm and invertebrate recolonisation processes. In 2014, only two of the four releases were carried out (due to natural flooding). It was observed that TDS peaks and diminishes rapidly during these releases. Superficial clogging was reduced (when release flows were sufficient), whereas O2, interstitial clogging and macroinvertebrate communities remained unchanged. Flow releases and monitoring will continue for several years, which will be necessary to evaluate the flow restoration efficacy (especially for fish populations).

Management of a meander cutoff using instream works to reduce the hydraulic gradient

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As a consequence of aggregate extraction in the adjacent floodplain and greater Orara River area along with degraded riparian vegetation within the entire reach, a bed level incision in a secondary channel of the Orara River in Northern New South Wales promoted the disconnection of low to medium flows through a 1200m section of the primary channel. This effectively produced a 40% reduction in channel length and subsequent 40% increase in channel gradient. Over a period of 13 years local catchment managers utilised a number of small grants, partnership arrangements and government funds to commission a series of geomorphic studies and instream works that aimed to stabilise the secondary channel and return flows to the primary channel. Works included innovative pin groynes and engineered deflector jams to promote aggregation of bed material and over time lower the gradient of the secondary channel. A rock ramp was then installed to consolidate the head of the secondary channel returning low to medium flows through the primary channel. But these efforts were not without risk or failure as works were undertaken between major flooding events which progressively modified the priorities for works within the site. Design of works were undertaken in conjunction with an appreciation of the life history requirements of native fish, in particular the Eastern Freshwater Cod (Maccullochella ikei), a locally found endangered fish heavily reliant on stable geomorphic conditions. Conducted as part of a wider analysis of native fish movement in the Clarence River Catchment, the NSW Fisheries Project 'Fishtrack', was utilised to inform the effectiveness of works in promoting fish passage through the study site.

Effects of river restoration on 13c and 15n isotope composition in river and floodplain food webs

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Worldwide, rivers are being restored to enhance biodiversity and to increase attractiveness and ecosystem services provision. Effects of river restoration can principally be monitored with a wide range of variables. In the context of the EU Water Framework Directive fish, phytoplankton and benthic fauna and flora are most commonly investigated. These variables used to assess success or failure of restoration projects are mainly of structural nature, e.g. the composition of biological assemblages. Functional components, even though widely applied in basic studies of aquatic systems, are almost never applied for monitoring the effects of river restoration; therefore, the consequences of restoration on ecological processes, including trophic patterns, remain poorly understood. We applied stable isotope analysis of ^{15}N and ^{13}C in context of river restoration. We sampled different components of food webs on paired restored and degraded sections of rivers in 20 different catchments throughout Europe. The sampling included elements of the resource base (particulate organic matter, most abundant aquatic and riparian plant material, periphyton), benthic macroinvertebrates containing the dominant taxa within different functional feeding groups and predatory riparian and non-riparian arthropods. We used these components to quantitatively characterize patterns in trophic structure related to river restoration. Preliminary results indicate e.g. (1) that the dataset is subject to large-scale patterns on European level (latitude, altitude, geology and land use intensity) influencing ^{15}N and ^{13}C enrichment and (2) that macroinvertebrate communities (commonly applied indicators of ecosystem health) were feeding from more diverse carbon sources in restored compared to the degraded river sections.

Quantifying and valuing river restoration effects: Thur and Töss rivers

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While the number of river restoration projects increases, decision tools for river management and integrative methods for valuing river restoration effects are scarce. Moreover, effect of restoration efforts on biodiversity is often measured with a unique biological indicator, and the effects on terrestrial biodiversity is often neglected.
For the purpose of this research, we analyzed the suitability of river assessment protocols to quantify and value the effect of restoration in two Swiss rivers. We used five indicators (fish, benthic invertebrates, macrophytes, ground beetles and riparian vegetation) to quantify the effect of restoration on instream and terrestrial biodiversity. We used value functions, and valued information about the morphological, chemical and biological conditions of the rivers. Uncertainty about environmental conditions were included and propagated throughout the framework.
The morphological state of the case studies improved with restoration, as well as the biological indicators. Ground beetles and fish communities improved most, followed by riparian vegetation, benthic invertebrates and aquatic vegetation. According to our framework and our results, limiting effect of water quality could be the reason of improvement deficits.
Propagation of uncertainty showed that the positive effect of restoration on the physical and biological states were mainly significant. Improvements were, however, uncertain in some cases for benthic invertebrates and riparian vegetation. By aggregation and uncertainty propagation, the ecological state of the studied rivers were showed to improve significantly with restoration.
We demonstrated a positive effect of restoration on biodiversity and the ecological state of the studied rivers. Integrative valuation with value functions showed to be useful and propagation of uncertainty helped to strength the measured improvement linked to restoration.

SESSION XII. LINKING SCIENCE TO PRACTICE: TOOLS TO ASSESS RIVER STATUS AND GUIDE REHABILITATION TO OPTIMIZE RIVER BASIN MANAGEMENT

New tools for an integrated hydromorphological assessment of European streams

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During recent decades, physical habitat survey has been the most common approach for assessing the hydromorphological state of a river. However, it has been increasingly recognised that broader river condition assessments with a stronger emphasis on river dynamics and processes are needed that go beyond an inventory of physical habitats.
In this paper, we propose a comprehensive and synergic hydromorphological assessment based on the integration of various tools. Specifically, we illustrate the integration of three tools, originally developed in Italy and then expanded to other European countries within the context of the REFORM project. The Morphological Quality Index (MQI) is a tool designed to assess the overall morphological conditions of a stream reach and to classify its current morphological state. The Morphological Quality Index for monitoring (MQIm) is a specific tool for monitoring the tendency of morphological conditions (enhancement or deterioration) in the short term, and is particularly suitable for the environmental impact assessment of interventions, including restoration projects. Most of the MQIm indicators are based on continuous mathematical functions rather than on discrete classes as for the MQI. Finally, the Geomorphic Units survey and classification System (GUS) has been designed to integrate the MQI by characterising the typical assemblage of geomorphic units of a given reach and establishing links between geomorphic units and morphological river conditions at reach scale. The three new tools, used synergically, can provide an overall assessment of stream reaches useful for understanding their functioning, and therefore for supporting the identification of appropriate management actions.

Hydraulic modelling & ecological evaluation of the 'process restoration' philosophy on the Allt Lorgy, Scotland

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The importance of hydraulic modelling as a tool to guide river rehabilitation is illustrated using the Allt Lorgy river restoration project (Cairngorm Mountains, Scotland). To achieve this, 2D model output for a sequence of stages in the process (pre-construction, post-construction and post-flood) are presented and used to inform discussion on the use of such data (in particular, the interpretation of non-uniform processes) to inform restoration design and quantify geomorphic change. The complexity and limitations of using a computational fluid dynamic approach are highlighted, with particular focus on the use of 2D depth-averaged hydraulics in predicting erosion and scour. Problems associated with capturing fluid vorticity and convected vortex structures are also emphasised.

Outputs from this high-resolution hydrodynamic modelling were then applied to indices of instream micro-habitat preference to evaluate 'ecological performance' of an application of the 'process restoration' philosophy. This provided the opportunity to monitor physical change and the associated implications for instream habitats. The pre-construction, post-construction and post-flood event model output determined the physical and ecological evolution of the site. Generally, a trajectory towards greater spatial and temporal availability of habitat and biodiversity was observed over the model run sequence. It was determined that it is necessary to characterise physical habitat at a sufficiently high spatial resolution in order to represent important unsteady and non-linear interactions between hydraulics and sedimentary character. However, it is important to stress that hydrodynamic modelling should be employed as one assessment tool of a larger strategy to determine appropriate methods to optimise ecological improvements.

Assessing alternative conservation strategies for the anastomosing River Narew

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Low energy anastomosing rivers would have been common in the lowland plains of Europe prior to extensive modification of rivers and their floodplains by humans. Presently the only significant example of this type of river remaining in Europe is in the upper River Narew, Poland. The anastomosing section, now protected as part of the Narew National Park, creates a wide floodplain wetland that supports a diverse assemblage of ecologically important plants and animals.
In the current park protection plan (completed in 2014), conservation of anabranching system got the highest priority. There is however open question how far active protection should take place. There is proposal of four pilot study places where technical intervention should help in maintain the multi-channel system. In our opinion analyzing the system using the conceptual model of vegetation-hydromorphology interactions and useful multi-scale framework (the hierarchy of spatial units within which relevant properties, forms and processes can be investigated to understand and assess hydromorphology) should support sustainable river management in the NNP.

Semi-automated riverscape units classification and active river channel delineation for the Piedmont region (Italy)

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Semi-automated procedures based on remote sensing (RS) datasets, allowing a continuous analysis of river systems on wider spatial scales, have a great potential to improve monitoring activities of hydromorphological indices, which can now be estimated in a quantitative rather than descriptive way, more objectively and less exposed to operator subjectivity. An essential step of any fluvial audit is the delineation of key riverscape units as the active river channel (AC), i.e. the part of the river channel regularly morphologically reworked and shaped by floods, composed by water channels and sediment bars, and the assessment of its connectivity with adjacent floodplain features. So far, the concept behind the use of RS for the delineation of the AC has been rather simple and mostly based on manual photo-interpretation of visible features.
In this paper, we present a new semi-automated method, based on the use of geographic object-based analysis (GEOBIA), for the classification of the main riverscape units: bare sediments, pioneer islands, forested islands, channel and floodplain. We integrate spectral and topographic information using VHR imagery and LiDAR-derived products within GEOBIA, along the regional fluvial network of the Piedmont Region. 265 image tiles were automatically processed: a two-level hierarchical object-based segmentation was produced for each tile and classification was performed with both random forest and support vector machine on different sets of input features. Results demonstrate the potentials of GEOBIA to efficiently automatizing the procedure, resulting in a 10,000 km^2 mapping of riverscape units and AC delineation of the main Piedmont Region river network in a semi-automated, robust and user-friendly environment.

Approaches to consider the recolonisation potential in restoration planning

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Restoration measures often do not lead to the expected response of fish and benthic invertebrate communities. A prominent reason, beside ongoing impacts, is that sensitive species were eradicated over decades from many catchments. Therefore only a subset of river type specific species is able to recolonise restored river sections. To consider the restoration potential in restoration planning helps to predict restoration success and to prioritize measures.

In a project funded by the German Federal Environmental Agency (UBA) we developed an approach to identify source sites of sensitive fish and invertebrate species. We categorized German monitoring data based on the number of sensitive species and conducted statistical modeling (Boosted Regression Trees) with environmental variables. The location of the fish and invertebrate source sites are highlighted in maps. In a next step we developed a method to predict the restoration success of non-restored river stretches in a catchment. The approach is based on deriving the recolonisation potential by estimating the dispersal from the source sites with a cost distance analysis (ESRI ArcGIS Tools), taking dispersal capacities and barriers into account. Further data, e.g. on habitat conditions or nutrient concentrations, can be added to the maps that show river stretches with high, medium or low recolonisation potential. The combination of data allows the identification of river stretches where impacts need to be diminished or habitats need to be created, and to estimate – after the method was applied – if a short term or rather long term success can be expected.

Oral presentations - Thursday July 2

SESSION XIII. HOW TO IMPROVE THE (COST-) EFFECTIVENESS OF RIVER REHABILITATION

Restoration success and failure: learning from an integrated restoration programme in a temporary Mediterranean river system

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We present and discuss findings from an integrated restoration programme in a Mediterranean catchment with a significant conservation value. The construction of the River Odelouca dam for improving water supply in the Algarve region of south Portugal, located in Natura 2000 protected area, involved the definition of a variety of compensation measures including environmental requalification of selected river segments not affected by the reservoir. We cover the whole sequence of the project: a) characterization and selection of reaches to rehabilitate based on the definition of physiographic units and the relative quantification of impacts; b) implementation of soil engineering techniques for improving riparian habitat, bank stability and to control invasive species c) defining best river channel habitat improvement options for endangered endemic fish populations using two-dimensional hydraulic modeling (R2D); d) post-project appraisal and monitoring of floristic succession, fish, benthic fauna and habitat . The success of the defined measures was hampered by three principal factors, firstly failure to engage local landowners early in the programme; the timing of key tasks, such as planting riparian trees; continued difficulty to control sources of environmental disturbance, in particular serious and continuous point pollution from animal husbandry. Consequently fish assemblages in all stream reaches were still dominated by aliens and highly tolerant species, and native cyprinids were low abundant or absent, revealing the fish index of biotic integrity a low environmental quality.

The ELMO toolbox: Ecological modelling for decision support in river restoration planning

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River managers are faced with the challenge of implementing appropriate actions to achieve a good ecological status of rivers. In light of this, it is important to understand which pressures should be addressed first. In this study an ecological toolbox ELMO is developed, which allows river managers to identify the most important stressors for a water body and to assess the ecological effects of management scenarios. The core of ELMO exists of a set of univariate habitat suitability models for frequently occurring taxa in three major aquatic biological groups (fish, macroinvertebrates and macrophytes). These models consider both physico-chemical and hydromorphological conditions. They have been developed by integrating ecological theory, expert knowledge and data analysis. The toolbox contains both an explanatory and predictive mode. In the explanatory mode, ELMO evaluates the existing biological community against a defined reference condition. The most critical stressors can thus be identified by calculating the current habitat suitability for missing reference taxa, in the predictive mode, ELMO can calculate the community composition and the resulting ecological quality ratio under different management scenarios. The community composition under novel conditions is simulated by combining the habitat suitability models as hierarchical environmental filters. By considering species source pools in the current and past condition the actual predicted species distribution and the related ecological quality ratio can be derived. The combination of the explanatory and the predictive modes provides a powerful toolbox for guiding cost-effective management and restoration of river systems under multiple pressures.

Restoration of Narew National Park buffer zone in context of ecosystem services

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River ecosystems are important elements of the European landscapes. They provide services for human well-being. Europe's rivers have been degraded by human activities in the floodplain and by direct interference with the channel. River restoration is complicated and long process which consumes time, work and large financial costs. Restoration aims to increase the quality of water resources so that future generations can also use them. After restoration it is necessary to evaluate the effects to assess importance and cost-effectiveness of undertaken actions. The aim of the paper was to assess the effect of restoration in the context of ecosystem services by comparing quality and quantity of chosen ecosystem services before and after the restoration. In this regard an ecosystem services evaluation was conducted. The bases for the analysis were maps of the land use. For the state before restoration historical topographic maps, and for the state after the restoration CORINE Land Cover 2006 maps were analyzed. Analysis were made by using ArcGIS10.2 software. The recognized types of land use were assigned to the appropriate services ecosystems. Later on using data from Central Statistical Office and algorithms (created by research team) monetary values were calculated for each ecosystem service in biophysical units. Assigning a monetary value allowed for comparison of the quality and quantity of services existing in this area before and after restoration. In the current situation ecosystem services have increased in terms of their quantity and quality. Analysis of changes in ecosystem services is useful in further planning of restoration scenarios.

SESSION XIV. BENEFITS OF RIVER REHABILITATION AND SYNERGIES WITH OTHER USES (FLOOD PROTECTION, NAVIGATION, AGRICULTURE, HYDROPOWER)

The revised water protection law of Switzerland and its implementation to practice

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Running waters in Switzerland have been under various anthropogenic pressures. Approximately 50% of streams and rivers in the Swiss lowland (< 600 m a.s.l.) show a deficient streambed morphology (straightened, bank fixations, low habitat variability) and numerous barriers and sills disrupt longitudinal connectivity. Due to the country's topology hydropower is a major branch of industry, providing 55% of the Swiss energy supply. Though this energy source is carbon-neutral, ecological drawbacks result from a disturbed sediment transport, disrupted fish migration and hydropeaking.
In 2009, the water protection law of Switzerland has been revised, as a consequence of a people's initiative. Legislative alterations are:

1) A riverine zone has to be defined for the majority of streams and rivers until 2018, (which protect riparian strips from future degradation; only extensive agricultural land use is permitted).
2) Measures to mitigate negative effects resulting from hydropower production will be implemented until 2030 (sediment transport, connectivity, hydropeaking).
3) Approx. one quarter of stream reaches (~4,000 km) with poor morphology should get restored within the next 80 years.

To reach those goals approx. 110 million CHF (110 million €) from federal funds are spent annually. Tools created by the FOEN support the cantons by implementing the revised water protection law into practice, and to provide a standardized protocol. The 26 Swiss cantons were asked to submit strategic planning by 2014. Details and results from the restoration planning are presented.

Social and economic perspectives of river restoration

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In the Netherlands floodplains have a history of intensifying land use mainly agriculture. In the 20th century also clay mining and sand extraction were important activities. With climate change we are facing more extreme floods and droughts in our river systems, causing water retention problems. The 1993 and 1995 peak levels in the rivers Rhine and Meuse were a wake-up call for the river authorities and the regional inhabitants to start mitigation projects. WWF and ARK Nature endorsed a new flood prevention approach based on the LIVING RIVERS strategy in which spatial solutions help solving future hydrological problems. Introducing sediment mining as co-actor (brick industry) to stimulate water retention capacity and nature restoration in floodplains. Being involved in a series of floodplain restoration projects, WWF and ARK Nature put special efforts in gaining local support and stimulating green tourism and awareness. Biodiversity profited, so did the local inhabitants. Transformation of the floodplain offered new leisure opportunities. Free access for visitors was a prerequisite to generate higher acceptance and to stimulate green tourism successfully.
The monitoring study `Free access pays off' (2012) shows the positive relationship between nature restoration in floodplains, free access and increasing local leisure economy. The leisure economy of the Gelderse Poort, a free accessible area, scores the highest, expressed in number of jobs and visitors' expenditures.

The concept and practice of locally driven environmental initiatives

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The aim of this paper is to discuss the possibilities of a paradigm change in agri-environmental governance. The current control driven approach responds poorly to environmental issues on the local, regional and macro-regional scales. Furthermore, it contributes to the distrust that exists between the agricultural and environmental sectors which emerges partly from the inefficiency of the implemented measures in delivering the required outcomes and partly from the frustration among farmers who feel that the policy is not addressing the right issues and is not taking the situational specifics on the farm into account. Thus, a paradigm change to a more management-oriented approach is needed. The paper reflects the issue and underlying elements of this paradigm change through case study examples and closes with a stakeholder specific overview of the needed change with respect to relevant policy and management processes. The cases studied and highlighted in this paper offer examples of different ways to integrate agricultural production with land and water management, and to utilize the opportunities the general EU CAP framework provides. It is largely up to the will and motivation of individuals, farmers, government officials and advisors alike to make the most of these opportunities. This paper suggests how different local, regional, national and international fora and networks can support the local management. Ultimately, as our cases demonstrate, strongly motivated persons can drive initiatives if they have the appropriate support tools and data available and over time this has the potential to contribute to adaptations on the system level.

SESSION XV. LINKING SCIENCE TO PRACTICE: TOOLS TO ASSESS RIVER STATUS AND GUIDE REHABILITATION TO OPTIMIZE RIVER BASIN MANAGEMENT

Towards an harmonized understanding of mitigation measures and implementation thereof to reach Good Ecological Potential (GEP) in water bodies impacted by water storage across Europe

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The intercalibration exercise according to the Water Framework Directive (WFD Annex V) have been essential for a Common Implementation Strategy (CIS). Its objective is to harmonise the understanding of 'good ecological status/potential', and to ensure that this common understanding is consistent with the definitions of the Directive. A more harmonized understanding of Good Ecological Potential (GEP) are presently in focus. A core group of water managers are presently compiling a GEP report and evaluating the best available mitigation measures for impacted HMWBs from water storage.

Evaluation and prioritization of river rehabilitation projects

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We use multi-criteria decision analysis (MCDA) techniques to support the transparent communication of the expected achievement of societal objectives in river management with a focus on river rehabilitation. In a first part, we apply the techniques to support the assessment of the trade-off between the expected gain in ecological value and ecosystem services versus costs for specific river rehabilitation projects. In a second part, we illustrate the application to the spatial prioritization of such projects. We show the similarity of the suggested methodology at its highest hierarchical level to cost-benefit analysis, but also emphasize that it makes it possible to include lower hierarchical levels within the same framework. The suggested methodology thus provides a unique framework from ecological river assessment to the support of societal decision making in river management. The conceptual considerations are supported by their application to specific sites and prioritization within the Thur and Töss catchments in Switzerland.

A methodology to assess the river and its surrounding area to inform project design and appraisal

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The Urban River Survey (URS) is a field survey method developed over the last decade to assess the physical quality of urban rivers. The methodology is compatible with the Environment Agency's River Habitat Survey (RHS) and a web-based geographical information system stores and manages the URS data (www.urbanriversurvey.org). The URS can be employed in the evaluation of urban river restoration projects by providing a tool to monitor changes in the river's physical quality. This presentation reports on recent research with the National Environmental Assessment Service (NEAS), UK, that has been extending the scope and application of the URS to develop a broad, high-level field survey assessment of both the river and its surrounding environment in terms of habitat and biodiversity, landscape, amenity and heritage. This ECOSTATUS Survey is designed to precede any commissioned specialist surveys (e.g. Phase 1 Habitat Survey) and the field data and calculated indices can be used to inform project design and development, and in post-project appraisals. Importantly, the new field assessments also capture the geomorphic dynamics of the river.

Poster presentation

ASSESSMENT AND REHABILITATION OF HYDROMORPHOLOGICAL PROCESSES IN RIVERS

Integrated analysis of habitat structure and river-floodplain processes as a basis for process-based river restoration in the upper Rhine

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Loss of connectivity between the river and its floodplain might be singled out as the main common cause of biodiversity degradation of European large rivers. Analysis of spatio-temporal heterogeneity in the unaltered state is crucial, but most large rivers lack pristine reaches. Therefore, in order to comprehend the reference condition and the current ecological deficit of a section of approximately 10 km of the Upper Rhine downstream Iffezheim (Germany), the habitat structure and fluvial dynamics have been analysed in a historical study of four important periods: original river-floodplain system (before straightening in the 1840's), effects of rectification (between 1850 and 1930), effects of regulation (between 1930 and 1980) and current situation (after Iffezheim's dam construction, from 1980 until now).

The "flood pulse" and the "flow pulse" determine the expansion and contraction of water bodies and, thus, by calculating areas and percentages within the active zone, it is possible to infer connectivity among river-floodplain habitats. Vegetation processes are identified for each time interval, by analysing changes in habitat patches: stable (no change), recruitment (from bare sediment to pioneer vegetation), succession (from pioneer vegetation to mature forest), and restructuring (from vegetated to bare sediment or water).

The results identify key processes of the river-floodplain system of this Upper Rhine river section that are now lost and whose recovery should be the objective of future process-based restoration measures.

Modeling of long-term development of riparian vegetation in the dike relocating area 'Lenzen an der Elbe' (Germany)

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The impact of the recent extreme flood events on large rivers in Germany has revealed an increasing need for enlarged retention areas. Beyond their function for flood protection, these riparian areas with their reestablished fluvial dynamics are important for nature conservation. In 2009, the so far largest dike relocation in Germany has been completed on the Middle Elbe near the town of Lenzen (Brandenburg). The reconnected inundation zone extending over an area of 420 ha has been taken out of agricultural use and is now subject to natural development.

Within the presented project, the long-term development of the riparian vegetation is simulated using an advanced version of the dynamic riparian succession model 'CASIMIR Vegetation'. The functional model is based on expert rules, combined and regenerated with a 2D-hydraulic model (IRH) in a dynamic way, including roughness, changing with progressing vegetation development.

The study under contract of the Federal Institute for Hydrology (Bundesanstalt für Gewässerkunde) investigates the successional development of fallow grassland towards hardwood forest under various site conditions and the importance of inundation for the vegetation development.

The model renders predictions of future vegetation developments under varying environmental conditions, including altered discharge, flooding and land use conditions, climate change and different morphological settings. In addition to the evaluation of the scenarios regarding conservation and ecological effects, the changing flood risk due to the developing vegetation is analyzed.

How is metapopulation resilience affected by longitudinal connectivity? a criterion for the restoration of river networks

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Climate change is rearranging the limits of geographic distributions of species. The populations inhabiting the latitudinal margins of a species' range are likely to be sensitive to climatic drivers. If these populations are extirpated, a latitudinal shift of the range is produced. When species are spatially structured into metapopulations, these will experiment a negative growth trajectory, and eventually become extirpated, when extinction rate (*e*) of local populations (*demes*) exceeds the rate of establishment of new colonies in available empty patches (*mp*).
Dispersal among patches is a process of central significance for the recolonization rate (*mp*). Therefore, the loss of longitudinal connectivity in river networks is likely to enhance the latitudinal displacement of a species' range in its rear edge, by reducing that rate. Moreover, if climate drifts towards more meridional conditions, the thermal habitat of some species can become constrained, and the extinction rates of local populations increased. This might be the case of salmonid species in southern Europe.
In this work the functioning of a salmonid metapopulation has been modeled by means of several coupled logistic population dynamics models with population viability thresholds. It has been parameterized for a very simple real metapopulation of introduced *Salvelinus fontinalis* in a glacier lakes system in the mountains of Central Spain. The resilience of the metapopulation has been expressed as a function of the connectivity among demes. Thus, the metapopulation resilience is proposed as a new criterion to assess the efficiency of the restoration of the longitudinal connectivity within a river network.

Automatic segmentation of rivers as a tool for assessing river responses. Case study: The Porma and Curueño Rivers, NW Spain.

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Identifying homogeneous units along rivers is necessary to understand river functioning. Automatic segmentation using univariate and multivariate techniques provides more objective and efficient segmentations of the river systems and can be complementary to the expert criteria traditionally used. Moreover, automatic segmentation could be a powerful tool to diagnose problems associated to human impacts and assess river responses affecting spatial variability of the studied variables.

The aim of this work has been to evaluate the potentiality of univariate and multivariate methods in the assessment of river adjustments produced by flow regulation. Multi-Response Permutation Procedures, non parametric techniques, have been applied on a univariate and multivariate way, considering the river as a set of sections every 200 m along valley axis, characterized by three geomorphic variables (valley width, active channel width and channel slope) from upstream to downstream, using Air-photographs from 1956 and 2011. The methods have been applied in two gravel-bed rivers, Porma and Curueño river, both of them located in NW Spain. The former is regulated by a large dam since 1968, and the later is a free flowing river tributary of the Porma river.

Automated segmentation along the Porma river revealed an increase of active channel-width homogeneity downstream from the dam and highlighted the influence of tributary confluences in channel morphology. Results using univariate and multivariate methods are discussed, together with the advantages and constrains of their use in the assessment of river responses at different spatial scales.

Morphological changes in rivers of South Tyrol (Italian Alps) attributable to climate variations occurred after the little ice age

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The consequences of the changes in climate and glaciers extension occurred after the Little Ice Age (LIA, early 19th century – early 20th century) in several river catchments of South Tyrol (Italy) were analyzed. Here, the anthropic influence during the same time frame can be considered minor. The assessment of evolutionary trajectories of river morphologies (river corridor scale) was performed in both glacialized and not glacialized basins with the use of GIS software, considering the changes occurred at the basin scale. Different historical maps (1820, 1858, 1917-30) and aerial photos (1945 and 1954) were used. Key parameters as drainage area, reach length, average slope, sinuosity and braiding index were derived for each reach, beside its classification, based on the definitions proposed by Rinaldi et al. (2013). Data on glaciers extension (at different times starting from 1850) and climate (temperatures and precipitations, mostly starting from the early 20th century) were also collected. Despite the definitely mountainous environment, partly to not confined reaches are quite common in the study areas due to the presence of relative wide valleys carved by glaciers during the Pleistocene. The preliminary results seem to indicate that rivers of South Tyrol varied their morphological pattern in response to climatic variations occurred after the LIA, but variations differed greatly in magnitude. The post-LIA changes in planform pattern appear to have been more pronounced in the less confined reaches, where the initial morphology was anastomosed or transitional.

On the estimation of the sediment transport and sediment budget in a long reach: application on the Middle Loire River, France

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This paper presents an evaluation of different methodologies used for estimating both bedload sediment transport and sediment budget in a long river reach. Three different methodologies are applied on the Middle Loire River, France, and discussed. The first methodology is based on the stream power concept. Its application is quite simple and yields reasonable results for the estimation of the sediment transport but poor results for the sediment budget. For the second method, hydraulic parameters are computed using the Manning-Strickler equation (or a 1D hydraulic model for steady flow). It provides interesting indicators for the understanding of the river dynamics but does not yields significant improvement compared to the first method for the sediment transport and budget estimation. At last, the third method presented corresponds to the use of a 1D numerical software with bed evolution. As soon as such a model is properly calibrated for both hydraulics and bed evolution, it can yield relatively accurate results for both sediment transport and bed evolution but requires more data and overall more work to construct the model.

Anti-erosive construction in the Morávka River – problematic approach to management of flysch Carpathian rivers, Czech Republic

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During the last century the Morávka River channel has been transformed from anabranching to single channel river pattern that incised as deep as into the bedrock. These changes have been caused by a strong and inappropriate management (as a bank stabilising, weir and valley dam constructing). Contemporary channel changes have not been evident at reach r. km 7.0 to 10.5 which has partly preserved the original anabranching river pattern with lateral erosion. In order to preserve this anabranching channel reach and the prevention of proceeding backward erosion and protection against destruction Vyšní Lhoty weir at r. km 11.3 anti-erosion construction of local channel widening was constructed at r. km 10.7. However, spring flood in year 2010 accelerated present erosive processes and channel incision to the bedrock and showed that the anti-erosive construction was not well designed. In some parts, the original river bed has lowered by as many as 2.5 m. The anti-erosion construction itself has also been affected by massive incision. This paper summarizes results of monitoring, processes and function of anti-erosion construction of local channel widening with connection to bad management of Water Authorities in Czech Part of the flysch Carpathian Mts and discuss the problematic management solution of destabilized channel reach and gives proposition of the future management.

Effects of river restoration on riparian ground beetles (Coleoptera: Carabidae) in Europe

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Studies addressing the effects of river and floodplain restoration on riparian communities are rare and mainly focus on single river sections. Riparian organism groups, e.g. ground beetles, are well adapted to specific habitats, thus reflecting habitat changes induced by restoration. However, it is not known if restoration effects on ground beetles differ between restoration measures or depend on the size of restored sections. We investigated ground beetle assemblages in riparian areas of 20 restored and 20 degraded rivers across Europe. We analysed (1) if morphological river restoration increases richness and diversity of ground beetles, (2) if effects of restoration on ground beetles depend on restoration measure types or the extent of restored sections, and (3) which environmental parameters determine changes in ground beetle assemblages. In general, restoration increased ground beetle richness by about 3 species, whereas the size of restored sections has no significant effect. In restored sections where widening was applied as a restoration measure, species richness was increased by around 7 species. Ground beetles mainly benefit from the creation of pioneer patches in rivers with strong hydraulic power. Suitable restoration measures should aim on a strong lateral connection between the river and its floodplain.

Improved hydromorphological assessment methods for European river systems

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Fluvial processes modify the physical characteristics of rivers and can strongly influence the behaviour of aquatic organisms. Recognition of the significance of fluvial processes in recent major pieces of European legislation (e.g. Water Framework Directive (2000), Floods Directive (2004)) has led to the development of a plethora of so-called "hydromorphological assessment methods" by environmental agencies seeking to determine the physical state of member states' rivers. To date, these have consisted of mainly field-based survey methodologies in which relative habitat quality is inferred from the presence/abundance of particular fluvial landforms within river channels. However, this type of approach assumes linkages between fluvial forms and the behavioural characteristics of aquatic biota that have yet to be fully tested, neglects floodplain features that are known to have ecological significance and fails to take into account the dynamic nature of rivers. To address some of these problems, the research focuses on the assessment of the hydraulic characteristics of a variety geomorphic units looking at different spatial and temporal scales to investigate on river dynamics and trajectories. The research will be conducted in the UK, Italy and Germany to ensure a range of European river types are represented. Preliminary results of turbulence characterization of geomorphic units in low-land river in UK will be presented.

The usability of hydromorphological data in the flood risk management on small streams

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The degree of flood risk is usually determined on the basis of data reflecting the water depth and flow velocity in a given place during the flood event. The result of this procedure are maps of flood areas, flood hazard and flood risk, whose processing arises from requirements of the national and European legislative (the EU Floods Directive 2007/60/EC). Since the above mentioned procedure requires the availability of large amounts of accurate data and their processing, it is currently realizable only on major rivers and a few selected small streams in the vicinity of built-up areas in the Czech Republic.

This contribution aims to evaluate the possibilities of hydromorphological data for purposes of identifying the risky areas, susceptible for formation of flood. In combination with data on the nature and extent of the flooded area, the selected morphometric parameters of streams are seen as an effective source of information useful when identifying critical locations. The significance of such a procedure can be seen especially in the watersheds of small streams, for which there are usually no suitable hydrological data and thus determining the extent of inundation areas is not possible. In addition, the impacts of global environmental change in the form of more frequent and more damaging flash floods are increasingly reflected just on the small streams. Therefore the issue is addressed on the example of several small, mutually very different catchments in the Czech Republic. The impact of human activities which affects the natural state of watercourses and thus participates on the shaping the final level of flood risk is emphasized significantly.

Past and Present Hydromorphological Assessment Techniques for the Water Framework Directive in Ireland

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Much focus has been placed on tackling water quality issues, such as eutrophication, in Europe, yet it is now becoming more apparent that hydromorphological pressures are also contributing significantly to the degradation of our waterbodies. In Ireland, as in many other European countries, characterising the risk associated with the hydromorphological elements, as part of the Water Framework Directive (WFD), was somewhat crude in the last planning cycle. Assessing hydromorphological pressures was mostly based on use of a desktop GIS technique and expert opinion. A number of recommendations were made to improve this technique yet were never followed through. There was less emphasis on hydromorphology following the publication of river basin management plans than on other pressure types due to both the scale of the issue (i.e. 38% of rivers at risk from morphological pressures) and the limited understanding of this area.

As the second cycle of the WFD approaches, hydromorphology has been highlighted as an area that requires more attention in Ireland. Good progress has been made to develop morphological classification methods for different waterbody types. Furthermore, work is currently underway to deal with the hydrological component of hydromorphological status.

This paper summarises both past and present hydromorphological assessment techniques in Ireland. It also presents a new approach for Ireland for assessing morphological pressures. Such an approach will place Ireland in a good position to strengthen our understanding of catchment processes and therefore enhance our ability to identify appropriate mitigation and rehabilitation measures to allow for better integrated catchment management.

Morphological assessment of reconstructed lowland streams in the Netherlands

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Channelisation measures taken halfway the 20th century have had destructive consequences for the diversity of the ecology in the majority of the lowland streams in countries such as the Netherlands. Re-meandering is the common practice in restoring these lowland streams. Three reconstructed streams were monitored during the initial two years after construction of a new channel. The monitoring program included morphological surveys, sediment sampling, habitat pattern surveys, and discharge and water level measurements. Adjustments of the longitudinal bed profile formed the main morphological response. These adjustments were most likely caused by a lack of longitudinal connectivity of the streams as a whole, interrupting transport of sediment at locations of weirs and culverts. Longitudinal channel bed adjustments and bank erosion were mainly caused by exogenous influences. In channel bends, the cross-sectional shape transformed from trapezoidal to an asymmetrical shape, as found in meandering rivers. This behaviour can be attributed to an autogenous response to the prevailing flow conditions. Due to the fine sediment characteristics, bed material is readily set in motion and is being transported during the entire year. The existing design principles fail to address the initial morphological development after reconstruction. An evaluation of pre-set targets to realise water depth and flow velocity ranges shows the current procedures to be deficient. Based on this unfavourable evaluation, and the two-dimensional nature of habitat patterns needed to improve the conditions for stream organisms, we recommend to predict morphological developments as part of the design procedures for lowland stream restoration in the Netherlands.

Assessment of river hydromorphological quality for restoration purposes: case study of the Biała River, Polish Carpathians

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Methods used to assess the hydromorphological quality of rivers vary between procedures requiring field-based evaluation of a large number of habitat parameters (River Habitat Survey) and map-based assessments of the river state (European Standard EN-15843) which are fast but of little use for river restoration practice. Planning and implementation of effective restoration projects requires appropriate assessment of a river's hydromorphological status and we indicate features of the methodology for assessment of river hydromorphological status useful for river restoration purposes. River Hydromorphological Quality assessment method based on the European Standard EN-14614 is presented with a case study of the Biała River, Polish Carpathians, where this assessment was used as basis for a restoration project aimed to establish an erodible river corridor. The results of the assessment revealed significant differences in hydromorphological quality between unmanaged and channelized river cross-sections, indicating channel regulation as a major cause of the hydromorphological degradation of the Biała and confirming the choice of the erodible river corridor as an appropriate method of its restoration. The assessment indicated hydromorphological features of the river that were severely modified within the channelized reaches and which improve the most with the removal of bank protection and allowing free channel migration.

DISCERNING THE IMPACT OF HYDROMORPHOLOGICAL MODIFICATION FROM OTHER STRESSORS

Heavy metals partitioning among matrices and habitats of polluted stream

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Restorations of hydromorphological conditions in streams modify hydraulic characteristics of habitats and substrate patterns. The distribution of the anthropogenically introduced heavy metals within fluvial ecosystems was studied in relation to hydromorphological characteristics of stream channel. We hypothesized that stream habitats and matrices have different potential to accumulate heavy metals in relation to channel hydraulics and bioconcentration by organisms.

Within the studied sites central channel units (riffles, pools) and marginal zones were distinguished. The different hydraulic conditions, substrate and the presence of stream vegetation within geomorphic units reflected the accumulation of heavy metals in analysed matrices. Stream sediments, Callitriche roots and shoots, Phalaris roots and shoots, biofilm from stones and stream water were sampled and analyzed for heavy metals content. Matrices were selected to reflect both dissolved and particulate forms of heavy metals.

The metal concentration in surface sediments taken from pools (PS) differed slightly from those in surface sediments which accumulated behind plants (CLS, MVS). We found only weak difference (Cr, Ni and V was $p<0.05$). All other comparisons were not statistically significant. There were significantly higher concentrations of most of the studied metals in sediments washed from roots of both Callitriche and marginal vegetation and in surface sediments accumulated behind the plants. Concentrations of all studied metals except Sb were significantly higher in plant roots than in shoots. Both roots and shoots of Callitriche contained higher concentration of heavy metals than in marginal vegetation.

Case study on the Svratka River provided useful data for estimation of interactions between metal pollution and hydromorphological changes. Understanding drivers of multiple stresses and how to stresses are interacting instream are also important during the planning phase of a restoration project.

Flood management at the river basin scale: a model framework for selecting the best location for a detention basin system

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Flood management has become a central issue in Europe with the European Union Flood Directive (2007/60/EC), and it has become clear that assessment of flood risk and mitigation measures should be envisaged at the river basin scale.
One of the basic principles of flood management is the retention of peak discharges, which can be achieved through an appropriate detention system. Detention/prevention measures can be either centralized, in the upstream neighbourhood of the flood prone area, or decentralized throughout the whole river basin. As a case study we investigated the Vez River, the principal tributary of the Lima River (N. Portugal), in the most humid region, which has a long history of flood events, causing both economic and social losses. We developed a framework model for the characterization of the parameters needed for the planning of a flood mitigation system based on detention basins: the dimensioning, that is, the storage volume and the release flow and, subsequently, the selection of a suitable siting of the system. The framework can be summarized by three separate but interrelated workflows: i) the hydrologic workflow; ii) the geomorphologic workflow; and iii) the water quality workflow. It begins with the analysis of the historical flood based on the existing literature and it goes till the implementation of a multi-criteria optimization model, which aims to select the best location(s) for the detention basin system.

Interpretation of the invertebrate-based BMWP-PL index in a gravel-bed river: insight from the Polish Carpathians

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Similar to its British prototype (Biological Monitoring Working Party score system), the Polish benthic invertebrate-based BMWP-PL index is commonly regarded as an indicator of river water quality. This interpretation of the index has been verified in a study of the gravel-bed Biała River. Benthic macroinvertebrates were sampled at 10 sites and compared in one channelized and one unmanaged cross-section per site. The resulting taxa richness and BMWP-PL index scores were compared with water quality and physical habitat characteristics in the cross-sections. Channelized and unmanaged cross-sections clearly differed in their physical habitat conditions, and water quality characteristics mostly varied in the downstream direction. Particular cross-sections hosted between 3 and 26 invertebrate taxa, with the respective BMWP-PL scores indicating the water in the surveyed cross-sections varied between high and poor quality. However, the BMWP-PL scores were unrelated to physicochemical characteristics of the river water, which consistently pointed to high water quality. Instead, the scores were significantly related to several physical habitat variables, with the number of low-flow channels in a cross-section explaining the largest proportion of the variance in the index values. The relationship of the scores with the complexity of flow pattern in the river and a lack of their dependence on physicochemical water characteristics show that the BMWP-PL index should not be regarded as an indicator of water quality but rather as an indicator of the ecological status of rivers, dependent both on their hydromorphological and water quality characteristics.

Flow and water temperature simulation with future scenarios for nature restoration project in the Kushiro River, Japan

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Global climate change and its impact on riverine ecosystem are most significant issues in watershed environmental management. However, the direct effects on aquatic organism are caused by drastic change of river water temperature. The main reason of the water temperature change is not only by climate change in the local level but also land-use change by human activities.

The Kushiro River watershed with Kushiro Mire National Park located in Northern part of Japan was rapidly developed from 1960's. Now however, the watershed is main target for nature restoration project after 2002. After various activities, some sections of the river were recovered to natural meandering reach. But the seasonal change of actual water temperature has not been monitored in the before-after assessment.

So, we focused on the impact of anthropogenic watershed change on water temperature using watershed hydrological model with sub-module of water temperature analysis. Then, predicted future land use scenario in 2050 was adapted as initial condition to our model.

The objectives of this research are as follows.

1) Set up the land-use scenario to the target watershed in 2050, and assembled GIS database that applicable to simulation model.

2) Numerical model simulation to forecast the change of water temperature in each future scenario.

3) Evaluation for the impact of land-use change on water temperature and riverine ecosystem.

As the result, we calculated the water temperature change though the year in the watershed. And we discussed the actual plans that we should start with local stake holders and local government.

ACHIEVEMENTS BY RESTORATION AND MITIGATION PRACTICES

Effectiveness of group of pile dikes for fish habitat

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In this study, the attention is focused on freshwater fish habitat and behavior in rivers. Especially, fish behavior depends on hydraulic quantities, and they vary depending on the presence or absence of river structures. It is known that groin has the hydraulic function to decrease flow velocity. There are numerous researches on hydraulic characteristics near groin. However, there are very few researches on effectiveness of groin for fish habitat. Therefore, its attention is focused on pile dike using wood. The purposes of this study are to examine the effectiveness of pile dike for fish habitat. To complete them, the experiments were done.

The experiments were carried out by using the small open channel in laboratory, to measure the flow and to observe the movement of real fish. The pile dike was made wooden column whose diameter is 0.5 centimeters, and set up in the right bank side of the channel. The alignment of group of pile dikes is zigzags alignment with high effect of the flow velocity decrease. Tribolodon hakonensis for the experiments are used. Its average body length was 5.0 centimeters.

Results are shown below. 1) Around and in the group of pile dikes are used by fish for the potential of relaxation, evacuation and hiding place, etc., because flow provide the favorite velocity for fish. 2) Fish move inside group of pile dikes easily, and turbulence of flow in the group of pile dikes shows 1/f fluctuation spectrum. This 1/f spectrum is said be good for live.

Evaluation of restoration success in the Danube Delta using fish assemblages

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One of the tasks of Danube Delta National Institute in the FP7-REFORM project was building on existing data or new data and analysed the available knowledge on the mandatory biological quality element of the Water Framework Directive – fish, as a response to hydromorphological degradation and restoration. From total surface of Danube Delta Biosphere Reserve about 580,000 hectares almost 103,000 hectares was dammed affecting fish fauna in sense decreasing stocks, but in last 25 years was restored more than 15,025 hectares. To assess the restoration success, in this paper was compared natural and reconstruction areas in Danube Delta using fish fauna which constant was sampled with 2 complementary methods: electric fishing near shore line and gillnets fishing (according UE sampling use) in open deeper water. Data analysing and adding sampling was done in period years 1997-2012, in 2 representative group-comparative zones along the same longitudinal parallel: in Letea unit between RE Babina (ecological reconstruction) and Matita-Merhei natural lakes-complex, also in Caraorman-Dranov units between RE Holbina-Dunăvat (ecological reconstruction) and Rosu-Puiu natural lakes-complex. Results of restoration success using fish biodiversity metrics show us overlapping more than 60 %, some few exceptions, means medium to small difference between near natural lakes and restoration areas in Danube Delta.

Habitat-scale evaluation of stream restoration effects: case study at Knehyne Stream

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Regulated channel of small mountain stream (Knehyne) was restored within 300 m long section. Straightened stream channel with fixed banks was changed to paired-channel pattern which has been evaluated as natural for this stream stretch. Short length of restored stretch and sedimentary unbalanced catchment required fixation of newly constructed channels by trunks anchored into river bed. Restoration aimed to change detrimental effects of vertical erosion in regulated channel into more natural channel forming processes. Furthermore coniferous forest in floodplain of restored stretch was replaced by more natural riparian vegetation.

Restored river stretch differs from regulated one by occurrence of specific hydromorphological structures (side pools, lateral channels, habitat heterogeneity in bank zone). We observed specific conditions in terms of water chemistry and thermal regime in lateral habitats (pools and temporary channels). Macroinvertebrates, phytobenthos and particulate organic matter characteristics were analyzed for response to hydromorphological changes at microhabitat scale.

Case study results were given into context of restoration effects in small streams obtained from 10 pairs of degraded-restored stretches (including Knehyne stream). Ecological consequences of altered hydromorphology were also compared between small and medium-sized streams studied at microhabitat scale.

Improving restoration tools for small lowland agricultural streams

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Small (1st-2nd order) lowland agricultural streams are often subjected to a number of pressures which degrade water quality and reduce aquatic diversity and impact stream communities. In particular, excessive nutrients (e.g., nitrate >6 mg/L), fine sediment (>20% cover) and macrophyte growth (>50% cover) all impact the health of these waterways. Despite widespread riparian planting and fencing, leaky plumbing (e.g., tile drains, bank slumping) can often circumvent riparian buffers and are sources of continual sources of impairment. We describe a research program; the Canterbury Waterway Rehabilitation Experiment (CAREX), which was designed specifically to find solutions to improving freshwater ecosystem health, and quantify the effectiveness of management tools in headwater agricultural waterways. Nine 1-km length headwater reaches were selected to represent independent gradients of in-stream nitrate and sediment impairment, and all are impacted by nuisance macrophytes. Combinations of tools and experiments are being applied at habitat and reach-scales. These include; riparian sediment flow experiments, in-stream sediment control using riffle creation and sediment traps, sediment removal using a sand wand, increasing in-stream denitrification by adding organic matter and macrophyte control trials. Initial results indicate a number of promising tools which used in combination should reduce nutrient-sediment-macrophyte pressures in these waterways.

Morphological and macroinvertebrates response to small-scale restoration interventions in mountain rivers

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Streams are one of the most threatened ecosystem worldwide. Due to the damaging human pressures on streams, the quality and variety of freshwater habitats has declined and biodiversity decreased. The severe river degradation has led to the spread of many river restoration projects that attempt to reverse the effects of habitat simplification and ecosystem degradation. In the Alps, most rivers are affected by channelization for flood mitigation and underwent intense channel degradation in terms of narrowing, incision and floodplain disconnection. In the Antholz River (Italian Alps), channel excavation and subsequent continuous bank protections were applied in the late 1960s in order to prevent agricultural lands and villages from flooding and erosion, resulting in a very uniform channel geometry with an armoured riverbed. A small scale (550 m) river restoration project was carried out during the winter 2011-2012 in order to create more suitable conditions for fishes. With the aim to assess the morphological characteristics of the river before and after the restoration, topographical surveys and pebble counts were performed before and after the works. Macroinvertebrate communities were also sampled before and after the restoration for assessing the response to the works.
Results show that despite an increase in channel width and an increased variability in grain size distribution following restoration, no significant changes are evident for the macrobenthonic communities before and after the restoration.

Evaluating the effect of river restoration techniques on reducing the impacts of outfall on water quality

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Urban developments release of a variety of heavy metal pollutants which enter rivers through outfall discharge. This results in local nutrient enrichment with adverse effects on the surrounding river ecosystem. Set-back outfalls indirectly discharge into rivers, aiming to reduce pollutant levels by dissipating energy before reaching the main channel. Riparian vegetation reduces sediment generation by decreasing flow velocities, acting as a sediment trap and buffering delivery. It is expected that the ability of the river to remove outfall pollutants will decrease with increased modification to the channel and surrounding land-use. This study aimed to investigate the following:

- Identify the influence of un-natural channel conditions and channel modification on the ability of a river to deal with outfall pollutants;
- Assess the impact of outfalls on the concentration of pollutants;
- Analyse the differing impact of direct or set-back outfalls.

BENEFITS OF RIVER REHABILITATION AND SYNERGIES WITH OTHER USES (FLOOD PROTECTION, NAVIGATION, AGRICULTURE, HYDROPOWER)

Lower Danube 4D Reconnection – Strategic Framework for LU/climate change adaptation

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Nowadays, about 80% of the Danube Floodplain – Romanian sector are embanked and arranged with desiccation works and locally with drainage. Once with increasing pressures on the system and the complexity of the issues, there has been developed a number of mechanisms by which human activity (LU change) influence the stability and services of ecosystems and the need for planning tools are changing rapidly. Motivated by dramatic climate change in recent decades and especially increased frequency of extreme events, we focused our efforts on developing models and scenarios of climate change, especially those related to land use change and flooding affecting local communities/ regions.

Thus, in the given circumstances, the best option is to foreseen a policy on the Lower Danube riverbed, followed by a series of advanced tools for exploring the 4D reconnection (longitudinal, lateral, vertical and temporal) and a well prepared monitoring system alert address to detected threats. With great importance into this policy there are planning issues which have to follow three aspects:

- Lower Danube System should be considered in its integrity as a whole.
- Second, human systems and natural systems are dynamic and constantly evolving and always change the equilibrium.
- The third aspect is that these systems are inherently spatial and temporal.

4D Reconnection of the Lower Danube floodplain will have to provide a spatial planning tool, developed in accordance with this three features, and built to design, analyse and evaluate long-term policies in an ecological, social, economic and cultural context. By transferring river restoration and risk information in spatial planning is assured the defining of the vision and strategy for sustainable development in the Lower Danube Valley, as an instrument for Integrated Management (ecosystem and adaptive).

Based on the flood risk maps, hydrological scenarios made with the hydraulic model of the Danube focused on quantifying the reduced Danube level at maximum levels and also on the spatial distribution of possible areas for intervention, was simulated 3 situations: 1) full restoration of Danube floodplain, 2) restoration of former permanent wetlands and 3) mixed solution of water storage in some farm precincts and restoration through natural flooding in others. A comparative analysis of the results highlights firstly, the substantial effect of reducing the maximum levels of the Danube in the mixed solution scenario (3): natural flooding of economic precincts areas (15.9%) and water storage at

maximum levels (40.8%). Using agricultural areas as water storage tanks during peak flood levels of the Danube, is a realistic solution that can combine flood protection requirement with the restoration, especially in terms of climate change and land use.

Green Rhine corridor a bottom up initiative from NGO's in the Rhine basin

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The Rhine Corridor partnership is an initiative of Aqua Viva and is a collaborative approach to improve the health of the River Rhine for the ecosystem and people. Partners involved in the initiative are Rheinaubund (Switzerland), BUND / Rhine Working Group (Germany), European Rivers Network (France), Institute for Geography and Geoecology - Department KIT-WWF Institute for Floodplain Ecology (Germany), Natuurmonumenten (the Netherlands), Platform Biodiversity Ecosystems and Economy (the Netherlands), Staatsbosbeheer (the Netherlands), WWF France, WWF Netherlands and WWF Switzerland. Additional partners are also encouraged to join and contacts have been made with stakeholders.

The health of the Rhine has improved in recent years, yet ecological and socio-economic problems still remain through existing pressures such as barriers to migratory fish, channelisation and simplification of the channel, all of which are intensified by climate change (low water level in summer & flooding). Nevertheless, 'A Green Rhine Corridor' includes many promising opportunities and is our overall vision that aims to strengthen the Rhine as a hydrological, ecological, economic and social backbone of Europe and to make it future-proof. We firmly believe that ICPR (International Commission for the Protection of the Rhine) and its members, together with business, non-governmental organizations and individuals, can step up to the challenge.

Evaluation of the impact of pressure and the sensitivity of habitats protected under the Natura 2000 network

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Ecological network Natura 2000 aims to protect rare habitats and species of both plants and animals before their complete disappearance in Europe. Natural but also transformed river valleys because of their unique qualities was and still are often taken in to this form of protection.
This study is aimed at answering the question - to which extent the quality of habitats localized in river valleys is dependent on the quantity or quality of water.
Research area covered valleys of large lowland rivers in Poland such as Narew and Warta. The method used in the study is based on the one hand on the structural study using the knowledge and experience of experts in the field of Phytosociology on the other, on the various indicators used to assess the quantity and quality of water in the analysed area. Pressure evaluation was made at three levels: the total catchment area, supply catchment and a Special Area of Conservation. The results of the analysis were compared with information on the conservation status of habitats included in the standard data forms.
The whole study was based on data from year 2010. For verification it should be repeated on the basis of data from another year.

Targeted river enhancement at a catchment level: maximising ecological return and cost effectiveness in addressing the Water Framework Directive

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Arterial drainage, undertaken on circa 11,000 km of channels in Ireland since 1950, has substantially altered the hydromorphology and ecology of impacted channels. Ongoing routine conveyance maintenance can exacerbate these impacts.

In response, under a 'Capital Works' programme, instream techniques previously developed to offset the ecological impacts of arterial drainage on salmonid populations have been adopted to address hydromorphological deficiencies identified in the Water Framework Directive (WFD). This 'Capital Works' programme involves the construction of instream works, gravel augmentation and the protection of the immediate riparian zone, aimed at improving hydromorphology.

Initial selection criteria for Capital Works used water quality (>Q3, Irish EPA scale) and bed gradient (>0.2%). The WFD Fish Ecological Quality Ratio (EQR) tool indicated that rivers already classified as 'good' or higher in WFD have been subject to Capital Works. This may not reflect cost-effective expenditure. The proposed assessment model incorporates water quality, gradient, WFD Fish EQR data and an assessment of river hydromorphology (River Hydromorphology Assessment Technique). Channels failing the selection criteria could receive 'Enhanced Maintenance', a suite of strategies developed to facilitate both conveyance management and physical modification of channel form to benefit hydromorphology.

The refined selection criteria facilitate an examination of needs, at the catchment scale, in terms of fisheries habitat and all elements of river hydromorphology – riparian and instream. The catchment view then permits a focus on specific requirements, allowing tailored enhancement programmes that address biological bottlenecks with specific enhancement strategies that are consistent with the expected hydromorphology.

Optimizing river management: integrated assessment of floodplain interventions

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The river system consists of three interacting components, which can be characterized as the hydrosystem, the ecosystem, and the socio-economic system. Over time, the autonomous development of the river system interferes with additional pressures from climate change and socio-economic developments, which necessitates landscaping interventions in the channel-floodplain zones. Selection of measures to be applied depends, amongst others, on the goals of the intervention, the perspective of the decision maker, and societal preparedness for change. Yet, there is a need for a 2D integrated model of the river system that represents hydro-morphodynamic processes as well as ecological processes to support an optimal choice of floodplain interventions. Therefore, the objective of this study is to determine an optimal set of interventions and evaluate the evolution of their effects over time to support decision making.
We establish a decision support model that includes the following methodological steps: (1) positioning and parameterization of river landscaping measures in a two dimensional model: floodplain smoothing, floodplain lowering, digging side channels, embankment relocation, (2) evaluation of hydrodynamic effects: peak water levels and flood hazard in a 2D flow model, and (3) evaluation of floodplain biodiversity, and riverine ecosystem services. Here we present the first results of single intervention types applied at varying intensity to get insight in their relative effect. For the case of the River Waal floodplains in The Netherlands, we applied floodplain smoothing and floodplain lowering over progressively larger areas, increased side channel depth, and we increased the extent of the embankment relocation.

LIFE+ triple lakes - catchment restoration and preventive action for aquatic habitats in a climate change perspective

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The Triple lakes-project, coordinated by the County Administrative Board of Jämtland - Sweden, is a water management project for restoration and improvement of lake and stream Natura 2000-habitats within three catchments. The major lakes in the project, Locknesjön, Näkten and Revsundssjön are deep with long retention time and with distinctive cold water characteristics and species. Most of the tributaries and larger streams in the area have been modified to facilitate timber floating, hydropower or agriculture and forestry. This has had negative effects on lake ecosystems and reports on deteriorating environmental quality within the project area has set focus on concrete actions but also preventive work, especially in the context of climate change.

The project aims to reduce both past and present environmental impact and thereby strengthen the ecosystem. The overall goal is to enhance biodiversity and preserve the aquatic habitats to the future. In addition, the project aims to facilitate sustainable recreational use e.g. game fishing.

To enhance the lake and stream ecosystems and thereby provide resilience in a changing climate perspective, the Triple lakes integrates physical stream and lake habitat restoration with dialogue processes and measures to raise awareness regarding water ecology and sustainable use of land and water. This involves managing sustainable recreational fishing, water friendly techniques in forestry and agriculture and information to land owners and people living in the area. To achieve this, forestry companies, farmers, private land owners, fishery managers, a hydropower company as well as local, regional and national authorities are working together.

LINKING SCIENCE TO PRACTICE: TOOLS TO ASSESS RIVER STATUS AND GUIDE REHABILITATION TO OPTIMIZE RIVER BASIN MANAGEMENT

Developing restoration patterns for heavily modified alpine rivers

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Complexities emerge both on theoretical and practical levels as soon as auto-sustaining river restoration of heavily modified alpine rivers segments is urgently required and socially desired.
Distances and deviations from dynamic equilibrium conditions characterize not only the hydro-morphological and ecological structure of the stream segment under consideration but the whole connectivity with respect to sediment fluxes both in upstream (i.e. feeding region) and downstream direction (i.e. emission region). Re-establishing developed connectivity networks as a prerequisite for the implementation of successful restoration schemes would be the preferred (ideal) option from a geomorphic perspective; seemingly irreversible land-use changes and constructive alterations of the stream network, however, render operationally impossible, economically unfeasible and socially unacceptable, such an approach under current conditions. Hence, we suggest general and flexibly applicable restoration patterns to achieve a locally effective restoration without precluding larger scale hydro-morphological restorations. The general characteristic is a tripartite structure of the restoration project area featuring an upper feeding region where sediment inflow fluxes can be artificially adjusted, a free development region where uncontrolled dynamics is allowed (ideally also for lateral mobility) and a control region where extreme evolutions implying flood risk consequences are buffered. Confluence regions merit particular monitoring attention. A retrospective account of efforts put so far in less-structured restoration projects in South Tyrol, Italy corroborates the necessity to develop structured restoration patterns and robust monitoring schemes.

Supplemental tools for natural channel design

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The Natural Channel Design (NCD) approach promoted by the U.S. Environmental Protection Agency and others is strongly dependent on the quantification of the bank full flow rate and associated channel geometries of a given stream. In an urban setting, the determination of bank full flows is often a difficult prospect given the complex nature of urban hydrology, the highly modified morphology and hydrology of urban streams, and the often subjective indicators of bank full stage that can be observed in the field. This presentation will describe the application of continuous simulation modeling (CSM) to supplement bank full flow interpretations on urban streams. CSM involves the application of a continuous record of historical precipitation data to hydrologic and hydraulic models for a given watershed. This technique is useful for the estimation of the frequency of flows of a given magnitude, such as the bank full flow, as well as the evaluation of the potential impact of future hydromodification within a watershed. Another difficulty that arises in the use of NCD in urban settings is the need for reference reach data. Reference reach data are intended in part, as a means to evaluate the long term dynamic stability of the restored reach. Given the degree of anthropogenic impacts to urban watersheds and their receiving streams, a suitable reference reach may be difficult to identify. This presentation describes the application of 2D modeling techniques to supplement the use of any available reference reach data.

Bayesian belief network models to support decision making in river basin restoration

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Economic growth is often based on the intensification of crop production, energy consumption and urbanization. In many cases, this leads to the degradation of aquatic ecosystems. Modelling water resources and the related identification of key drivers of change are essential to improve and protect water quality in river basins. This study evaluates the potential of Bayesian belief network models to predict the ecological water quality in a typical multifunctional and tropical river basin. Field data, expert knowledge and literature data were used to develop a set of Bayesian belief network models. The developed models were evaluated based on weighted Cohen's Kappa (κw), percentage of correctly classified instances (CCI) and spherical payoff. On top, a sensitivity analysis and practical simulation tests of the two most reliable models were performed. Cross-validation based on κw (Model 1: 0.44 ± 0.08; Model 2: 0.44 ± 0.11) and CCI (Model 1: 36.3 ± 2.3; Model 2: 41.6 ± 2.3) indicated that the performance was reliable and stable. Model 1 comprised of input variables main land use, elevation, sediment type, chlorophyll, flow velocity, dissolved oxygen, and chemical oxygen demand; whereas Model 2 did not include dissolved oxygen and chemical oxygen demand. Although the predictive performance of Model 2 was slightly higher than that of Model 1, simulation outcomes of Model 1 were more coherent. Additionally, more management options could be evaluated with Model 1. As the model's ability to simulate management outcomes is of utmost importance in model selection, Model 1 is recommended as a tool to support decision-making in river management. Model predictions and sensitivity analysis indicated that flow velocity is the major variable determining ecological water quality and suggested that construction of additional dams and water abstraction within the basin would have an adverse effect on water quality. Although a case study in a single river basin is presented, the modelling approach can be of general use on any other river basin.

Morphological measures improve the low flow habitats in rivers

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The WFD objective to achieve good ecological status/ potential in rivers along with potential impacts from climatic change have emphasised the need for us to have a better understanding of the dynamic nature of catchments for targeting improvement measures and preventing deterioration in ecological quality as part of river basin planning. We want to identify and develop evidence of morphological measures that enhance physical habitats, particularly during low-flow conditions and channel forming flows, to promote ecological resilience.

There is a growing body of practical experience, but we are keen to develop evidence and understanding through the use of remote sensing and 2D hydrodynamic modelling. The 2D model output was analysed using a range of tools including hydraulic biotope mapping and fisheries habitat modelling to assess the changes and benefits that can be realised from a few examples of interventions that have the potential to be widely used. We use worked examples that illustrate the application of the monitoring technique in assessing changes that can be achieved in river physical habitat from appropriate morphological interventions. The results emphasise the need to consider measures at a catchment scale and how they perform under the full hydrological regime. We consider how the techniques developed within this study lend themselves as a catchment or water body screening tool and could be applied to focus more detailed field investigations.

The impact of hydromorphological restoration measures on macroinvertebrates diversity; Narew and Warta river case studies

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Water Framework Directive (2000/60/EC), obliged Member States to achieve a good status or good potential of water bodies by the year 2015, thus necessity of conducting of complex monitoring. Assessment of water bodies status requires determining of numerous hydromorphological and biological parameters of watercourse as well physicochemical water quality parameters. Occurrence of macroinvertebrates, one of the monitored biological elements, is considered to be dependent on hydromorphological parameters and water quality. In order to fulfil WFD objective – improvement of conditions of degraded areas - restoration measures are undertaken which can lead to raise of biological status by increasing macroinvertebrates diversity and richness.

Our study focuses on relationship between restoration measures and macroinvertebrates diversity. We referred species richness and diversity to hydromorphological features (microhabitats, mesohabitats characteristics, e.g. quantity of channel features or substrate types), as well as water quality parameters (e.g. pH, electroconductivity, alkalinity or nutrients). Moreover we tried to link macroinvertebrates with macrophyte presence (species diversity and richness). We investigated two areas with large and small restoration projects, respectively in Narew and Warta mid-sized lowland river catchments, chosen as Polish case studies sites within REFORM project (REstoring rivers FOR effective catchment Management). Besides assessing the role of restoration extent on restoration effects (Narew vs. Warta case studies) we compared restored river section to degraded one (two sections for each case study site). Macroinvertebrates sampling was carried out in July 2012 and 2013.

Results of our study showed positive restoration effects on macroinvertebrates diversity while comparing restored and non-restored river sections within one case study site. As far as comparing scale of restoration projects, better environmental conditions were present in small restoration project (Warta river case study), which was opposite status than expected. We noted higher Margalef's diversity index for restored river sections. Diversity index equals 7.20 for Narew and 8.28 for Warta restored reaches (respectively 6.30 and 5.33 for degraded reaches). The biological monitoring working party (in Polish modification) (BMWP-PL) shows, basing on macroinvertebrates taxon richness, higher water quality for restored river sections. BMWP-PL equals 74 for Narew and 96 for Warta restored river sections (respectively 43 and 58 for degraded river sections).

Approach to investigate and assess hydromorphological conditions at large and navigable surface waters in Germany

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The Federal Institute of Hydrology generated the Module Valmorph for the detection and evaluation of hydromorphological changes of Federal Waterways and their floodplains. Valmorph is part of the modelling framework of INFORM (INtegrated FlOodplain Response Model) that considers interactions between hydrology, morphology and organisms.
The hydromorphological component Valmorph is a quantitative method based on representative indicators, e.g. river depth and width variation, substratum and sediment continuity. Especially large rivers are affected by anthropogenic impacts such as hydropower, navigation or flood protection. Valmorph is an innovative approach to assess modified surface waters like this. An evaluation becomes possible by comparing recent and reference conditions. References are variously defined for natural, heavily modified or artificial designated waterways.
The method shows how to measure and classify hydromorphological degradation in five evaluation classes. The deliverables for the investigated indicators can be visualized for 1 km river sections to finally averaged river stretches with a length of 5 km up to water bodies or the whole watercourse.
The results of classification provide e.g. focus areas for improvement measures. Recommendations for actions can be derived. The procedure was used e.g. for the German inland Elbe River on behalf of the Elbe River Basin Association and the ICPER for the currently published integral Sediment Management Plan that serves as background documentation for the second Elbe River Basin Management Plan.
Consequently, the applied Valmorph-method that allows also e.g. an utilization for efficiency control of measures supports rehabilitation aspects regarding hydromorphological attributes and offers an optimized river basin management.

Fish fauna as indicator for large river-floodplain alterations. Case study: Danube Delta

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In the Danube Delta, out of a total 540,200 ha, 30% has been lost due to embankments by 1990 but still preserve near-natural reference habitats. The human interventions are consequences of different land-use policies and priorities starting from the end of the 19th century: navigation improvements, capture fishery, reed harvesting, agriculture.
Fishes are the only group of aquatic organisms for which historical information is available. Long term reliable data on commercial fishing and the history of hydrotechnical works could provide valuable information on the responses of the fish fauna at the catchment scale of the Danube Delta.
At a reach scale, a relevant example of the impact of interruption of lateral connectivity on fish population is given by the case of blocking the canal between the Danube River and a group of lakes in May 2002, for sediment management purposes. These group of lakes are shalow lakes, characterised by a connectivity gradient which induced a specific typology and fish community structures defined by species ecological guild for current preferences. A sharp decrease of euritopic fish species abundance was recorded in June 2002, after blocking the canal in all lakes, except remote lake. The rheophilic species were represented in small number by Asp (*Aspius aspius*) in all lakes before blocking river connection as adults and young specimens, but recorded after only at immature stages in some lakes.
A set of indicators to assess the status of river-floodplain connectivity is proposed.

The RiverWiki: a platform for sharing best practice river restoration

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The RiverWiki is a tool for sharing best practice river restoration and lessons learned. It showcases river restoration examples from across Europe in a Wiki-style format that anyone can freely add to and edit. It provides project data (including objectives, techniques and outcomes) as well as information on ecosystem benefits, stakeholder participation and costs. This poster will showcase the benefits of the RiverWiki as an interactive platform where practitioners can communicate and exchange river restoration knowledge. It also provides some examples on how the evidence and data from the RiverWiki can be used to enhance our understanding of river restoration.

Integrated project planning framework

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REFORM has developed a new integrated project planning framework to support the design of Water Framework Directive (WFD) Programme of Measures (PoM) for the 2nd round of River Basin Management Plans (RMBPs). The framework systematically guides practitioners through two main planning stages of river restoration 1) catchment scale & 2) project cycle, to support the success of hydromorphological restoration in a cost-effective manner, whilst integrating social & economic aspects in to the decision making. The framework provides detailed information for each of the planning stages and offers tools and guidelines for users, some of which have been developed in REFORM, including Plan Check Do Act (PDCA), Driver Pressure State Impact Response (DPSIR), Logical Framework, SMART objectives (Specific Measurable Achievable Realistic Timely), Multi Criteria Decision Analysis (MCDA) and Cost Benefit Analysis (CBA). The framework will reduce the uncertainty of management actions by providing:

- A logical path to design projects linking policy and watershed/catchment assessment
- Concise structured information for each stage of the project cycle, relating this to RBMPs and PoMs
- Easy access to relevant tools & guidelines that can be used at different stages of the planning process
- Tools to identify restoration goals through application of specific measurable endpoints to identify restoration success
- Tools for selection & prioritisation of projects

It will also be included on the REFORM WIKI, a web-based tool that offers guidance and tools for hydromorphological assessment and physical restoration of rivers and streams in Europe.

REFORM Partners

REstoring rivers FOR effective catchment Management