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REstoring rivers FOR effective catchment Management

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Cover photo: The long and winding road to favourable hydromorphological conditions

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1 Introduction

Dr. Eleftheria Kampa (Ecologic Institute) and Dr. Tom Buijse (Deltares)

1.1 REFORM background

REFORM is a four-year (2012-2015) EU-funded FP7 research project which will provide tools and procedures to increase the success and cost-effectiveness of river restoration measures and to monitor the biological responses to hydromorphological changes with greater precision and sensitivity. The main aim of the project is to make the state-of-the-art knowledge on hydromorphology, the interaction with ecology and wider environmental aspects, timely available to support river basin managers while preparing the next round of River Basin Management Plans (RBMPs).

The restoration framework in REFORM addresses the relevance of dynamic processes at various spatial and temporal scales, the need for setting end-points, the analysis of risks and benefits, and the integration with other societal demands (e.g. flood protection and water supply). This multidisciplinary work is being organized in eight work packages (WPs) belonging to three modules: (1) *natural processes*, (2) *degradation*, and (3) *restoration & mitigation*.

As part of its objective to foster and maintain a dynamic exchange amongst stakeholders, REFORM will develop a web-based dissemination tool – the REFORM WIKI – that will benefit from stakeholder consultation to share experiences with specific river restoration measures (http://wiki.reformrivers.eu). The results of REFORM will also be made available through this tool.

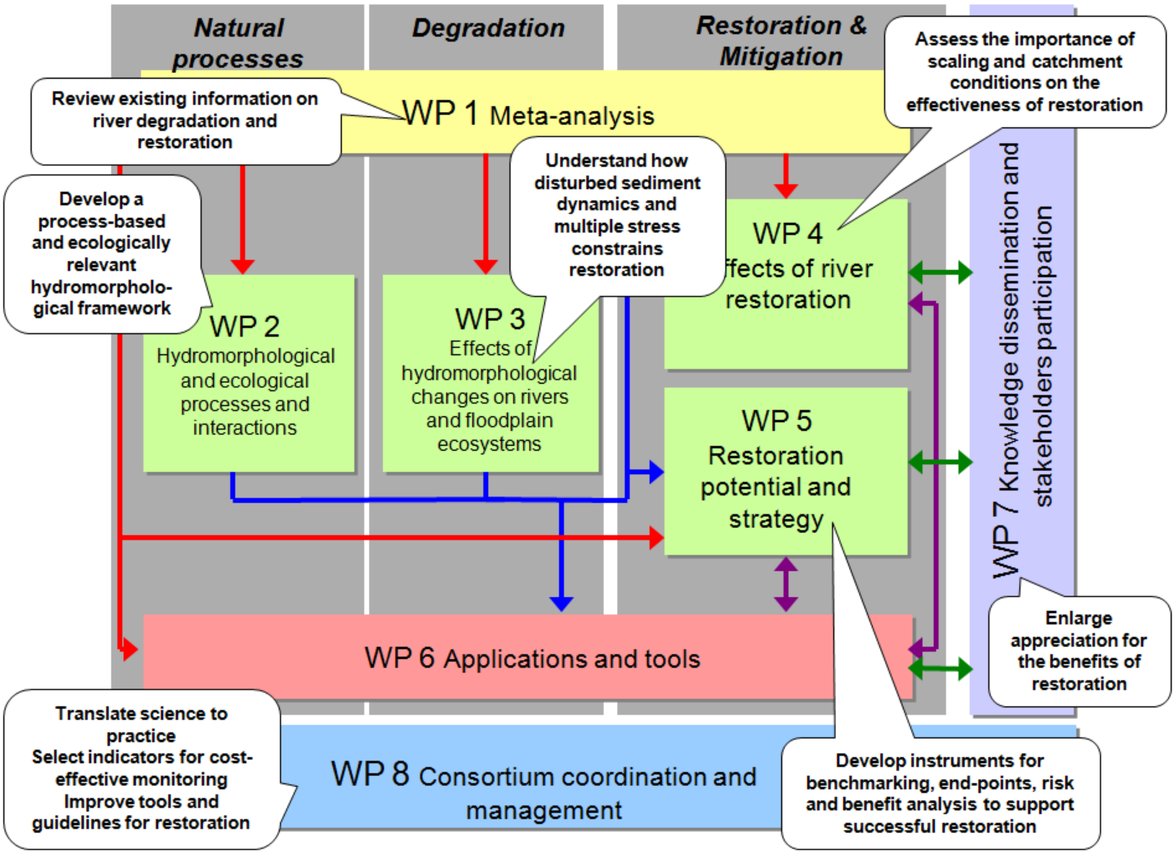

Figure 1 REFORM approach and outcome

1.2 Aims of the stakeholder workshop

The technical and interactive Stakeholder Workshop on River Restoration to Support Effective Catchment Management will be held on 26-27 February 2013 at the Hotel Silken Berlaymont in Brussels (http://www.reformrivers.eu/events/stakeholder-workshop). Its main aim is to provide a platform for consultation and exchange between REFORM scientists, European technical experts working on river degradation and restoration, and members of the WG A Ecological Status (ECOSTAT) of the CIS for the WFD (2000/60/EC).

At the workshop, the first results of REFORM will be presented and invited experts will have the opportunity to give their feedback during breakout sessions. One of the goals of these sessions will be to gather stakeholders' perspectives on how the management tools and approaches created by the project can contribute to the next round of RBMPs. Keynote speeches will be given by the REFORM partners, the ECOSTAT leaders, the EEA, DG Env, the WISER project, and the Life+ RESTORE project, among others. The workshop will include presentations on the following:

- An overview of the initial outcomes of REFORM to support the drafting of the second RBMPs
- Feedback on assessment methods and measures for river restoration in the first RBMPs
- Methods for understanding the root causes of degradation and specifying the expected outcome of restoration
- Reporting on tools for assessing the effectiveness of restoration for river basin planning considering project scale and catchment status
- Discussion of a European multi-scale ecohydromorphological assessment framework (prioritization of assessments in different scales)
- Knowledge sharing on hydromorphological degradation and restoration
- Dissemination of information from related European research projects and activities and their relationship to REFORM

The workshop will be an interactive event with parallel working groups addressing different topics relevant to the various types of rivers and pressures across Europe. The parallel groups will address REFORM's outputs and plans for the next stages of the project and will also reflect on relevant activities in the EU Member States and other European countries. Table 1 gives an overview of the status of the output from REFORM during its first 2 years (November 2011 – October 2013).

1.3 Aims of this discussion paper

The workshop is intended to be a working meeting and will require the active participation of the delegates. The purpose of this discussion paper is to stimulate dialogue at the workshop by providing a progress update on the REFORM results with brief problem descriptions and conclusions from the main work-packages, as well as establishing connections between the workshop programme and the REFORM deliverables.

The paper also presents some of the key topics which should be addressed at the workshop.

Table 1 Status of REFORM deliverables scheduled for the first 2 years (Nov 2011 - Oct 2013). N.A. = not applicable; website = www.reformrivers.eu

#	Description	Planning	Status	Where to find?	Will content be in WIKI?
D7.1	Communication and Dissemination Strategy	Jan-12	√	Website (results > deliverables)	No
D4.1	Field protocols and associated database	Apr-12	√	Submitted	To be decided
D7.2	project website: structure and functionality	Apr-12	√	www.reformrivers.eu	N.A.
D7.6	Project leaflet	Apr-12	√	Website in EN, ES, FR, GE and IT	No
D7.6	Project newsletters (8)	Every 6 months	√	Website: #1 and #2	No
D1.1	Review on eco-hydromorphological methods	Oct-12	√	Website (results > deliverables)	**Yes**
D7.2	REFORM GEOWIKI	Nov-12	√	http://wiki.reformrivers.eu	N.A.
D2.1	Multi-scale framework and indicators of hydromorphological processes and forms	Jan-13	Test version		**Yes**
D1.2	Review on effects of pressures on hydromorphological variables and ecologically relevant processes	Feb-13	Final draft		**Yes**
D1.3	Review on ecological responses to hydromorphological degradation and restoration	Feb-13	Final draft		**Yes**
D7.7	Policy brief (3)	Every 16 month #1: Feb-13	In prep		No
D7.3	Proceedings of the End-user workshop	Mar-13	In prep		No
D5.1	Review of methodologies for benchmarking and setting end-points for restoration projects	Apr-13	1st draft		**Yes**
D6.1	Synthesis of interim results for practical application to support the compilation of the 2nd RBMPs	Apr-13	In prep		**Yes**
D1.4	Inventory of the cost of river degradation and the socio-economic aspects and costs and benefits	Oct-13	1st draft		**Yes**
D2.3	Framework to analyse ecosystem services provided by European river systems	Oct-13	1st draft		**Yes**
D3.1	Impacts of hydromorphological degradation and disturbed sediment dynamics on ecological status	Oct-13	In prep		**Yes**
D4.2	Evaluation of hydromorphological restoration from existing data	Oct-13	In prep		**Yes**

2 Workshop topics

2.1 Challenges and bottlenecks for river restoration with reference to the first RBMPs

Dr. Christian Wolter (Leibniz Institute of Freshwater Ecology and Inland Fisheries)

Introduction

The status assessment in 2012 clearly revealed that the majority of European rivers will fail in reaching the environmental objectives of the WFD by 2015. Hydromorphological degradation has been identified as one of the predominant reasons for not achieving good ecological status (GES) or good ecological potential (GEP) in rivers. This was not unexpected, since the initiation and aims of the WFD encompass more than just water quality improvements.

The deteriorating water quality problems of the 1970's have been resolved widely throughout Europe. Thus, the WFD initiated a paradigm shift in river management from chemical water quality to environmental objectives. For the first time, the GES of a water body has been defined as a legally-binding environmental target where biological quality elements form the basis for assessing the ecological status, in addition to indicators for water quality and hydromorphology.

Because of the WFD, new water management targets require the development of sufficient assessment systems, indicators, and rehabilitation measures. This process is ongoing and presents various challenges and knowledge gaps. Therefore, the main objectives of WP1 of REFORM are compiling, reviewing, and analysing existing data and information on hydromorphology-ecology interactions and their underlying physical and ecological processes. This review focuses specifically on the linkages between hydromorphological variables that influence ecological status and functioning and on the tolerance thresholds of species.

It is widely accepted that hydromorphological integrity provides the foundation required to support ecological functioning. However, hydromorphological degradations first appeared as a main impact on rivers only after the overarching water quality problems had been resolved. This has significant implications for the status assessment, the strength of indicators, the potential of ecological improvements, and the uncertainties of restoration at all scales.

Improvements in the chemical water quality of rivers have resulted in dramatic improvements in the biotic communities of river ecosystems. Today, the abundance and diversity of river biota are limited by the availability of water, followed by structural variability and habitat complexity. Thus, the hierarchical scale of factors that limit biotic communities (Figure 2) has moved down to the level of mesohabitats and substrates. At these levels, the number of species that would potentially benefit from or respond to restoration decreases. Thus, the sensitivity of more general ecological indicators and the ability of restoration measures to improve overall ecology decrease, while assessment uncertainties increase.

There is an emerging need and challenge for developing new indicators for specific bottlenecks/limitations for species in river systems. Riverine hydromorphological processes and variables, as well as the related aquatic communities, are not stable-state ecosystems; rather, they vary through time and according to environmental disturbances. Accordingly, typical riverine species and communities have evolved adaptations to these disturbances and tolerate substantial environmental variations.

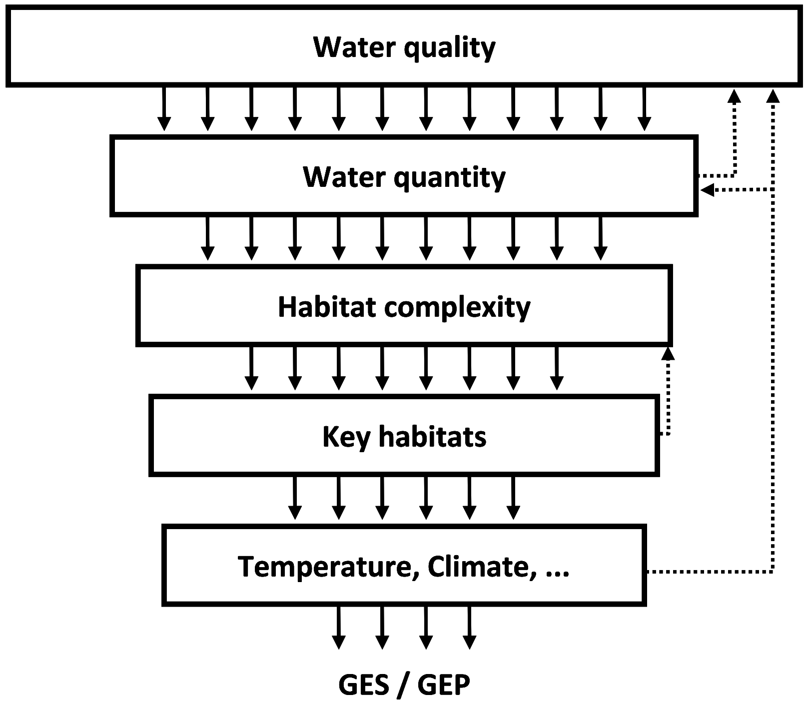

Figure 2 Habitat bottlenecks and confounding factors as hierarchical faunal filters.

Review and analysis of environmental tolerances against physical pressures, substrate and habitat requirements of selected species groups

To improve existing indicators and to develop new metrics, published environmental tolerances to physical pressures and the specific substrate and habitat requirements of macrophytes, invertebrates, and fish were reviewed and analysed.

The most specific species requirements refer to substrates. Thus, in rivers, species which are dependent on coarse sand or gravel substrates provide the best indication for hydromorphological processes responsible for gravel cleaning, that is, bed-forming flows. In addition, large wood not only contributes to habitat complexity, but also it provides substrate for specialised phytobenthos and macroinvertebrates. Specific substrate requirements were compiled and analysed for over 30 macrophyte species, 77 macroinvertebrates, and 26 European gravel-spawning lampreys and fishes. These species provide measurable environmental targets and serve as indicators for substrate improvements, gravel additions, and the rehabilitation of flow dynamics.

On the one hand, flow dynamics provide gravel sorting and essential habitats for certain species, while on the other hand, high flow velocities limit the habitat maintenance and habitat availability for aquatic organisms. The resilience against such physical disturbances is more unspecific, and in fish for example, this is primarily mediated by size. Thus, at higher hierarchical levels (Figure 2), there is a more general response to disturbance thresholds and less indication at the level of specific species. Although the generally positive relationship between habitat complexity and species number or diversity is well established, the improvements in specific species resulting from increased habitat complexity are less predictable.

For instance, the German fish-based assessment system uses the fish region index (FRI) as a sum parameter of how the fish community composition at a certain site corresponds to the river type and region. This appears to be a highly suitable indicator for fish assemblages of a river stretch/type in good hydromorphological and ecological status and works beyond the level of specific species. So far, 157 European lampreys and fish species have been classified according to their frequency of occurrence in specific river regions. The European FRI has been harmonised by various fish experts from the Member States and covers all common species that appear in the different fish monitoring programs. Therefore, the index has the potential to become an additional common fish-based indicator for all Member States, and it will be further evaluated within the REFORM project.

Regarding the limiting physical thresholds for species, the tolerated maximum flow velocities and shear stresses have been compiled for about 40 macrophytes, 151 macroinvertebrates, and 75 fish species. These physical thresholds provide guidelines for mitigating disturbances, like those induced by inland navigation, and underline the importance of flow velocity gradients, increasing habitat complexity, and shelter as objectives of rehabilitation measures.

Conclusions and key insights

In summary, the review of available literature and project results revealed specific substrate requirements of indicative value for a rather limited number of species, that is, potential indicators or target species for environmental improvements. For a substantially higher number of species, physical thresholds (e.g. currents, wave action, and shear stress) have been established to guide river rehabilitation work. For measuring environmental improvements beside general biodiversity measures and species numbers, a river type- and region-specific index, namely the FRI, is suggested and will be evaluated within the REFORM project.

A summary report (REFORM Deliverable D1.3) delivers the compiled relationships between hydromorphological processes and variables and the biotic responses of WFD-relevant aquatic taxa, with special reference to species tolerance curves and habitat bottlenecks, to support river basin managers in preparing the next RBMPs.

Review of first RBMPs

The effects of different pressures on hydromorphology have also been analysed in the first RBMP and Programmes of Measures (PoM) of the Member States. This task complemented the review of hydromorphology-species interactions and aimed to identify gaps in knowledge and application of restoration measures and the predicted ecological improvements.

The use of the WISE database was agreed on by the Member States to analyse eco-hydromorphology in the first RBMPs and PoMs. These data have been analysed at the available spatial level in river basin districts (RBDs). Pressures and measures at the RBD level have been translated from the National RBMPs and classified according to groups of pressures and measures that were compiled earlier.

Conclusions and key insights

In general, two major findings seemed highly relevant:

1. The **hydromorphological degradation identified as main reason of failing the WFD environmental targets is not the same throughout Europe**. Most countries consider impacts at the level of hydromorphological variables and processes within permanent river systems, which have to be improved to achieve GES. With their measures, these countries typically address connectivity and impacts at the level of habitat complexity or substrate availability (Figure 2). In contrast, many Mediterranean river catchments suffer from water scarcity. Large reservoirs retain surface water runoff for irrigation and drinking water, significantly altering the natural flow regime. Here, bottlenecks to river biota already appear at the level of water availability. Thus, **measures ensuring environmental flows are much more relevant than in-stream habitat improvements in Mediterranean countries**. In addition, low flow situations are more subjected to water quality degradation as a confounding factor. This cascading significance of effects and measures has to be considered in European harmonisation strategies like the intercalibration process.

2. There is a highly obvious uncertainty about suitable efficient measures. This was particularly indicated by the dominance of conceptual measures in the RBMPs (Figure 3). This clearly reflects the existing knowledge gap, which presents both a challenge and an opportunity for the REFORM project to provide highly requested scientific support in a timely fashion. Measures classified as “conceptual”, such as *further investigations, information exchange, interventions, modified legislations*, and *cooperation*, contributed to nearly 70% of all measures designated for the RBD. In contrast, **hydromorphological improvements were designated for less than 15% of all RBD measures** (Figure 3). Measures classified as *investigations* had the biggest share of about 50% of the “conceptual” category, which includes research, project planning, monitoring, further investigations, and method development, followed by *information* (40%), which includes guidance, consultancies, information provision, and public participation.

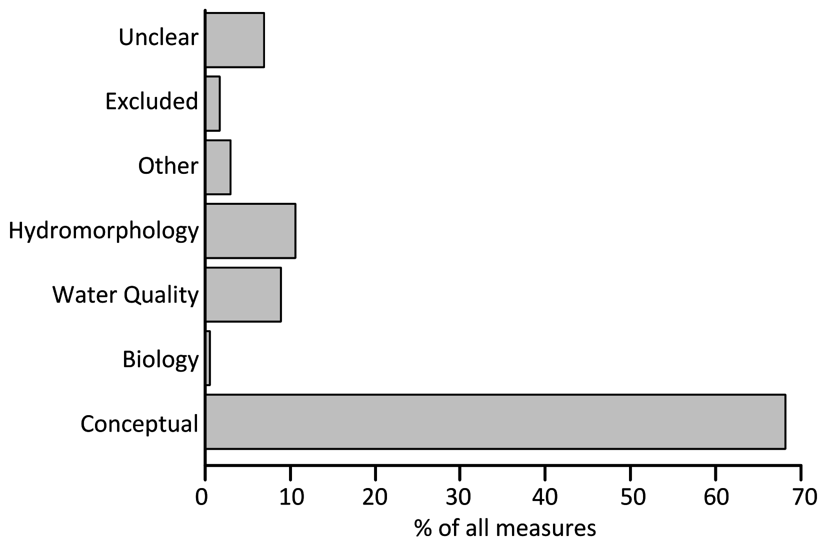

Figure 3 Categories of measures in the European RBMPs according to their appearance in the river basin district planning as percentage of all measures mentioned

2.2 Hydromorphological assessment methods: Limitations and strengths

Dr. Massimo Rinaldi (Università di Firenze)

Introduction

For the aims of the WFD, there is an increasing need to improve the characterisation and analysis of the hydromorphological conditions of water bodies, as this is recognised to be a fundamental step for the implementation of rehabilitation actions.

A large variety of hydromorphological assessment methods is available, with notable differences in terms of aims, spatial scales, and approaches. Each type of method, while being extremely useful for some aim, may be unsuitable to provide an adequate characterisation and understanding of other aspects and problems. In many cases, it is not completely clear what can or cannot be achieved by each type of method, and there is only partial awareness of their limitations and strengths.

The deliverable D1.1 of REFORM (Rinaldi et al., 2013) has made a comprehensive analysis of existing hydromorphological assessment methods in order to describe their main features, classify them, identify limitations and strengths, and provide some recommendations for future progress.

Review of existing hydromorphological assessment methods and analysis of their limitations, strengths and application in Europe

According to the WFD, the assessment of stream hydromorphology requires the consideration of any modifications to flow regime, sediment transport, river morphology, and lateral channel mobility.

Hydromorphological assessment consists in the application of methods and procedures developed to characterise the hydromorphological conditions and classify the status of a stream. For the scope of this review, five broad categories of methods have been distinguished as follows.

1. Methods for physical habitat assessment: methods used to identify, survey and characterise physical habitats.

2. Methods for riparian habitat assessment: methods specifically developed for characterising and assessing riparian habitats and vegetation.

3. Methods for morphological assessment: methods performing a geomorphological evaluation of river conditions, including morphological characteristics and/or human pressures on hydromorphology.

4. Methods for the assessment of hydrological regime alteration: methods specifically used to assess the deviation of the hydrological regime from unaltered conditions.

5. Methods for the assessment of longitudinal fish continuity: methods specifically developed to evaluate the alteration of the longitudinal continuity for fish communities related to human barriers.

The general characteristics of a total of 139 methods (European and non-European) have been reviewed (Table 2; Table 3). Following previous reviews (e.g. Fernandez et al., 2011; Raven et al., 2002; Weiss et al., 2008), a series of synthetic tables were developed to summarise main features, indicators, and characteristics of the various methods.

Then the analysis has been focussed on a selection of European methods (in total 22), that is, those methods that have been formally approved or that are commonly used by EU Member States for the implementation of the WFD. Characteristics, recorded features, indicators, processes and strengths of each of these selected methods have been revised.

Limitations and strengths

Based on the comprehensive review of hydromorphological methods, the main limitations and strengths of existing methods were identified and discussed, comparing them to current hydromorphological theories. This analysis was initially carried out for each of the five categories of hydromorphological methods previously identified, and then some general considerations concerning the methods implemented by EU Member States for the implementation of the WFD were outlined.

A synthesis of limitations and strengths for each category of methods is reported as follows.

<u>Methods for physical habitat assessment</u>

Strengths:

- They provide an accurate inventory and description that is useful to characterize the range of physical habitats, their heterogeneity, and the structure of ecosystems, and to link them to the biological conditions.

Limitations:

- The spatial scale of investigation (in most cases a 'site' of a few hundred meters) is usually inadequate for the accurate diagnosis and interpretation of any morphological alteration, since physical site conditions commonly stem from processes and causes that occur at a wider scale.
- They generally require very detailed site-specific data collection, and their application to large numbers of water bodies may be impracticable.
- Limited consideration of the processes generating and maintaining the morphological units and the temporal context within which channel processes operate and river channels adjust.
- The use of reference conditions based on statistical analyses of empirical data obtained from reference sites can be a limitation.
- Related to the previous point, inherent to many physical habitat assessment methods is the tendency to define high status/reference conditions on the basis of the presence and abundance of features.
- There is usually a notable difference between the terminology used to describe morphological units in habitat surveys, and the present state of the art in Fluvial Geomorphology.

<u>Methods for riparian habitat assessment</u>

Strengths:

- As for the physical habitat methods, they generally provide an accurate inventory useful to characterise the range of riparian habitats, and to link them to the biological status of the water body.

Limitations:

- Many limitations are similar to the previous category (generally small spatial scale of investigation, limited consideration of processes, etc.).
- Most methods have been developed in Southern European Member States (e.g. Spain, Italy), with specific morphological and climatic conditions.

Consequently, the recorded types of vegetation are not fully representative of all Europe.

<u>*Methods for morphological assessment*</u>

Strengths:

- The main strength of morphological assessment methods is the use of a more robust geomorphologically-based approach, with a stronger consideration of physical processes at appropriate spatial and temporal scales. Such an approach supports the development of a better understanding of cause-effect relationships.

Limitations:

- Physical processes are generally difficult to assess.
- Practical application of some of the methods by public agencies within the context of the WFD implementation can be problematic, as they need to be applied by specialists.
- The analysis of channel adjustments is often critical, given that it is difficult and requires specialist expertise, specific data, GIS analyses (e.g. to analyze channel planimetric changes).
- Definition of a reference state for morphological conditions is problematic.
- The focus of these methods is generally on fluvial forms and processes at wider spatial and temporal scales compared to the physical habitat assessment. On the other hand, there is often limited attention given to a systematic inventory of the morphological units.

<u>*Methods for the assessment of hydrological regime alteration*</u>

Strengths:

- The main strength of this category of methods is the use of robust indicators based on quantitative, statistical or physically-based models. Most European methods are based on some or all of the Indicators of Hydrologic Alteration (IHA) proposed by Richter et al. (1996) and Poff et al. (1997).

Limitations:

- The use of such indicators and models generally requires large data sets and long- time series, which are often not available. In particular, the application of such methods to ungauged streams is problematic.
- Analysis of hydrological alterations that occur at short time scales, such as hydropeaking, is not assessed by standard hydrological methods.

- The effects of groundwater alterations are generally not included.

Methods for longitudinal fish continuity assessment

Strengths:

- Most of these methods are based on a basic inventory of existing barriers: they provide straightforward information relatively simple to obtain.

Limitations:

- The previous strength is on the other side a main limitation, as these methods provide some basic information, but while relatively few of them carry out any deeper assessment.
- Assessing fish longitudinal continuity is complex, as it should account for variability in fish biology, structures, hydrological regimes, as well as for the temporal variability of all these factors.
- Few standardised protocols/structured methods exist.

Methods implemented by EU Member States *for the WFD*

Physical habitat methods, which are useful to characterise the range and diversity of habitats, have been identified with hydromorphological assessment for a long time. However, it is now recognised that a characterisation of physical habitats alone without a consideration of physical processes and morphological alterations does not allow a sufficient understanding of causes of pressure-response (i.e. cause-effect), that are extremely important for the implementation of rehabilitation actions. Furthermore, physical habitat assessment methods generally require very detailed site-specific data collection, and their application to large numbers of water bodies may be impracticable.

The number of methods formally adopted by Member States for the implementation of the WFD divided into the five broad, previously identified categories of hydromorphological assessment is reported in Figure 4.

It is evident that because most of the EU Member States have selected a physical habitat method for the assessment of hydromorphology, the consideration of physical processes remains as the main gap for the WFD implementation. The development and use of morphological assessment methods has significantly increased in past years, while the inclusion of methods for the assessment of hydrological regime alteration is still limited due to the requirement of large data sets.

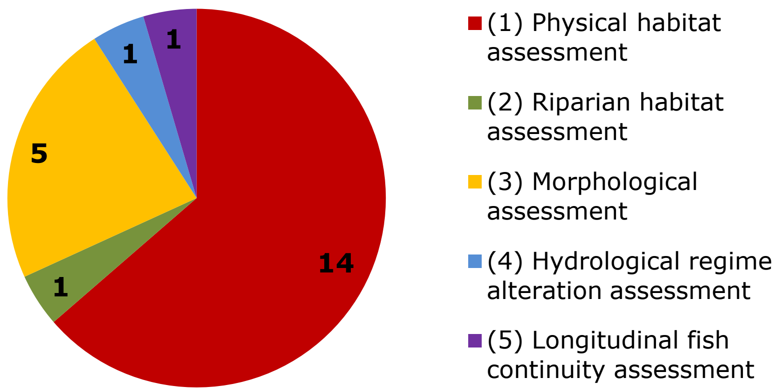

Figure 4 Number of methods used by EU Member States for the WFD divided into the five broad categories of hydromorphological assessment.

Conclusions and key insights

Two major initial findings emerged as highly relevant:

1. There is a **need for a more comprehensive hydromorphological assessment**. The previous analysis has clearly shown that most of EU Member States only use some component of an overall hydromorphological assessment, with a particular gap in the consideration of physical processes. This should be considered for future hydromorphological assessment and monitoring, and an integrated use of more components of the overall assessment is recommended.

The core of the hydromorphological evaluation should be represented by the morphological and hydrological components, with physical, riparian, and longitudinal fish continuity assessments providing a further characterization of the overall stream conditions at representative sites.

Assessments of morphological processes and alterations should be included in an appropriate spatial hierarchical framework and scaling methodology that emphasises the relevant spatial units and temporal timescales and identifies key controlling factors at each spatial scale and appropriate morphological indicators.

2. There is a **need for initial screening tools***.* Although from one side there is a need for more comprehensive hydromorphological analyses, it is also clear that the application of more methods and components of an overall hydromorphological assessment requires many efforts, in terms of time and financial resources. The application of various hydromorphological methods to large numbers of water bodies may be impracticable.

As a consequence, there is an increasing need for initial screening tools, which should be able to make a first characterisation and selection of potential critical reaches at the catchment scale, where more detailed assessments could proceed.

This type of tool should be mostly based on an initial analysis by remote sensing and acquiring the available information and data on existing pressures, and should not require fieldwork. The possible development of an initial screening tool for hydromorphological assessment will be explored during WP6 of REFORM.

Table 2 Summary of the total number of reviewed methods divided for each category

	(1) Physical habitat	(2) Riparian habitat	(3) Morphological assessment	(4) Hydrological assessment	(5) Fish continuity	TOT
Europe	**39**	**5**	**12**	**4**	**13**	**73**
Austria	6				1	7
Belgium	2				2	4
Czech Republic	1		1			2
Denmark	5					5
England & Wales	4		4		2	10
France	3		2		2	7
Germany	5				1	6
Ireland	1					2
Italy	2	1	1	1	1	6
Netherlands	1				1	3
Poland	3		1			4
Portugal	1					1
Scotland			1	1	1	4
Slovakia	1					1
Slovenia	1					1
Spain	2	4	3	2	2	13
Sweden	2					2
US	**24**	**5**	**8**	**4**	**5**	**46**
Australia	**4**	**2**	**1**			**7**
Switzerland	**1**					**1**
Others*	**4**	**2**	**2**	**2**	**2**	**12**

*South Africa, Canada/Quebec, China, New Zealand, Taiwan, Ukraine

Table 3 Summary of European methods divided for each category (in bold are the methods implemented for the WFD) (more details and references are reported in Rinaldi et al., 2013).

Country	(1) Physical habitat assessment	(2) Riparian habitat assessment	(3) Morphological assessment	(4) Hydrological assessment	(5) Fish continuity assessment	References of methods for WFD
Austria	**Hymo guidelines**, Werth, WatercSt, GEBD*, AssRivSt, NOMOORPH, RATyrol				QSS	HYMO guidelines (Mühlmann, 2010)
Belgium	SEvalW, SK				R-T, WebDB	NA
Czech Rep.	EcoRivHab		**HEM**			HEM (Langhammer, 2007, 2008)
Denmark	**DHQI**, DSFI, Aarhus, NPHI, PhysSC					DHQI (Pedersen et al., 2003)
England Wales	**RHS***, MesoH, URS, GeoRHS		FA, SRH*, GAP, MorphoAlt		NFPIPM, RDB, DRN	RHS (Raven et al., 1997)
France	**CarHyCE**, Qualphy, SEQ-P		**SYRAH-CE**, **AURAH-CE**		**ICE**, **ROE**	CarHyCE (ONEMA, 2010), SYRAH-CE (Chandesris et al., 2008), ICE & ROE (Onema, in progress)
Germany	**LAWA-FS**, **LAWA-OS**, BfG – WW, GSI				BA & QuIS	LAWA-FS (LAWA, 2000, 2002a); LAWA-OS (LAWA, 2002b)
Ireland	**RHAT**					RHAT (Murphy & Toland, 2012)
Italy	IFF, **CARAVAGGIO**	BSI-WSI	**MQI**	**IARI**	IPs & IPt	MQI (Rinaldi et al., 2011); IARI (Ispra, 2011); CARAVAGGIO (Buffagni et al., 2005)
Latvia			Methodology for the assessment of HYMO changes			Methodology for the assessment of HYMO changes (PPT Sigita Šulca, 2012)
Netherldands	**Handboek H.**				EAPW	Handboek HYMO (Dam et al., 2007)
Poland	**MHR**, EcomorphEval		RHQ			MHR (Inicki et al., 2009)
Portugal	HCI					Adaptation of RHS
Romania						Criteria and parameters for assessment of HyMo significant pressures and designation of HMWB
Scotland			**MImAS**	DHRAM	MPD	MImAS (UKTA, 2008)

Country	(1) Physical habitat assessment	(2) Riparian habitat assessment	(3) Morphological assessment	(4) Hydrological assessment	(5) Fish continuity assessment	References of methods for WFD
Slovakia	**HAP - SR**					HAP-SR (Lehotský & Grešková, 2007)
Slovenia	**SI_HM**					SI_HM(Tavzes & Urbanic, 2009)
Spain	**IHF**, IDRI	**QBR**, IVF, RFV, RQI	IHG, IDRI-P1	IAHRIS, QM	ICF, IF-IC.ICL.IPA	IHF (Pardo et al., 2002) ; QBR (Munné & Prat, 1998)
Sweden	**BiotopeMap**, RCE					BiotopeMap, Hllde'n et al., 2002

2.3 Understanding the root causes of degradation

Dr. Nikolai Friberg (Aarhus University)

Human activities influence stream ecosystems on multiple scales, ranging from direct manipulation of the in-stream environment (e.g. channelisation, removal of large woody debris etc.) to altering the landscape and land use in the catchment, thereby influencing the hydrological pathways and morphological structure (Harding *et al*., 1998; Fitzpatrick *et al*., 2001; Allan, 2004). The sum of these activities has been a substantial hydromorphological degradation of streams and rivers across Europe. There are several unknowns that hamper an effective management and mitigation of hydromorphological degradation which relates to the following points:

- Limited understanding of natural hydromorphological conditions and processes
- Generally insensitive biological assessment methods and a rudimentary understanding of the links between hydromorphology and biota
- Lack of guidelines of how to design hydromorphologically relevant restoration and mitigation measures

River regulation has had a substantial impact not only on channel planform, but also on riparian zones, and large areas of floodplain habitat have been lost. Along the lower part of Skjern River, Denmark, more than 40 km^2 of meadows and wetlands were lost as part of a 20 km regulation in the 1960s (Figure 5), and in the Odense River basin, it has been estimated that rivers have decreased in length by 43 % and 70 % of wetland areas have been lost during the last 150 years (Baattrup-Pedersen, unpublished). These examples are from lowland areas, but similar large scale modifications have occurred in most of Europe’s river systems. The majority of today’s streams and rivers have fundamentally changed from their natural state. However, the assessment of ecological status using biological quality elements is all undertaken in the river channel, thereby ignoring the entire element of larger scale degradation of riparian areas and floodplains. Furthermore, drainage, embankments, and channelizing have impaired natural processes that are likely to have strong negative impact on ecological quality. The whole issue regarding heavily modified water bodies and their ecological potential is inevitably linked to how detached a river is from its natural settings, and the costs to restore them could be disproportionally high.

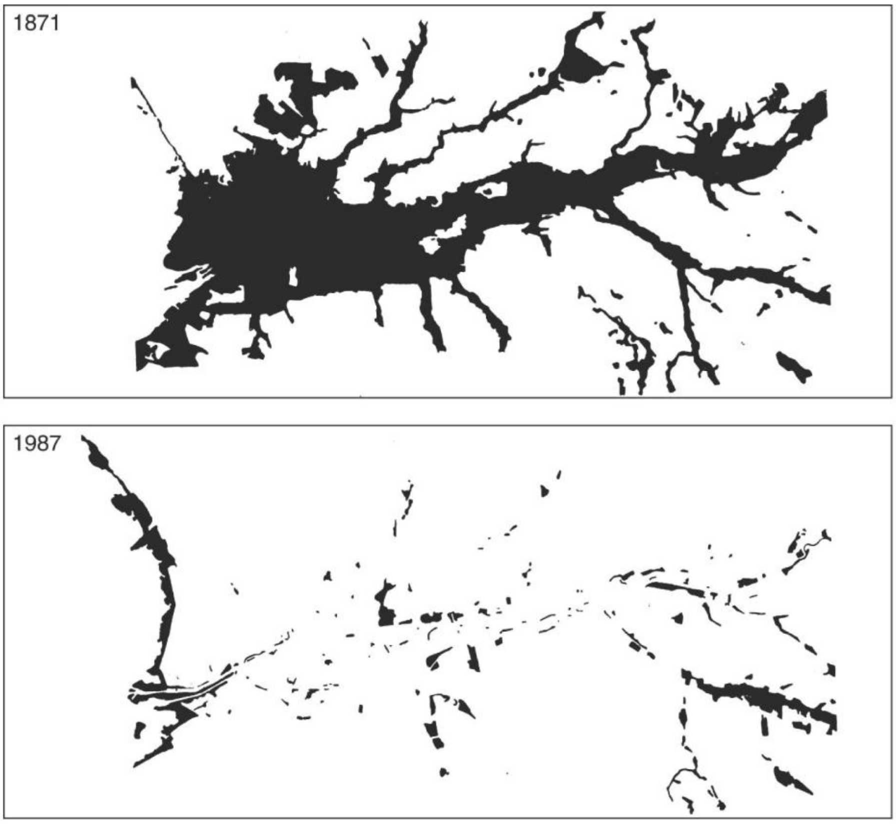

Figure 5 Loss of wetlands and wet meadows (both black) in the Skjern River valley from 1871 to 1987. The main drainage occurred in 1960s, while minor drainage projects and local channelization were already starting by the turn of the 19th and 20th century.

The importance of a physically heterogeneous stream environment for macroinvertebrates is indisputable (see Mackay, 1992; Hart & Finelli, 1999; Lake, 2000 for reviews) as it is for fish and vegetation. However, relatively few studies have documented clear impacts of habitat degradation on macroinvertebrates (Armitage et al., 1995; Feld & Hering, 2007). Furthermore, there are only few assessment methods that target hydromorphological degradation and specifically include flow (Extence et al., 1999; Barbour et al., 1996, Lorenz *et al*., 2004), and these are primarily used in the countries where they are developed. In a study based on a previous EU project REBECCA, Friberg et al. (2009) found only weak relationships between various measures of hydromorphological stress (e.g. the River Habitat Survey) and commonly used macroinvertebrate indices using large-scale data sets. These findings reflect that the majority of metrics, indices, and indicators are primarily sensitive to water chemistry, as they, or their basic concept, originate from an era when water pollution was the main concern. Another reason for our inability to detect hydromorphological impacts is that the interpretation of assessment outcomes is often confounded by multiple pressures that influence freshwater communities and may act synergistically (Folt *et al.*, 1999; Matthaei *et al*., 2006; Ormerod *et al.*, 2010).

There is a clear need to better understand how degradation of areas surrounding rivers influence ecological quality and if a good quality can be obtained without restoring key processes. It is furthermore vital that more sensitive indicators and assessment systems are developed to enable the detection of hydromorphological stress on biological quality elements and to separate these effects from other pressures.

In REFORM WP3, we are aiming to provide the following:

- Select and develop candidate indicators for WFD quality elements that quantify impacts of hydrological and morphological degradation in rivers, including disruption of sediment dynamics and groundwater connectivity
- To quantify the impact of hydrological and morphological degradation of floodplains and riparian ecosystems and the interaction with in-channel conditions
- To develop biological indicators capable of diagnosing hydromorphological pressures in a multiple pressure environment
- To quantify the influence of hydromorphological degradation on catchment water quality dynamics

The work is on-going with analyses of existing data and setting up experiments to test suitable indicators for hydromorphological degradation. It is of key importance that the indicators we develop are tailored to meet the demands of water managers and to help improve the ecological quality of European rivers by identifying which mitigation measures to use when the status class is not satisfactory.

2.4 Evidence of success of river restoration measures

Dr. Daniel Hering (Universität Duisburg-Essen)

Problem description

In the past years, European rivers have intensively been monitored to address the demands of the EU Water Framework Directive. Europe-wide, about 56% of river water bodies do not reach GES. According to the programme of measures specified in the first River Basin Management Plans (RBMPs), less than 30% of the rivers in Germany are still affected by point source pollution, while more than 70% of all rivers are affected by diffuse pollution, hydromorphological deficits, and altered habitats (http://www.eea.europa.eu/themes/water). Consequently, the vast majority of restoration measures proposed within the RBMPs target hydromorphological improvements. A large number of restoration projects are expected to come along in the next decades, although just a small proportion has been implemented up to now (Kail and Wolter, 2011). Among those projects, habitat enhancement on a local or reach scale is most popular, as they are easier to implement when compared to other measures such as riparian buffer strips.

River ecological status is derived from different aquatic organism groups (fish, benthic invertebrates, and aquatic flora), which are mandatory in official EU-WFD compliant assessment systems. While the response of riverine habitat composition to those projects is well documented and shows relatively consistent improvement of hydromorphology (Lepori et al., 2005; Jähnig et al., 2011), the biological response to river restoration is less obvious (Bernhardt et al., 2005). Water managers, however, nowadays require data on how ecological status is expected to change with restoration, as measures eventually need to lead to status improvements. As most assessment methods have been developed relatively recently, the response of these indices to restoration has not been analysed. Biodiversity indices and ecological status do not necessarily respond in a similar way to restoration, as most assessment methods are multimetric indices employing functional and sensitivity indices along with more classical biodiversity metrics.

In a recent investigation, Haase et al. (2013) examined the effects of 24 hydromorphological river restoration projects in Germany covering a wide range of river types and restoration methods. In the restored and nearby un-restored sections, we recorded hydromorphological parameters, along with biological diversity of benthic invertebrates, fish, and macrophytes, and applied the official EU WFD based assessment system for the first time. While hydromorphology changed significantly in the restored sections, differences between restored and un-restored sections, in terms of biological parameters such as biodiversity indices or assemblage similarity, were lower. The fish fauna responded strongest, followed by macrophytes, while there was no significant effect on benthic invertebrates. Positive effects on assessment results were observed for fish (11 of 24 cases) but not for macrophytes and invertebrates. Combining the results achieved with different organism groups only one of the 24 restored sections reached a “good” ecological status as demanded by the EU-WFD. These results indicate that stressors other than hydromorphological degradation still affect the biota in restored sections and sensitive taxa have not yet colonized restored sites.

Effects of hydromorphological restoration – the programme in REFORM (WP4)

A part of REFORM is dealing with the effects of hydromorphological degradation on a wide range of indicators and with factors determining restoration success. In contrast to the above cited studies, **REFORM is particularly addressing the catchment scale to analyse restoration effects**.

Indicators include the "classical" Biological Quality Elements supposed to benefit from habitat restoration (fish, invertebrates, macrophytes), but also include riparian organism groups (ground beetles, floodplain vegetation) and functional parameters (land-water interactions measured through stable isotopes). Our aims are the following:

- To investigate the effects of hydromorphological restoration on (1) river habitats, (2) biota, and (3) ecosystem services, broken down by different restoration measures and scales
- To analyse the rationale of strong and weak effects of common hydromorphological restoration strategies at catchment, reach, and local scales and to relate effects sizes to costs
- To compare socio-economic costs and benefits at the project appraisal stage and compare them with actual expenditures
- To test and improve standard protocols for evaluating the success of hydromorphological restoration, which are developed elsewhere in REFORM

This field study uses 12 examples of "restored catchments" in which either one large-scale measure or several smaller hydromorphological restoration measures have been implemented. These catchments are being compared to "control catchments", which are comparable to the related "restored catchment" in terms of size, stream types and catchment land use, but which lack large-scale restoration measures. The catchments cover restoration cases addressing different hydromorphological stressors, such as regulated flow, impoundment and river channelization. Paired field studies at the reach scale are used to test the linkage of key hydromorphological parameters and ecological and functional response parameters along the hydromorphological restoration gradient. This is being done in a nested design comparing restored and non-restored stretches separately within restored and control catchments, respectively, and comparing the restored and control catchments (Figure 6).

In addition, field surveys (or acquisition of existing data) on variables potentially supporting or "spoiling" the effects of hydromorphological restoration, such as water quality, sedimentation and source populations, are being performed.

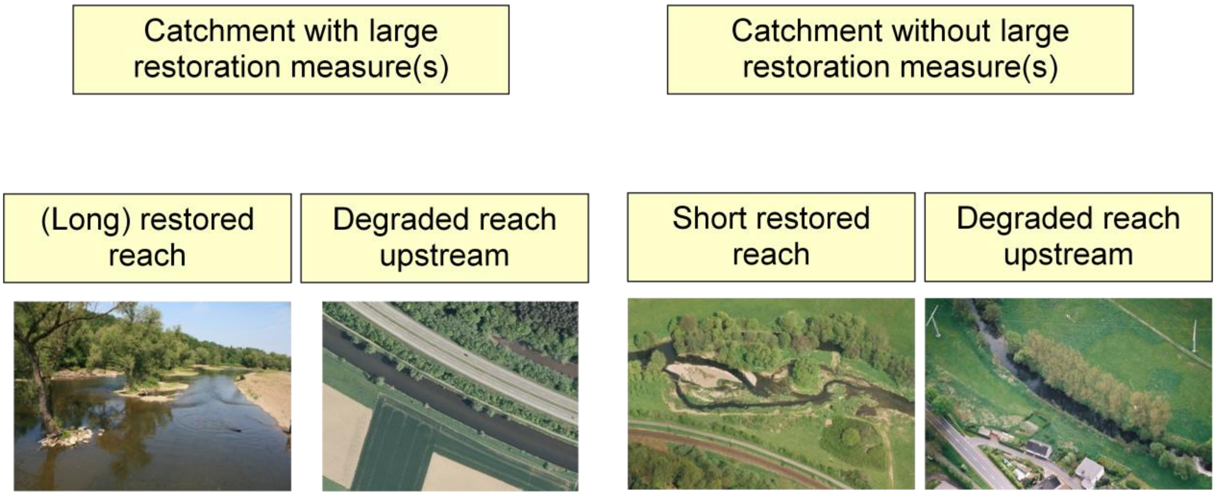

Figure 6 Sampling design. In each case study four sites are being investigated, using a large number of response variables indicating restoration success.

The case studies spread around Europe and include some of the “flagship restoration sites” Europe wide (Figure 7).

Mid-sized lowlands rivers			Mid-sized mountain rivers	
Where?	Who?		Where?	Who?
Em / Mörrum	SLU		Ruhr / Lahn	UDE
Skjern / Stora	NERI		Thur / Töss	EAWAG/UDE
Regge / Dommel / Dinkel	Alterra		Drau / Enns	BOKU
Spree / ?	IGB		Becva / Morava	MU
Narew / Warta	WULS		Kuivajoki/Vääräjoki	SYKE

Figure 7 Restoration case studies investigated in REFORM.

Consequently, we will be able to express “success” of restoration measures using a variety of hydromorphological, biological and functional response variables. These can be rated against a variety of factors, which might determine restoration success, such as:

- The magnitude of restoration (e.g. expressed as restored river length)
- The restoration method applied

But also factors which are nested within the catchments, such as:

- Water quality upstream the restored section
- Hydromorphological quality upstream or downstream of the restored section
- Recolonisation potential

To rate the catchment variables, extensive data available on the study catchments are being compiled and analysed. These include water quality, hydromorphological quality and recolonisation potential, as exemplified in Figure 8 and Figure 9 for the Ruhr catchment.

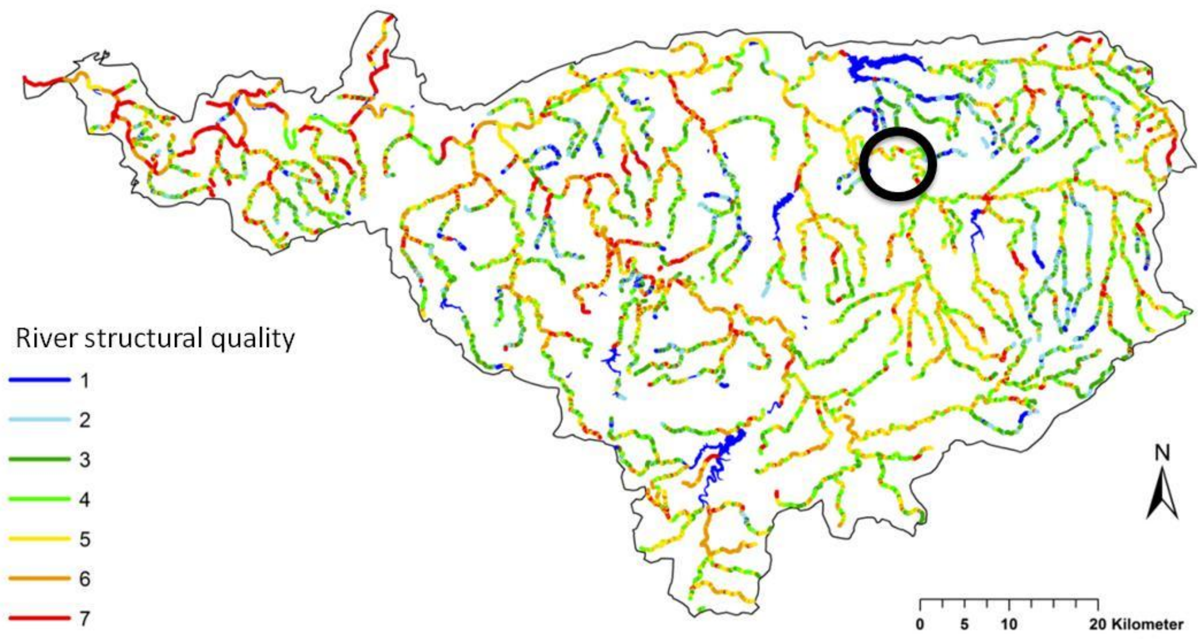

Figure 8 Hydromorphological quality according to the standard German method in the Ruhr catchment as a possible explanatory variable for restoration success. Restored site circled.

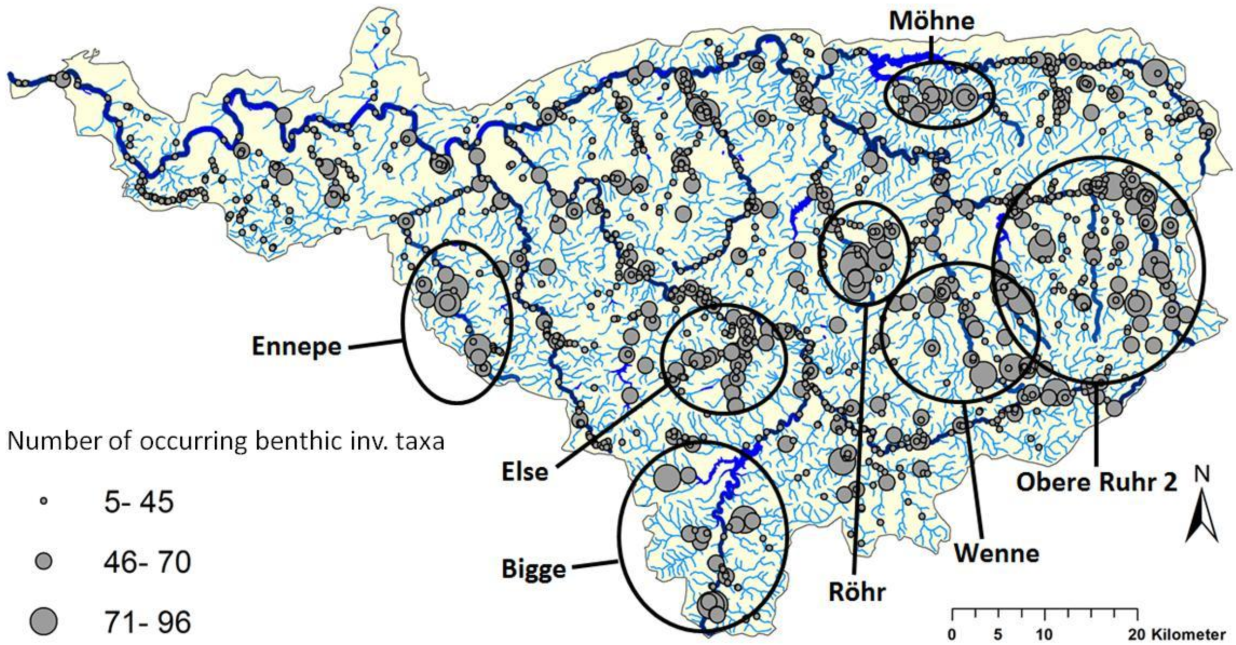

Figure 9 Recolonisation potential in the Ruhr catchment as a possible explanatory variable for restoration success.

Questions for the Workshop

- What rules river restoration success?
- Which share of river length needs to be restored to gain good status in a catchment?
- What is the ideal spatial configuration of restored stretches?

2.5 European multi-scale ecohydromorphological assessment framework

Dr. Angela Gurnell (Queen Mary, University of London)

Introduction

WP2 of the REFORM project builds on existing WFD typologies and hydromorphological and ecological data sets and methods identified in WP1. This is done to produce a suite of scale-dependent, ecologically-relevant, process-based indicators, relationships, and models applicable to the assessment of reference hydromorphological river and floodplain conditions across Europe.

In simple terms, the hydromorphological character of a naturally-functioning river reach is driven by:

- regional characteristics (e.g. climate and geology),
- catchment characteristics that translate the properties of the regional climate into flows of water and sediment through the river network,
- the valley setting, which dictates the topographic slope and lateral confinement of river reaches, and
- local reach-scale factors, such as the calibre and structure of river margin and floodplain sediments and the assemblage of aquatic, wetland and terrestrial vegetation, which moderate the local hydromorphological responses to the rivers flow and sediment transport regime.

Many of the current assessment methods employed within EU member states emphasise the reach scale. For example, hydromorphological assessment methods frequently combine a reach-scale census of the frequency and extent of individual habitat units or morphological features (e.g. flow types, pools, riffles, etc) with measurements of physical channel properties (e.g. bankfull width, substrate size, etc). Such surveys provide a wealth of useful, reach information, that characterises the river corridor at the time of survey, but they have at least **five limitations** when they serve as the only data source for assessment:

- They rarely record information beyond the current channel and its immediate margins, whereas broader floodplain properties provide important clues to past states of the river and include many habitats that are crucial to the ecological health of the river
- They give a single snapshot of river characteristics that focuses on forms rather than processes, providing restricted understanding of the continuous, dynamic adjustments in response to physical processes that can be either natural or anthropogenic in origin.
- They tend to focus on the reach scale, and so take limited account of the cascade of larger-scale factors and processes that influence the hydromorphology and ecology of a river and cause them to change.

- They also rarely take account of time lags between changes at one spatial scale and adjustments to those changes at a smaller (e.g. reach) scale.
- Whilst they often provide a description or count of features that are present, they provide little interpretation or diagnosis of those features as indicators of the way the reach is functioning now, has functioned in the past and may function in the future.

Many hierarchical approaches have been proposed previously to support better understanding of the functioning of river catchments, corridors and networks. In chronological order, some well documented examples include Frissell et al. (1986); Montgomery and Buffington (1998); Habersack (2000); Thomson et al. (2001); Snelder and Biggs (2002); Kondolf et al. (2003); González del Tánago and García de Jalón (2004); Brierley and Fryirs (2005); Thorp et al. (2006); Dollar et al. (2007); Beechie et al. (2010); Rinaldi et al. (2012 a,b); Wang et al. (2012). Each of these was developed with a particular application or set of applications in mind. In the present work, we are aiming to develop an approach that makes optimum use of available data and is suitable for application across Europe.

The Multi-scale Hierarchical Framework

The framework aims to make best use of currently available (physical habitat, riparian habitat, morphological, hydrological regime and fish continuity etc) surveys and readily-available (mainly free) Pan-European data sets to guide users on:

- What information is required at which spatial scale in the context of the data sets that are available and any new data that may be needed.
- How the above information can be collected or generated, and how it can be analysed, in order to:
    - Describe and, crucially, explain variation in river character and behaviour within a catchment.
    - Provide users with a basis upon which they are able to understand past and present behaviour and predict how a particular reach might react to changes (e.g. removal of local engineering modifications, flow regime naturalisation, reinstatement of longitudinal sediment connectivity).
    - Allow users to define potential, site-specific, “reference” conditions against which current hydromorphological and ecological condition could be assessed.

The framework comprises four stages:

1. Definition of a hierarchy of spatial units within which relevant properties, forms, and processes can be investigated to understand and assess hydromorphology and its potential impact on ecology (Figure 10). The units are arranged according to their relative size (indicative spatial scale) and persistence (indicative time scale). ***The reach is the key spatial scale*** at which the mosaic of features found within river channels and floodplains (i) responds to the cascade of influences from larger spatial scales and (ii) is influenced by interactions and feedbacks between geomorphic and hydraulic units and smaller elements such as plants, large wood and sediment particles within the reach.

2. Delineation methodology

For catchment assessment and management purposes, the aim should be to subdivide the entire catchment into a complete set of units at all spatial scales from catchment to reach. In large catchments, this may not be possible, but it is necessary to subdivide the catchment to the scale of its major landscape units, after which representative subcatchments within each landscape unit can be analysed, delineating segments and reaches along the main channel and major tributaries for detailed analysis.

For assessment of a particular reach or segment, a minimum assessment needs to focus on the specific reach or segment and larger spatial units that contain and are immediately upstream of the reach or segment under consideration

3. Characterisation methodology

Characterisation of spatial units at the different scales attempts to draw together readily-available information, surveys, and data sets in ways that will promote understanding of the units and the linkages between them. Recommendations for characterisation take account of WFD requirements and make best use of existing pan-European and National data sets, including the outputs from physical habitat, riparian habitat, morphological, hydrological regime and fish continuity assessments, where they are available. Essential components of the characterisation are stressed.

4. Indicators

Key (primary) and secondary indicators are proposed at each spatial scale. Wherever possible, these are derived from information already assembled during characterisation. However, recommendations concerning new data collection and analyses are made where crucial information on these components is lacking. Indicators are used to support interpretation and process-based understanding of:

- Present condition of reaches and segments of river and floodplain
- Past condition of reaches and segments of river and floodplain
- Likely response of reaches and segments of river and floodplain to future scenarios.

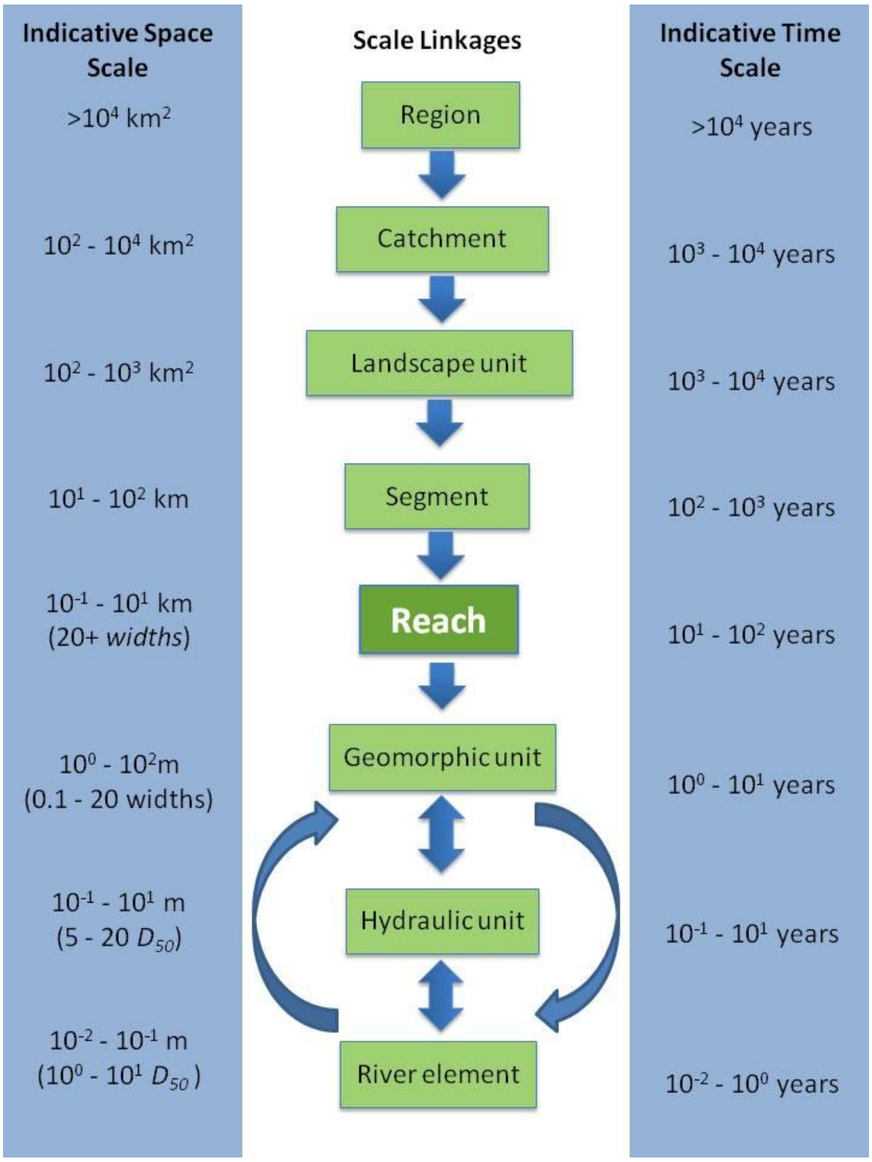

Figure 10 Hierarchy of spatial scales for the European Framework, including indicative spatial dimensions and timescales over which these units are likely to persist.

2.6 Measuring success of river restoration actions using end-points and benchmarking

Prof. Ian Cowx (University of Hull)

Introduction

Recent trends in the management of inland waters have erred towards rehabilitation of rivers and lakes to improve the aquatic environment for biodiversity and allow for sustainable exploitation of the resources. The costs of these rehabilitation projects vary from a few Euros to many millions, depending on the scale and intensity of rehabilitation taking place. As the interest in aquatic restoration has increased, several texts have been produced over the last few decades to assist with various aspects of river restoration. Most have focused on habitat improvement techniques specific to trout and salmon (e.g. Beechie & Bolton 1999) or design considerations for specific techniques (Iversen et al. 1993; Ward et al. 1994; Brookes & Shields 1996; Katz et al. 2007). A few have provided more comprehensive regional overviews of riverine and wetland restoration planning and techniques (e.g. Cowx and Welcome 1998; Roni et al. 2011). Collectively, these publications cover many of the tools, techniques and concepts needed for restoration planning, but not the planning and integration of restoration process from initial assessment to monitoring of results.

This increased emphasis on restoration has brought the need for new techniques and guidance for assessing stream and watershed condition, identifying factors degrading aquatic habitats, selecting appropriate restoration actions, and monitoring and evaluating restoration actions at appropriate scales. Unfortunately, despite the rapid increase in river restoration projects, little is known about the effectiveness of these efforts (Rumps et al. 2007). Restoration outcomes have not really been evaluated and information about project motivations, actions and results are not necessarily available (Bernhardt et al. 2007). Evaluating how successful the restoration measures have been, as well as determining reasons for success or failure, seem essential if restoration measures are to be carried out in an efficient and cost effective manner, especially in the European context with respect to meeting obligations under the WFD. This will require detailed consideration of regulations and socio-economic constraints at local, regional and national levels.

REFORM strives to meet this need through WP 5 and WP6 in particular by integrating the information from other WPs and linking catchment assessment and problem identification to identification of appropriate restoration measures, project selection, prioritization, project implementation, and effectiveness monitoring.

Despite large economic investments in what has been called the “restoration economy” (Cunningham 2002), many practitioners do not follow a systematic approach for planning restoration projects throughout a watershed or basin. As a result, a number of restoration efforts fail or fall short of their objectives, if they have been explicitly formulated, which often appears not to be the case. Some of the most common problems or reasons for failure of a restoration programme or project include:

- Not addressing the root cause of habitat degradation
- Upstream processes or downstream barriers to connectivity
- Inappropriate uses of common techniques (one size fits all)
- No or an inconsistent approach for sequencing or prioritizing projects
- Poor or improper project design
- Failure to get adequate support from public and private organizations
- Inadequate monitoring to determine project effectiveness

Proposal

These challenges and problems can be overcome by systematically following several logical steps that are critical to developing a successful restoration programme or project (Figure 11).

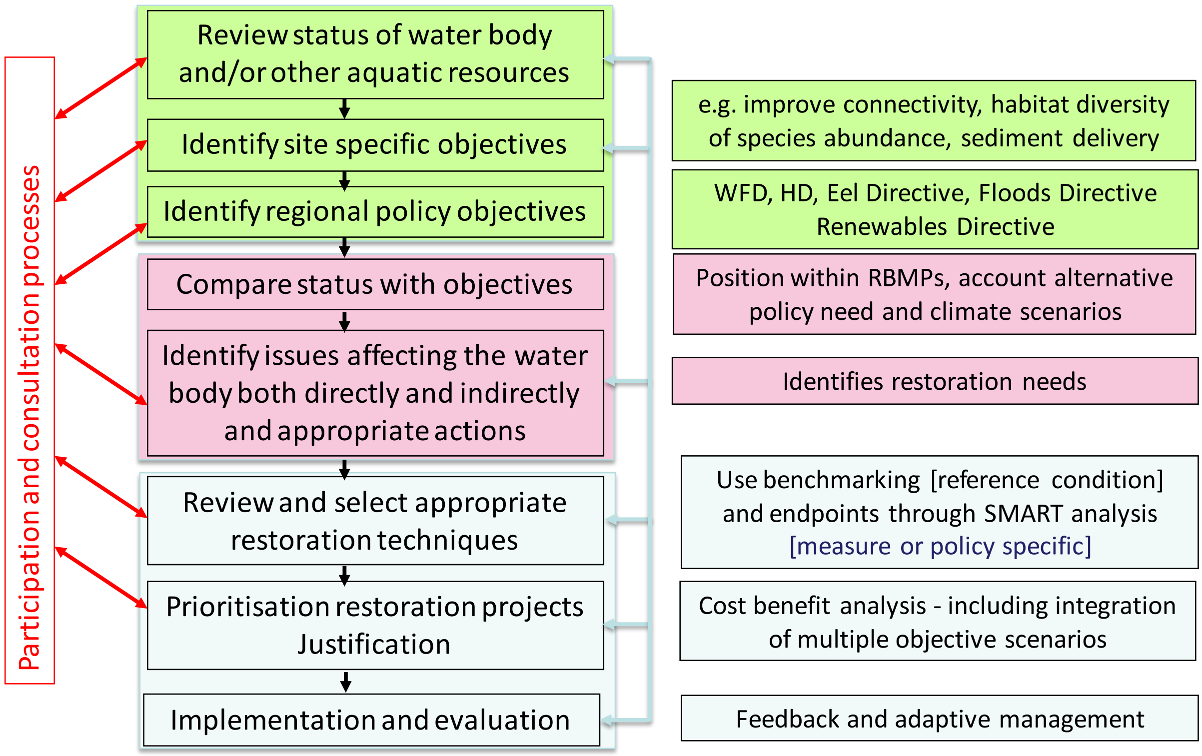

Figure 11 Proposed planning protocol for restoration projects. Green represents project identification, orange, project formulation and blue represents project implementation

One of the first steps in improving the design and evaluation of river and catchment restoration is that of establishing benchmark conditions against which to target restoration measures. This requires assessment of catchment status and identifying restoration needs before selecting appropriate restoration actions to address those needs, identifying a prioritization strategy and prioritizing actions (WP6), and developing a monitoring and evaluation programme. In addition to these steps, a basic understanding of the social dimension of watershed restoration is needed. This work takes place within the context of the River Basin Management Plans, but it is our impression that this diagnosis is inadequately specified and insufficiently quantified to identify the causes and bottlenecks of degradation and thus do not necessarily help plan the most effective ways for improvement. Goals and objectives need to be set at multiple stages of the restoration process, and there are multiple steps within each stage, but the initial stage is to identify endpoints and benchmarks against which to measure performance. This needs be reviewed against reference conditions, to determine appropriate targets for restoration, rehabilitation and mitigation activities. However, this step is often missing from most restoration planning, although excellent examples exist on which to base the process e.g. Kissimmee River Restoration in Florida, US (Anderson et al. 2005). In this prime example, the managers have defined their expectations based on nine abiotic responses for hydrology, geomorphology, and water quality, five related to changes in plant communities in the river channel and floodplain, six related to invertebrate and amphibian and reptile communities and five expectations to describe anticipated changes in fish and bird communities (Table 4). Twelve elements of information (Table 5) are required for each of these expectations that provide criteria against which evaluate the outcomes of the restoration programme.

Table 4 Criteria for defining success of restoration of the Kissimmee River (after Anderson et al. 2005)

Hydrology geomorphology, and water quality responses
1 Continuous River Channel Flow
2 Annual Distribution and Year-to-Year Variability of Monthly Mean Flows
3 Stage Hydrograph Characteristics
4 Stage Recession Rates
5 River Channel Velocities
6 River Channel Bed Deposits
7 Sand Deposition and Point Bar Formation Inside River Channel Bends
8 Dissolved Oxygen Concentrations in the River Channel
9 Turbidity and Suspended Solids Concentrations in the River Channel
River channel and floodplain plant communities responses
10 Width of Littoral Vegetation Beds Relative to Channel Pattern
11 Plant Community Structure in the River Channels
12 Areal Coverage of Floodplain Wetlands
13 Areal Coverage of Broadleaf Marsh
14 Areal Coverage of Wet Prairie
Invertebrate and amphibian and reptile community responses
15 River Channel Macroinvertebrate Drift Composition
16 Increased Relative Density, Biomass, and Production of Passive Filtering-Collectors on River Channel Snags
17 Aquatic Invertebrate Community Structure in Broadleaf Marshes
18 Aquatic Invertebrate Community Structure in River Channel Benthic Habitats
19 Number of Amphibians and Reptiles Using the Floodplain
20 Use of Floodplain for Amphibian Reproduction and Larval Development
Fish and bird community responses
21 Densities of Small Fishes within Floodplain Marshes
22 River Channel Fish Community Structure
23 Guild Composition, Age Classes, and Relative Abundance of Fishes Using
24 Density of Long-Legged Wading Birds on the Floodplain

25 Winter Abundance of Waterfowl on the Floodplain

Using this example, the process of bench-marking can be broke down into a number of steps:

- Deriving reference criteria – need to establish reference conditions of specific river types or river styles as defined by WP2

- Transfer reference conditions to end points for target systems – different for each river style including temporal and spatial dimensions. This will require comparison of status against objectives for restoration that are appropriate to accommodate variability in river style/types (WP2).

Table 5 Standardized information required for expected outcome of restoration criteria

Title	identifies the expectation.
Expectation	states the success criterion that will be evaluated to determine restoration success and concisely describes the anticipated change including values for quantitative metrics.
Author	identifies the person(s) responsible for creating the expectation and who should be contacted to answer any questions.
Date	identifies when an expectation was developed.
Relevant Endpoints	identifies characteristics of concern that reflect the restoration goal.
Metric	identifies the attributes that will be measured to evaluate the expected change.
Baseline Condition	characterizes the state of the metric for the disturbed (pre-restoration) system.
Reference Condition	describes the state or value of the metric if the system had not been disturbed (i.e., an ecosystem with ecological integrity).
Mechanism for Achieving Expectation	explains how the restoration will cause the system to change, so that the metric achieves the expected value.
Adjustment for External Constraints	explains any adjustments to the reference condition because of constraints external to the restoration project.
Means of Evaluation	describes how the expectation will be evaluated including the sampling design (sampling sites, control sites, sampling methods, replication, and frequency), the calculation of metrics, and the evaluation of the expectation (statistical test, comparison to a threshold).
Time Course	estimates the time required to achieve an expectation.

- Undertake deficit analysis (to identify what hydromorphological limitations and processes are constraining the recovery of the biota) and explore the potential for restoration to establish ‘endpoint’ target conditions

- Once the end points have been established these restoration targets need integrate into wider catchment-based activities to deliver win-win scenarios (e.g. flood mitigation, hydropower, agriculture, navigation) and take due account of the cost and benefits, specifically in relation to ecosystem services delivery, to ascertain the most effective measures to meet specific objective.

To support this process REFORM develops a protocol for benchmarking and setting specific and measurable targets for restoration and mitigation measures. This includes the following steps

- Step 1: Data mining of existing projects to determine how objectives of schemes were established, if at all, and against what criteria.

- Step2: Determine whether the objectives have been achieved and if not why not
- Step 3:Determine criteria for establishing endpoints and benchmarks against which to measure performance - and determine appropriate targets for restoration activities
- Step 4: Develop a protocol to set realistic quantifiable endpoints for restoration projects

This process of evaluating restoration is ongoing and will be finalized in spring 2013, but examples of good restoration practice are limited to assist the outcomes of REFORM. Workshop participants are requested to:

- Establish whether the concept of bench marking and end-points is a realistic and needed component of measuring success;
- Provide examples (literature, web links, contacts) of good practice;
- Advise on examples where restoration measures have been integrated into wider catchment scale activities to promote optimal solutions for mutual benefit;
- Consider the role and feasibility of using the ecosystem services concept for evaluating the benefits of programmes of measures.

2.7 Knowledge sharing on hydromorphology – the REFORM WIKI

Dr. Erik Mosselman (Deltares)

Introduction

River restoration research has produced a wealth of scientific information, but this information is still used insufficiently in restoration design and implementation. This can be ascribed partially to restricted accessibility, but also to the differences in language between river science and water management. Conversely, scientists are often too little aware of and involved in planning, implementing, and evaluating restoration and mitigation projects. Novel approaches are required to bridge the gaps in the transfer of knowledge between science and practice. REFORM argues that the key issues in such novel approaches are active involvement, interaction, and open-access to high-quality information suitable for application.

Peer reviews are a well-established approach to improve and safeguard the quality of scientific publications. Web of Science, Scopus, and Google Scholar are the search engines to exploit this wealth of literature. The drawback is that literature that is not traceable through these search engines is in fact lost. This is the fate, for instance, of many text books that appeared in the early days of river restoration when scientific journals were less prone to publish the initial experiences. REFORM calls on publishers to unlock these books, especially those out of stock, similarly to what has been done with their journal issues from the pre-digital era. An example is the Large Rivers supplement series of the Archiv für Hydrobiologie, which until recently was difficult to trace, but is now completely available on-line as part of the journal River Systems (http://www.schweizerbart.de/journals/rs). The scientific, peer-reviewed way of sharing experiences, however, is mostly fed and exploited by scientists and only to a limited extent by practitioners. Without refraining from writing peer-reviewed papers, we advocate that the scientific community also invests substantially in other forms of communication, making connections between practice and know-how. This will even contribute to the exchange of pure scientific knowledge between different disciplines, as interdisciplinary scientific communication is often established along the lines of practical applications. In river restoration, this is particularly true for scientists in biology and ecology, as well as scientists in hydromorphology (geomorphologists, hydraulic engineers).

The REFORM WIKI

Effective tools to better link science to practice are, in our view, thematic and well-designed, open-access web-based knowledge management systems, in short: WIKIs. The WIKI developed within REFORM (http://wiki.reformrivers.eu) will be presented at the workshop. It is a successor of Forecaster, the first-generation WIKI for river restoration (developed in the framework of an EU project funded by IWRMnet). The philosophy behind the design of Forecaster was to use the language of water management as the point of departure. The WFD terminology and categorization was used to design the structure for river typology, hydromorphological pressures, restoration, and mitigation measures and hydromorphological and biological quality elements. The strength of a WIKI lies in the live link between scientific knowledge and practical know-how (Figure 12). This link can be fully exploited if the design of the WIKI is straightforward and self-explanatory. Otherwise, users get lost and become discouraged and reluctant to explore the WIKI. Forecaster has a simple multilayer approach linking geographical positioning with thematic clustering. A database holds the most essential facts meant to filter relevant case studies. The case-study WIKI is the actual portal to inform users in brief, while links to background information allow multiple sources and forms of background information (DOI of peer-reviewed papers, photographs and movies, grey literature in multiple languages, and weblinks). Hyperlinks connect case studies of river restoration to one another and to knowledge pages on hydromorphological pressures and restoration measures, allowing users to trace relevant information efficiently.

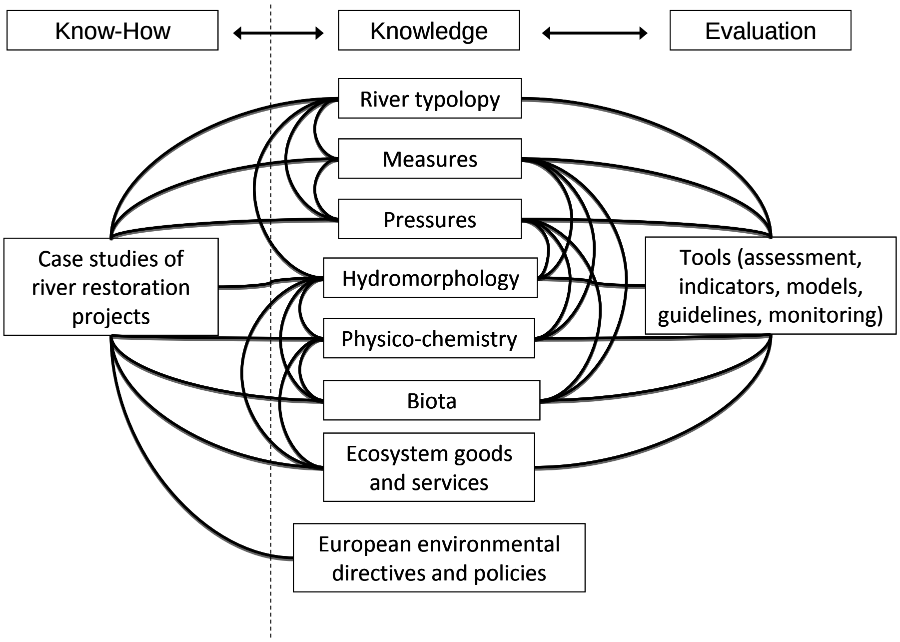

Figure 12 REFORM WIKI structure linking practical know-how, scientific knowledge to evaluation tools

The REFORM team is convinced that the large number of restoration projects realised and planned in Europe and elsewhere, along with the wealth of literature on river restoration, motivate and require tools such as WIKIs to avoid reinventing the wheel by ignoring existing scientific and practical expertise. Once designed and developed, the longevity of the river restoration WIKI merits special attention. REFORM actively seeks financing of future hosting and maintenance by public bodies to guarantee a post-project life in which scientists and practitioners continue to populate and update the WIKI. This is not trivial as it will require perseverance and awareness raising to obtain the added value. At the same time, practitioners need to be stimulated to consult such WIKIs. The history of WIKIPEDIA demonstrates that it can work.

REFORM extends the themes in the WIKI with hydromorphological models and tools. This addresses the problem of the relatively static approach to hydromorphology in the original WFD, which is seen as a major gap. Hydromorphology is not a matter of static form, but a matter of hydrodynamic and morphodynamic processes that exhibit complex responses to both degradation and restoration. Giving more space to a river, for instance, will initially produce erosion upstream, but in the long run, this will become sedimentation over long distances. Degradation and restoration may also change the cross-sectional characteristics of rivers from single-thread to multi-channel systems or vice versa, corresponding to important changes in physical habitats for biota. Finally, hydromorphological responses closely interact with vegetation development. Existing knowledge on hydromorphological responses to degradation or restoration is often ignored. REFORM makes knowledge on hydromorphological models and tools available in the WIKI, with recommendations for use, seeking a balance between state-of-the-art sophistication and suitability for practical application. What is appropriate in a particular situation will depend on the size of the river or catchment area considered. The WIKI will include guidance for this.

Questions for Workshop

- Could you recommend other forms of effective and sustainable communication in addition to the WIKI?
- On which hydromorphological aspects of river restoration would you like to receive guidance from REFORM?
- Could you give examples of unexpected hydromorphological responses to river restoration from your own experience?

3 Discussion topics for working groups

The working groups (breakout sessions) will address REFORM's outputs and plans for the next stages of the project and will also reflect on relevant activities in the EU Member States and other European countries. The following are proposed key topics to consider for the interactive exchange of participants:

FIRST DISCUSSION SESSION

Working Group 1: Lowland rivers

This block will cover key questions regarding the important hydromorphological pressures and restoration and mitigation measures in lowland rivers across Europe, such as: changing planform, meandering to straight, hardening river banks, deepening channels, main and side channels and their relation in various senses and sediments, riparian zones and floodplains, agriculture, floods, water abstraction, small-scale run of river hydropower, and navigation drivers.

Discussion points:

- What are the key factors constraining/impeding ecosystem functioning and restoration processes?
- Issues currently unresolved in RBMPs for lowland rivers and key hydromorphological measures for the 2nd round of PoMs
- River restoration in catchments largely affected by land use changes (especially by agriculture). Successful experiences and future approaches for restoration at the catchment and at a more local scale.
- Should restoration in low energy rivers be process-based or pattern-based?

Working Group 2: Highland/midland rivers

This block will cover key questions regarding the important hydromorphological pressures and restoration and mitigation measures in highland/midland rivers across Europe such as: land use change, hydropower, storage pressures, flow disruptions, break of continuity, and sediments.

Discussion points:

- What are the key factors constraining/impeding ecosystem functioning and restoration processes?
- Integration of hydropeaking and flushing flows in medium and long term decision making (river basin management planning).
- Issues currently unresolved in RBMPs for highland/midland rivers and key

hydromorphological measures for the 2nd round of PoMs.

Working Group 3: Mediterranean rivers

This block will cover key questions regarding the important hydromorphological pressures and restoration and mitigation measures in Mediterranean rivers across Europe such as: flow regulation and water storage (dams, reservoirs), water withdrawal (e.g. potable supply, irrigation, power generation, intercatchment transfer), and sediment retention.

Discussion points:

- What are the key factors constraining/impeding ecosystem functioning and restoration processes?
- Environmental flow regime definition (in intermittent rivers, connected to hydropeaking, flushing flows); Successful experience with minimum flow regime establishment (role of consultation)
- Integration of hydropeaking and flushing flows in medium and long term decision making (river basin management planning)
- Successful experiences with measures for sediment management in reservoirs
- Issues currently unresolved in Mediterranean rivers and key hydromorphological measures for the 2nd round of PoMs

SECOND DISCUSSION SESSION

Working Group 4: Unravelling the impact of hydromorphological pressures in multiple-pressure settings

This block will cover cause-effect issues (e.g. DPSIR in multi-pressure environments).

Discussion points:

- What are your views on disentangling hydromorphological pressures from one another and from other types of pressures?
- What do you need to manage hydromorphological pressures in multi-pressure systems? What influence does delivery of the 2nd round of RBMPs have on your requirements?
- How would you develop road maps that deliver hydromorphologically sensitive indicators for the biological quality elements?

Working Group 5: Designing programmes of measures

This block will cover scaling issues and programmes of measures for river basins.

Discussion points:

- How to design cost-effective programmes of measures for river basins? What tools are needed to support this design?
- How do we estimate the effectiveness of some potential measures?
- How to start drafting the 2nd round of PoMs while the above-mentioned tools are still in development?
- Are the sets of measures considered for the first RBMPs enough for the drafting of the 2nd round of PoMs or are key measures for specific pressures still missing?
- How can we integrate PoMs with other users water resource needs and priorities, e.g. hydropower and flood prevention measures?

Working Group 6: Heavily modified water bodies

This block will cover target setting in highly modified environments (e.g. HMWBs)

Discussion points:

- How do we select the type and size of restoration and mitigation measures for Heavily Modified Water Bodies? How do we forecast the benefits of these measures in HMWBs?
- How can we quantify the influence of hydromorphology for HMWB, as this will set the scope for reaching good ecological potential?
- Criteria for designation of HMWBs (based largely on expert judgement in the first RBMPs)
- Approaches for quantifying targets for GEP at water body level. Main indicators to be implemented for GEP definition
- Integrating river restoration with the socio-economic drivers modifying river ecosystems.

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