THEME: Environment (including climate change)

TOPIC: ENV.2011.2.1.2-1 Hydromorphology and ecological objectives of WFD

Collaborative project (large-scale integrating project)

Grant Agreement 282656

Duration: November 1, 2011 – October 31, 2015

REFORM

REstoring rivers FOR effective catchment Management

Deliverable	D7.4 Summer school lecture notes
Title	Lecture notes of the summer school 'Restoring regulated streams linking theory and practice'
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Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
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)	

Summary

This deliverable presents the overview and structure of the REFORM 3-day summer school ‘Restoring regulated streams linking theory and practice’ for early career researchers and young scientists. On the first day participants took part in a field excursion to river restoration projects in the vicinity of Wageningen in The Netherlands. On the second day they listened to a set of seven complementary lectures on river restoration and then provided interactive discussion. The lectures covered the following aspects: restoration planning, how does my river work?, what’s wrong?, hydromorphological and biological assessment and how can we improve through restoration? On the last day participants used the theory and information from the lectures to prepare and present their view on how to restore the streams visited during the field visit.

The summer school took place in Wageningen (The Netherlands) from 27 – 29 June 2015. Careful planning of the course has made it possible to use the course outputs for those interested in teaching river restoration, wherever river or stream restoration projects are available. The complete PowerPoint presentations and the video-recorded lectures are available online and can be used for teaching and training purposes.

Acknowledgements

REFORM receives funding from the European Union’s Seventh Programme for research, technological development and demonstration under Grant Agreement No. 282656.

Table of Contents

1. Summer school scope and objectives

The REFORM summer school was held in Wageningen, The Netherlands. It was aimed at students and early career researchers and covered the topic “Restoring regulated streams linking theory and practice”. Experts in a range of disciplines such as hydrology, morphology and ecology addressed key topics for cost-effective river rehabilitation planning, discussed problems and identified solutions. The 3-day programme was interactive, it encouraged group discussions and participants applied theory to practice by drafting a restoration strategy.

Despite the rapid increase in river restoration projects, many restoration efforts fail or fall short of their objectives. There is a paucity of information about the effectiveness of restoration efforts because often they are not fully evaluated in terms of success or reasons for success or failure. This largely arises because a fundamental lack of understanding of the planning, design and implementation stage of rehabilitation schemes. Current river restoration also encounters obstacles as a result of societal demands, particularly through a selected number of ecosystem services. The summer school overviewed these common problems or reasons for failure and the potential for restoring river ecosystems to optimize benefits accrued for biodiversity and ecosystem services, whilst considering climate change effects on the ability to deliver these outcomes.

A planning framework systematically guided participants through the two main planning stages of river restoration 1) catchment scale & 2) project cycle. Project planning at a catchment scale ensures river restoration objectives are set to improve ecological status at a river basin level through the Programme of Measures, defined by institutional, regional and national policy. Therefore, subsequent decisions for smaller, local scale river restoration will still benefit at a larger catchment scale. Tools and techniques to solve problems and produce strategies for the execution of appropriate restoration projects to meet specific environmental and social objectives as well as project evaluation methods were discussed throughout the summer school.

The summer school was a 3-day event:

- Day 1 – Introduced the summer school and field visit to two contrasting stream restoration projects.
- Day 2 – Lectures in the conceptual background of assessing hydromorphological modification of streams and rivers, ecological status and identifying appropriate restoration measures considering the socio-economic context.
- Day 3 - Participants applied theory on the visited restoration project to draft a restoration plan.

2. Time schedule

2.1 Day 1 – Saturday 27th June Field excursion

The field excursion visited two contrasting streams (Leuvenumse /Hierdense beek; Lunterse beek) with different forms of land use and stream restoration. During the field visit experts overviewed the reasons for river degradation and the restoration options applied at each of the sites. The excursion was guided by Christian Huising and Maarten Veldhuis (Water Board Vallei and Veluwe), Rob Gerritsen (recently retired; formerly Water Board Vallei and Veluwe) and Ralf and Piet Verdonschot (Alterra). Participants were encouraged to ask questions and initiate discussions to solve problems and produce strategies to meet specific environmental and societal objectives.

Table 1 Time schedule for the field excursion

TIME	LOCATION
09:00	Travel Wageningen – Leuvenum
10:00	Restaurant de Zwarte Boer - welcome with coffee Introduction Summer School & Excursion
10:45 – 11:00	Travel Leuvenum - Uddel
11:00 – 11:45	Agricultural land use around Uddel
11:45 – 12:00	Travel Uddel – Leuvenum
12:00 – 15:00	Restoration programme Leuvenumse & Hierdense Beek
15:00 – 16:00	Travel Leuvenum – Renswoude
16:00 – 18:00	Stream restoration project Lunterse Beek
18:00 – 18:45	Travel Lunterse beek – Hof van Wageningen

2.2 Day 2 – Sunday 28th June Lectures

During the second day of the programme students were taught how to plan restoration schemes, considering the two main planning stages 1) catchment scale and 2) project specific scale. The theory for assessing degradation, identifying suitable restoration measures and other stages of the planning process were taught and discussed. A number of tools and guidelines for best practise, to measure performance and determine appropriate targets for river restoration were discussed through a sequence of lectures (Table 2). Lectures were video-recorded and are available for viewing at https://www.youtube.com/playlist?list=PLKAZHri1nLrYituXeVn4KR_5p3_y6J0vF.

Table 2 Time schedule for the lectures

TIME	LECTURE *30 minutes followed by 10 minute discussion*
09:00	Planning + CBA (Prof. Ian Cowx)
09.40	Hydromorphological Framework (Prof. Angela Gurnell)
10.20	Coffee break
11.00	Hydromorphological Assessment (Prof. Massimo Rinaldi)
11.40	Biological Assessment (Dr. Christian Wolter)
12.20	Lunch
13.30	Hydromorphological degradation & impact on biota (Dr. Nikolai Friberg)
14.10	Selection of restoration measures (Dr. Jochem Kail)
14.50	Coffee break
15.30	Applying REFORM (Dr. Gertjan Geerling)
16.10	Restoration schemes set up (Dr. Ian Cowx & Dr. Christian Wolter)
17.00	FINISH
18.30	SUMMER SCHOOL DINNER

2.3 Day 3 – Monday 29th June Planning restoration schemes

Participants were divided into groups and were given the task to produce draft restoration planning frameworks using the knowledge they acquired from the previous two days. Each group chose one of the restoration schemes from the field visit and discussed current restoration measures and possible options for improvement. They were encouraged to use the experts around them in addition to the REFORM WIKI, a knowledge and information web-based tool developed to guide practitioners through the planning stages of river restoration. The Summer School ended with participants presenting their restoration schemes and a fruitful discussion.

Table 3 Time schedule day 3 to draft a restoration plan

TIME	AGENDA
09:00 – 10.30	I. Group work – Planning restoration scheme
10.30 – 10.45	Coffee
10.45 – 11.30	II. Discussion time – Lecturers present
11.30 - 12.30	III. Group work – Planning restoration scheme
12.30 – 13.30	Lunch
13.30 – 14.30	IV. Presentations
14.30 – 15.15	V. Discussion
15.15 – 15.30	Closure

Task list Day 3

Preparation of restoration plan

- Split into your groups and use one of the case study sites to plan your own restoration scheme.
- Apply what you have been taught in the previous two days to guide you through the planning process.
- You will have time allotted to discuss your ideas with lecturers, who will advise on best practise restoration.
- Day will finish with each group presenting their restoration scheme.

Session I. Group work: review of study visits

- Review objectives of case study restoration schemes: Needs for preparing restoration schemes - Defining objectives (SMART).
- Pressures and issues arising in study sites – preparation of a problem tree – cause effect.
- Decide on specific measures – needs assessment, impact assessment.
- Constraints – regulatory, cost, conflicting societal objectives, ownership.
- Discussion with experts.

Session II. Discussion with experts

- Opportunity to ask questions of experts.
- Discussions with presenters from Day 2 on feasibility of actions.

Session III. Group work - Development of restoration project plan

- Prepare provisional scenarios for restoration at study sites
  - Opportunities for restoration
  - Options analysis – measures (advantages and disadvantages)
- Develop planning framework, constraints, other options for restoration etc…
- Preparation of presentations of planning framework for case study areas.

3. Field excursion

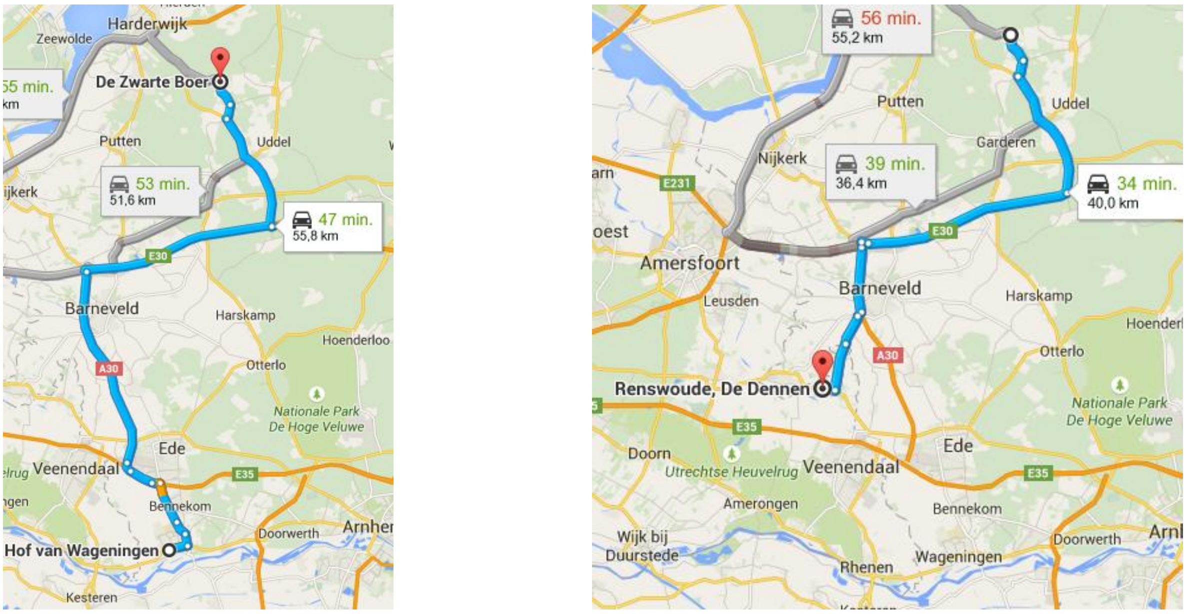
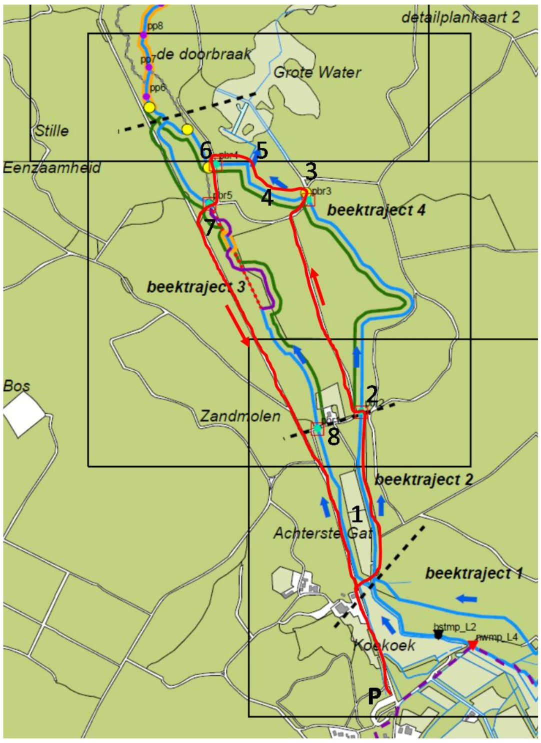


Figure 1 Excursion sites: 1. Hierdense / Leuvenumse beek; 2. Lunterse beek



Leuvenumse beek walk

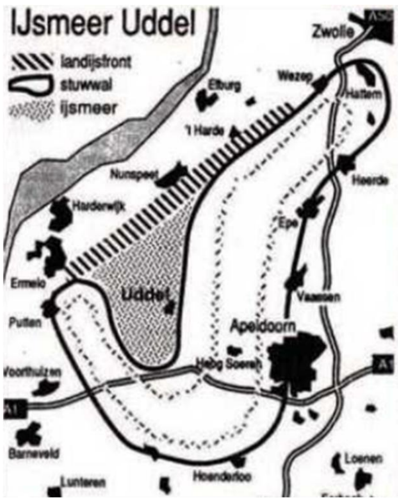
1. Floodplain reconnection (fish spawning area)
2. Not restored, example of typical channelized reach
3. Sand suppletion
4. Addition of wood
5. Floodplain reconnection (water retention area)
6. Sand suppletion
7. Reconnection of old meanders
8. Historical site (former water mill)

route

Figure 2 Walking route and points of interest Hierdense and Leuvenumse beek

3.1 *"Building with nature" in the Hierdense Beek*

The Hierdense Beek is a lowland stream situated on the north site of the Veluwe; the largest push moraine in The Netherlands and for a lowland stream it has a considerable slope. The catchment consists of a main stream and more than 20 tributaries. The upstream part lies in the agricultural enclave Uddel-Elspeet and flows approximately 18 km to the north where it discharges in to Lake Veluwe. The stream responds quickly to rainfall. At the middle part of the stream, in the Leuvenumse forest, water is lost due to the absence of a clay layer that is present further upstream. For the rather flat Netherlands the slope is relatively large with 1.3 m/km. There is year-round discharge with peak around 1 m^3/s (1 year ARP).



A stream exists at the bone-dry sandy Veluwe with deep ground water levels and the reason for this is that the catchment is situated on an impermeable clay layer at a depth of 20-25 m below surface. This clay layer originated from the Saale glaciation, 150,000 years ago. There used to be a glacial lake locked between the push wall and the ice wall. Erosion of the push moraine resulted in clay deposition. In a later stage the lake was filled with sand and gravel of 20 m thick. Due to this clay layer the stream can exist.

Approximately 12,000 years ago peat was present and acted like a sponge and as a consequence the discharge was much more stable than today. In the 19th Century the peat was mined and the stream became increasingly more dynamic, resulting in erosion at peak discharges and causing the stream to incise. From the 1300s the stream was also used for hydropower. The stream was straightened, channelized and impounded to conserve the energy. There were several paper mills. Occasionally, sand blows threatened the stream and as a result embankments were constructed along the stream. In the 20th Century agriculture and sewer overflows polluted the stream and reduced the ecological health of the stream, but this has improved considerably by regulation and techniques.

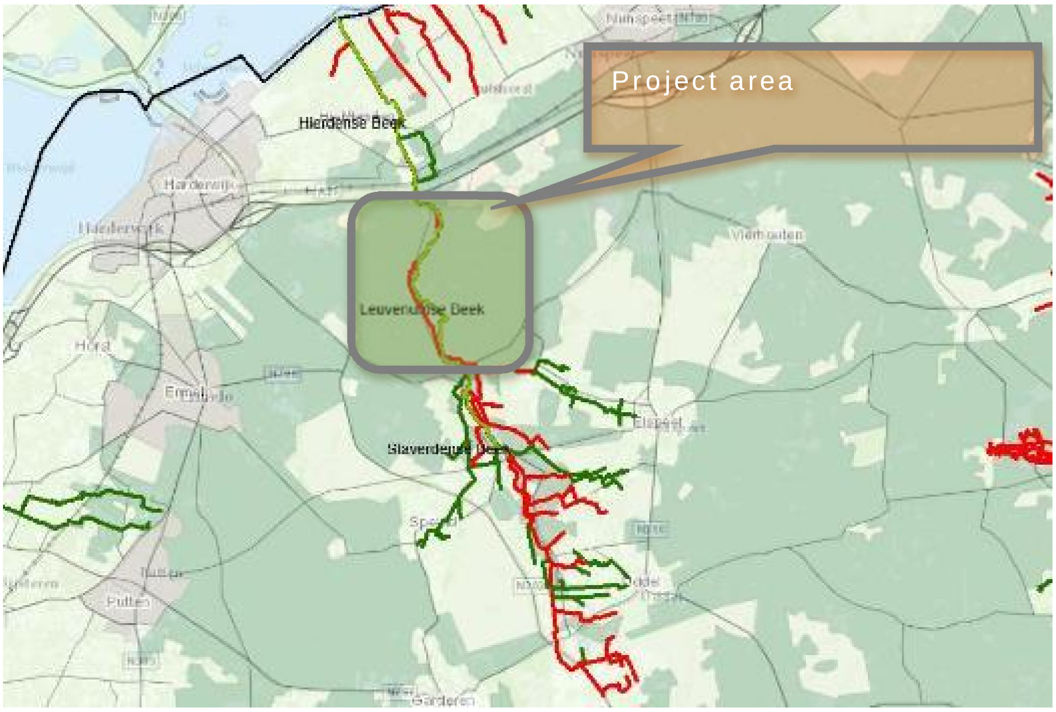


Figure 3 Overview of the project area

3.1.1 Problem definition

The Hierdense Beek does not meet the requirements of the EU Water Framework Directive (WFD 2000/60/EC) and HEN (provincial ecological policy) objectives. Desiccation of wetland nature occurs (not enough water with the proper quality) in the stream valley. Causes are:

- The stream has incised too deep, there is lack of structure and it has a straight stream path;
- There is pile planking throughout
- There is too much discharge dynamic
- There are fish migration bottlenecks
- Too much maintenance is undertaken
- Nutrient levels are too high

3.1.2 Objectives

The main objectives for the Hierdense Beek are:

- To reach Good Ecological Potential (GEP) in the designated WFD body
- Increase habitat diversity (more wood and leaves, gravel and mud) and flow velocity
- Desiccation prevention
- Conservation of the Natura 2000 area
- Contribution to the provincial HEN objectives
- Reduce the inundation downstream in the catchment

- Contribute to the ecological connection zone (EVZ) Hierdense Poort

3.1.3 Measures

The following measures have been realized:

- Shallow the stream by inserting sand
- Insert dead wood patches to improve structure and sedimentation of sand
- Restoration of historical meanders
- Restoration of the natural spring sources by filling excavated channels
- Better utilization of the natural depressions of inundation areas

3.1.4 Building with Nature

The measures were proposed according to the 'Building with Nature' concept, to make use of natural processes instead of constructing instant solutions. An example is the introduction of sand with the idea that the stream will transport the sand to deep areas where the flow velocities are low. Furthermore, dead wood is a natural phenomenon in a forest stream. Introducing this process will allow wood to fall in to the stream and aid future management. The reasons that the Building with Nature concept was used are:

- The effectiveness of the existing restoration principles (design/realisation) is limited
- Enthusiasm and drive for innovation and implementation of 'new' design and realisation principles
- Sufficient space available (physical and time/money)
- Positive experiences and results from other projects
- Building with Nature has lower investment costs and offers more perspectives

Figure 4 "Old-fashioned" restoration (left) and building with nature (right)

3.2 *Impression from the field excursion* – *Leuvenumse & Hierdense Beek*

Figure 5 Agricultural land use in the upstream parts of the catchment

Figure 6 Floodplain reconnection: fish spawning area (left); naturalised stream with aquatic vegetation (right)

Figure 7 Sand supplementation (top); wood addition (bottom)

Figure 8 Explanation of the socio-economic context and the need and choice for the restoration measures

3.3 *Stream restoration Lunterse Beek*

The “Creek” the Lunterse Beek is a relatively small stream with high dynamics and has a maximum flows are around 7 m^3/s (return period of 100 years). In the summer it almost stops flowing, but after rainfall the stream discharge responds very directly and falls back to its base flow quickly. The catchment has a size of about 12,000 hectares and 90% of the catchment is unpaved (agriculture or nature). Part of the catchment is the Veluwe Massive, the largest push moraine in The Netherlands and has considerable slopes for Dutch standards. This part of the catchment is mainly sandy underground. A high nutrient load characterizes the stream, which complicates restoration and the options to create a more natural environment. Two restoration projects have been identified in the neighborhood of the village Renswoude (Figure 9). The most upstream project: Wittenoord was completed in 2012 and the more downstream project Wolfswinkel-Klein Engelaar was finished in 2014. A summary is given for each project.

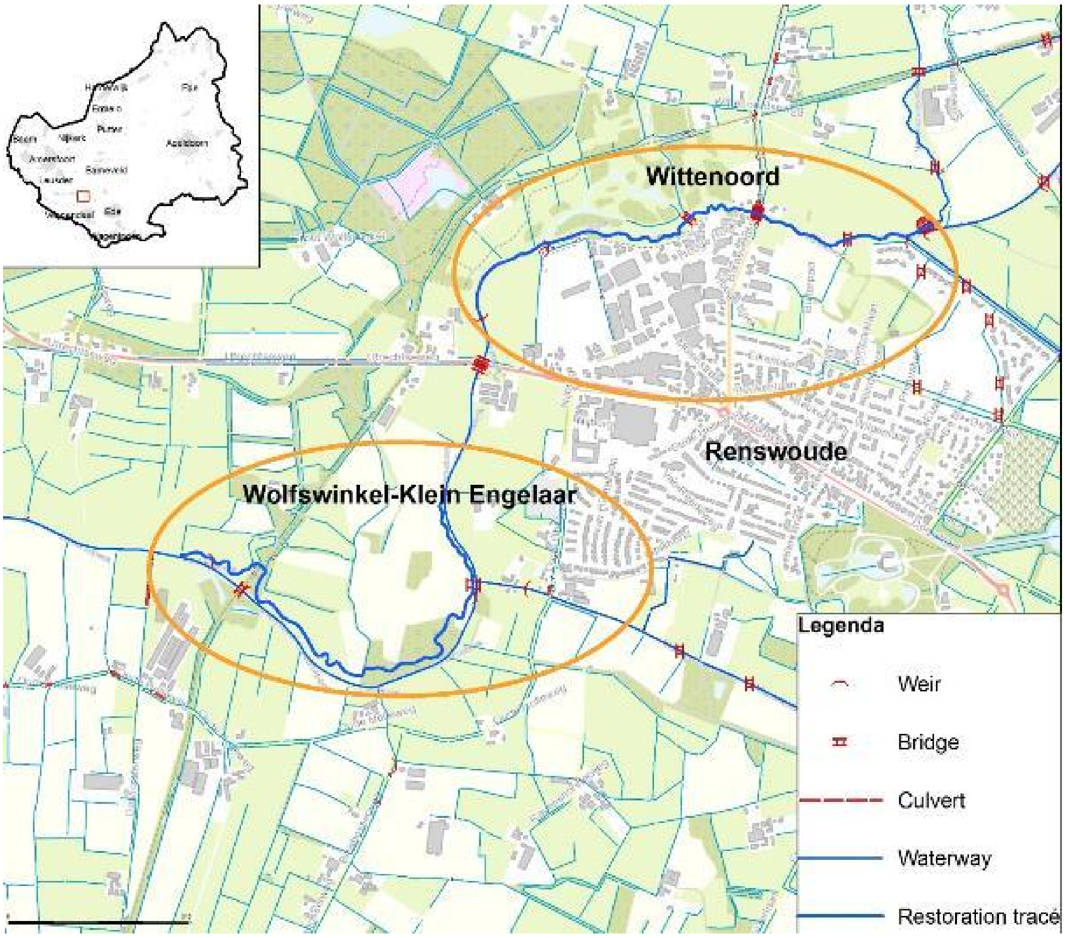


Figure 9 Restoration projects Wittenoord and Wolfswinkel

The upstream project: Wittenoord

Together with STOWA (foundation for applied water management), other water boards and universities, a research program was undertaken for several river restoration projects in The Netherlands, among which the Lunterse Beek. In this program existing and innovative measures for improving water quality were investigated. Water quality is the backbone of the WFD. The goal of the restoration programme was to establish moderated discharge dynamics and stable and diverse habitat patterns by taking coherent hydrological and morphological measures.

Creating a more natural creek was not as easy as it seems. The Lunterse Beek catchment has changed radically. The dynamics have changed by deforesting, urbanization, agriculture (drainage) and regulation of the rivers. The Lunterse Beek was channelized, widened and deepened. Due to these changes the water hardly flows and almost stands still in summer. Another disturbance factor is maintenance, because all vegetation, dead trees and sometimes sediment are removed several times a year. These are the natural obstacles that provide shelter and habitat for various organisms. As mentioned the water quality is poor and has exacerbated by intensive agriculture, which causes a large inflow of nutrients.

A key characteristic of a natural creek is the continuity of flowing water and a varied creek bed, including structures like dead wood to create stream variation. For the project Wittenoord in the Lunterse Beek several measures were taken:

- Making the creek shallow and less wide. Inundation may occur more often;
- Creating a inundation zone, which contains accompanying creek nature;
- Inserting dead wood in the creek.

Monitoring of the Lunterse Beek

- On forehand the null-situation was quantified;
- After the measures this was done again to evaluate the effects;
- There is a reference track to determine temporal changes.

In the creek hydrological, morphological and biological changes are monitored (discharge, velocities, creek bed, substrate patterns, sediments, chemicals, macro fauna, inundations, vegetation and seeds).

Hydrology:

- Discharge measuring equipment was placed;
- Several water level measuring equipment was placed.
- Q-h relations and cumulative frequency curves are derived and analyzed. These show how often certain discharges/depths occur in a year. Also to show how often inundation of the floodplain occurs.

Morphology:

- With GPS the creek bed is measured every 6-8 weeks
- Length profiles are derived

Figure 10 shows the high dynamics of the Lunterse Beek compared to 3 other creeks.

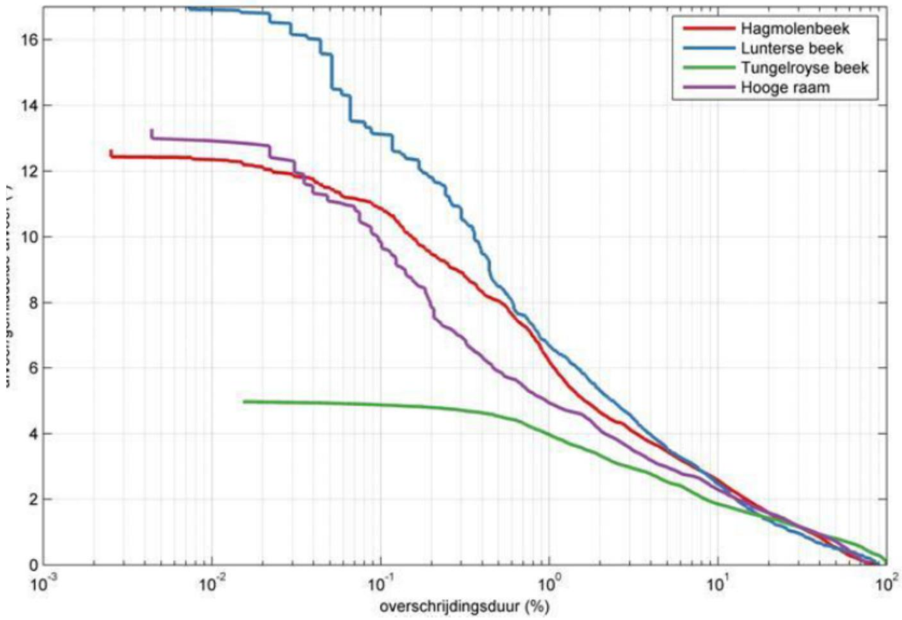


Figure 10 Discharge duration graph

Figure 11 shows the water depths duration. The circles show when the winter bed inundates. The change in water depth of the Lunterse Beek is lower. This is because Lunterse Beek at Wittenoord has a relatively wide and deep floodplain, which mitigates the peaks.

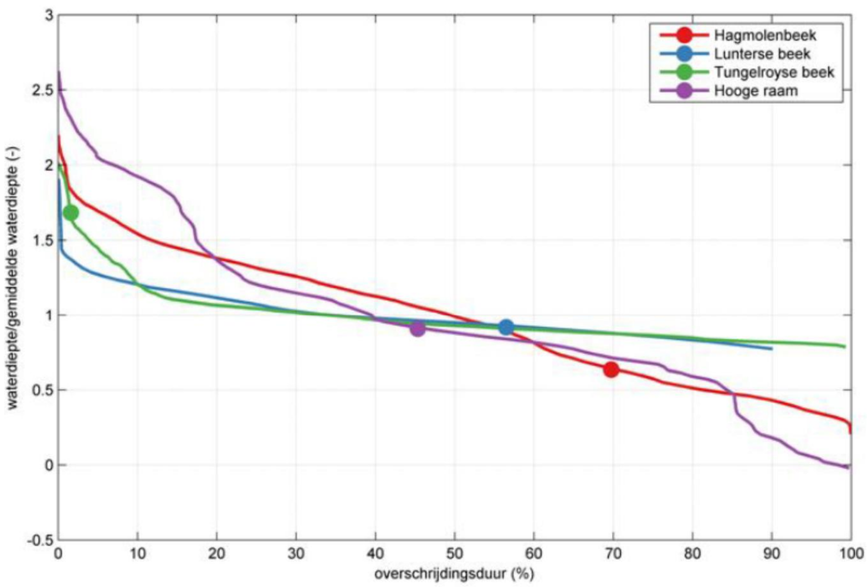


Figure 11 Water depth

Figure 12 shows the length profile. The red line shows the initial slope. The slope started with 0.9 m/km and has decreased to 0.2 m/km in 191 days. This shows a lot of morphological activity. Upstream erosion and downstream sedimentation.

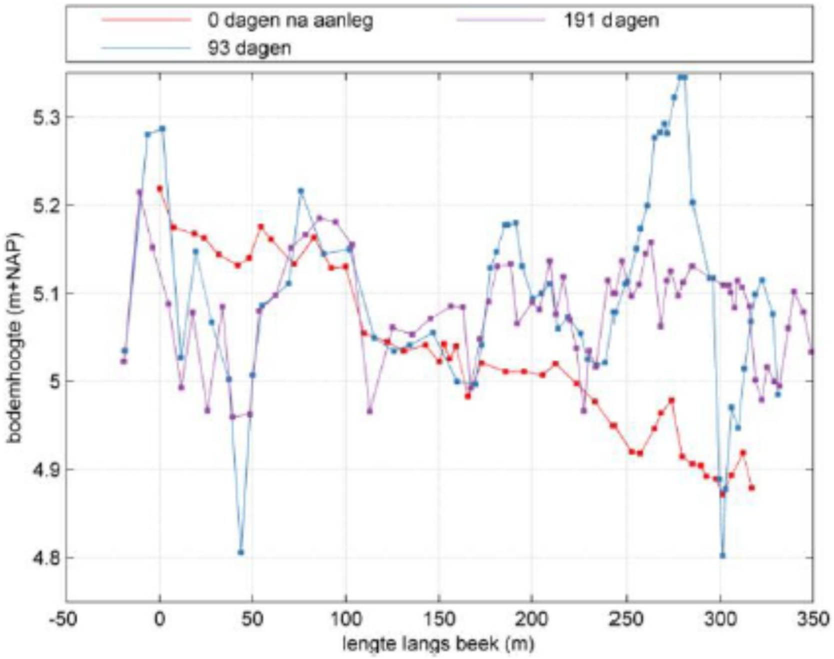


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Figure 12 Length profile

Figure 13 shows the cross sections. The meander curves are incised. On the inside curves sedimentation takes place and on the outside erosion. Along the straight sections less changes occur.

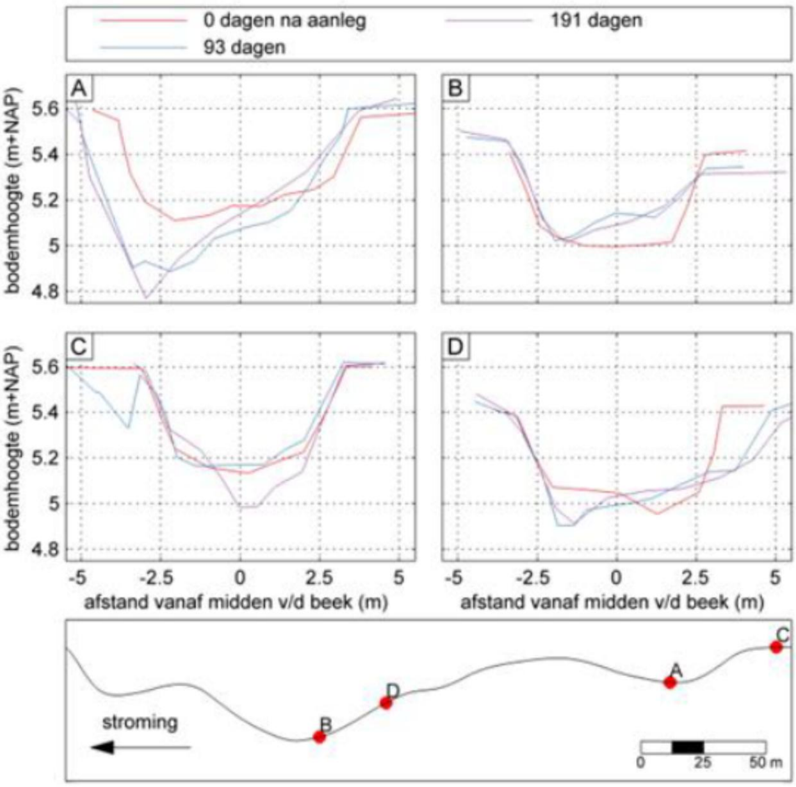


Figure 13 Cross sections

Figure 14 shows the morphological changes. A lot of sand transportation was observed. Also one of the meanders was cut off. The old meander was filled with sediment. An explanation for this phenomenon is that the newly constructed meanders consist of loss material and are susceptible for erosion. The creek has 'searched' its old canalized track. Another explanation can be that the meander wave length of the excavated meanders does not match this type of creek.

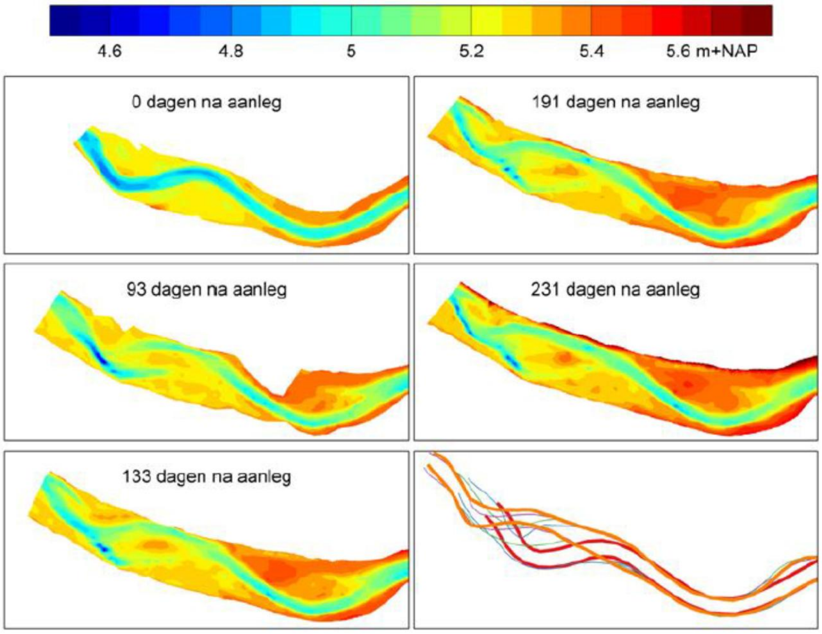


Figure 14 Morphological changes

Vegetation:

- Perpendicular to the creek, moisture gradient was measured
- Different seed traps were placed
- Water levels were measured
- Deposition, sprouting and survival were measured

Good results are not available yet. First observations seem to indicate lots of seed input in the creek dip; selective sprouting of species along the moisture gradient; increase in species after the restoration project. Closer to the creek more seeds were found. This indicates that many seeds are transported and deposited by the creek.

Macro-invertebrates:

- Insertion of dead wood
- Macro-invertebrate sampling with a Surber-sampler.
- Velocity measurements
- Substrate characterization

There are no good results available yet. The first results show that many rheophilic species cannot resist higher flow velocities (>50 cm/s). For species that can live in stagnant water as well as streaming water the threshold is even lower (>20-30 cm/s). Also it seems that the number of species have slightly decreased in the first year after restoration. In the second year there were more species and less indicators of stagnant water present.

The dead wood was inserted in the creek. However after a few peaks the creek 'decided' to find its way around the dead wood patches and flows now alongside of the dead wood instead of through it.

The results so far are that the density of the individuals of the macro-invertebrates (bio-mass) has strongly increased. In the downstream section of Wittenoord, where sedimentation has taken place, most observed species are mainly eutrophic species living in muddy environment. In the upstream section there are more species indicative for streaming water. Overall the total biomass has strongly increased and the diversity to some degree.

The downstream project: Wolfswinkel Klein-Engelaar

For this project the same issues existed as for Wittenoord. The main goals were to convert the straight and deep channel to a meandering shallow stream and bringing back flow velocity and variation in the stream. Due to different land uses, landscape characteristics and different interest of stakeholders the restoration project exists of 3 different sections with their own characteristics. The most upstream section exists as a two-phase profile: a narrow summer bed of 5 meter for base flow conditions and a wider flood plain to accommodate peak discharges. The summer bed meanders through the flood plain.

The middle section exists of two waterways: the partly restored historical stream bed and the existing channel. At low flow the water of the Lunterse Beek flows completely through the restored historical bed and through the existing channel flows only water of the tributary Munnikenbeek. During peak discharges the Lunterse Beek flows over a division structure into the existing channel, to limit the flood peaks through the restored stream. At this middle section the restored stream flows through existing woods and here there is no flood plain excavated. Also downstream from the division structure the summer bed is smaller, because the peak discharges are lower.

The most downstream section starts at the transition from woods to more open land. There is a smaller flood plain excavated than at the most upstream section and the flood plain is a bit higher than at Wittenoord, therefore, other vegetation will settle there. Trees have been planted in the flood plain. The stream flows back to the existing channel downstream of the existing weir. Due to this a considerable incline is realized.

3.4 *Impression from the field excursion – Lunterse Beek*

Figure 15 Remeandering, lowering of the surrounding floodplain, shoreline protection with wood and tree planting (so-called 2-stage profile)

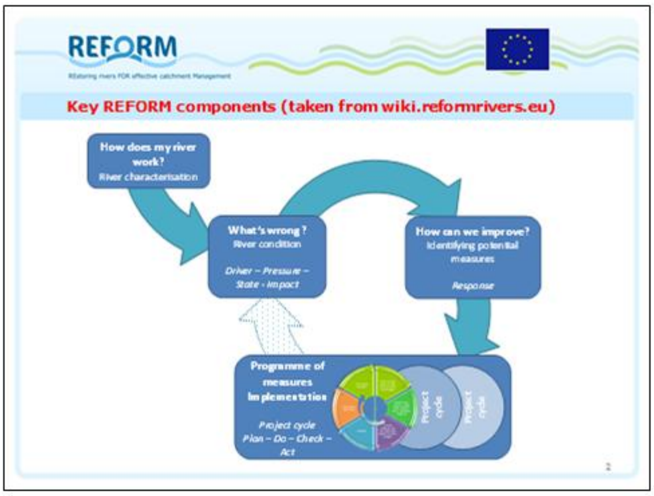
Figure 16 Excavating the former channel

Figure 17 Trade-offs and synergies with the surrounding land use: a culvert (left) controls the discharge in the restored channel and a weir (right) is still in operation to regulate water levels for the surrounding agriculture

4. Lectures

#	LECTURER	TITLE
1	Dr Tom Buijse	Opening - Hydromorphology of rivers and floodplains. What is at stake and how will REFORM contribute?
2	Prof. Ian Cowx (University of Hull International Fisheries Institute, UK)	Planning Stream and River Restoration and Cost- Benefit Analysis
3	Prof. Angela Gurnell (Queen Mary University London, UK)	The REFORM Hydromorphology Framework: Working with River Processes
4	Prof. Massimo Rinaldi (Università di Firenze, Italy)	Hydromorphological assessment
5	Dr Christian Wolter (Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany)	Biological assessment
6	Dr Nikolai Friberg (Norwegian Institute for Water Research NIVA, Norway)	Coupling hydromorphology to biotic responses: challenges in assessing river restoration outcomes
7	Dr Jochem Kail (University of Duisburg- Essen, Germany)	Selection of restoration measures: general principles and approaches, potential restoration measures and effects on river morphology and biota
8	Dr Gertjan Geerling (Deltares / Radboud University, Nijmegen, The Netherlands)	Recap of the key REFORM steps for effective river restoration
9	Prof. Ian Cowx & Dr Christian Wolter	Restoration schemes set up

Lectures 1 to 8 have all been recorded and are available online on the video channel of STOWA (Netherlands Foundation for Applied Water Research) under the title: Summer Course | REFORM Rivers | 2015. The content of each presentation is given as an appendix. The full PowerPoint presentations are available separately on the REFORM website under summer school in the Events section. Where relevant the PowerPoint slides are supplemented with explanatory text in the note section (Figure 18).



The "Catchment Planning Cycle" as shown on the wiki.reformrivers.eu. It shows the 4 key steps in catchment planning in layman words: How does my river work?; What's wrong?; How can we improve?; Programme of measures (detailed planning and implementation). This is at the same time the structure of this lecture.

Figure 18 Where considered relevant, all PowerPoint presentations do have supplementary explanation in the note section.

5. Drafting a restoration plan

On day 3, participants prepared and presented their views on how to restore the streams visited during the field visit by applying theory and information from the lectures.

Figure 19 Preparing and presenting the participants' view on the issues at stake and the need for restoration for one of the projects visited during the field trip.

Appendix 1 – List of participants

First name	Last name	Organisation	Country
Emma	Quinlan	Environmental Protection Agency	Ireland
Enrico	Marchese	Free University of Bolzano	Italy
José Pedro	Ramião	University of Minho	Portugal
Tomáš	Galia	University of Ostrava	Czech Republic
Vaclav	Skarpich	University of Ostrava	Czech Republic
Jasper	Candel	Wageningen UR	Netherlands
Angela	Esposito	University of Naples "Federico II"	Italy
Kate	de Smeth	Vrije Universiteit Amsterdam	Netherlands
Ana	Bermejo	Polytechnic University Madrid	Spain
Ulrika	Åberg	River Restoration Centre	UK
Ela	Doganay	Temple University	USA
Tjitske	Geertsema	Wageningen University	Netherlands

Appendix 2 – overview of lectures

REFORM
REstoring rivers FOR effective catchment Management

Hydromorphology of rivers and floodplains – What is at stake and how will REFORM contribute?

Tom Buijse
Deltares
Utrecht, the Netherlands
E: tom.buijse@deltares.nl

REFORM
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Hydromorphological pressures in European surface waters

- 127 000 surface water bodies
  - 82% rivers
  - 15% lakes
  - 3% coastal and transitional waters
- HYMO pressures affecting ..
  - 40% river and transitional waters
  - 30% lakes
- Causes
  - Hydropower
  - Navigation
  - Agriculture
  - Flood protection
  - Urban development

Source: EEA report 8/2012 European waters – assessment of status and pressures

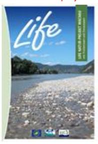
REFORM
REstoring rivers FOR effective catchment Management

How do we share expertise on river restoration?

Examples of EU funded River River restoration projects

http://wwwlife-donau-ybbsat/

Count of ProjectName	Programme		
Global objective	INTERREG	LIFE	Grand Total
Flood management	20	1	21
Integrated River Basin Management	26	1	27
River & floodplain restoration	17	114	131
Water quality improvement	4	1	5
Species conservation and management	14	55	69
Grand Total	81	172	253



http://wwwlife-wachauat/

http://webarchivenationalarchivesgovuk/20110303155229/http://wwwstreamlifeorguk/

http://wwwnaturstyrelsendk/Naturoplevelser/Beskrivelser/Vestjylland/SkjernEnge/Skjern_River_Wetlandshtm

wwwwwf.se/flodparlmussla

http://wwwhammde/lifelippeauehtml

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REstoring rivers FOR effective catchment Management

November 2011 – October 2015

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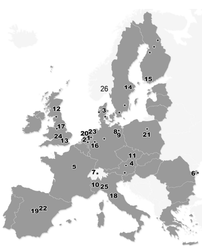
Partners



26 partners from 15 European countries

No	Name	Short name	Country
1	Stichting Deltares	Deltares	Netherlands
2	Stichting Dienst Landbouwkundig Onderzoek	Alterra	Netherlands
3	Aarhus University	AU-NERI	Denmark
4	Universitaet fuer Bodenkultur Wien	BOKU	Austria
5	Institut National de Recherche en Sciences et des Technologies pour l'Environnement et l'Agriculture	IRSTEA	France
6	Institutul National de Cercetare-Dezvoltare Delta Dunarii	DDNI	Romania
7	Swiss Federal Institute of Aquatic Science and Technology	EAWAG	Switzerland
8	Ecologic Institut Gemeinnützige Gmbh	Ecologic	Germany
9	Forschungsverbund Berlin E.V.	FVB.IGB	Germany
10	Joint Research Centre- European Commission	JRC	Belgium
11	Masaryk University	MU	Czech Republic
12	Natural Environment Research Council - Centre for Ecology and Hydrology	NERC	United Kingdom
13	Queen Mary University of London	QMUL	United Kingdom
14	Swedish University of Agricultural Sciences	SLU	Sweden
15	Finnish Environment Institute	SYKE	Finland
16	Universitaet Duisburg-Essen	UDE	Germany
17	University of Hull	UHULL	United Kingdom
18	Universita Degli Studi Di Firenze	UNIFI	Italy
19	Universidad Politecnica de Madrid	UPM	Spain
21	Warsaw University of Life Sciences	WULS	Poland
22	Centro de Estudios y Experimentacion de Obras Publicas	CEDEX	Spain
23	Dienst Landelijk Gebied	DLG	Netherlands
24	Environment Agency	EA	United Kingdom
25	Istituto Superiore per la Protezione e la Ricerca Ambientale	ISPRA	Italy
26	Norsk Institutt for Vannforskning	NIVA	Norway
27	Stichting VU-VUmc	VU-Vumc	Netherlands

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Objectives of REFORM

APPLICATION

1. Select indicators for cost-effective monitoring
2. Improve tools and guidelines for restoration

RESEARCH

1. Review existing information on river degradation and restoration
2. Develop a process-based hydromorphological framework
3. Understand how multiple stress constrains restoration
4. Assess the importance of scaling on the effectiveness of restoration
5. Develop instruments for risk and benefit analysis to support successful restoration

DISSEMINATION

1. Enlarge appreciation for the benefits of restoration


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Cooperation with ...
WISER
make use of earlier research projects (e.g. REBECCA, WISER, FORECASTER)
Restoring Europe's Rivers
RESTORE (LIFE+ Information & Communication)
ECRR
European Centre for River Restoration (ECRR)
WFD Implementation: common implementation strategy (CIS)
Lourdes Alvarellos, Gary Brierley, Johan Kling, Margaret Palmer, Hervé Piégay, Peter Pollard, Ursula Schmedtje, Bas van der Wal
Advisory Board of REFORM
MARS PROJECT
Connecting to new research projects (e.g. MARS)
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Planning for Restoration success

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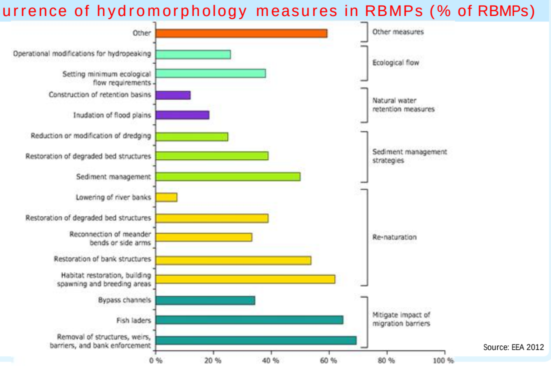
Overview

- Determining restoration success
  - Benchmarking and endpoints
  - Project planning approach
- Synergies with other sectors to improve outcomes
- Project planning and the WIKI

Why do we restore rivers? Habitat improvement

Why do we restore rivers? Improve connectivity

Occurrence of hydromorphology measures in RBMPs (% of RBMPs)



Source: EEA 2012

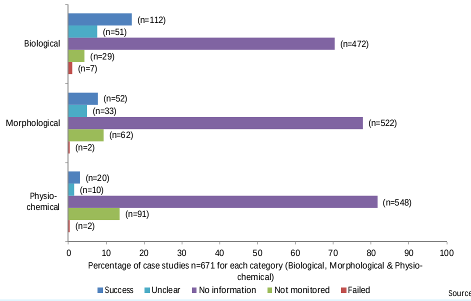
Why do we restore rivers?

Reviewed 670+ European projects, 250+ Life/Interreg, [37,000 NA projects]

- few projects establish well defined endpoint criteria
- usually linked to WFD objectives of GES/GP, HD conservation status or local actions [biodiversity improvement, habitat modification etc.]
- Rarely quantitative - weaknesses in monitoring or assessment, defining success or outcomes, and often costs and benefit information not available.

How successful are these measures? Defining outcomes

Success rate of 671 European case studies



Source: REFORM D5.1

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

- Many practitioners do not follow a systematic approach for planning restoration projects.
- Objectives often have not been explicitly formulated.
- Many restoration efforts fail or fall short of their objectives, if at all set.

Need project management tools working at river basin scale

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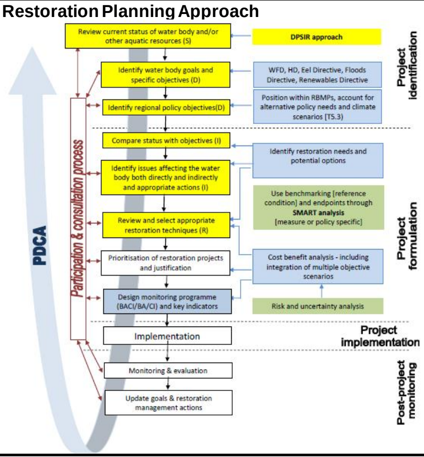
Restoration Planning Approach



It applies various planning tools:

PDCA
Plan, Do, Check, Act

DPSIR (Yellow)
Driver, Pressure, State, Impact, Response

SMART
Specific, Measurable, Attainable, Relevant, Time bound.

Source: REFORM D5.1

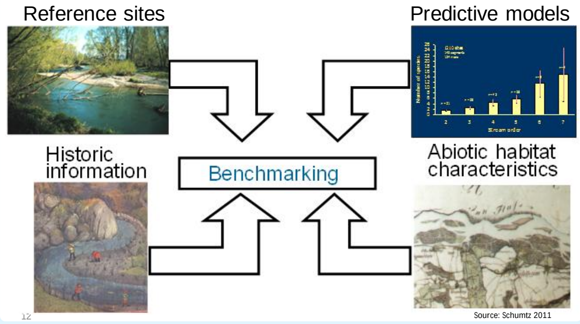
Restoration Planning Approach

- Need to capture risks and uncertainties
- Need to consider effectiveness in different river styles
- Need to recognise biological responses have long timescales
- Need tool that accounts for social ecological coupling ecosystem services)
- Need to explore synergies between sectors
- REQUIRE TOOL FOR MANAGING EXPECTATIONS AND DESCRIBING MILESTONES AND INCLUDE TIMESCALES

Programme of measures

- What is the way forward?
- We cannot wait for a complete understanding of river ecosystem before we decide how to target improvement programmes.
- Need some type of benchmarking to define objectives
- Benchmarking as a tool should be feasible, practical and measureable; the latter especially to help guide future decision support tools.
- Questions need to be answered on what needs to be restored, why and how?
- This must be coupled within a social and economic framework to meet societal needs and aspirations to address stakeholder/user interactions and conflicts.

Developing benchmarking conditions



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Source: Schumtz 2011

Draw on example of the Kissimmee River Restoration

DEFINING SUCCESS: EXPECTATIONS FOR RESTORATION OF THE KISSIMMEE RIVER

Edited by D.H. Anderson, S.G. Bousquin, G.E. Williams, and D.J. Colangelo (2005)

Expectations of the Kissimmee River Restoration

Nine describe abiotic responses for hydrology, geomorphology, and water quality.

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

Five expectations describe changes in plant communities in the river channel and floodplain

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

Six expectations describe invertebrate and amphibian and reptile communities.

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

Five expectations describe anticipated changes in fish and bird communities.

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

Source: Anderson et al. 2005

Expectations of the Kissimmee River Restoration

Modify standardized format from Kissimmee: each expectation document contains the following twelve pieces of information

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.

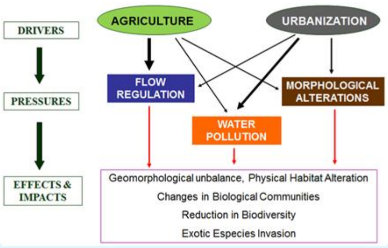
Source: Anderson et al. 2005

Expectations of the Kissimmee River Restoration

- Capture risks and uncertainties as new attribute
- Social ecological coupling and integration with other drivers incorporated into external constraints
- Time course provides milestones where adjustments are made to expectations and expected outcomes

Develop synergies between ecological restoration and ....

Promote current approaches where climate and land use change are taken into account for the choice and design of river restoration practices that promote wider ecosystem and societal benefits



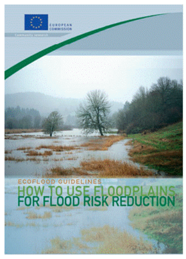
Synergies between ecological restoration and ....

- Flood protection (Room for Rivers, Ecoflood)
- Navigation (parallel dams; wave action)
- Agriculture (land use of riparian zones; sediment dynamics)
- Hydropower (Environmental flows; hydropeaking)
- Urban development

To ...

Expand the potential for restoration

Widen societal accpetance for restoration



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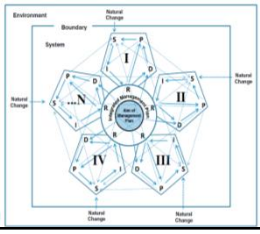
DPSIR approach

Use nested DPSIR approach to assess scope for coupled strategies to incorporate responses to climate [flood protection] and land use [e.g. sedimentation] and renewable energy demands [hydropower] with improvements of ecological status – win-win scenarios.



Nested DPSIR framework for the management of the aquatic environment (source: Atkins *et al.*, 2011a).

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DPSIR approach

Structure of inputs related to DPSIR

- Drivers - what are the underlying needs and motives of the sectors
- Pressures –link to WFD pressures
- State – current and future status of pressure status
- Impact – what is the impact on BQEs in terms of change in status - how is the hydromorphological state and functioning altered
- Response – what measures are adopted to respond to impact -

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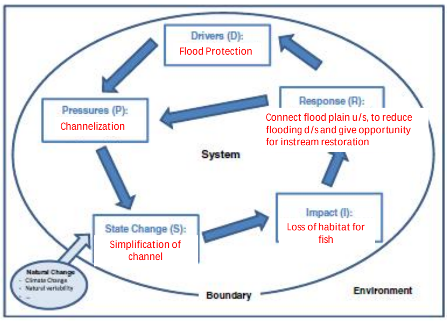
DPSIR approach



Atkins et al. 2011

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Example of DPSIR tables – hydropower

DRIVER	Pressures	State	Impact	Response
HYDROPOWER Renewable Energy Directive	Hydropeaking	Disturbance of flow regime	Loss of habitat diversity and disturbance or normal feeding and growth patterns of aquatic fauna & flora	Improve water discharge regime to mitigate hydropeaking amplitude
	Change to hydrological regime	Altered sediment & transport		
	Impoundments	Disruption to longitudinal & lateral connectivity	Restrict or hinder fish migration.	Develop environmental flow standards
	Channelisation			
	Construction phase	Removal of top soil and vegetation	Fish mortality	Install fish pass/ bypass channels
	Turbines	Mechanical damage	Delay fish mortality to stress	Facilitate d/s migration

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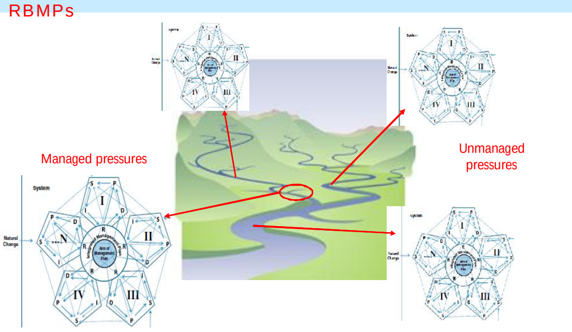
But we work on a complex system.....Nested DPSIR for RBMPs



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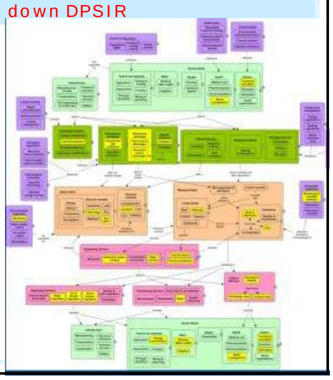
BENEFIT from breaking down DPSIR

Concept maps for managers

- Shows how a decision maker or researcher can visualise key concepts related to particular pressures.
- To simplify important stages or examples for different pressures & sectors in to concept maps.
- Shows how a decision maker or researcher can visualise key concepts related to particular pressures.



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DPSIR approach -cross sectoral integration

Multi-criteria decision analysis – allows decision makers to examine situations where different stakeholders have different concepts of what is important and what outcomes they desire.

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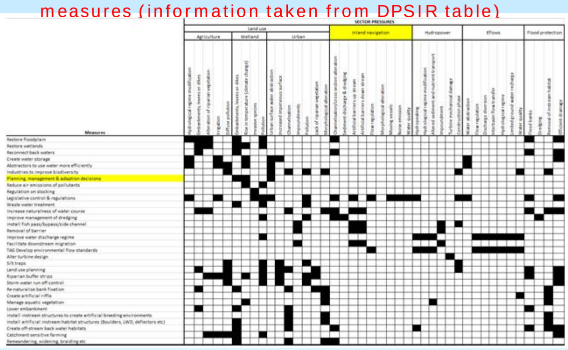
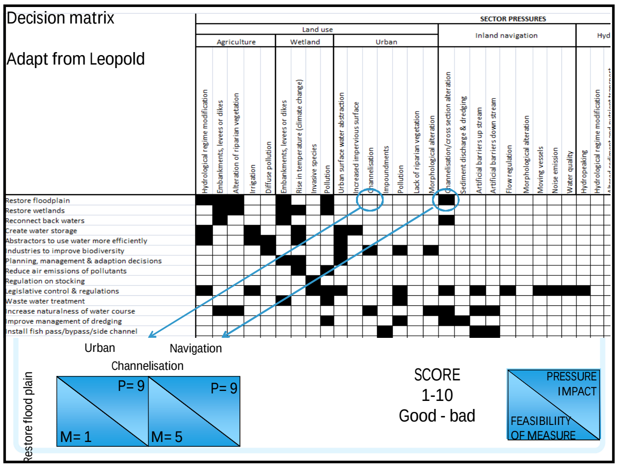
Interaction Matrix for sector pressures and measures (information taken from DPSIR table)



Decision matrix

Adapt from Leopold



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Cost Effective Restoration

1) Use protocol for reporting & predicting cost of river restoration
   - economic analysis
   - socio-economic cost
   - the role of economic assessment in policy: CBA & CEA
   - recommend cost typology

2) Requires evidence & practical guidance for cost assessment in river restoration with examples

Problem – acute lack of CBA and CEA analysis so using ecosystem services concept

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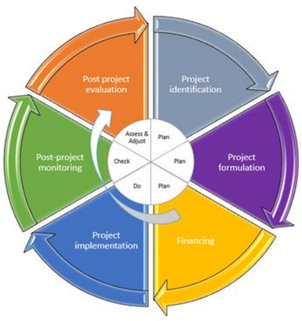
Integrated planning approach for practitioners



- Bite size pieces
- Incorporates the PDCA
- Feedback loop
- User friendly manual
- REFORM WIKI

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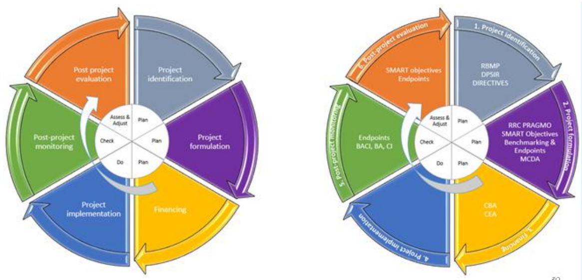
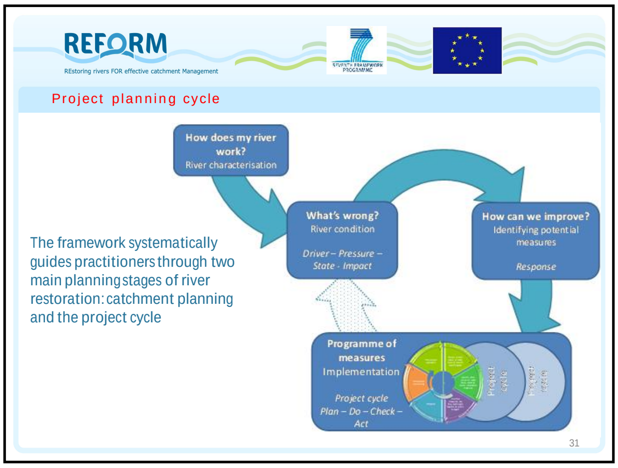
Tools & Guidelines — Tools available on REFORM WIKI

Integrated planning approach

Tools

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Project planning cycle
How does my river work?
River characterisation
What's wrong?
River condition
Driver – Pressure – State - Impact
How can we improve?
Identifying potential measures
Response
Programme of measures
Implementation
Project cycle
Plan – Do – Check – Act
The framework systematically guides practitioners through two main planning stages of river restoration: catchment planning and the project cycle
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REFORM WIKI
REFORM
Main Page
REFORM river restoration wiki
How does my river work?
What's wrong?
How can we improve?
Extra
REFORM river restoration wiki

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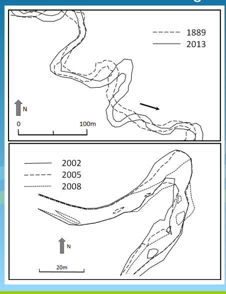
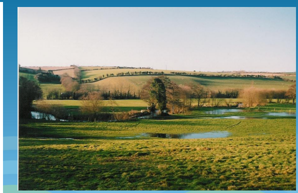
The REFORM Hydromorphology Framework: Working with River Processes





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OUTLINE

The REFORM Framework: Working with river processes

- Aims
- Analysis stages
  1. Delineation
  2. Characterisation -> Indicators
  3. Assessment
     - I: River Type
     - II: Within Reach Features (and Human Interventions)
     - III: Catchment to Reach Processes (and Human Interventions)
     - IV: Space-time linkages and trajectories of change
  4. Future scenarios
- An Example

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THE REFORM HYMO FRAMEWORK: AIMS

- to develop understanding of the space-time controls at region to reach scales on river reach hydromorphology
- to understand how reach hydromorphology has responded to processes and human interventions in the past and present and may respond in the future to a variety of likely scenarios
- to support development of sustainable management / rehabilitation solutions for river reaches that work with river processes in the context of human constraints.

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THE REFORM HYMO FRAMEWORK: ANALYSIS STAGES

ANALYSIS STAGES

1. DELINEATION: define the spatial units for which information needs to be assembled
2. CHARACTERISATION: assemble information for the spatial units
3. INDICATORS: extract indicators from the assembled information to guide assessments of the current and past character of the spatial units and how processes operating within spatial units affect their character and also the character of receiving spatial units
4. ASSESSMENT: summarise understanding of linkages across space and time, assess temporal trajectory of reach type, condition, function
5. SCENARIOS: assess likely responses to future scenarios

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THE REFORM HYMO FRAMEWORK: 1. DELINEATION

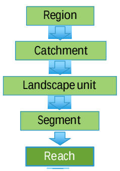
<u>Region</u>: Biogeographical region (climate-vegetation).

<u>Catchment</u>: enclosed by watershed

<u>Landscape unit</u>: topography, geology, land cover

<u>Segment</u>: major changes in gradient, catchment area, valley confinement

<u>Reach</u>: consistent planform / features, bounded by major artificial longitudinal discontinuities.



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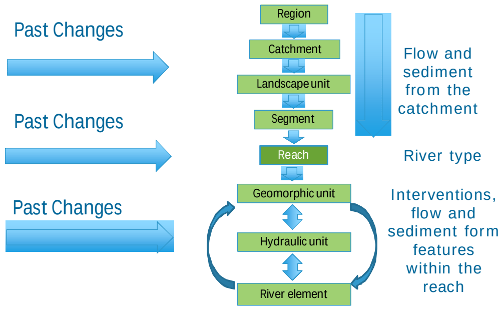
THE REFORM HYMO FRAMEWORK: 2. CHARACTERISATION -> INDICATORS



THE REFORM HYMO FRAMEWORK : 2. CHARACTERISATION -> INDICATORS

UNDERSTANDING FLOW-SEDIMENT DELIVERY

SCALE	KEY PROCESSES	EXAMPLE INDICATORS
Catchment	Water production	Average annual precipitation, Average annual water yield
Landscape Unit	Runoff production / retention	% Exposed aquifers, % Soil permeability class, % land cover classes
	Fine and coarse sediment production	Annual soil erosion, Coarse sediment source areas
River Segment	Valley features	Valley confinement and gradient, River confinement
	Flow regime and extremes	Flow regime type, Average annual flow, Base flow index, Median, 2yr 10 yr floods
	Sediment delivery and transport regime	Eroded soil delivery , Segment sediment budget
	Disruption of longitudinal continuity	Number of major blocking and spanning structures (e.g. dams, drop structures, weirs, bridges)
	Riparian corridor size, functions, succession, wood delivery	Average riparian corridor width, Continuity of riparian vegetation along river edge, Age structure of riparian vegetation

THE REFORM HYMO FRAMEWORK: 2. CHARACTERISATION -> INDICATORS

UNDERSTANDING PROCESS-FORM WITHIN A REACH

SCALE	KEY PROCESSES	EXAMPLE INDICATORS
Reach	Stream power	Specific stream power at contemporary bankfull width
	Flooding extent	% Floodplain accessible by flood water
	Channel type and dimensions	River type, Floodplain type, Average bankfull channel width, depth, slope, Bed and bank sediment size, Presence of geomorphic units typical of channel and floodplain type
	Contemporary evidence of channel adjustments	Eroding, laterally aggrading banks, Channel widening, narrowing, bed incision, bed aggradation, Vegetation encroachment
	Historical evidence of channel adjustments.	Changes in channel width, Sinuosity, braiding, anabranching indices, Rate of lateral channel movement
	Constraints on channel adjustments, water, sediment, wood continuity	Average width of erodible corridor, Longitudinal continuity, Lateral continuity
	Vegetation dynamics (riparian, aquatic vegetation and wood)	% Riparian corridor under riparian vegetation, Riparian vegetation age structure, Large wood and fallen trees in channel and riparian corridor, Aquatic plant extent, Abundance of riparian tree and large wood associated geomorphic units, Abundance of aquatic plant associated geomorphic

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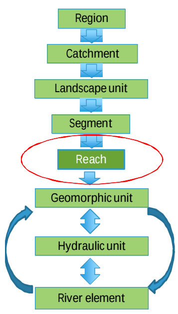
THE REFORM FRAMEWORK: 3. ASSESSMENT, I RIVER TYPE



I: RIVER TYPE. What does my reach look like?

Present river type?

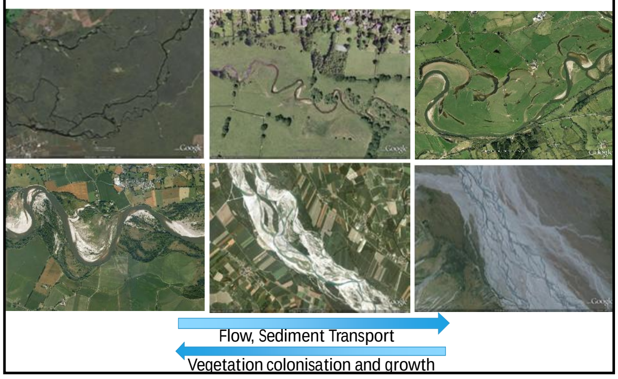
- Confined by its valley?
- One or more flowing channels?
- Straight, sinuous, meandering?
- River bed sediment (bedrock, boulders, cobbles, gravel, sand, silt, clay)?

Historical changes?

- Has the river type changed?
- Has the river moved laterally?

THE REFORM FRAMEWORK: 3. ASSESSMENT, I RIVER TYPE

THERE ARE MANY HYDROMORPHOLOGICAL RIVER TYPES



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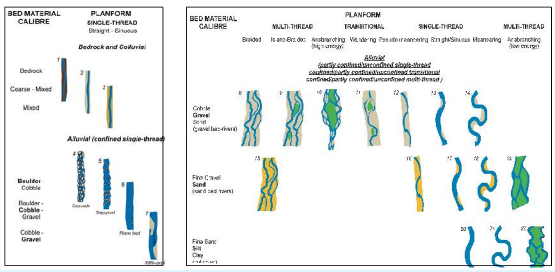
THE REFORM FRAMEWORK: 3. ASSESSMENT, I RIVER TYPE

22 river (reach) types
(Type 0 = 'artificial' if bed material is artificial)



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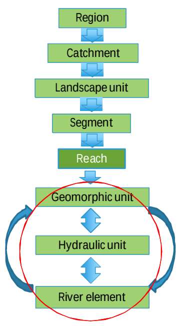
THE REFORM FRAMEWORK: 3. ASSESSMENT, II WITHIN REACH FEATURES



II: WITHIN REACH FEATURES.

Are features appropriate for the hydromorphological river type and in good condition?

Present Features?

- Features in the river channel appropriate?
- Features in the river margins appropriate?
- Features in the floodplain appropriate?

Feature Types and Causes of Changes?

- Features degraded or inappropriate?
- Features been removed / constrained by human actions?
- Floodplain features suggest a different river type in the past?

THE REFORM FRAMEWORK: 3. ASSESSMENT, II WITHIN REACH FEATURES

Type	Geomorphic Units	Stability	Description
0	Possible occasional B	Very Stable	Highly modified reaches
1	RS, C, Ra	Usually strongly confined and highly stable	Sediment supply-limited channels with no continuous alluvial bed
2	BL, C, SS, AC	Can be highly unstable	Small, steep channels at the extremities of the stream network
3	Poorly defined, featureless.	Very stable, shallow (often ephemeral) channels	Small, relatively low gradient channels at the extremities of the stream network
4	C, P	Stable for long periods but occasional catastrophic destabilisation	Very steep with coarse bed material consisting mainly of boulders and local exposures of bedrock
5	SP	Stable for long periods but occasional catastrophic destabilisation	Sequence of channel spanning accumulations of boulders and cobbles (steps) separated by pools
6	G, Ra, FB, FP	Relatively stable for long periods, but floods can induce lateral instability and avulsions	Predominantly single thread but secondary channels are sometimes present
7	R, P, G, LB	Subject to frequent shifting of bars	Coarse cobble-gravel sediments sorted to reflect the flow pattern and bed morphology
8	MCB, R, P	Usually highly unstable both laterally and vertically	Multiple channels separated by active bars (bar-braided)
9	I, MCB, R, P	Usually unstable both laterally and vertically	Distinguished from type 11 by > 20% channel area covered by islands of established vegetation
10	I, R, P	Lateral instability usually present	Islands covered by mature vegetation extend between channels
11	I, MCB, MB, R, P	Usually highly unstable both laterally and vertically	Exhibit switching from single to multi-thread

THE REFORM FRAMEWORK: 3. ASSESSMENT, II WITHIN REACH FEATURES

Type	Geomorphic Units	Stability	Description
12	Large, continuous AB, R, P	Usually unstable both laterally and vertically	Differs from type 11 in its lower sinuosity and very pronounced alternating lateral bar development
13	Large alternate (continuous) PB, R, P	Subject to frequent shifting of bars	Sinuous pattern with discontinuous bars of coarse sediment
14	R, P, PB, Ch, Co, SB, Pbe	Laterally unstable channels subject to lateral migration	Meandering pattern with frequent point bars of coarse sediment
15	B, RD	Unstable both laterally and vertically	Same morphology of 8 but with predominant sand material
16	Continuous, large AB, P, RD	Vertically unstable due to bar movement and sometimes migrate laterally	Highly sinuous baseflow and alternating bars within a straight to sinuous channel
17	R, P, PB, RD, occasional Be, SB, L, Bs	Laterally unstable channels subject to lateral migration	Same morphology of 13 but with predominant sand material
18	P, PB, RD, S, L, RSw, Bs, AC	Unstable channels subject to meander loop progression and extension with cut-offs	Same morphology of 14 but with predominant sand material
19	I, RD, L, VIB, VIBe, RD, AC	Stable	Vegetation stabilising bars between channel threads, forming islands that develop by vertical accretion of fine sediment
20	L, Bs	Very stable	Silt to silt-clay banks often with high organic content are highly cohesive
21	L, Bs, Pbe	Very stable	Similar to 20 but with higher sinuosity
22	I, L, CC, CS, Po, VIB, VIBe, AC, Bs	Very stable	Silt to silt-clay banks often with high organic content are highly cohesive; extensive islands covered by wetland vegetation

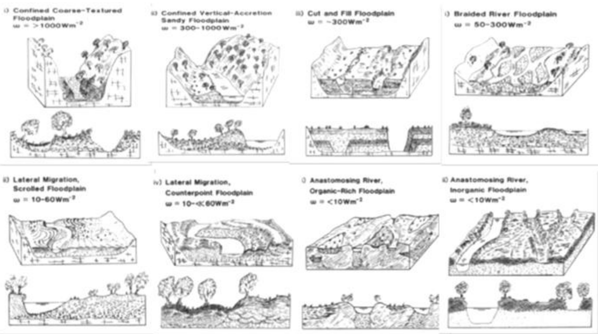
THE REFORM FRAMEWORK: 3. ASSESSMENT, II WITHIN REACH FEATURES

ERT	Floodplain Class	Floodplain Type	Bankfull Unit stream power (W m^{-2})
(1), 2, 4, 5	High energy, non-	A. Confined, coarse textured	> 1000
3, 6, 7	cohesive floodplains	B. Confined, vertical accretion	300 – 1000
8, 9, 15	Medium energy, non-	C. Braided	50 – 300
10, 11	cohesive floodplains	D. Wandering, gravel-bed	30 – 200
12, 13		E. (Sinuous / meandering) lateral migration, non-scrolled	10 – 60
13, 14		F. (Sinuous / meandering) lateral migration, scrolled	10 – 60
16, 17, 18		G. (Sinuous / meandering) lateral migration, backswamp	10 – 60
17, 18		H. (Partly-confined, sinuous / meandering) lateral migration, counterpoint	10 – 60
20, 21	Low energy,	I. Laterally stable	< 10
19, 22	cohesive floodplains	J. Anabranching (low energy), organic rich	< 10
Floodplain types defined by Nanson and Croke (1992) that are unlikely to be encountered in Europe			
20 (semi-arid)	High energy, non-cohesive floodplains	K. Unconfined, vertical accretion, sandy	300 – 600
16 (semi-arid)		L. Cut and fill	~ 300
19, 22 (semi-arid)	Low energy, cohesive floodplains	M. Anabranching (low energy), inorganic	< 10

(Classification from Nanson and Croke, 1992)

THE REFORM FRAMEWORK: 3. ASSESSMENT, II WITHIN REACH FEATURES

Different floodplain types have distinctive sets of geomorphic units reflecting the formative river type



Diagrams from Nanson & Croke, 1992, Geomorphology

THE REFORM FRAMEWORK: 3. ASSESSMENT, REACH & WITHIN-REACH

Reach and within-reach indicators feed into reach-based assessments:

- CHANNEL TYPE AND DIMENSIONS: River type, floodplain type, river channel dimensions and dynamics, bed and bank sediment type.
- HYDROMORPHOLOGICAL FUNCTION: (based on for example) Channel and floodplain units typical? Extent of bars, benches and islands. Extent of eroding and aggrading banks. Presence of aquatic plant, riparian tree and wood dependent geomorphic units.
- HYDROMORPHOLOGICAL ALTERATION / ARTIFICIALITY: (based on for example) Interruptions to longitudinal continuity. Interruptions to lateral continuity. Potential for the river to adjust its dimensions and position.
- RIPARIAN CORRIDOR ALTERATION / ARTIFICIALITY: (based on for example) Extent of riparian vegetation. Naturalness of spatial and age structure of riparian vegetation. Presence and abundance of large wood.
- HYDROMORPHOLOGICAL ADJUSTMENT: Extent of indicators of contemporary adjustment. Degree and nature of past channel adjustments.

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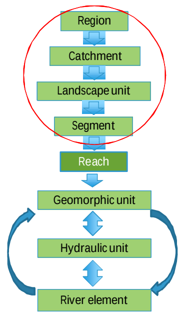
THE REFORM FRAMEWORK: 3. ASSESSMENT, III CATCHMENT–REACH PROCESSES



III: CATCHMENT TO REACH PROCESSES

How is the reach affected by larger-scale influences?

Present Flow and Sediment Supply Processes?

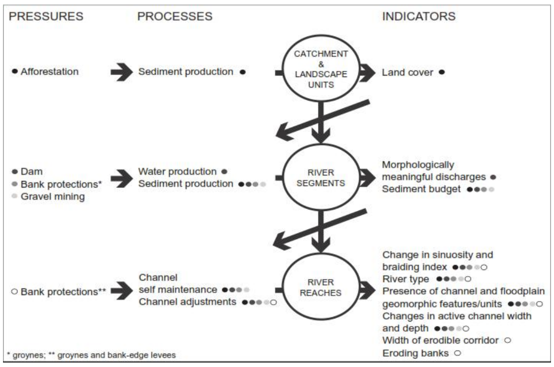
- Reach type appropriate for current flow and sediment supply?
- Are other river types in the same landscape unit more appropriate for current flow and sediment supply?

Process Changes Induced by..?

- Changes in catchment land use?
- Changes in channel interventions (dams, weirs, reinforcement)?

THE REFORM FRAMEWORK: 3. ASSESSMENT, IV SPACE-TIME-TRAJECTORIES

SPACE-TIME LINKAGES AND TRAJECTORIES OF CHANGE

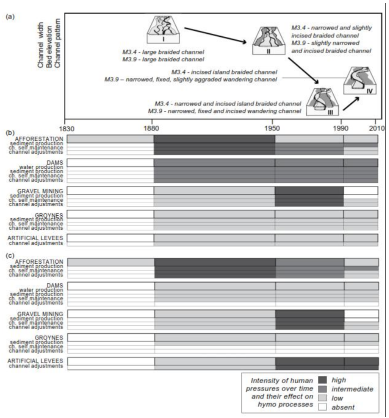


RIVER MAGRA, ITALY: SPATIAL LINKAGES

from Belletti et al., 2015, Aquatic Sciences

THE REFORM FRAMEWORK: 3. ASSESSMENT, IV SPACE-TIME-TRAJECTORIES

RIVER MAGRA, ITALY: TEMPORAL LINKAGES AND CHANNEL TRAJECTORIES



from Belletti et al., 2015, Aquatic Sciences

THE REFORM FRAMEWORK: 4. SCENARIOS

Based on integrated understanding of space-time responses and trajectories of change, likely future responses to different scenarios over forthcoming decades can be assessed:

1. Climate change but no change in current interventions
2. Other likely scenarios for the catchment, such as:
   - Change in land use type / intensity
   - Change in flow manipulation
   - Change in channel management

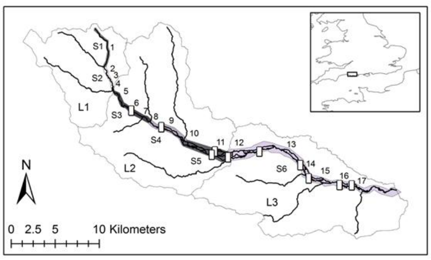
THE REFORM FRAMEWORK: INPUT TO DESIGN

Questions to answer in context of management / rehabilitation design

1. To what extent can reach interventions be removed (in channel, in riparian margins)?
2. To what extent can natural processes to the reach be reinstated (catchment and local)?
3. How may processes change in the near future (catchment and local scenarios)?
4. Given 1 to 3, is current reach type the most sustainable option or is another type (of those present within landscape unit) more appropriate?
5. Design rehabilitation to allow river to recover its form and function as far as is possible given human constraints.

River Frome, Dorset: 1. Delineation

Catchment -> 3 Landscape Units - > 6 Segments - > 17 Reaches

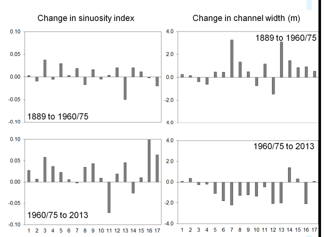


River Frome, Dorset: 3. Assessment I: River Type

Three reach types present

Reach	Bed sediment	Channels	Planform	Type
1	Gravel/sand	Single	Sinuous	17
2	Sand/gravel	Single	Sinuous	17
3	Sand/gravel	Single	Meandering	18
4	Sand/gravel	Single	Sinuous	17
5	Gravel/sand	Single	Sinuous	17
6	Gravel/sand	Multi-thread	Anabranching	19
7	Sand/gravel	Single	Sinuous	17
8	Sand/gravel	Single	Sinuous	17
9	Sand/gravel	Multi-thread	Anabranching	19
10	Sand/gravel	Multi-thread	Anabranching	19
11	Gravel/sand	Multi-	Anabranching	19
12	Gravel/sand	Multi-	Anabranching	19
13	Sand/gravel	Multi-thread	Anabranching	19
14	Sand/gravel	Multi-thread	Anabranching	19
15	Sand/gravel	Multi-thread	Anabranching	19
16	Sand/gravel	Multi-thread	Anabranching	19
17	Sand/gravel	Single	Meandering	18

Types unchanged; Most reaches have become narrower and more sinuous, particularly in the last 50-60 years



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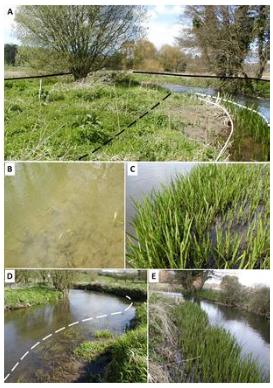
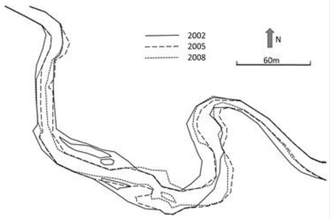
River Frome, Dorset: 3. Assessment II: Within-reach features

Reach	Hydromorphology function assessment (presence of features indicating natural function)	Channel / floodplain features typical of type	Artificiality assessment (constraints on natural function)	Longitudinal Continuity (impact of weirs on downstream flow of water and sediment)	Lateral Continuity (access of flood water to floodplain)	Adjustment Potential (space for channel to move, unreinforced banks)
1	Intermediate	Some	Moderate	Intermediate	Good	Intermediate
2	Intermediate	Some	Very Low	Good	Good	Intermediate
3	Intermediate	Some	Low	Intermediate	Good	High
4	Good	Some	Moderate	Poor	Good	Intermediate
5	Good	Some	Moderate	Poor	Good	Intermediate
6	Good	Some	Moderate	Poor	Good	Intermediate
7	Good	Some	Moderate	Poor	Good	High
8	Intermediate	Some	Moderate	Poor	Good	Intermediate
9	Intermediate	Some	Moderate	Poor	Good	Intermediate
10	Intermediate	Some	Moderate	Poor	Good	Intermediate
11	Intermediate	Some	Moderate	Poor	Good	Intermediate
12	Intermediate	Some	Moderate	Poor	Good	High
13	Good	Some	Moderate	Poor	Good	High
14	Intermediate	Some	Moderate	Poor	Good	Intermediate
15	Intermediate	Some	Moderate	Poor	Good	Intermediate
16	Good	Some	Moderate	Poor	Good	High
17	Intermediate	Some	Moderate	Poor	Good	Intermediate

River Frome, Dorset: 3. Assessment II: Within-reach features



1. Lack of natural riparian zone.
2. Few riparian trees.
3. Plentiful aquatic vegetation in unshaded channels.
4. Features in channels and edges formed mainly by sediment trapped by aquatic vegetation.



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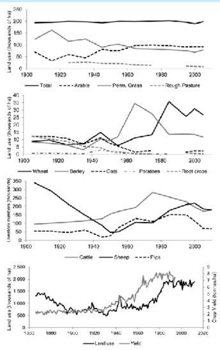
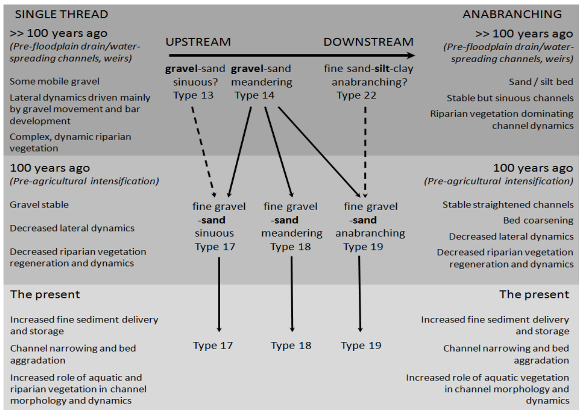
River Frome, Dorset: 3. Assessment III: Catchment to reach processes



1. Land use intensification increases soil erosion:
   more & different animals,
   increased cereals and yields.
2. Agriculture close to channel (no riparian woodland to intercept eroded sediment).
3. Therefore, eroded sediment delivered to river channel.
4. River flows have insufficient energy to move sediment.
5. Fine sediment accumulates in river channel.
6. Aquatic vegetation traps sediment causing channel narrowing and increased sinuosity

River Frome, Dorset: 3. Assessment IV: space-time and trajectories of change



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River Frome, Dorset: 4. Scenarios

(i) A warming climate with increased intensity of rain storms

More peaked flow hydrographs (unlikely to be significant). Increased fine sediment delivery to the river network (intense rain on bare arable fields). Increased fine sediment retention, further channel narrowing, siltation of the channel bed, and potential siltation and blockage of side channels.

(ii) Removal of some structures from the river network

Improve sediment transport with some local sediment flushing.

(iii) A change in agricultural land cover and management practices (maintain cover on fields when rainfall most intense (e.g. spring rather than autumn planting) and break up runoff using grass strips)

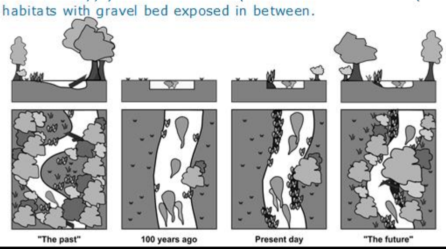
Maintain fine sediment delivery at current levels under a changing climate.

(iv) A relaxation of riparian and aquatic vegetation management.

Reduced fine sediment delivery to river; increased complexity of in-channel and marginal landforms; overall improvement in riparian and aquatic habitat diversity and turnover.

River Frome, Dorset: Rehabilitation actions under Scenario (iv)

1. River type is appropriate but need to improve process-form interactions
2. Where possible, increase width of riparian zone: reduces eroded sediment delivery to channel; increases shade; reduces aquatic vegetation and cools water temperatures.
3. Where possible, remove weirs and other blocking structures: improves potential of river flows to transport sediment.
4. Where possible remove bank reinforcement: allows river to adjust course.
5. Leave vegetation and river morphology to co-adjust:
   i. existing river types have persisted so are quite stable
   ii. aquatic plants and wood from riparian trees will retain a reduced fine sediment supply to build a more dynamic mosaic of naturally-functioning habitats with gravel bed exposed in between.



FURTHER READING AND RESOURCES

Gurnell et al. (2014) REFORM Deliverable 2.1

Part 1: A hierarchical multi-scale framework and indicators of hydromorphological processes and forms

Part 2: Thematic Annexes

Part 3: Catchment Case Studies: Full applications of the Hierarchical Framework

Part 4: Catchment Case Studies: Partial applications of the Hierarchical Framework

Aquatic Sciences (Special issue on the REFORM Framework) expected 2015:

A hierarchical framework for developing understanding of river behaviour.

Classification of river morphology and hydrology to support management and restoration.

Indicators of river system character and dynamics, past and present: understanding the causes and solutions to river management problems.

The use of Remote Sensing to characterise hydromorphological properties of European rivers.

Several papers illustrating different applications of the REFORM framework.

www.reformrivers.eu wiki.reformrivers.eu

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Hydromorphological assessment

Massimo Rinaldi – Università di Firenze

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What is hydromorphology

Discipline at the interface between hydrology and geomorphology, and linked to ecology. It concerns the physical component of fluvial ecosystems, including forms, processes, and related physical habitats.

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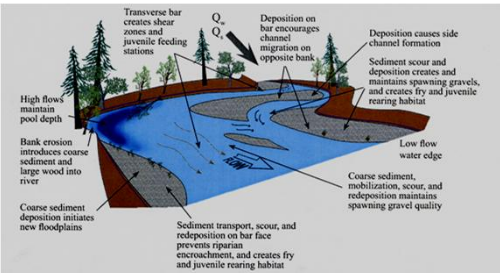
Why is hydromorphology important

Functioning of physical processes spontaneously promotes ecosystem diversity and functioning.



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What is an 'assessment'

- Delineation (or segmentation): delimitation of the boundaries of the spatial units
- Characterization: description of river (reach) *'How does my river work?'*
- Assessment: evaluation of the conditions and functioning of the spatial units of a catchment and its river system *'What's wrong?'*

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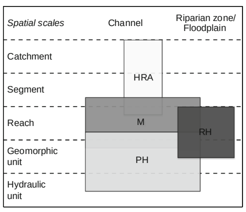
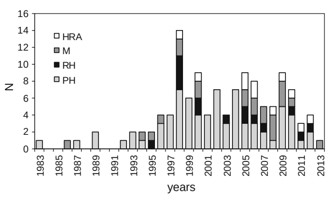
What kind of methods should be used to assess hydromorphology





PH: Physical habitat assessment
RH: Riparian habitat assessment
M: Morphological assessment
HRA: Hydrological regime alteration assessment

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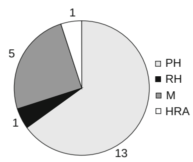
What kind of methods should be used to assess hydromorphology

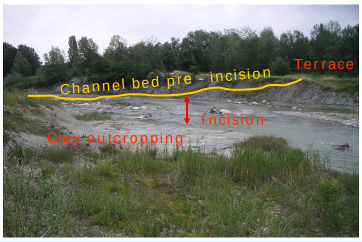
- Number of methods sub-divided according to the assessment category, used by European countries for the implementation of the WFD



- Future developments need to incorporate physical processes.
- This can be achieved by a wider use of morphological assessment rather than physical habitat methods in order to increase the capability to assess geomorphic processes.

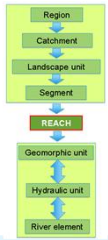
Why is consideration of processes important

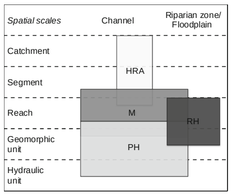
- Processes are responsible for the creation and maintenance of fluvial forms and related physical habitats
- Sustainable habitat conditions need that the processes responsible for the habitats are functioning



Why appropriate spatial scales need to be considered

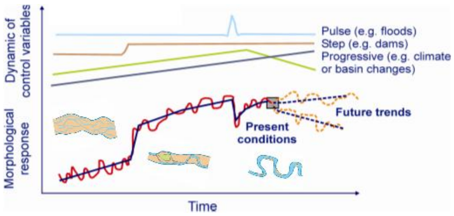
- A multiscale hierarchical approach fundamental for (i) understanding controls and off-site impacts, (ii) selecting monitoring sites; (iii) extrapolating information.
- Key scale: river reach





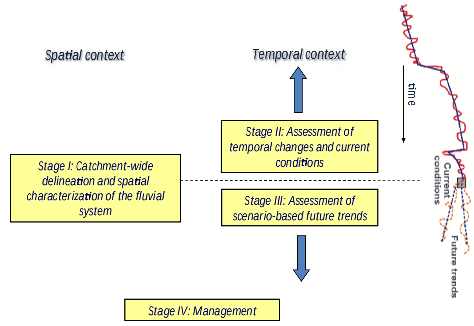
PH: Physical habitat; RH: Riparian habitat; M: Morphological; HRA: Hydrological regime alteration.

Why are temporal scale and historical analysis important



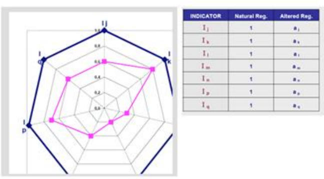
Frameworks that consider temporal dynamics and trajectories of historical change are particularly effective in developing understanding of processes and the impacts of changed processes through time and across spatial scales.

The overall REFORM hydromorphological assessment framework



Hydrological assessment

- Indicators of Hydrological Alteration (IHA) describing 5 flow components (magnitude, frequency, duration, timing, rate of change)
- Hydrological alteration quantified as deviation between current and unaltered hydrological regime



IAHRIS: Polygons showing indicator values for reference and actual conditions.

Morphological assessment

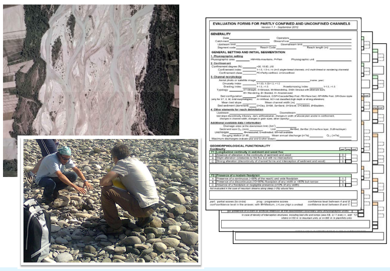
Morphological Quality Index (MQI)
Aim: to assess and classify (WFD) the morphological conditions of a given river reach

Main characteristics
1. Specific tool which is part of the much broader REFORM framework
2. Spatial scale: hierarchical nested approach (REFORM): “reach” key spatial unit
3. Emphasis on processes
4. Temporal component explicitly accounted
5. Integration of GIS- remote sensing and field survey

REFORM: Extended European Version (Deliverable 6.2)

Morphological assessment

Three sets of indicators: (1) Geomorphological functionality, (2) Artificiality, (3) Channel adjustments



What hydromorphological aspects need to be assessed

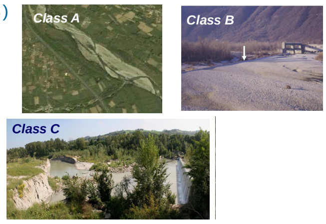
Functionality	
Continuity	
F1	*Longitudinal continuity in sediment and wood flux*
F2	*Presence of modern floodplain*
F3	*Hillslopes – stream connection*
F4	*Processes of bank retreat*
F5	*Presence of a potentially erodible corridor*
Morphology	
Channel pattern	
F6	*Bed configuration – valley slope*
F7	*Forms and processes typical of the channel pattern*
F8	*Presence of typical fluvial forms in the alluvial plain*
Cross-section configuration	
F9	*Variability of the cross-section*
Bed substrate	
F10	*Structure of the channel bed*
F11	*Presence of in-channel large wood*
Vegetation	
F12	*Width of functional formations in the fluvial corridor*
F13	*Linear extension of functional vegetation*

Artificiality	
Upstream alteration of longitudinal continuity	
A1	*Upstream alteration of channel-forming discharges*
A2	*Upstream interception of sediment transport*
Alteration of longitudinal continuity in the reach	
A3	*Alteration of channel-forming discharge in the reach*
A4	*Interception of sediment transport in the reach*
A5	*Crossing structures*
Alteration of lateral continuity	
A6	*Bank protections*
A7	*Artificial levees*
Alteration of channel morphology and/or substrate	
A8	*Artificial changes of river course*
A9	*Other structures of alteration of channel profile and/or substrate*
Interventions of removal	
A10	*Sediment removal*
A11	*Wood removal*
A12	*Vegetation cutting*

Channel adjustments	
CA1	*Adjustments in channel pattern*
CA2	*Adjustments in channel width*
CA3	*Bed-level adjustments*

Morphological assessment

Functionality (13)



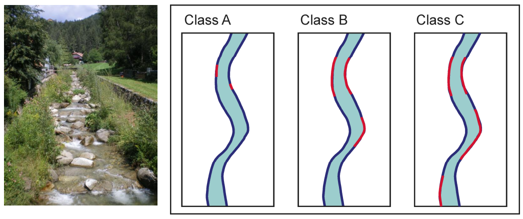
GEOMORPHOLOGICAL FUNCTIONALITY

Continuity

		part.	prog.	conf.
F1	**Longitudinal continuity in sediment and wood flux**			
A	Absence of alteration in the continuity of sediment and wood	0		
B	Slight alteration (obstacles to the flux but with no interception)	3		
C	Strong alteration (discontinuity of channel forms and interception of sediment and wood)	(5)	5	

Morphological assessment

Artificiality (12)

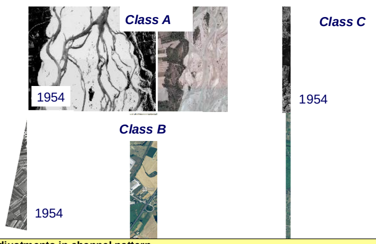


Alteration of lateral continuity

A6	**Bank protections**		
A	Absence or localized presence of bank protections (≤5% total length of the banks)	(0)	
B	Presence of protections for ≤33% total length of the banks (sum of both banks)	3	
C	Presence of protections for >33% total length of the banks (sum of both banks)	6	41

Morphological assessment

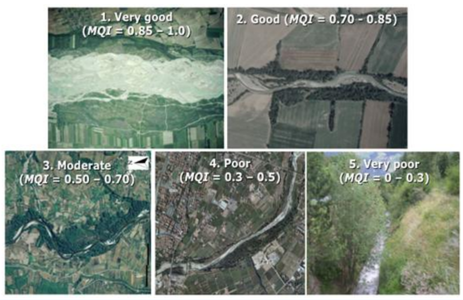
Channel adjustments (3)



CA1	**Adjustments in channel pattern**		
A	Absence of changes of channel pattern from 1930s - 1960s	0	
B	Change to a similar channel pattern from 1930s - 1960s	(3)	
C	Change to a different channel pattern from 1930s - 1960s	6	55

Morphological assessment

MQI = 1 – Stot/Smax



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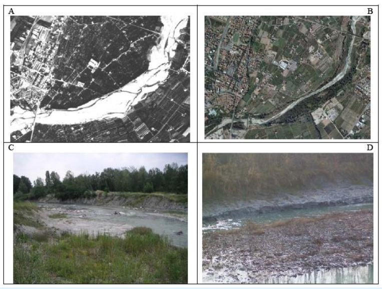
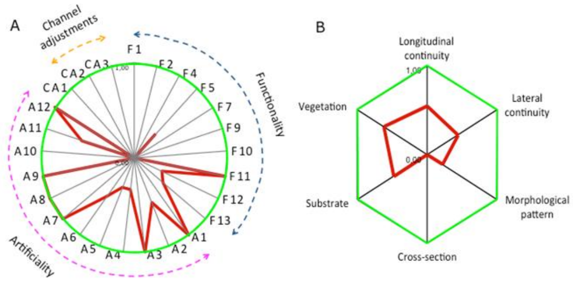
Results: implications

Limited artificial elements but heavy degradation of forms and processes related to channel adjustments



REFORM — REstoring rivers FOR effective catchment Management

Morphological assessment



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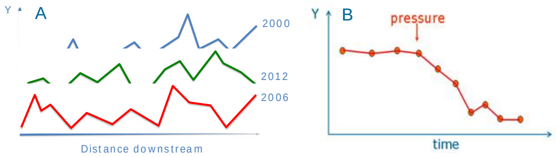
What is monitoring

Periodic measurement (or evaluation) of parameters or indicators to assess the changes that are occurring.

(1) Monitoring and analysis of temporal trends of hydromorphological indicators



Representation and visualization of temporal changes of a morphological parameter. A) Spatio-temporal distribution; B) Temporal trend.

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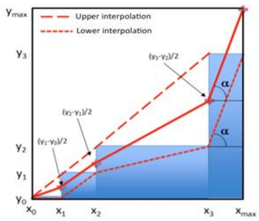
Morphological assessment

(2) Periodic evaluation by assessment methods

Morphological Quality Index for monitoring (MQIm)



Procedure for the definition of the mathematical functions of a MQIm indicator deriving from the discrete classes of the same MQI indicator.

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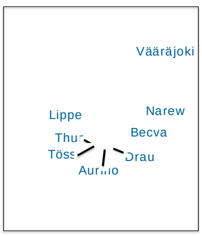
Use of MQI and MQIm for evaluating effects of restoration



The MQI and MQIm were applied to eight REFORM case studies with the objectives of analyzing the hydromorphological response to various restoration measures.

Restoration measures: removal of bank protections and/or artificial levées; channel widening; reconnection or construction of secondary channels; bed level raising; instream measures for habitat enhancement; introduction of large wood.

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Results: Becva River (Czech Republic)

Restoration: removal of bank protections and channel widening occurred in response to an intense flood event.

Degraded reach MQI=0.34

Restored reach (2.04 km, 22% restored): MQI Pre= 0.34; MQI Post= 0.58; ΔMQIm= 0.24

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Results: Thur River (Switzerland)

Restoration: removal of bank protections and channel widening

Degraded reach
MQI=0.64

Restored reach
(1.77 km, 87.6% restored)
MQI Pre= 0.65
MQI Post= 0.80
ΔMQIm= 0.14

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Results: Töss River (Switzerland)

Restoration: local (site scale) removal of bank protections and channel widening

Restored reach
(4.74 km, 4.4% restored)
MQI Pre= 0.54
MQI Post= 0.56
ΔMQIm= 0.01

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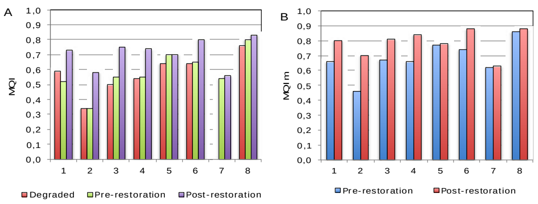
Use of MQI and MQIm for evaluating effects of restoration



Summary of results. A: MQI for degraded, before restoration, and after restoration conditions. B: MQIm before and after restoration. 1: Aurino; 2: Becva; 3: Drau; 4: Lippe; 5: Narew; 6: Thur; 7: Töss ; 8 : Vääräjoki.

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How to evaluate geomorphic units

- The spatial scales of geomorphic and smaller units are the most appropriate to assess physical habitats.
- A geomorphic unit is defined as a landform created by erosion and/or deposition inside or outside the channel.

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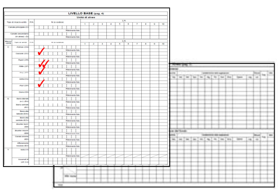
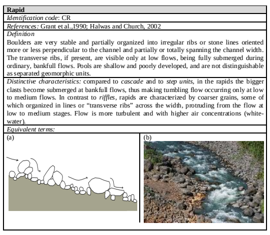
How to evaluate geomorphic units

- GUS (Geomorphic Units survey and classification System) developed in REFORM, and integrated with MQI

Forms



Guide to the classification of Geomorphic Units


Rapid

Identification code: CR

References: Grant et al.,1990; Halwas and Church, 2002

Definition
Boulders are very stable and partially organized into irregular ribs or stone lines oriented more or less perpendicular to the channel and partially or totally spanning the channel width. The transverse ribs, if present, are visible only at low flows, being fully submerged during ordinary, bankfull flows. Pools are shallow and poorly developed, and are not distinguishable as separated geomorphic units.

Distinctive characteristics: compared to *cascade* and to *step units*, in the rapids the bigger clasts become submerged at bankfull flows, thus making tumbling flow occurring only at low to medium flows. In contrast to *riffles*, rapids are characterized by coarser grains, some of which organized in lines or "transverse ribs" across the width, protruding from the flow at low to medium stages. Flow is more turbulent and with higher air concentrations (white-water).

Equivalent terms:

(a) (b)

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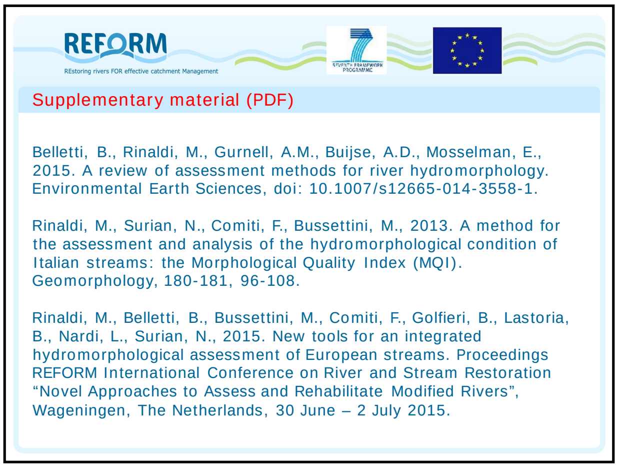
Morphological assessment

Outputs: Mapping geomorphic units, Presence/absence, density, sizes, other information
Geomorphic Units Richness Index; Geomorphic Units Density Index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Supplementary material (PDF)
Belletti, B., Rinaldi, M., Gurnell, A.M., Buijse, A.D., Mosselman, E., 2015. A review of assessment methods for river hydromorphology. Environmental Earth Sciences, doi: 10.1007/s12665-014-3558-1.
Rinaldi, M., Surian, N., Comiti, F., Bussettini, M., 2013. A method for the assessment and analysis of the hydromorphological condition of Italian streams: the Morphological Quality Index (MQI). Geomorphology, 180-181, 96-108.
Rinaldi, M., Belletti, B., Bussettini, M., Comiti, F., Golfieri, B., Lastoria, B., Nardi, L., Surian, N., 2015. New tools for an integrated hydromorphological assessment of European streams. Proceedings REFORM International Conference on River and Stream Restoration “Novel Approaches to Assess and Rehabilitate Modified Rivers”, Wageningen, The Netherlands, 30 June – 2 July 2015.

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Biological Assessment

Christian Wolter
Leibniz-Institute of Freshwater Ecology and Inland Fisheries

REFORM Summer School, Wageningen (NL), 28 June 2015

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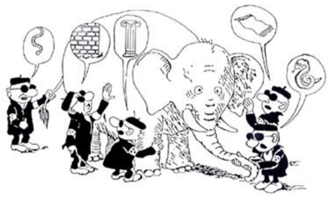
Aim

Learn about the what and how
to assess ecologic effects of hydromorphological change,
degradation and rehabilitation



- Taxa
- Indicators & metrics
- Methods
- Application

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Aim What is lost or gained? How do biota respond?

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What is lost

- Littoral habitats
- Habitat complexity
- Large wood
- Depth & width variability
- Flow velocity patterns
- Lateral connectivity
- Flood plains

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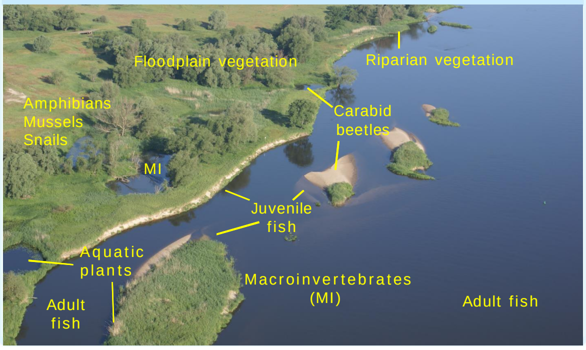
Who is affected



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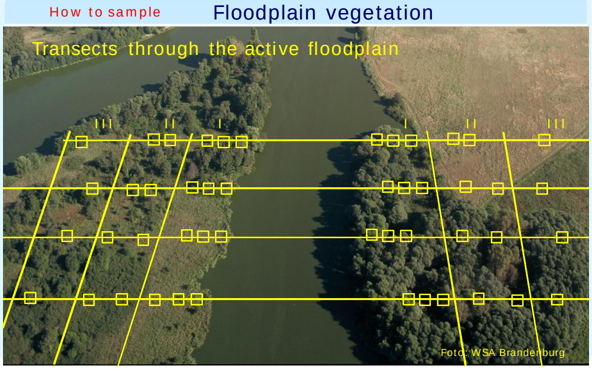
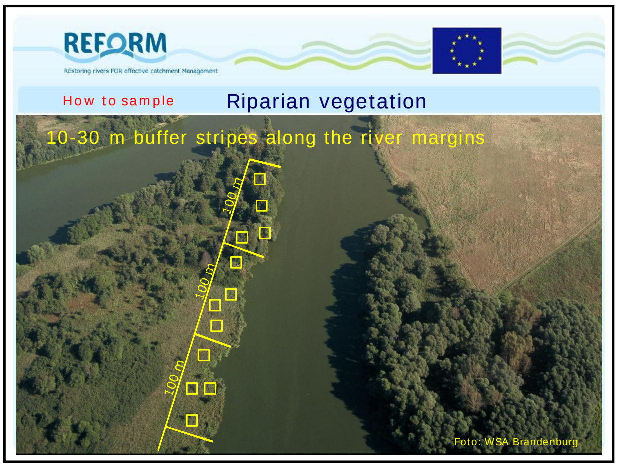
How to sample Floodplain vegetation

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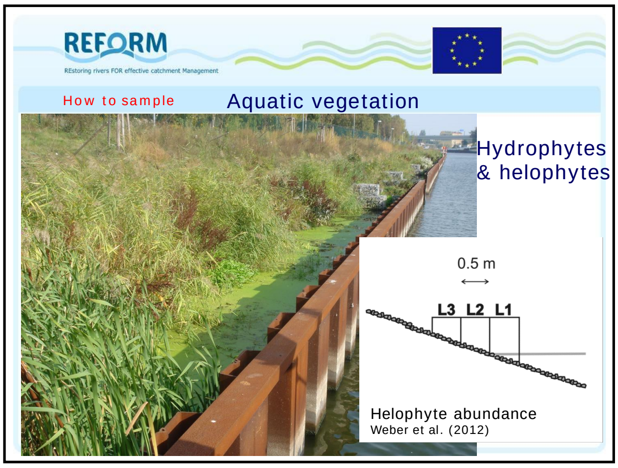
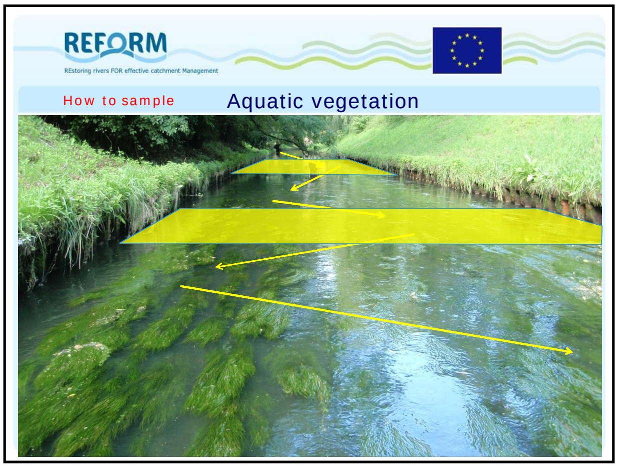
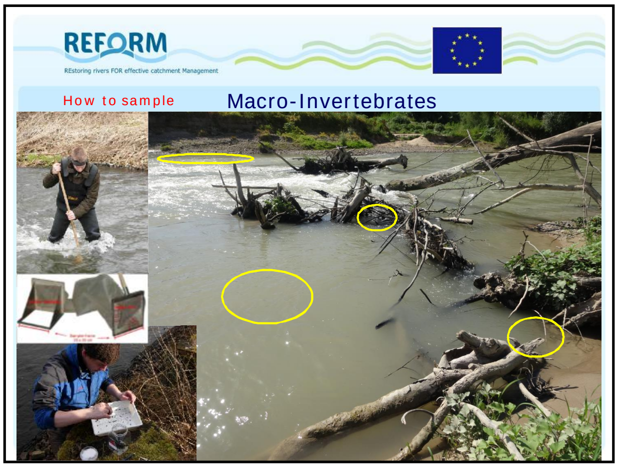
How to sample
Riparian vegetation
10-30 m buffer stripes along the river margins
100 m
100 m
100 m
Foto: WSA Brandenburg


REFORM
REstoring rivers FOR effective catchment Management
How to sample
Aquatic vegetation
Hydrophytes
& helophytes
0.5 m
L3 L2 L1
Helophyte abundance
Weber et al. (2012)


REFORM
REstoring rivers FOR effective catchment Management
How to sample
Aquatic vegetation


REFORM
REstoring rivers FOR effective catchment Management
How to sample
Riparian beetles
pitfall traps
Hand collection
Pitfall trap
(source
REFORM
sampling
protocols)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REstoring rivers FOR effective catchment Management
How to sample
Macro-Invertebrates


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How to sample
Fish
Standard
electric
fishing
Wading:
1 anode per
5 m wetted
width
Boat:
1 anode
along the
banks
Single pass

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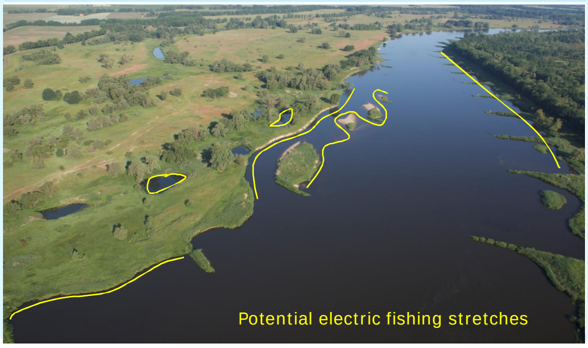
How to sample — Fish



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How to sample — Fish — Add. gears in large rivers

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Methods overview

Sampling objectives determine effort

1. Biodiversity / species inventories
All gears/sources of evidence; qualitative sampling; all habitats, seasons, …; highest species identification efforts

2. Stock development / abundance trends
Species of interests only; standardised gears / sampling; quantitative sampling; time series

3. Status assessment / measure evaluation
Indicator taxa; standardised gears / sampling; quantitative sampling; all habitats; BACI

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Methods overview — European methods

21 macrophyte-based assessment schemes
Metrics: abundance, biomass, composition, diversity, growth forms

29 benthic inverts assessment schemes
Metrics: abundance, biomass, composition, diversity

20 fish-based assessment schemes
Metrics: abundance, biomass, composition, diversity, age structure

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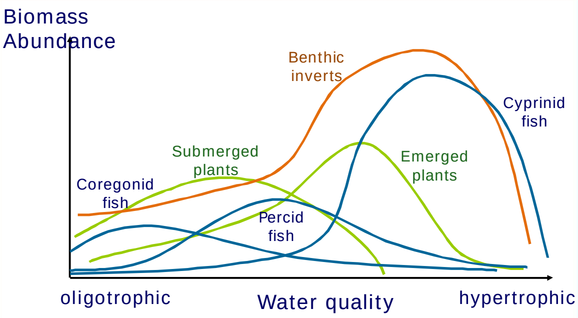
Status assessment — Indicators



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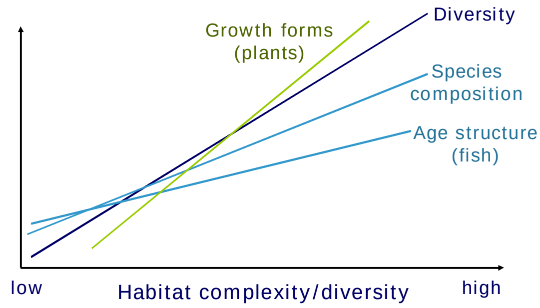
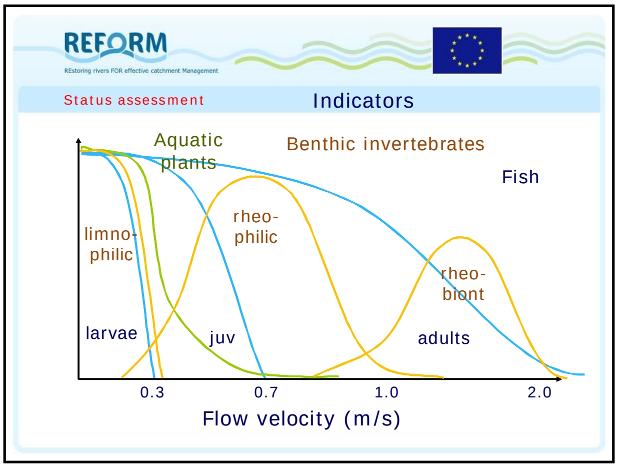
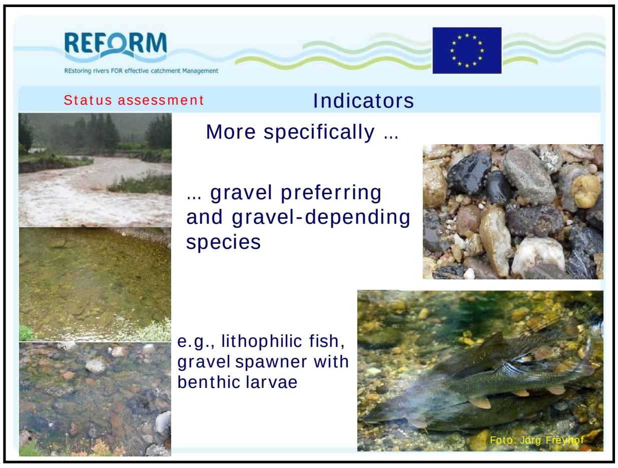
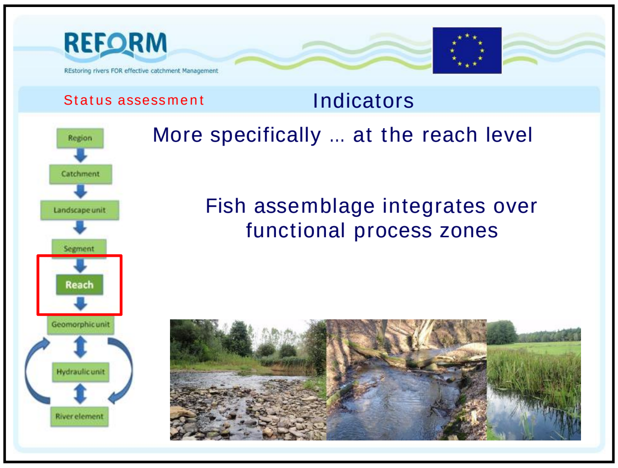
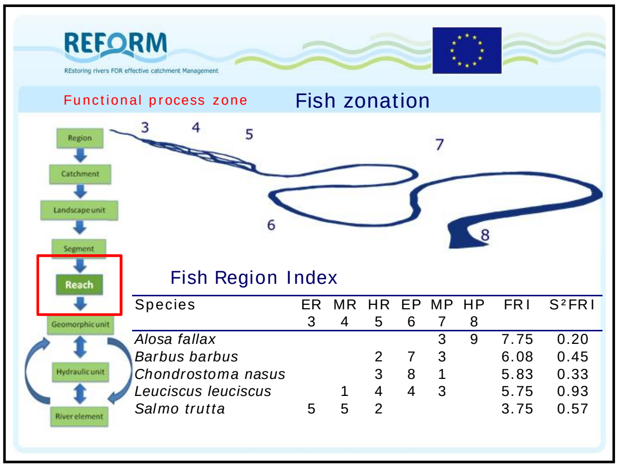
Status assessment — Indicators



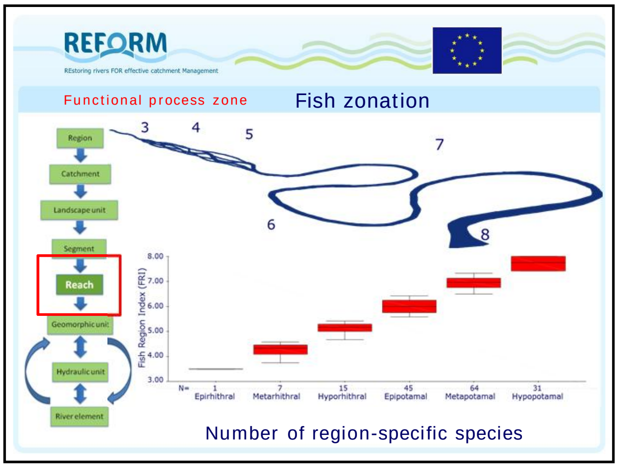


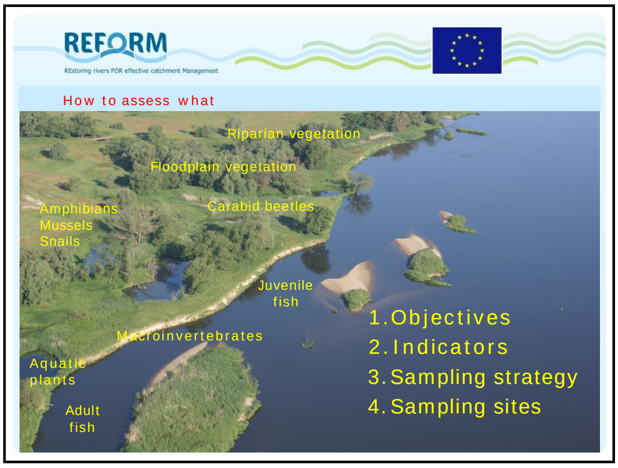






Species	ER 3	MR 4	HR 5	EP 6	MP 7	HP 8	FRI	S^2FRI
Alosa fallax					3	9	7.75	0.20
Barbus barbus			2	7	3		6.08	0.45
Chondrostoma nasus			3	8	1		5.83	0.33
Leuciscus leuciscus		1	4	4	3		5.75	0.93
Salmo trutta	5	5	2				3.75	0.57





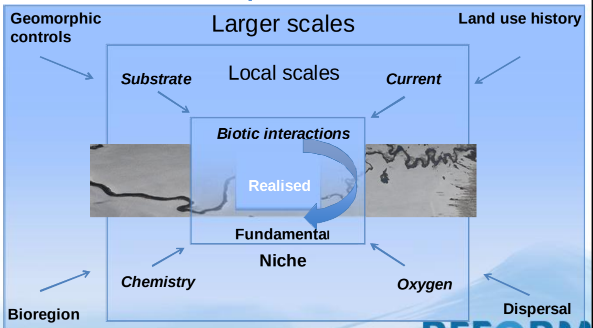
Coupling hydromorphology to biotic responses: challenges in assessing river restoration outcomes

Nikolai Friberg
Research Manager – Section of Freshwater Ecology
Norwegian Institute for Water Research (NIVA)
Cheney honoury fellow, water@leeds, University of Leeds

Lecture outline

- Drivers of community composition in lotic organisms
- Sensitivity of biomonitoring metrics towards HYMO change
- Interaction between HYMO and other stressors
- The influence of confounding variables in assessing HYMO restoration effectiveness
- HYMO restorations and how they resemble natural conditions
- Ways to assess HYMO restorations

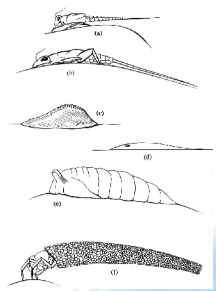
What drives community composition?

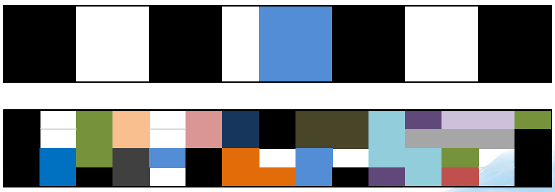


Lotic organisms

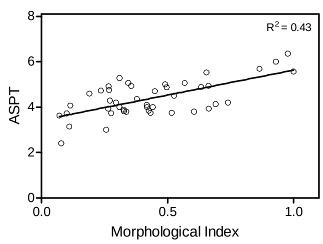
Adaptations are frequent in:

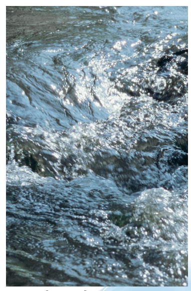
- body shape to reduce drag forces
- behavioral response to a life in flowing water
- life cycle strategies





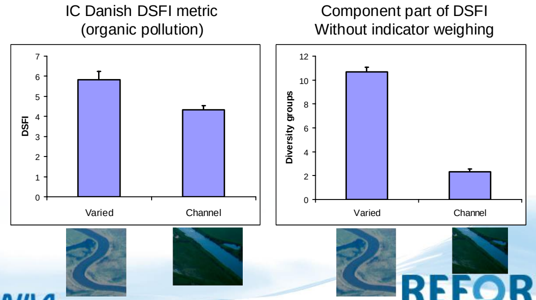
A standard metric





Morphological index ranging from completely uniform (0) to very complex (1)

Paired comparison – BACI type design



Metrics sensitive to hydrological alterations

	MESH	LIFE			
Normal flow	0.61	0.52			
Low flow	-0.58	-0.47			

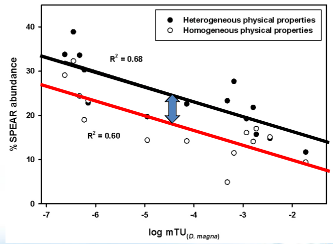
high positives = good/low negatives = bad (+1 to – 1)

Metrics sensitive to hydrological alterations vs. other stressor specific metrics

	MESH	LIFE	ASPT (organic)	EPT (general)	SPEAR (pesticides)
Q90	0.61	0.52	0.59	0.44	0.6
Q10	-0.58	-0.47	-0.52	-0.43	-0.55

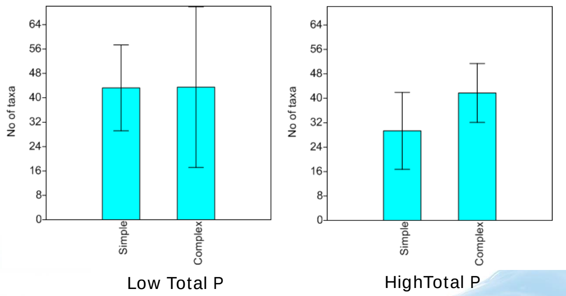
high positives = good/low negatives = bad (+1 to – 1)

Good habitat conditions lower the effects of pesticides or?



Rasmussen et al. 2012, *Environ. Poll.* **164**, 142-149

Good HYMO conditions can mitigate other effects of other stressors



In HYMO simple and complex stream channels
(Sandin unpublished, STAR project)

What is the problem?

- Assessment systems were developed primarily to be sensitive to water quality
  - Focus on macroinvertebrates
  - Sampling method
  - Metrics based on primarily sensitivity towards oxygen concentration
- Hydromorphology
  - Measured on a different spatial scale than macroinvertebrates
  - Static rather than dynamic measurements
- Hydrology
  - Few hydrological stations compared with biological monitoring stations and often not at the same place

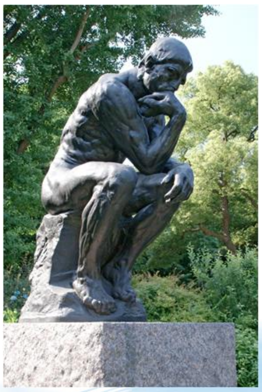
A tendency of overreliance on the explanatory power of local *environmental* filters ignores:

- Biotic interactions (alternative steady states)
- Dispersal (meta-community theory)
- Larger scales controls (temporal and spatial) on local conditions
- Interaction of multiple stressors across scales

Forfatternavn 20.07.2015 13

HYMO River Restoration

- •Spawning gravel
- •Remandering
- •Floodplain restorations
- •Removal of barriers



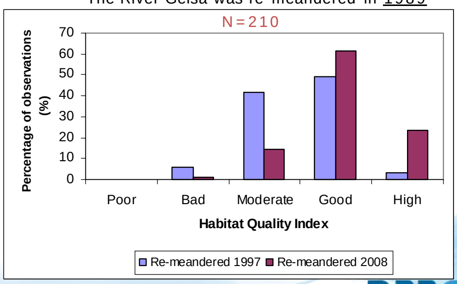
How to single out effects of HYMO degradation

- Measurements of important (and detailed) features at both 1) local and 2) larger (catchment/regional) scales
- Robust statistical design such as a BACI design
- Control for confounding variables in both time and space

Nikolai Friberg 16

Even hydromorphology takes time to improve

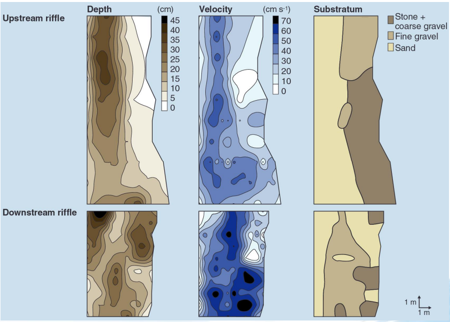
The River Gelså was re-meandered in 1989



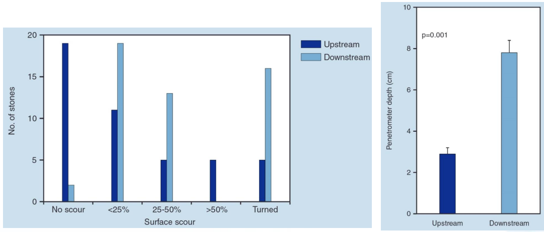
Gelså project – Kronvang upubl.

+ the unmeasured: Spatial variations in physical structure and macroinvertebrates in lowland stream riffles

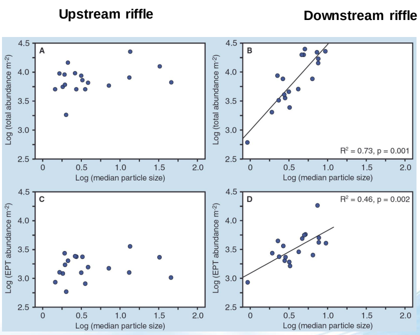
Spatial patterns: depth, current velocity and substratum



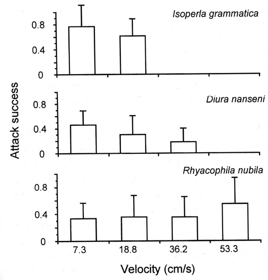
Stream bed stability - stones and penetrometer measurements



Macroinvertebrates – particle size



Physical-biotic interactions



Allan 1996

Nikolai Friberg

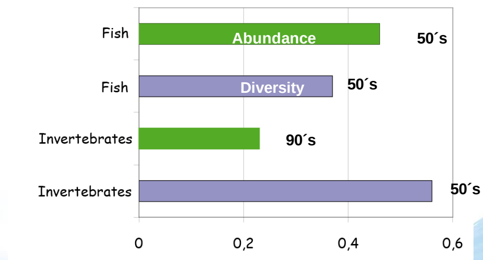
Catchment scale impacts: Upstream perturbations

Clogging of sediment

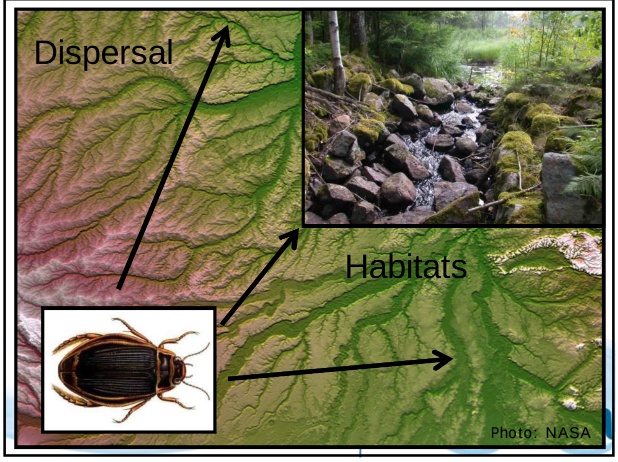
Potential links

- *Loss of hyporheic zone (macroinverts, fish)*
- *Low oxygen levels*
- *(macroinverts)*
- *Scouring at high flows*
- *(perifyton)*
- *Biotic interactions (realised habitat)*

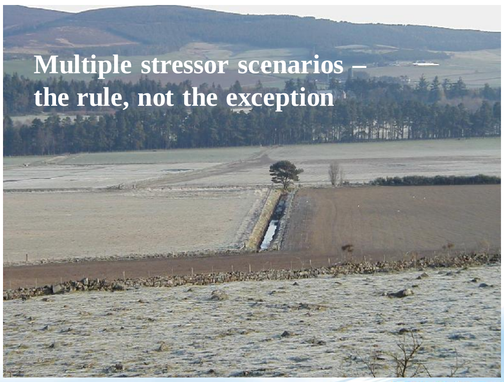
Acknowledge Ghosts of the past - the temporal dimension



Harding et al. *Proc Natl Acad Sci* 95, 1998

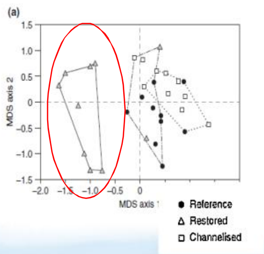


And multiple stress: a reality



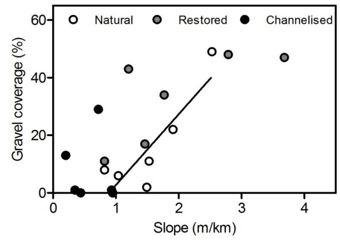
HYMO restorations ≠nature

Not natural



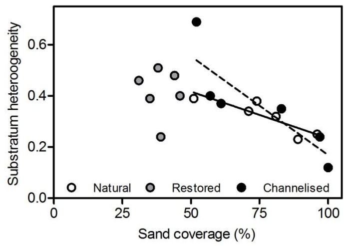
Kristensen at al. 2011

The laws of geomorphology are disobeyed

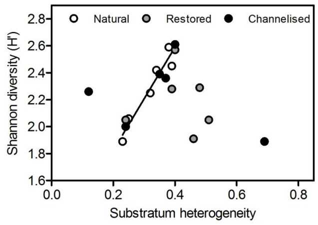


Pedersen, Kristensen & Friberg 2014

Sand is *naturally the dominant substrate type in Danish lowland streams*

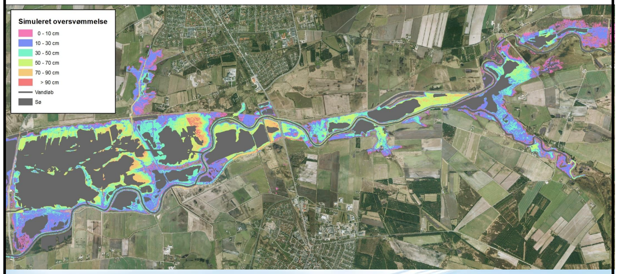


Substrate-invertebrate relationships disconnected



Adult aquatic insects

Modelled (MIKE-11) inundation of the floodplain at Q_{10} for the period 2001-2011



NIVA REFORM

Possible indicators

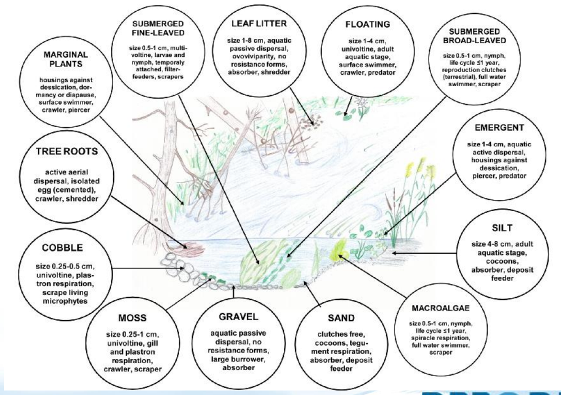
- Use of species traits: habitat template theory
- Riparian organisms (ground beetles, amphibians)
- Ecosystem functioning
- Alternative sampling strategies incl. habitat/biotope mapping
- Contempory and historic land-use at the catchment scale

NIVA REFORM

The use of species traits

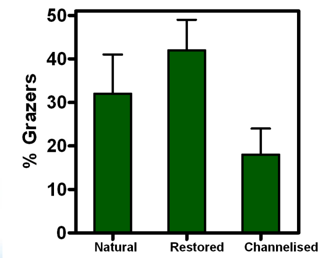
- Closely related to *habitat template*
- Less influenced by differences in biodiversity than identity based metrics
- Contain directly information on linkages between hydromorphology and the biota
- Link to aspects of ecosystem functioning

NIVA Nikolai Friberg REFORM 39



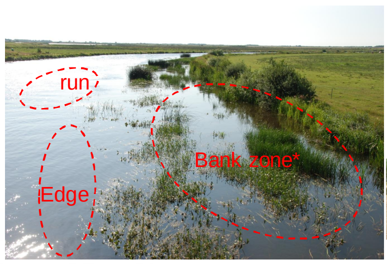
NIVA Demars et al. 2012 REFORM

Functional response – feeding traits



NIVA REFORM

Rivers has many habitats – example: the restored river Skjernå

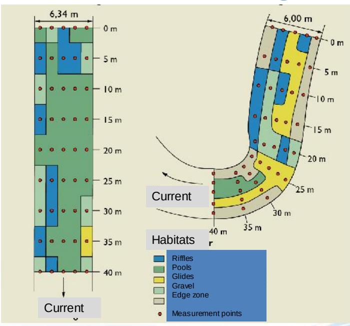


*especially negatively impacted by the regulation

Back waters*

NIVA REFORM 42

Habitat changes



NIVA REFORM

Conclusions

- Many ecological reasons and human impacts explain why the linkage between HYMO and biota at the local scale is not clear-cut
- Standard monitoring approaches are not very sensitive in detecting HYMO changes
- To assess effectiveness of a HYMO restoration project we need a specifically designed monitoring strategy that includes:
  1. Robust statistical design
  2. Habitat/biotope specific sampling
  3. Quantification of the impact of confounding variables in time and space

NIVA Nikolai Friberg REFORM

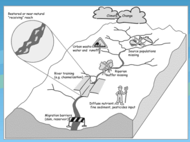
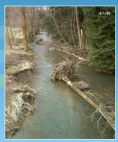
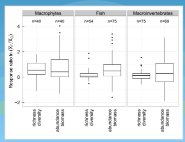
REFORM
REstoring rivers FOR effective catchment Management

Selection of restoration measures

General principles and approaches

Potential restoration measures

Effects on river morphology and biota

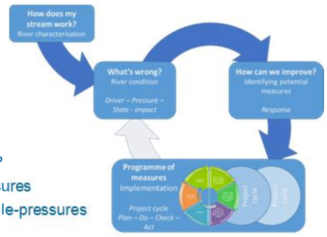




Jochem Kail, University of Duisburg-Essen

REFORM

Setting the scene

- **Planning cycle – steps prior to selection of measures**
  - How does my river work?
    - Natural river type
    - Reference conditions
  - What's wrong?
    - What's missing?
      - Hymo assessment
      - Bio assessment
    - What's the reason? Why?
      - Identify limiting pressures
      - Difficult due to multiple-pressures
  - How can we improve? – select measures



REFORM

Setting the scene

- **Planning cycle – two spatial and administrative levels**

A: Programme of Measures (PoM)	B: Individual restoration projects
Catchment-scale	Catchment to reach-scale
All water bodies	Often single water bodies
Conceptual	Technical
Good chemical status is a must!	Have to work in given catchment context
Costs not limiting even in HMWB! (except less stringent environmental objectives)	Have to work given the property situation and financial constraints
Regional to national water agencies	Local river managers

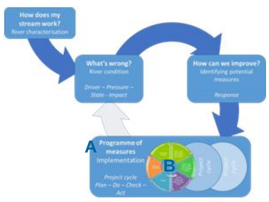


Figure: N. Angelopoulos

REFORM

Setting the scene

- **Planning cycle – presentation is about restoration at project level!**

A: Programme of Measures (PoM)	B: Individual restoration projects
Catchment-scale	Catchment to reach-scale
All water bodies	Often single water bodies
Conceptual	Technical
Good chemical status is a must!	Have to work in given catchment context
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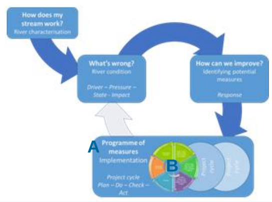


Figure: N. Angelopoulos

REFORM

1 General principles and approaches

REFORM

General principles and approaches

- **Holistic vs. sectoral**
  - Apply river restoration in the broader context of river management
  - Consider the different claims to rivers
  - Conflicts (e.g. restoration vs. agricultural use), but also…
  - Synergies (e.g. restoration and flood protection, eco-services in general)
  - Stakeholder involvement, public participation

Conflicts	Synergies
	

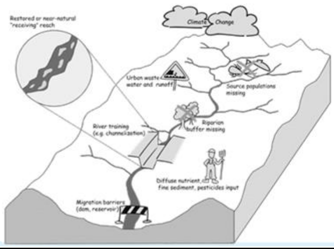
Photos: Hydrotec, BUND

- General principles and approaches
- Potential restoration measures
- Effects on river morphology and biota

REFORM

General principles and approaches

- **Catchment vs. reach-scale restoration**
  - Apply river restoration in a catchment context
  - Multiple pressures at different spatial scales → must be considered
  - Large-scale pressures (e.g. land use) can constrain reach-scale restoration
  - Hierarchy: Water pollution, nutrient / fine sediment, hydrology, morphology



REFORM

General principles and approaches

- **Processes vs. forms**
  - Passive restoration: Restoring natural channel dynamics
  - Active restoration: Building channel features
  - Favour passive over active but not applicable in all reaches (e.g. altered morphogenic flows, sediment deficit, cohesive banks)

Passive restoration (processes)

Active restoration (forms)

Photo right: Patt et al. 1998

REFORM

General principles and approaches

- **Processes vs. forms**
  - Passive restoration: Restoring natural channel dynamics
  - Active restoration: Building channel features
  - Other pros and cons of the two approaches:

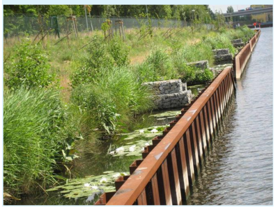
Passive restoration (processes) | Active restoration (forms)

REFORM

General principles and approaches

- **Biologically relevant vs. esthetically pleasing**
  - New or limiting habitats created?
  - See things from a fish's or invertebrate's perspective!

Biologically relevant (if limiting)



Esthetically pleasing (effect?)

Photo right: Wallpaper.com

REFORM

General principles and approaches

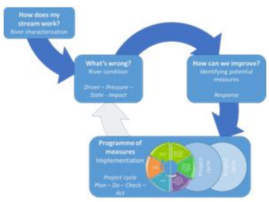
- **Bottlenecks vs. unspecific measures**
  - Bottlenecks addressed?
  - Consider Liebigs "Law of the minimum"

Figure: Wikipedia

REFORM

General principles and approaches

- **Adaptive management**
  - Not (yet) possible to predict the effect of restoration
  - Necessary to monitor restoration effect
  - Adapting measures if necessary



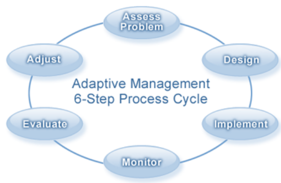
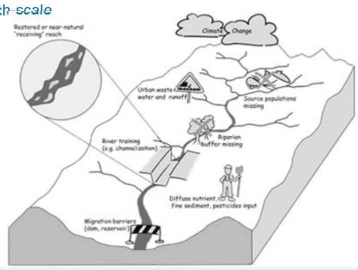


Figure: N. Angelopoulos, http://www.for.gov.bc.ca

2 Restoration measures

Potential restoration measures

- **Restoration measure are applied at different spatial scales**
  - Pressures at different spatial scales → measures at different spatial scales
  - Catchment scale
  - River network scale
  - Reach scale



Potential restoration measures

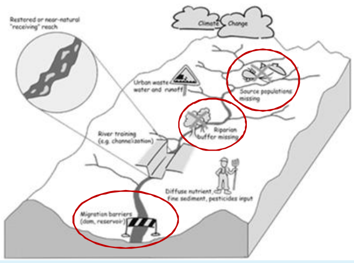
- **Restoration measures for catchment scale pressures**
  - Land use change (extensification, organic farming)
  - Waste water treatment
  - Reduce urban runoff and peak flows
    - Unsealing
    - Rainwater retention and infiltration

Rainwater retention basins

Rainwater infiltration systems

Potential restoration measures

- **Restoration measures for river network scale pressures**
  - Source populations and stepping stones
  - Riparian buffer strips
  - River continuity



Potential restoration measures

- **Restoration measures for river network scale pressures**
  - Source populations and stepping stones
    - Consider re-colonization potential (source population, migration barriers, dispersal abilities)
    - Establish source populations and stepping stones

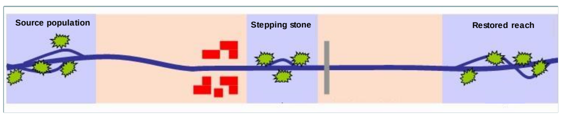


Figure: B. Heitmann, modified

Potential restoration measures

- **Restoration measures for river network scale pressures**
  - Riparian buffer strips
    - Effects
      - Nutrient / fine sediment retention
      - Shading / temperature
      - Organic matter input (leaves, large wood)
      - Habitat for aquatic (e.g. cover) and terrestrial life stages
    - ! Biota highly related to buffer land use
    - Potentially key restoration measure
    - Research need!

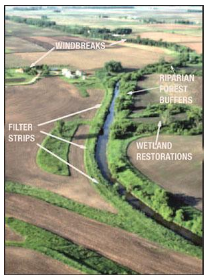
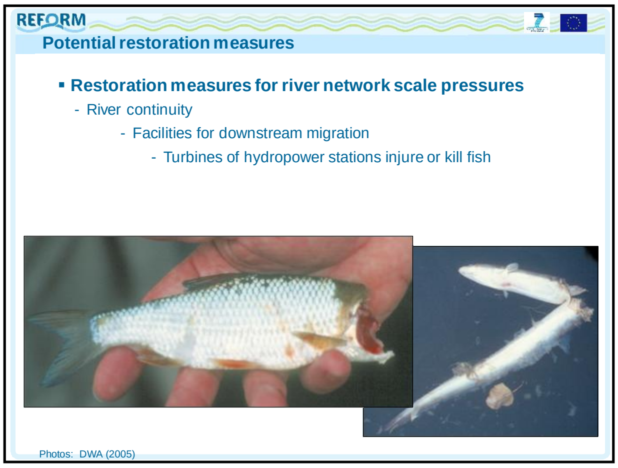
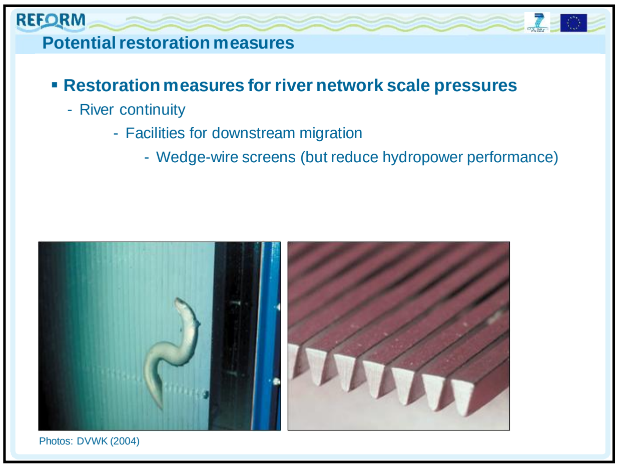
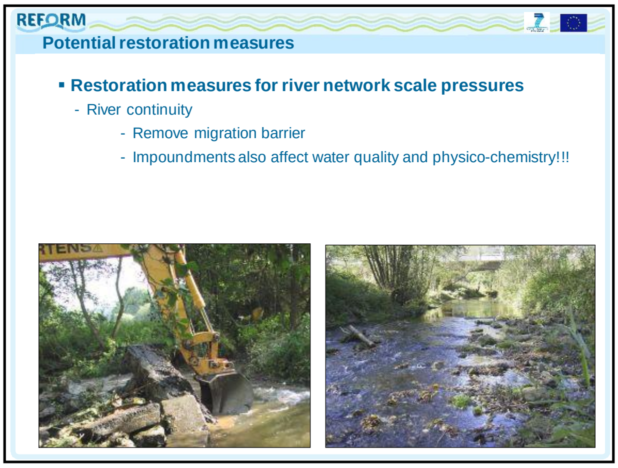


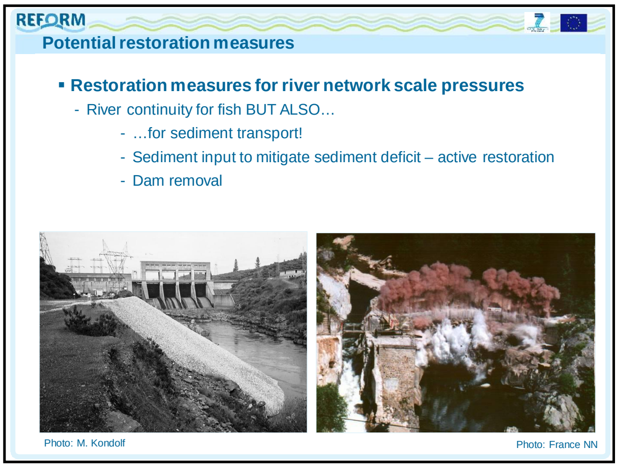
Photo: Ohio Department of Natural Resources

- General principles and approaches
- Potential restoration measures
- Effects on river morphology and biota







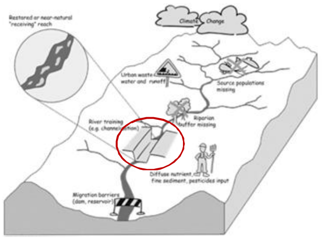


- General principles and approaches
- Potential restoration measures
- Effects on river morphology and biota

REFORM

Potential restoration measures

- **Restoration measures for reach scale pressures**
  - Widely used / most common
  - Increasing lateral extent / restrictions
    - Instream
    - Riparian
    - Planform
    - Floodplain



REFORM

Potential restoration measures

- **Restoration measures for reach scale pressures**
  - Instream (mainly to increase habitat diversity)
    - Large wood and boulder placement
    - Sediment input
    - Create artificial bar or riffle (e.g. glides)
    - Manage aquatic vegetation
    - Creating habitats like cover or shallow wave-protected areas
    - Remove bed and bank fixation
    - …

REFORM

Potential restoration measures

- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood and boulder placement – active restoraiton

Photo: J. Scherle

REFORM

Potential restoration measures

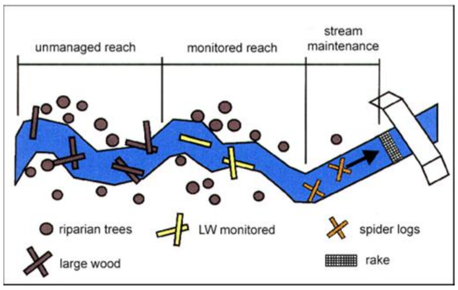
- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood and boulder placement – active restoration

Photos: W. Klein

REFORM

Potential restoration measures

- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood recruitment management strategy – passive restoration



according to Gerhard und Reich (2001), modified

REFORM

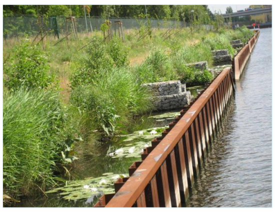
Potential restoration measures

- **Restoration measures for reach scale pressures**
  - Instream
    - Manage aquatic vegetation (alternating weed-cutting)

Photo: R. Bostelmann

Potential restoration measures

- Restoration measures for reach scale pressures
  - Instream
    - Creating habitats like cover or shallow wave-protected areas

Potential restoration measures

- Restoration measures for reach scale pressures
  - Planform
    - Re-meandering
    - Widening / re-braiding
    - Narrow over-widened channel
    - Create secondary floodplain
    - Initiate / tolerate natural channel dynamics
    - …



Potential restoration measures

- Restoration measures for reach scale pressures
  - Planform
    - Re-meandering – Fixed meanders are a no-go!

Photo: Patt et al. 1998, I. Cowx

Potential restoration measures

- Restoration measures for reach scale pressures
  - Planform
    - Re-meandering PLUS natural morphodynamics
    - Consider natural setting (e.g. bank material)
    - ⇒ active restoration

Photo: H. Diehl & W. Gleim

Potential restoration measures

- Restoration measures for reach scale pressures
  - Planform
    - Initiate / tolerate lateral channel dynamics
    - ⇒ passive restoration




Photo upper left: A. Lorenz

3 Restoration effect on morphology and biota

…and implications for future projects and selection of measures

REFORM

Restoration effect

- **Key messages / conclusions of REFORM WP4**

01 General: Monitor and adjust your project – nobody can fully predict restoration effects

02 Societal benefits: Restoration pays – it increases ecosystem services

03 Organism group: Terrestrial and semi-aquatic species benefit most from restoration

04 Measures: There is no single "best measure" but widening generally has a high effect

05 Biological metric: Restoration results in a higher number of individuals but few new species

05 Biological metrics: Restoration rather affects specific species or traits than increasing mere richness

06 Habitats: It is important to restore specific habitats not necessarily mere habitat diversity

07 Project size and age: Small restoration projects work but better act big and long-term

08 Catchment characteristics: Slightly higher effect in gravel-bed mountain rivers / low land-use pressure

REFORM

Restoration effect

- **01 General**
  - Monitor and adjust your project - nobody can fully predict restoration effects
    - Mainly info on simple metrics (richness, diversity) – objective?
    - Contrasting results

No effect

A comparative analysis of restoration measures and their effects on hydromorphology and benthic invertebrates in 26 central and southern European rivers

DOES RESTORATION OF STRUCTURAL HETEROGENEITY IN STREAMS ENHANCE FISH AND MACROINVERTEBRATE DIVERSITY?

River rehabilitation and fish populations: assessing the benefit of instream structures

Positive effect

Quantifying Macroinvertebrate Responses to In-Stream Habitat Restoration: Applications of Meta-Analysis to River Restoration

Ecological effects of rehabilitation measures at the Austrian Danube: a meta-analysis of fish assemblages

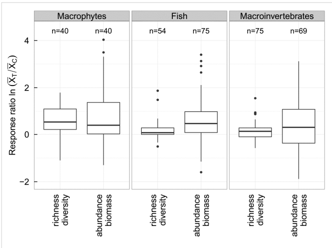
Macrophytes respond to reach-scale river restorations

Effects of stream restorations on riparian mesohabitats, vegetation and carabid beetles

REFORM

Restoration effect

- **01 General**
  - Monitor and adjust your project - nobody can fully predict restoration effects
    - Mainly info on simple metrics (richness, diversity) – objective?
    - Contrasting results
    - Meta-analysis: high variability, ~$^1/_3$ no or negative effect



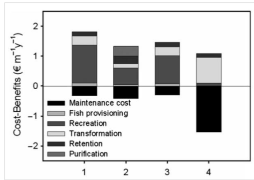
Kail et al. (2015)

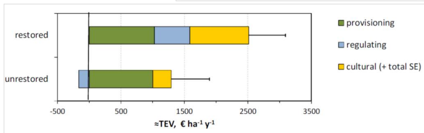
REFORM

Restoration effect

- **02 Societal benefits**
  - Restoration pays – it increases ecosystem services
    - Few studies (research need!)
    - Restoration increases ES (total economic value)
    - Depends on assumptions?

→Select measures to maximise overall benefit



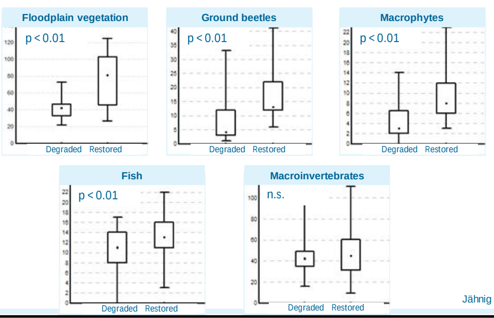


Acuña et al. (2013), Vermaat et al. (2015)

REFORM

Restoration effect

- **03 Organism group**
  - Terrestrial and semi-aquatic species benefit most from restoration
    - Higher richness (short term, few years)

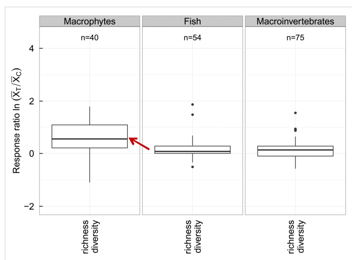


Jähnig et al. (2009)

REFORM

Restoration effect

- **03 Organism group**
  - Terrestrial and semi-aquatic species benefit most from restoration
    - Higher richness (short term, few years)



Kail et al. (2015)

REFORM

Restoration effect

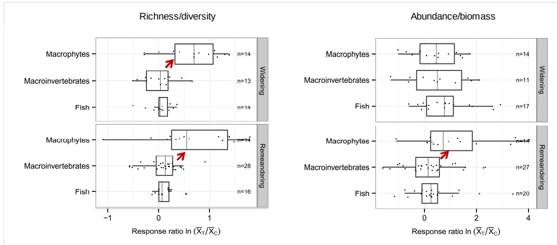
- **03 Organism group**
  - Terrestrial and semi-aquatic species benefit most from restoration
    - Higher richness (short term, few years)
    - Mainly widening projects (pioneer habitats, early successional stages)
    - Long-term effects?

Ruhr near Binnerfeld R2, Germany, restored in 2009

REFORM

Restoration effect

- **04 Restoration measures**
  - There is no single “best measure” but widening generally has a high effect
    - High effect especially on macrophytes…

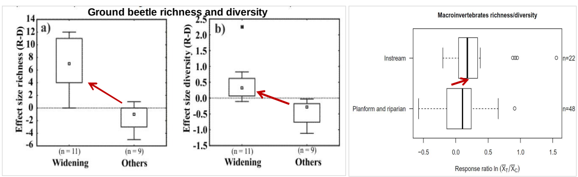


Kail et al. 2015

REFORM

Restoration effect

- **04 Restoration measures**
  - There is no single “best measure” but widening generally has a high effect
    - High effect especially on macrophytes and ground beetles
    - Instream measures highest effect on fish, macroinvertebrates



Januschke and Verdonschot (2015)

Kail et al. (2015)

REFORM

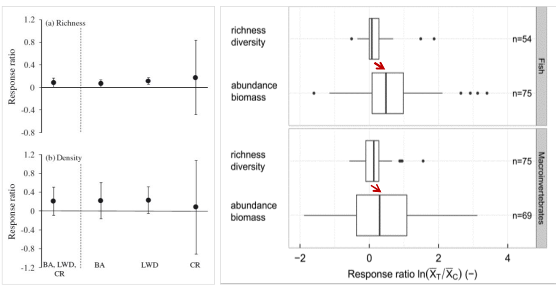
Restoration effect

- **03 Organism group 04 Restoration measures**
  - → Select measures for targeted organism group
  - → Restore natural morphodynamics to rejuvenate habitats

REFORM

Restoration effect

- **05 Biological metric**
  - Restoration results in a higher number of individuals but few new species
    - Abundance/biomass > richness/diversity (fish, macroinvertebrates)



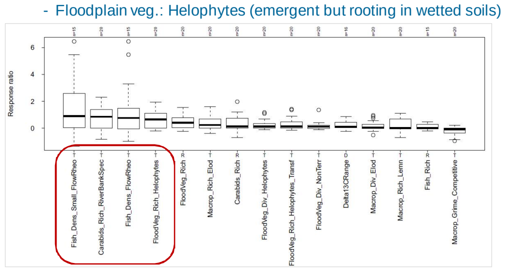
Miller et al. (2010)

(Kail et al. (2015)

REFORM

Restoration effect

- **05 Biological metric**
  - Restoration rather affects specific traits than increasing mere richness
    - Fish: small rheophilic fish (abundance)
    - Ground beetles: Sparsely vegetated river banks specialists
    - Floodplain veg.: Helophytes (emergent but rooting in wetted soils)



Januschke and Verdonschot (2015), Göthe et al. (2015), Schmutz et al. (2015), figure summary analysis unpublished

REFORM

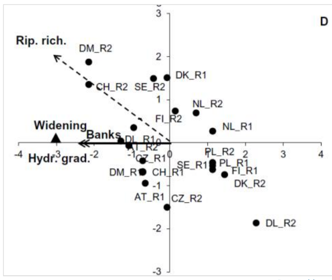
Restoration effect

- 05 Biological metric
  - → Easier to increase abundance, difficult to establish new species
  - → Set realistic objectives, e.g.:
    - → fish richness in small mountain streams is low naturally
    - → re-colonization potential might be limited (source pop. missing)

REFORM

Restoration effect

- 06 Habitats
  - It is important to restore specific habitats not mere habitat diversity
    - Ground beetles: sparsely vegetated bars and banks

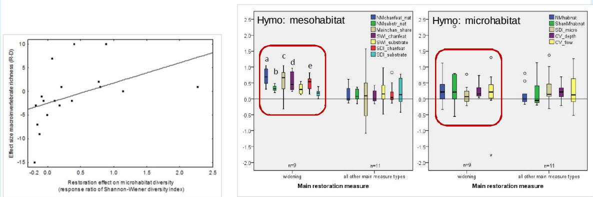


Januschke and Verdonschot (2015)

REFORM

Restoration effect

- 06 Habitats
  - It is important to restore specific habitats not mere habitat diversity
    - Ground beetles: sparsely vegetated bars and banks
    - Macroinvertebrates: microhabitat (substrate) diversity (low effect on microhabitats may explain low effect on inverts)
  - → Select measures which restore specific habitats at relevant scales

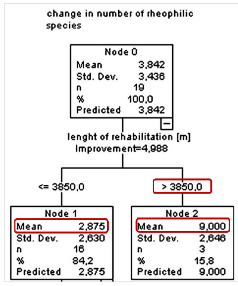


Verdonschot et al. (2015)
Poppe et al. (2015)

REFORM

Restoration effect

- 07 Project size and age
  - Small restoration projects work but better act big and long-term
    - Restoration effect does only depend on size if projects are large

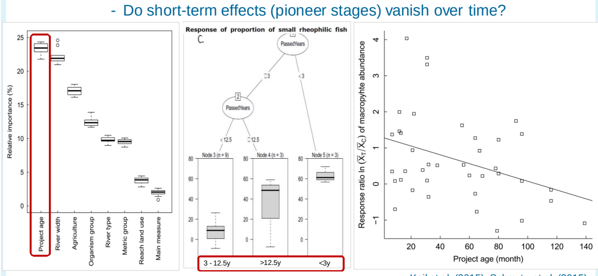


Schmutz et al. (2014)

REFORM

Restoration effect

- 07 Project size and age
  - Small restoration projects work but better act big and long-term
    - Restoration effect does only depend on size if projects are large
    - Restoration effect depends on project age, but no simple increase!
    - Do short-term effects (pioneer stages) vanish over time?

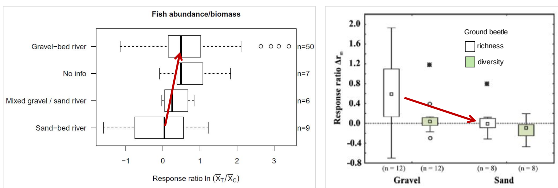


Kail et al. (2015), Schmutz et al. (2015)

REFORM

Restoration effect

- 08 Catchment / river characteristics
  - Slightly higher effect in gravel-bed mountain rivers / low land-use pressure
    - Gravel-bed > sand bed, mountain > lowlands, widening > other
    - …but highly co-correlated



Kail et al. (2015
Januschke and Verdonschot (2015)

REFORM

Restoration effect

- **Further readings**
  - Peer-reviewed scientific literature (> 300 papers)
  - REFORM WP4 deliverable D4.2 (meta-analysis)
    - http://www.reformrivers.eu/evaluation-hydromorphological-restoration-existing-data
    - Kail et al. (2015, Ecological Indicators)
  - REFORM WP4 deliverable D4.3 (20 case-studies)
    - http://www.reformrivers.eu/results/effects-of-river-restoration
    - Hering et al. (2015, Journal of Applied Ecology)
    - Hydrobiologia special issue (several papers)
  - REFORM WP4 deliverable D4.4 (ecosystem services)
    - http://reformrivers.eu/assessing-societal-benefits-river-restoration-using-ecosystem-services-approach
    - Vermaat et al. (2015, Hydrobiologia)

REFORM

Summary

- **How can we improve? - selection of measures**
  - Set clear, measurable, **realistic** objectives (given catchment and river char.)
  - Identify main pressures / bottlenecks
  - Select appropriate approach
    - catchment or reach-scale sufficient?
    - passive or active restoration?
  - Select measures and consider
    - river type (e.g. low dynamics with cohesive banks, gravel-bed>sand-bed)
    - targeted organism group (terrestrial, semi-aquatic, aquatic)
    - specific habitat needs (e.g. microhabitats)
    - possible constraints (e.g. source pop., water quality, hydrology, sediment)

REFORM

Summary

- **How can we improve? - selection of measures**
  - Set clear, measurable, **realistic** objectives (given catchment and river char.)
  - Identify main pressures / bottlenecks and constraints!
  - Select appropriate approach
    - catchment or reach-scale sufficient?
    - active or passive restoration?
  - Select measures and consider river type, organism group, constraints…
  - Monitoring (high variability, changes over time)
  - Assess (including terrestrial groups and ES)
  - Adaptive management
  - Try!

REFORM
REstoring rivers FOR effective catchment Management

Recap of the key REFORM steps for effective river restoration

See also (wiki.)reformrivers.eu

Gertjan Geerling
Deltares / Radboud University, Nijmegen
gertjan.geerling@deltares.nl

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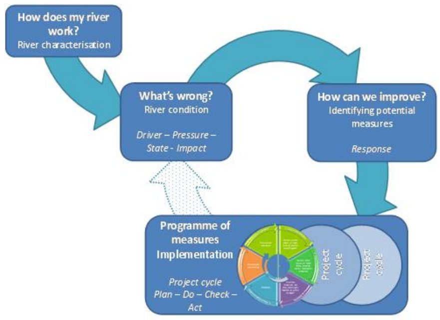
Key REFORM components (taken from wiki.reformrivers.eu)



2

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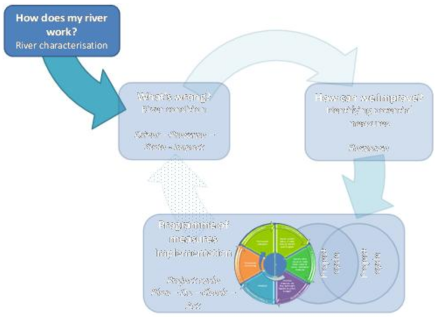
How does my river work?



3

REFORM
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THE REFORM HYMO FRAMEWORK: AIMS

- to develop understanding of the space-time controls at region to reach scales on river reach hydromorphology
- to understand how reach hydromorphology has responded to processes and human interventions in the past and present and may respond in the future to a variety of likely scenarios
- to support development of sustainable management / rehabilitation solutions for river reaches that work with river processes in the context of human constraints.

Source: REFORM Summer school lecture A. Gurnell

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THE REFORM HYMO FRAMEWORK: 1. DELINEATION

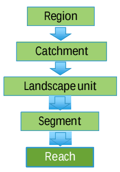
Region: Biogeographical region (climate-vegetation).

Catchment: enclosed by watershed

Landscape unit: topography, geology, land cover

Segment: major changes in gradient, catchment area, valley confinement

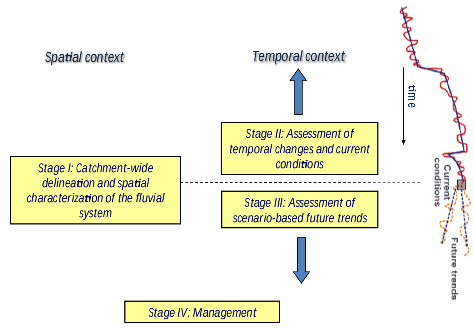
Reach: consistent planform / features, bounded by major artificial longitudinal discontinuities.



Source: REFORM Summer school lecture A. Gurnell

REFORM
REstoring rivers FOR effective catchment Management

The overall REFORM hydromorphological assessment framework



Source: REFORM Summer school lecture M. Rinaldi

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THE REFORM HYMO FRAMEWORK: ANALYSIS STAGES

Analysis stages:

1. DELINEATION: define the spatial units for which information needs to be assembled
2. CHARACTERISATION: assemble information for the spatial units
3. INDICATORS: extract indicators from the assembled information to guide assessments of the current and past character of the spatial units and how processes operating within spatial units affect their character and also the character of receiving spatial units
4. ASSESSMENT: summarise understanding of linkages across space and time, assess temporal trajectory of reach type, condition, function
5. SCENARIOS: assess likely responses to future scenarios

Source: REFORM Summer school lecture A. Gurnell

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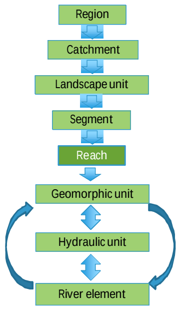
THE REFORM FRAMEWORK: 3. ASSESSMENT



I: RIVER TYPE. What does my reach look like?

II: WITHIN REACH FEATURES.

Are features appropriate for the hydromorphological river type and in good condition?

III: CATCHMENT TO REACH PROCESSES

How is the reach affected by larger-scale influences?

Source: REFORM Summer school lecture A. Gurnell

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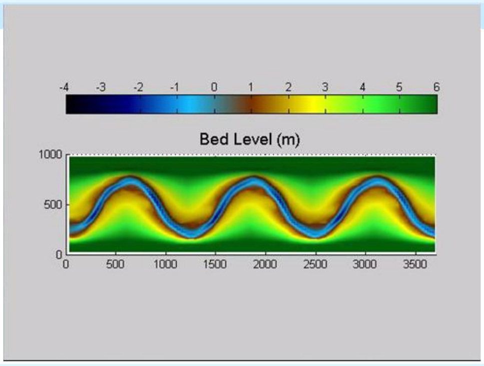
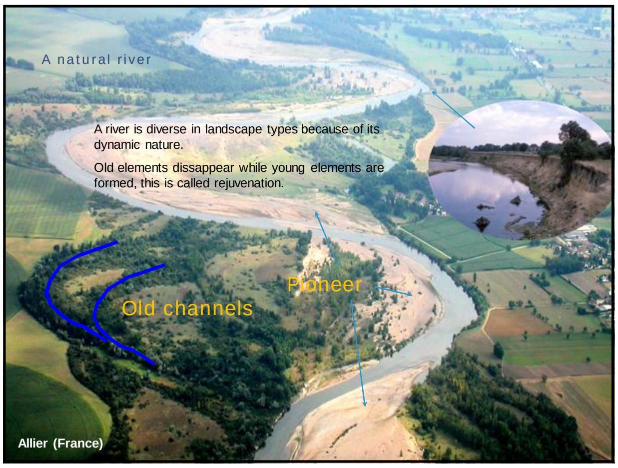


Source: Mijke van Oorschot, Deltares / UU

9



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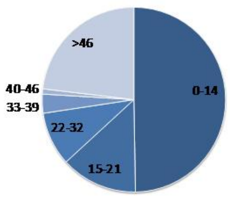
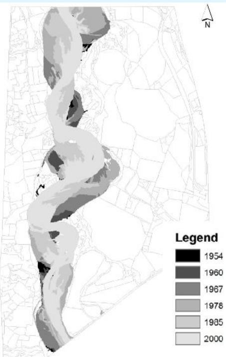
Mozaïc of old and young

Spatial distribution of floodplain age.



Age distribution of floodplain area in years



Geerling, G. W. G., Ragas, A. M. J., Leuven, R. S. E. W., van Den Berg, J. J. H., Breedveld, M., Liefhebber, D., & Smits, A. J. M. (2006). Succession and rejuvenation in floodplains along the river Allier (France). Hydrobiologia, 565(1), 71–86.

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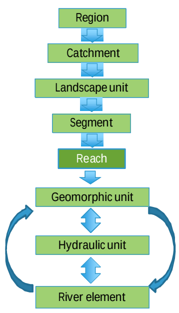
THE REFORM FRAMEWORK: 3. ASSESSMENT



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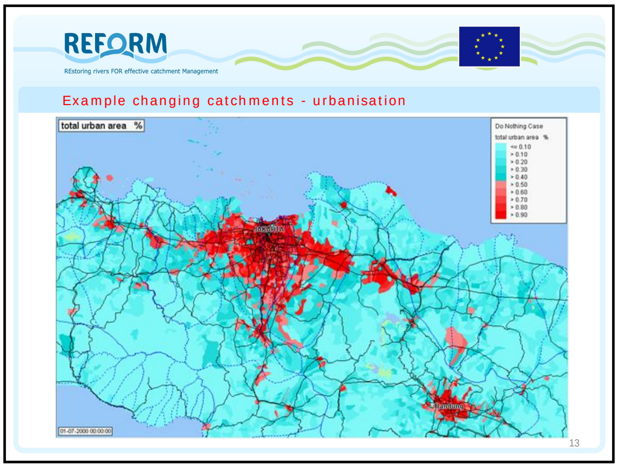
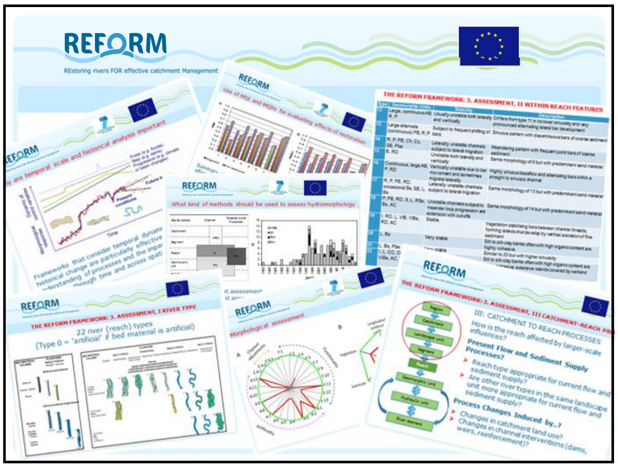

REFORM
REstoring rivers FOR effective catchment Management
Example changing catchments - urbanisation
total urban area %
Do Nothing Case
total urban area %
13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REFORM
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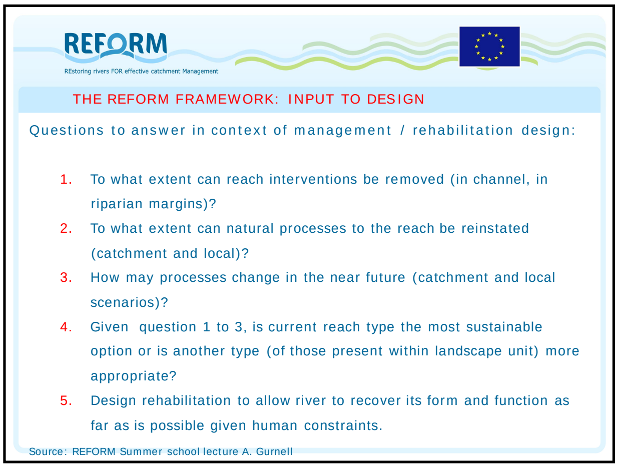
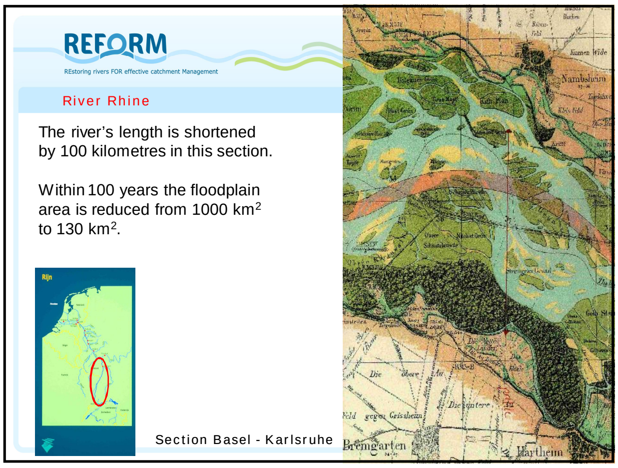
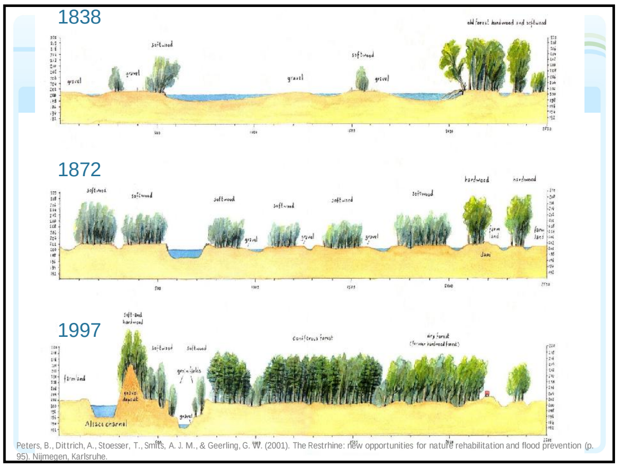
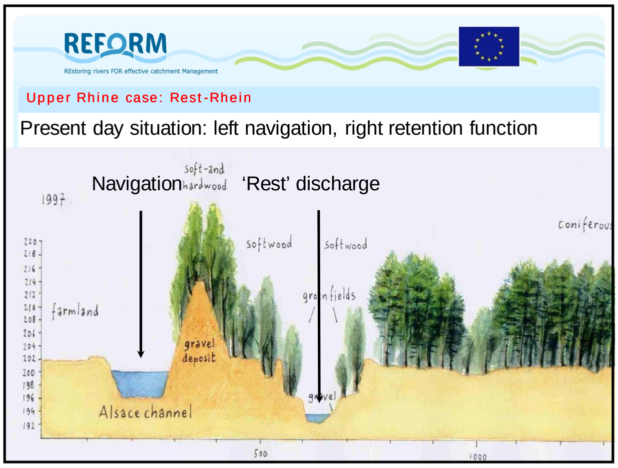
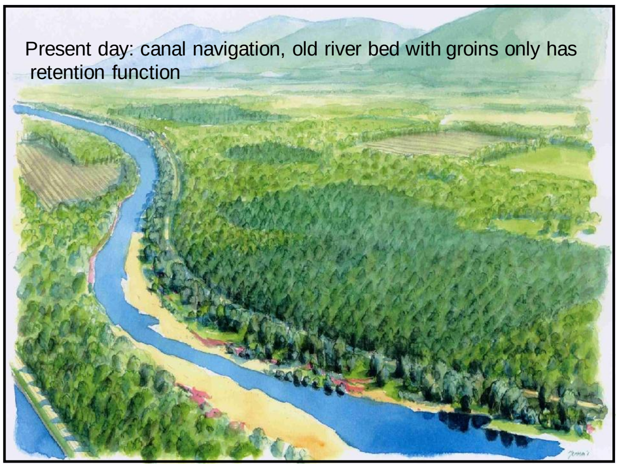
Angela's and Massimo's total perspective vortex (Hitch Hikers Guide to the Galaxy)
DON'T PANIC
wiki.reformrivers.eu

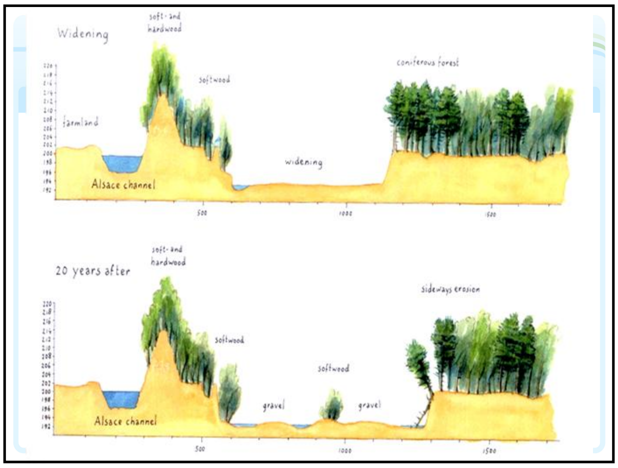

REFORM
REstoring rivers FOR effective catchment Management
THE REFORM FRAMEWORK: INPUT TO DESIGN
Questions to answer in context of management / rehabilitation design:
1. To what extent can reach interventions be removed (in channel, in riparian margins)?
2. To what extent can natural processes to the reach be reinstated (catchment and local)?
3. How may processes change in the near future (catchment and local scenarios)?
4. Given question 1 to 3, is current reach type the most sustainable option or is another type (of those present within landscape unit) more appropriate?
5. Design rehabilitation to allow river to recover its form and function as far as is possible given human constraints.
Source: REFORM Summer school lecture A. Gurnell

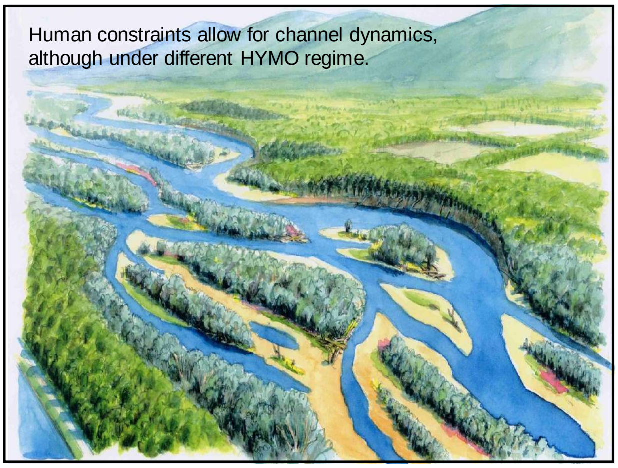

REFORM
REstoring rivers FOR effective catchment Management
River Rhine
The river's length is shortened by 100 kilometres in this section.
Within 100 years the floodplain area is reduced from 1000 km² to 130 km².
Section Basel - Karlsruhe

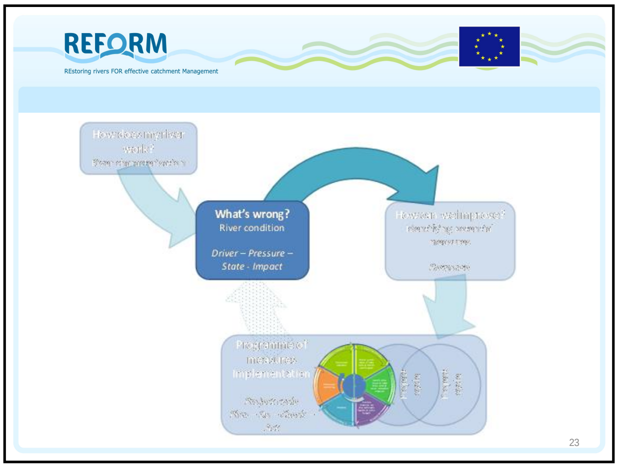

1838
1872
1997
Peters, B., Dittrich, A., Stoesser, T., Smits, A. J. M., & Geerling, G. W. (2001). The Restrhine: new opportunities for nature rehabilitation and flood prevention (p. 95). Nijmegen, Karlsruhe.

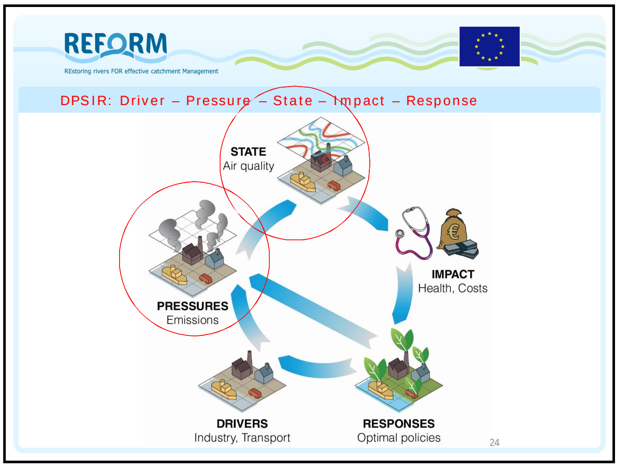

REFORM
REstoring rivers FOR effective catchment Management
Upper Rhine case: Rest-Rhein
Present day situation: left navigation, right retention function
Navigation
'Rest' discharge
1997
soft-and hardwood
softwood
softwood
coniferous
farmland
gravel deposit
groin fields
gravel
Alsace channel
500
1000

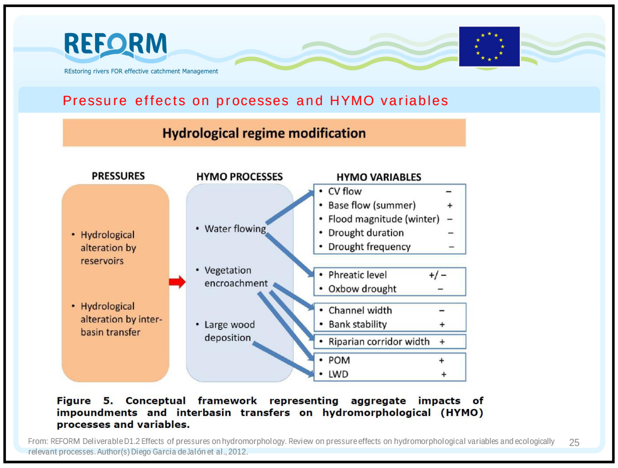

Present day: canal navigation, old river bed with groins only has retention function

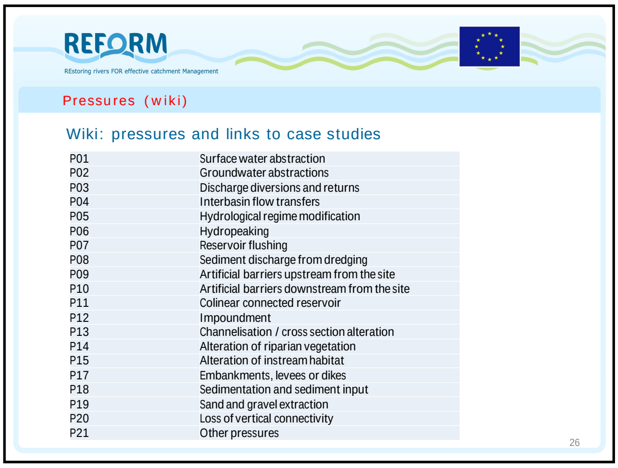

Widening
soft- and hardwood
softwood
coniferous forest
farmland
widening
Alsace channel
20 years after
soft- and hardwood
sideways erosion
softwood
softwood
gravel
gravel
Alsace channel

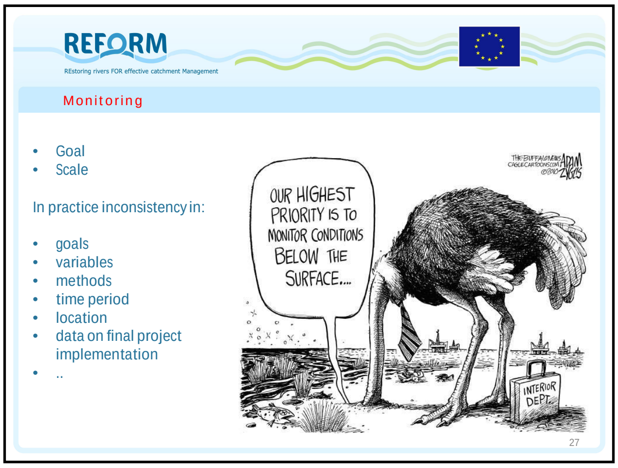

Human constraints allow for channel dynamics, although under different HYMO regime.

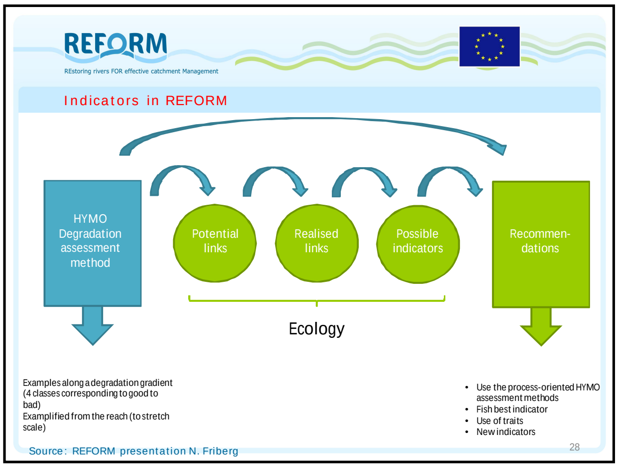

REFORM
REstoring rivers FOR effective catchment Management
What's wrong?
River condition
Driver – Pressure – State - Impact
23

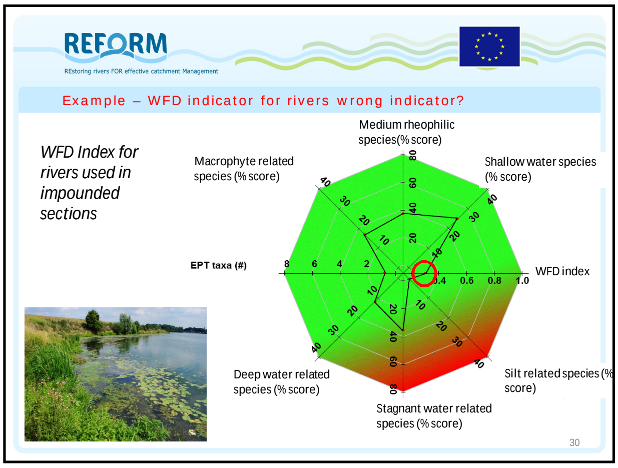

REFORM
REstoring rivers FOR effective catchment Management
DPSIR: Driver – Pressure – State – Impact – Response
STATE
Air quality
IMPACT
Health, Costs
PRESSURES
Emissions
DRIVERS
Industry, Transport
RESPONSES
Optimal policies
24

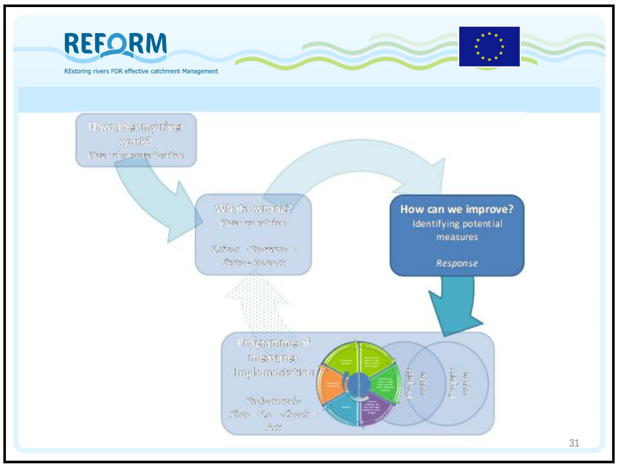

REFORM
REstoring rivers FOR effective catchment Management
Pressure effects on processes and HYMO variables
Hydrological regime modification
PRESSURES
HYMO PROCESSES
HYMO VARIABLES
• Hydrological alteration by reservoirs
• Hydrological alteration by inter-basin transfer
• Water flowing
• Vegetation encroachment
• Large wood deposition
• CV flow –
• Base flow (summer) +
• Flood magnitude (winter) –
• Drought duration –
• Drought frequency –
• Phreatic level +/ –
• Oxbow drought –
• Channel width –
• Bank stability +
• Riparian corridor width +
• POM +
• LWD +
Figure 5. Conceptual framework representing aggregate impacts of impoundments and interbasin transfers on hydromorphological (HYMO) processes and variables.
From: REFORM Deliverable D1.2 Effects of pressures on hydromorphology. Review on pressure effects on hydromorphological variables and ecologically relevant processes. Author(s) Diego García de Jalón et al., 2012.
25

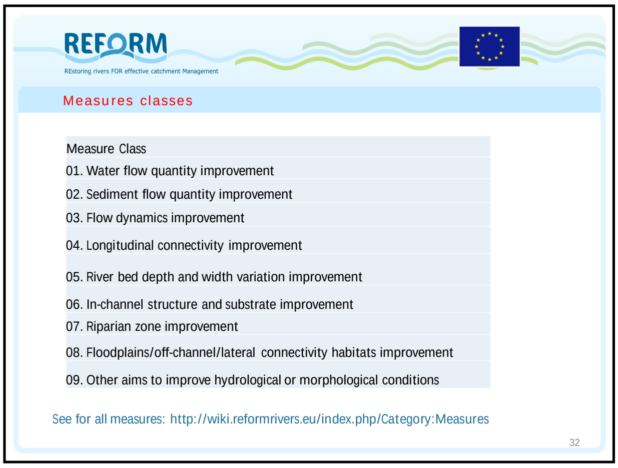

REFORM
REstoring rivers FOR effective catchment Management
Pressures (wiki)
Wiki: pressures and links to case studies
P01 Surface water abstraction
P02 Groundwater abstractions
P03 Discharge diversions and returns
P04 Interbasin flow transfers
P05 Hydrological regime modification
P06 Hydropeaking
P07 Reservoir flushing
P08 Sediment discharge from dredging
P09 Artificial barriers upstream from the site
P10 Artificial barriers downstream from the site
P11 Colinear connected reservoir
P12 Impoundment
P13 Channelisation / cross section alteration
P14 Alteration of riparian vegetation
P15 Alteration of instream habitat
P17 Embankments, levees or dikes
P18 Sedimentation and sediment input
P19 Sand and gravel extraction
P20 Loss of vertical connectivity
P21 Other pressures
26


REFORM
REstoring rivers FOR effective catchment Management
Monitoring
• Goal
• Scale
In practice inconsistency in:
• goals
• variables
• methods
• time period
• location
• data on final project implementation
• ..
OUR HIGHEST PRIORITY IS TO MONITOR CONDITIONS BELOW THE SURFACE...
INTERIOR DEPT.
27

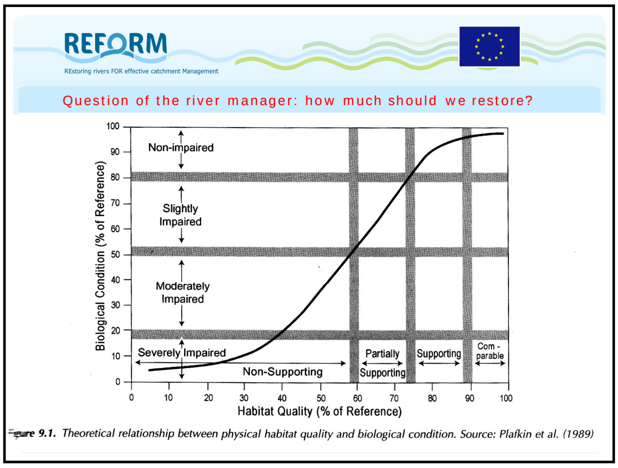

REFORM
REstoring rivers FOR effective catchment Management
Indicators in REFORM
HYMO Degradation assessment method
Potential links
Realised links
Possible indicators
Recommen-dations
Ecology
Examples along a degradation gradient (4 classes corresponding to good to bad)
Examplified from the reach (to stretch scale)
• Use the process-oriented HYMO assessment methods
• Fish best indicator
• Use of traits
• New indicators
Source: REFORM presentation N. Friberg
28

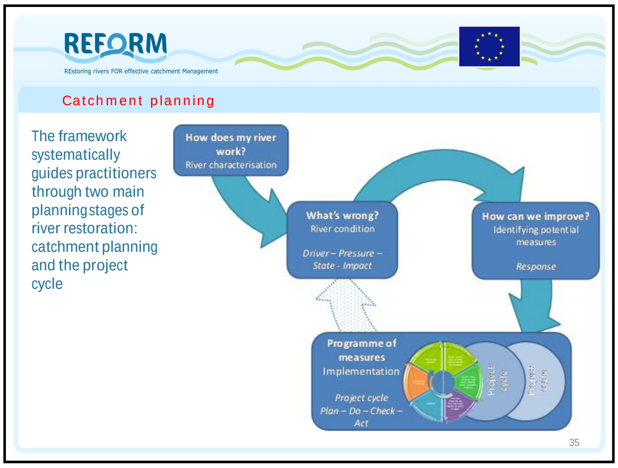

REFORM
REstoring rivers FOR effective catchment Management
Example – WFD indicator for rivers wrong indicator?
WFD Index for rivers used in impounded sections
Medium rheophilic species (% score)
Shallow water species (% score)
WFD index
Silt related species (% score)
Stagnant water related species (% score)
Deep water related species (% score)
EPT taxa (#)
Macrophyte related species (% score)
30

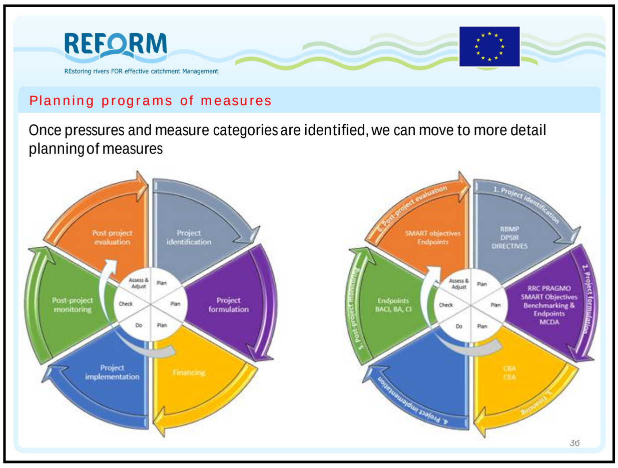

REFORM
REstoring rivers FOR effective catchment Management
How can we improve?
Identifying potential measures
Response
31


REFORM
REstoring rivers FOR effective catchment Management
Measures classes
Measure Class
01. Water flow quantity improvement
02. Sediment flow quantity improvement
03. Flow dynamics improvement
04. Longitudinal connectivity improvement
05. River bed depth and width variation improvement
06. In-channel structure and substrate improvement
07. Riparian zone improvement
08. Floodplains/off-channel/lateral connectivity habitats improvement
09. Other aims to improve hydrological or morphological conditions
See for all measures: http://wiki.reformrivers.eu/index.php/Category:Measures
32


REFORM
REstoring rivers FOR effective catchment Management
Pressure - Measure relations in wiki
Pressures
01. Water abstractions
Surface water abstraction (P0
Groundwater abstractions (P02
02. Flow regulations
Hydropeaking (P06)
Sediment discharge from dredg
Reservoir flushing (P07)
Hydrological regime modificatio
Interbasin flow transfers (P04)
Discharge diversions and retur
03. River fragmentation
Colinear connected reservoir (F
Artificial barriers downstream fr
Artificial barriers upstream from
04. Morphological alterations
Alteration of instream habitat (F
Sand and gravel extraction (P1
Sedimentation and sediment in
Embankments, levees or dikes
Loss of vertical connectivity (P
Measures
01. Water flow quantity improvement
01.5 Improve/Create water storage
01.9 Reduce water consumption
01.6 Increase minimum flows
01.8 Recycle used water
01.3 Improve water retention
01.2 Reduce surface water abstraction with return
01.7 Water diversion and transfer
01.1 Reduce surface water abstraction without return
01.4 Reduce groundwater extraction
02. Sediment flow quantity improvement
02.2 Reduce undesired sediment input
02.6 Manage dams for sediment flow
02.4 Reduce erosion
02.1 Add/feed sediment
02.3 Prevent sediment accumulation in reservoirs
02.5 Improve continuity of sediment transport
02.7 Trap sediments
33


REFORM
REstoring rivers FOR effective catchment Management
Question of the river manager: how much should we restore?
Non-impaired
Slightly Impaired
Moderately Impaired
Severely Impaired
Non-Supporting
Partially Supporting
Supporting
Com-parable
Biological Condition (% of Reference)
Habitat Quality (% of Reference)
Figure 9.1. Theoretical relationship between physical habitat quality and biological condition. Source: Plafkin et al. (1989)


REFORM
REstoring rivers FOR effective catchment Management
Catchment planning
The framework systematically guides practitioners through two main planning stages of river restoration: catchment planning and the project cycle
How does my river work?
River characterisation
What's wrong?
River condition
Driver – Pressure – State - Impact
How can we improve?
Identifying potential measures
Response
Programme of measures
Implementation
Project cycle
Plan – Do – Check – Act
35


REFORM
REstoring rivers FOR effective catchment Management
Planning programs of measures
Once pressures and measure categories are identified, we can move to more detail planning of measures
Post project evaluation
Project identification
Project formulation
Financing
Project implementation
Post-project monitoring
Assess & Adjust
Plan
Check
Do
6. Post-project evaluation
1. Project identification
2. Project formulation
3. Financing
4. Project implementation
5. Post-project monitoring
SMART objectives Endpoints
RBMP DPSIR DIRECTIVES
RRC PRAGMO SMART Objectives Benchmarking & Endpoints MCDA
CBA CEA
Endpoints BACI, BA, CI
36

REFORM
REstoring rivers FOR effective catchment Management

How? Tools provided in the wiki

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)
- Cost Benefit Analysis (CBA)

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"Using natural processes" (Yellow River China)