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PRACTICAL IMPLEMENTATION OF FRESHWATER PEARL MUSSEL CONSERVATION MEASURES

CONFERENCE

Conference Proceedings
Letterkenny, County Donegal
15th February 2013

TABLE OF CONTENTS

Opening Address

Donegal County Council and the Northern Ireland Environment Agency were delighted to welcome delegates to this one day conference in Letterkenny which was hosted by the ***Practical Implementation of Freshwater Pearl Mussel Measures Project*** (FPM Project). Donegal County Council, in partnership with Northern Ireland Environment Agency, has been awarded funding under the European Union's European Regional Development Fund for the FPM project aimed at securing the conservation of the Freshwater Pearl Mussel (FPM). The project is grant aided under the European Union's INTERREG IVA Programme, as part of the Environment strand, under Priority 2.2.

A tradition of coordination has been maintained for many years in relation to cross-border water quality management on the island of Ireland. Before the introduction of significant EU water policy legislation, i.e. the Water Framework Directive, this coordination was less structured and formalised, but it included arrangements on notification of pollution incidents and responses to these incidents. During the early 1990s water quality management strategies were jointly developed for the Foyle and Erne catchments. The responsible government authorities in both jurisdictions have maintained a high level of coordination in conservation management and river basin planning. The primary means of ongoing co-ordination for river basin planning is through the North-South Water Framework Directive Coordination Group, which is supported by a number of technical working groups with representatives from the implementing authorities in Ireland and Northern Ireland.

The island of Ireland supports a major proportion of the FPM populations remaining in Europe. Virtually all of these populations are at unfavourable conservation status and evidence suggests that recruitment of juvenile mussels to the adult population has substantially failed in recent decades. The FPM Project aims to help advance the conservation of the pearl mussel through a number of tasks, including the development of conservation strategies for SAC rivers in Northern Ireland, the trialling of practical measures to address catchment pressures, and the development of guidance for various sectors to allow for a sustainable approach in FPM catchments. The project is carrying out its work in the relevant part of the Interreg IVA area i.e. Northern Ireland and the border region of Ireland, and is scheduled for completion in 2014. The project is managed through a Steering Group and supported by a Technical Group which are comprised of relevant stakeholders in both jurisdictions. More information on the project can be found on the project website www.freshwaterpearlussel.com which provides links to the key supporting agencies websites.

This conference focused on the trialing of practical measures and has brought together experts in FPM conservation from across Europe to facilitate exchange of information and experience, both successes and failures. In the days before this conference, the FPM Project hosted a meeting in Belfast of an expert group convened to develop a standard for the requirements of the freshwater pearl mussel under the aegis of the European Committee for Standardisation (CEN; Comité Européen de Normalisation). If successful, this will be the first CEN standard for the requirements of a living species and will act as a prototype for standards for other endangered species. Most of this group also attended and presented at the FPM Conference in Letterkenny, sharing their vast experience with other delegates. The conference provided a unique opportunity for a pan-European review of FPM conservation strategies and practical efforts. It highlighted the critical status of this flagship species throughout its range and the common nature of many of the pressures that need to be addressed to restore it to favourable conservation status. The conference was attended by

over 100 delegates with Northern Ireland, Scotland, England, Wales, Ireland, Norway, Finland, Sweden, France, Germany, Spain, Portugal and Luxemburg all in attendance – just about anywhere there are pearl mussels in Europe! Indeed, one extremely important aspect of the conference was its role in consolidating and extending the network of FPM conservation interests throughout Europe.

These abstracts are provided as a succinct account of the material covered during the conference. Much of the material outlined has been, or is currently being prepared for peer-reviewed publication by the authors. The contact details of all contributors are provided for those who wish to continue conversations initiated at the conference, or who would like to seek further information.

Finally, we would like to take the opportunity to thank the project funding agency, the European Regional Development Fund which has grant aided the project under the European Union's INTERREG IVA Programme, administered by the Special EU Programmes Body (SEUPB), all our speakers and those who contributed to the informed and lively discussions that ensured the resounding success of the conference. Thanks are also due to our project partners, and members of the steering and technical groups for their continued support and guidance.

Gabriel Nelson
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Donal Casey
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Donegal County Council

Conference Contributors
Left to Right: R. Vandre (Germany), M. Capoulade (France), F. Thielen (Luxembourg), P. Oulasvirta (Finland), H. Soderberg (Sweden), M. Lopez Lima (Portugal), Gabriel Nelson (Northern Ireland), T. Mc Nally (Ireland), J. Geist (Germany), E. Moorkens (Ireland), P.E. Aspholm (Norway), L. Henrikson (Sweden), L. LaVictoire (England), D. Casey (Ireland), I. Killen (England), M. Magee (Ireland)

Conference Schedule

Radisson Hotel, Letterkenny, County Donegal, Ireland

Held Friday 15th February 2013

Welcome and Introduction

Session 1 - Chair: Evelyn Moorkens, EMA Associates

Moving from population monitoring to practical measures for catchment improvement. ***Evelyn Moorkens, Interreg project, Ireland***.

Practical measures undertaken in Donegal and Northern Ireland as part of the Interreg project. ***Mark Magee, Interreg project, Ireland***.

Dam removal and habitat improvements in River Nätraån, Sweden. ***Håkan' Söderberg, Sweden***.

Session 2 - Chair: Juergen Geist, Technische Universität München

Informing catchment management requirements from data collected from pearl mussel populations. ***Ian Killeen, England***.

Habitat restoration measures for the freshwater pearl mussel (*Margaritifera margaritifera*) in the low mountain range of the Ardennes in Luxembourg. ***Frankie Thielen, Luxembourg***.

Restoration of freshwater pearl mussel populations with new methods - an EU Interreg project in the northern Fennoscandia. ***Panu Oulasvirta, Finland***.

Session 3 - Chair: Ian Killeen, Malacological Services

Substratum restoration measures in freshwater mussel streams. ***Juergen Geist, Germany***.

Investigations into factors causing pearl mussel decline in the North Tyne catchment, north east England. ***Louise Lavictoire, England***.

A view on some practical measures for improvement and restoration of northernmost *Margaritifera* populations. ***Paul Eric Aspholm, Norway***.

Freshwater Pearl Mussel Conservation in the Armorican Massif. ***Marie Capoulade, France***

Session 4 - Chair: Evelyn Moorkens,

Overview of FPM conservation actions in Sweden. ***Lennart Henrikson, Sweden.***

Influences from and management of catchments supporting rivers with mussel populations. ***Christine Schmidt and Robert Vandre, Germany.***

Discussion

Summary of Conference Papers

Please be aware that the trials and measures undertaken and reported on in the abstracts relate to specific catchment conditions and may not be relevant or appropriate in all circumstances. The views and opinions expressed in these abstracts do not necessarily reflect those of the FPM Project, the Project Partners or funding agencies, nor does this document purport to represent policy of any government.

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Moving from population monitoring to practical measures for catchment improvement

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The freshwater pearl mussel (FPM) has been a source of attention since Roman times, and the subject of ecological investigation since the birth of this science. The decline of the species has been highlighted and investigated since the 1980s. Such investigations took on a wider and faster pace since the species was protected by law under the European habitat's and species Directive, and under the national laws of the countries in which it lives.

The more research that has been carried out on the species, the more sensitive and complicated it has shown itself to be. We have continually revised our best estimate of water quality and sediment quality requirements upwards over the years.

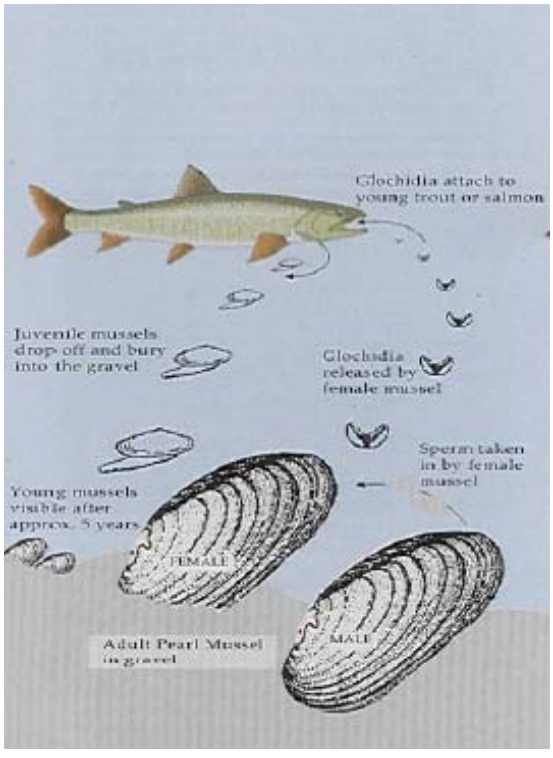

Figure 1. FPM Lifecycle

Because the FPM can live for over 100 years, it has become a demonstration species for slow decline and how changes in the landscape relate back to the river bed sediment. The survival of juvenile mussels 5cm below the sediment surface for their first 5 years has been demonstrated since the early 1990s as being the key stage of loss, and became the focus of research for many scientists working subsequently. Other key areas of research have been population genetics, in order to prioritise conservation units to focus attention on, and captive breeding, as a medium term means of maintaining genetic supply until river bed conditions can be improved.

From 2008 to 2010, the Republic of Ireland put together sub-basin catchment management plans that assessed the status of 27 Natura 2000 populations, and the potential means of returning them to favourable condition. The data gathered during this exercise reinforced our knowledge of pearl mussel requirements and sensitivities.
Information on catchment activities was used to assess and prioritise populations for the next stage of pearl mussel conservation – catchment management measures.

Extinction curves can be used to predict the future of FPM populations if we know the approximate age profile of the mussels, and the recruitment success of various age classes. This gives us an indication of how much time we have to rehabilitate the flow and river bed sediment quality. An assessment of the Upper Catchment function can indicate the potential and the time needed for rehabilitation of enough function to allow for sustainable flows and sediment levels.

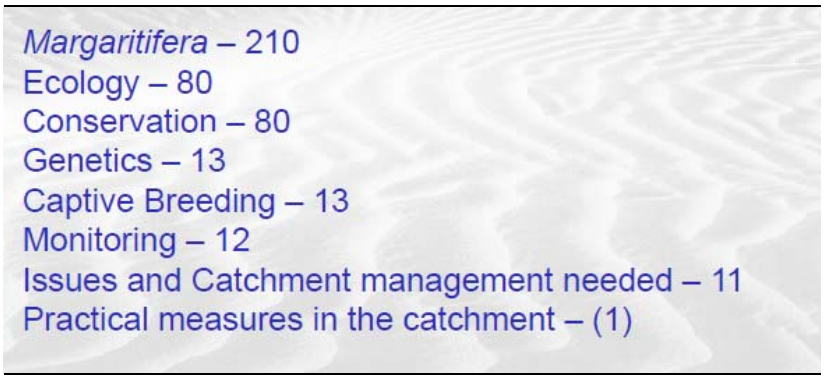

Table 1. A breakdown of 210 peer reviewed FPM papers by research areas

As an area of research, the last 40 years has been spent in understanding the requirements of the FPM, particularly through monitoring programmes. What is absolutely clear is that unless upper catchment conditions are improved to the level of rehabilitation of function of adequate flow and low sediment and nutrient levels, our populations will continue to move toward extinction. Therefore, the new phase of FPM research needs to be on practical measures that help this rehabilitation.

Practical measures undertaken in Donegal and Northern Ireland as part of the Interreg project

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The Practical Implementation of Freshwater Pearl Mussel Measures project, which runs from 2011 to 2014, is funded by the European Union's INTERREG IVA programme, as part of the environment strand, under Priority 2.2 and is being undertaken in Northern Ireland and the border region of Ireland. The project is being managed in partnership between Donegal County Council and the Northern Ireland Environment Agency. Further details are available at (www.freshwaterpearlmussel.com).

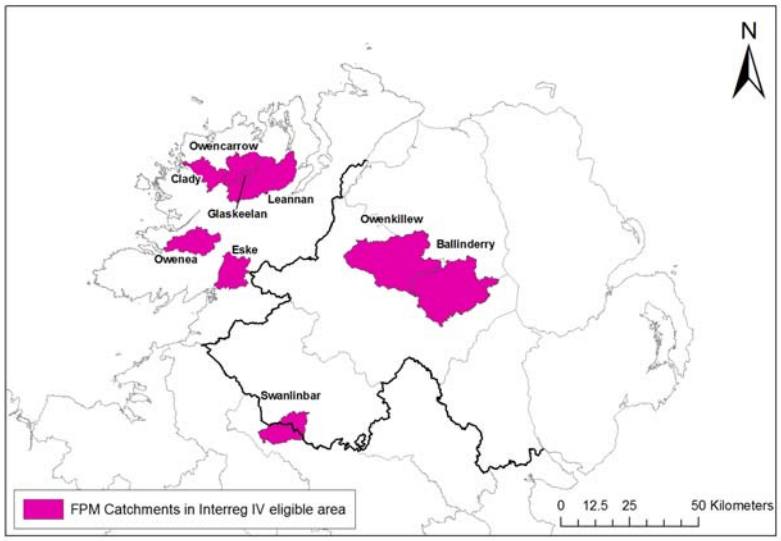

Figure 1. FPM catchments in the project study area

The project has three main tasks:

1) Preparation of management strategies for the 3 Northern Ireland Natura 2000 FPM catchments.
2) Trialling of practical measures aimed at protecting mussel populations.
3) Preparation of guidelines for various sectors to ensure sustainability in pearl mussel catchments.

The focus of this presentation is on task 2, trialling of practical measures, and outines project experiences to date in trialling measures to address agricultural, forestry and on-site waste water treatment systems pressures in freshwater pearl mussel catchments. High frequency telemetry monitoring at upstream and downstream sites in trial catchments is being used to assess efficacy of measures trialled.

Agricultural Measures

The project focussed on measures relating to sediment movement in two catchments, the upper Leannan in County Donegal, Ireland, and the Owenreagh (part of the Owenkillew catchment) in County Tyrone, Northern Ireland. Agriculture is the predominant land use in both these sub-catchments.

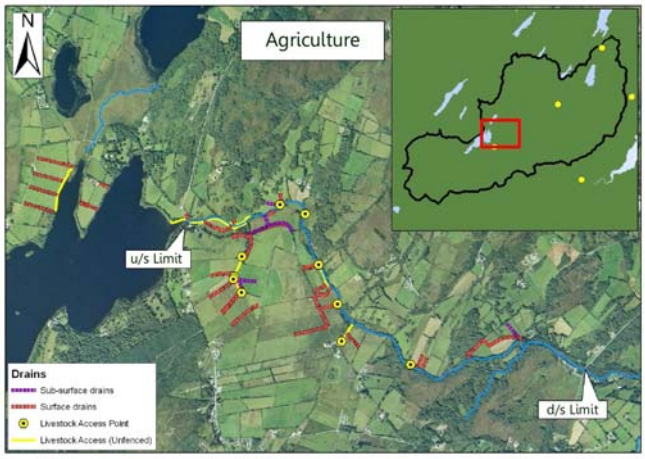

Figure 2. Sample catchment survey identifying drainage and animal access points

Figure 3. Sediment sampling box in drainage ditch

Initial catchment surveys identified land drainage as the pressure of most significance (Figure 2). Sediment sampling boxes were installed in drainage ditches in mini-catchments to assess the nature and volume of sediment being exported and how this related to rainfall events (Figure 3). The information informed minimum design requirements for effective sediment traps and allowed consideration of the practicability of such measures in FPM catchments.

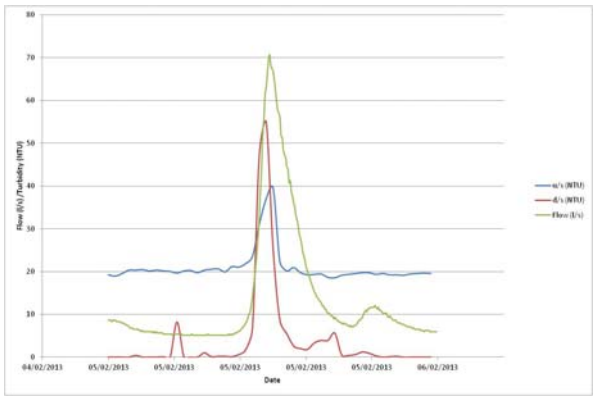

Figure 4. Sediment box upstream (blue) and downstream (red) turbidities and flow (green)

Sediment particle sizes were predominantly in the 10 - 100 µm range and while there was significant removal in sediment sampling boxes, sediment was subject to resuspension during rainfall events (Figure 4). Large scale sediment traps required for effective removal are impracticable due to their size, maintenance requirements and numbers necessary in intensively drained catchments.

Alternative catchment modelling approaches using Sensitive Catchment Integrated Modelling and Analysis Platform (SCIMAP) and Universal Soil Loss Equation are being trialled to identify areas at high risk of erosion (Figure 5). The accuracy of these models and the adequacy of datasets on which they are based are being assessed through ground truthing in selected areas. These models will be used in testing several catchment management scenarios.

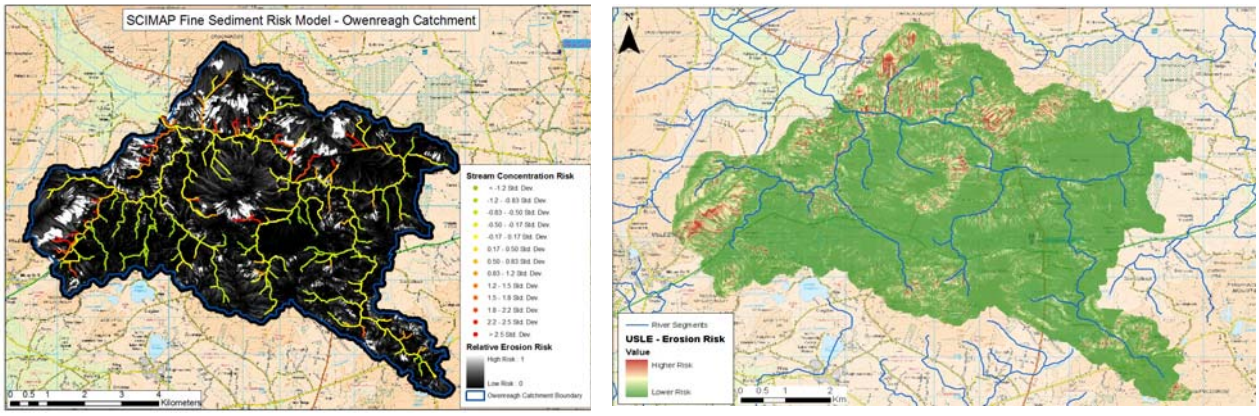

Figure 5. Catchment models showing areas at high risk of erosion based on Sensitivie Catchment Integrated Modelling and Analysis Platform (SCIMAP) and Universal Soil Loss Equation (USLE)

Forestry Measures

The use of a continuous cover system as an alternative to clear felling is being trialled in the Derryveagh forest, Donegal. Trial plots with various underplanting/regeneration have been established. Vegetation, forest productivity and export of materials are being monitored (Figure 6).

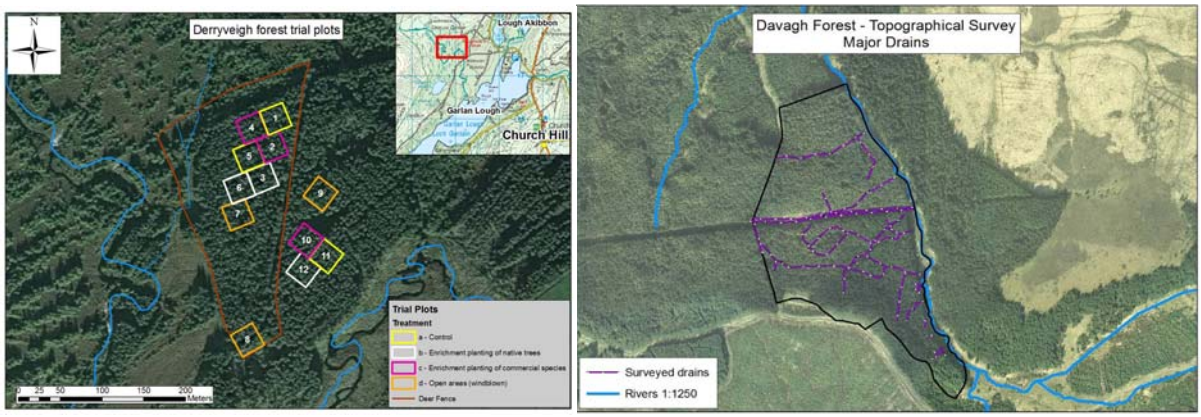

Figure 6. Trial plots in the Derryveagh forest and drainage mapping in the Davagh forest

At the Davagh forest detailed drainage audits have been carried out using a variety of techniques to identify critical drainage features for focused measures during felling operations. The effectiveness of implemented measures will be monitoried during clear felling of this coupe.

On-site Waste Water Systems

Surveys of public awareness, household water usage and wastewater system audits were carried out in FPM sub-catchments. Tank desludging and dye testing provided additional information on system condition and performance.

Acknowledgements: The project gratefully acknowleges the support and assistance of DARD Forest Service, Coillte and other land and house owners in allowing access to trial sites.

Dam removal and habitat improvement in River Nätraån

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The river Nätraån is situated in the county Västernorrland, in northern part of Sweden. The length of the river is approximately 100 km and the drainage area is 1024 km2. In the mid 1970's a dam, "Kubadammen", was built on the outlet of river Nätraån in order to supply a nearby industry with freshwater. The industrial activities ended in the 1980s, soon after the dam was built and this has since then been an unsightly monument.

Figure 1. Dam on Nätraån. Left image shows scale of dam (top 42m long and fall 2.3m). Image on right shows non-functional fishway.

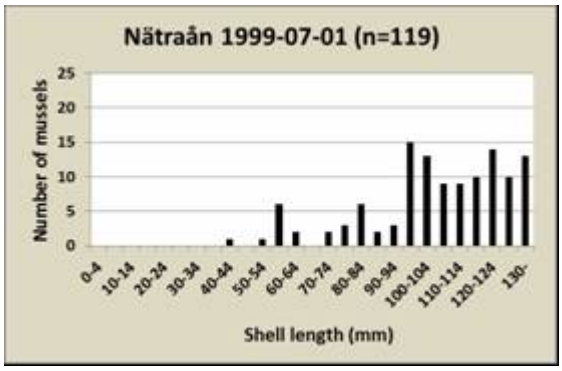

Figure 2. Size profile of FPM population showing lack of recruitment

Before the dam was built anadromous fish species like salmon and sea trout inhabited Nätraån. The river also supports a population of freshwater pearl mussel, *Margaritifera margaritifera* (FPM). Studies of the population status in the late 1990s reveal problems with recruitment, probably due to scarcity of host fish.

In a survey, initiated by the Swedish Environmental Protection Agency (SEPA), Nätraån was assessed as a river with national conservation value mainly because of the occurrence of the FPM population. The environmental court approved an application in 2006 from the dam owner to remove the dam and soon after that SEPA

Figure 3. Site post removal of the dam

approved an application for removal from the County Administrative Board of Västernorrland.

There are four rapids close to and upstream of the dam position that have been impaired by channelizing, and cleaned of boulders and trees in order to create good conditions for timber rafting. Restoration of the rapids was included in the application. The occurrence of FPM in the rapids complicated the improvement activities and required special efforts.

Figure 4. Removal of mussels during restoration works

Figure 5. Restoration works involving replacement of spawning substrate by helicopter and excavator (472 tonnes) and large boulders. 486m of shoreline was also restored.

The restoration project was followed up by assessing FPM, fish, invertebrates and riparian vegetation. Invertebrates were sampled in spring and summer over 3 years at 5 localities. Plant colonisation in the new riparian zone was fast and species composition became increasingly similar to that of the reference reach.

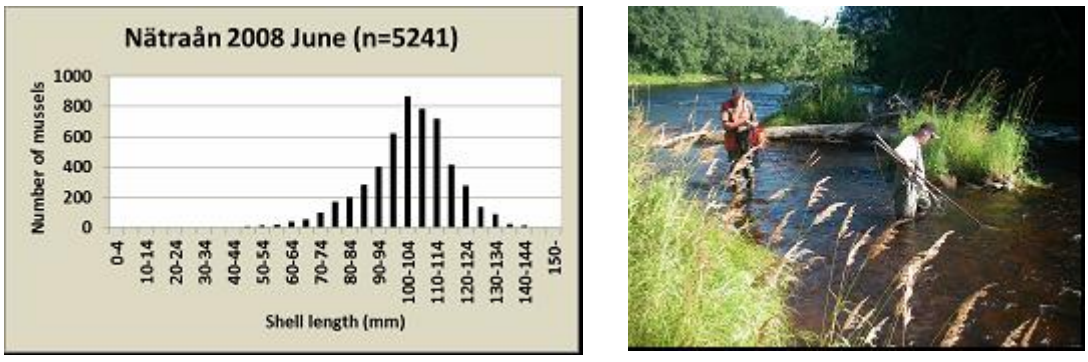

Figure 6. Post restoration FPM and electrofishing surveys.

REFERENCE:

Vegetation; 2012. Lejon, A.G.C, Renöfält, B.M. and Nilsson, C. Dam removal effects on riparian vegetation. Manuscript in doctoral thesis *"Ecosystem response to dam removal"*, Anna G.C. Lejon, Umeå University, Sweden.

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Informing catchment management requirements from data collected from pearl mussel populations.

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The River Ehen in NW England supports the country's largest population of pearl mussels with an excess of half a million individuals. However, recruitment levels are very low and mussels under 15 years of age comprise less than 1.5% of the total number. Juveniles are found only in the stable, fast-flowing riffles. Without major intervention, the population is destined for a long and slow extinction. Since 2006, the Ehen population has been the focus of annual detailed studies. Many of the catchment issues such as sources of sediment and nutrient input have been identified and are in the process of being addressed. This will continue as part of a new LIFE+ project which commenced in January 2013.

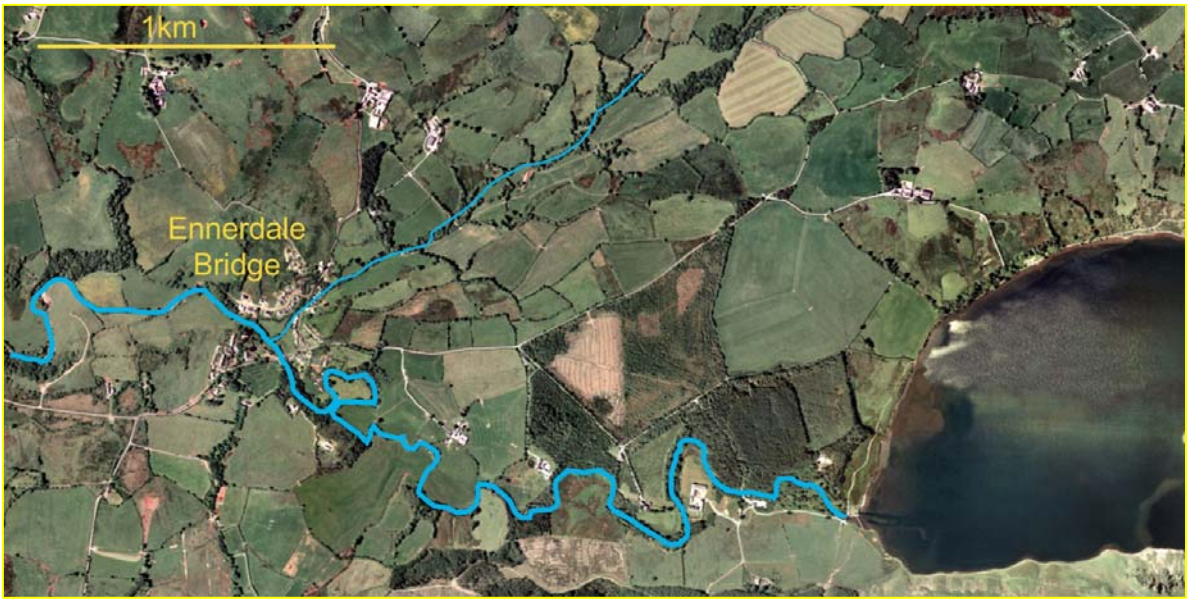

Figure 1. River Ehen, draining a relatively deep oligotrophic lake with farming, tourism and forestry as the predominant land-uses.

The major ongoing studies that have been successfully employed and developed to inform catchment management have included redox measurements and permanent transects. However, in spring 2012 a series of extreme low flow events focused attention towards flow management. The low flows accelerated growths of large quantities of algae and diatoms, and placed high stress on the mussels such that they lifted from the substrate, and which was followed by mussel kills.

The Ehen is a regulated river that operates within a daily abstraction and a minimum compensation flow regime. Monitoring of the mussels and their habitat and environment need to be focused to be able to ultimately achieve a sustainable population. As flow is the key issue in this catchment, measurement of water velocity at river bed level is an essential element of monitoring for this population.

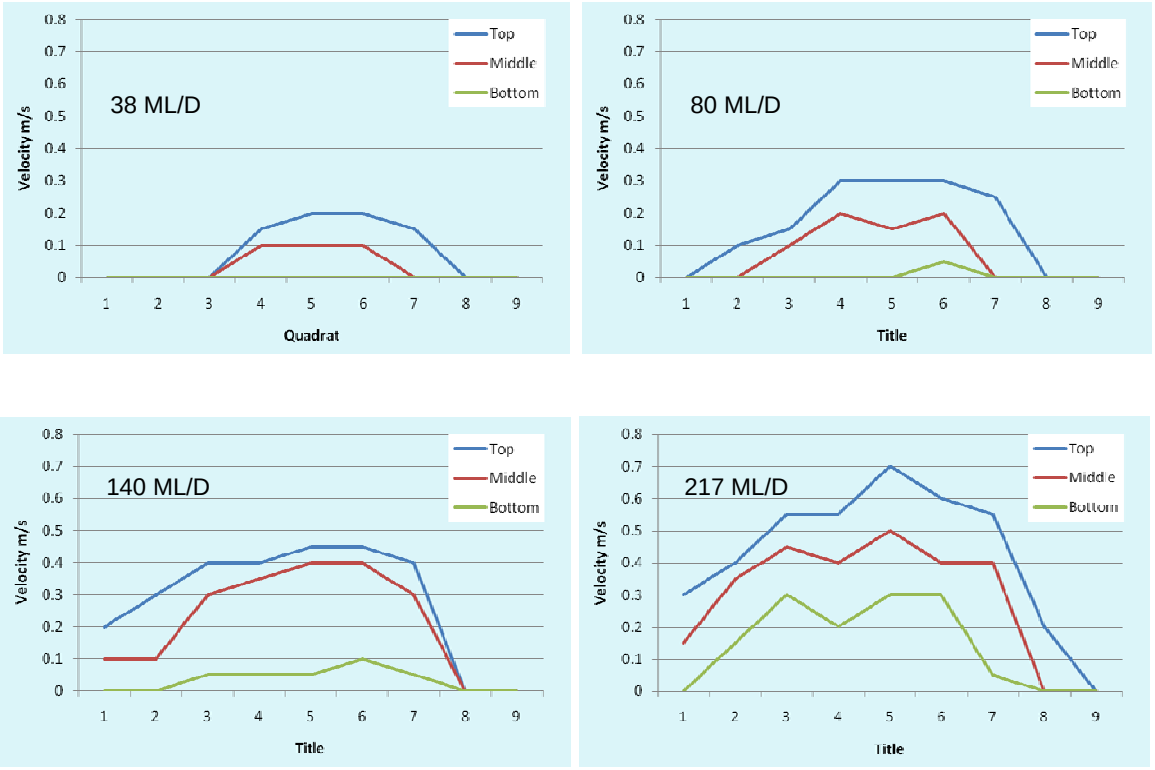

Figure 2. Water velocity measurements taken at three different depths in a FPM quadrat under a range of river flow conditions (Megalitres per day)

Habitat Restoration Measures for the Freshwater Pearl Mussel (*Margaritifera margaritifera*) in The Low Mountain Range of the Ardennes in Luxembourg

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Freshwater mussels belong to the most imperiled animals worldwide. Particularly the long lived species, *Margaritifera margaritifera,* shows a dramatic decline within its distribution area. Many local populations have become extinct or are close to extinction. Eutrophication and siltation of the river due to anthropogenic changes in the catchment area are the main factors responsible for the non functional populations of FPM populations showing little to no recruitment. Propagation programmes can help avoid the complete disappearance of local populations. The only sustainable way to protect a mussel population is to restore the habitat, although this process may take many years.

In order to protect the last existing Freshwater Pearl Mussel population in the River Our in northern Luxembourg (Europe) a LIFE NATURE project commenced in 2005 and finished in August 2011. The aim of this project was to enhance the declining population by captive breeding and restoring its habitat.

Figure 1. Removal 7.15ha of spruce, and plantation of 6.44ha of deciduous forest.

The following habitat restoration measures have been completed within the project:
To reduce the amount of fine sediment entering the river 7.15 hectares of inappropriate spruce forest was removed. 6.44 hectares of deciduous forest have been planted. To reduce the impact of cattle on the river banks, 2.5 km of fence, ten watering facilities and four cattle bridges were constructed. As the natural transport of gravel in the river system is still disturbed by 3 smaller dams, 500 m^3 of gravel has been added into the river during the past five years. To aid the host fish (brown trout) reaching their spawning grounds; twelve migration obstacles were removed in smaller creeks.

Figure 2. Installation of 2.5km fencing, cattle bridges and watering points.

These restoration measures have surely a positive impact on the biota of the river Our and hopefully also on the freshwater pearl mussel population. However with monitoring methods (e.g. electrofishing, redox measurements, water analysis…) it is extremely difficult to see any obvious results in the short term in the main stream, which has a catchment of about 700km2 distributed over three countries. On the other hand results of removing fish migration obstacles are rapidly evident.

Figure 3. Addition of gravels to main channel and removal of obstacles to host fish migration in tributaries.

"Restoration of freshwater pearl mussel populations with new methods" – an EU Interreg project in northern Fennoscandia

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Figure 1. Northern Fennoscandia (red circle)

The main goal of this Finnish-Norwegian-Swedish project is to develop co-operation between Nordic authorities and research institutes for the conservation of freshwater pearl mussel (*Margaritifera margaritifera*). Moreover, we aim to develop new methods for restoration of declined and non-recruiting mussel populations. The project started in June 2011 and ends in May 2014. An important part of the project is to provide updated information on the conservation and management of freshwater pearl mussel populations for those target groups who are involved with management of the river environment or whose decisions or activities may influence the state of the rivers. The project area covers the whole of northern Fennoscandia.

The project is funded by the European Union Interreg IV A program and by the nine participating project partners. Seven project work packages have been identified as follows:

1. Network - Establish a co-operative network of experts and institutes involved in FPM management and conservation. Promote exchange of information and experiences across national borders and harmonizing of methods.
2. Analyses of state of FPM populations and their habitats - Assess the state of key FPM populations in northern Fennoscandia (especially Finland). Define the categories of habitats providing successful recruitment for young mussels, establish a base for the regular monitoring program for FPM populations in Finland.
3. Analyses of toxic substances - Evaluate the role of toxic substances in the decline of FPM populations based on measurements from water, sediment and mussels (shell and tissue).
4. Genetic Analyses - Describe the current genetic structure and colonization history of FPM populations. Assess the genetic diversity and differentiation of the FPM in the project area. Compare the genetic diversity (allelic richness, heterozygosity) of FPM populations which depend on different host fish and determine the potential genetic dependence on host fish. Compare genetic diversity of recruiting with non-recruiting populations.
5. Host Fish and Juvenile Mussel Cultivation - Develop methods to artificially infect host-fish by FPM larvae both *in situ* with fish cages and in the laboratory. Develop and test methods for cultivating juvenile FPM in the laboratory and thereafter plant them into the river. Determine the degree of host specificity in main channel/tributaries of a selected river. Study the importance of the host fish density to the glochidia infection rate and develop protocols for fish farms to infect cultivated fish with FPM larvae.

6. Search for New Populations – Trial a method for population detection in remote areas based on host fish glochidial infection.
7. Information – Produce and disseminate information for decision makers and local people.

Initial results of some of the work packages are outlined below.

Analyses of the state of the FPM populations and their habitats.
Mussels under 5 years old are too small to be detected visibly without digging sediment, which may explain why none of the rivers show very recent recruitment. However, size distribution is dependent on sampling site, and common criteria are required for sample design and judging the state of the population.

Table 1. Effect of sample site selection on mussel length class distribution in the tributary of the Tornionjoki River.

	Length class proportion (%)					Classification system		
Sample sites	**0-20 mm**	**0-30 mm**	**0-50 mm**	**0-65 mm**	**n**	**CEN**	**Scottish**	**Nordic**
Whole river, random transects	0	0	1	6	195	Non-functional	Non-functional	Non-functional
Optimal area, random sample 0,2X0,2 m	0	0	0	9	43	Non-functional	Non-functional	Non-functional
Optimal area, random sample 0,5x0,5 m	1	3	5	6	103	Non-functional	Non-functional	Non-functional
Optimal area, non-random sample 0,5X0,5 m	9	16	23	24	104	Functional (?)*	Functional	Functional
"Kinder garden", non random sample 0,2x0,2 m	5	10	100	100	21	Functional (?)*	Functional	Functional
						*not very recent recruitment (< 5 years)		

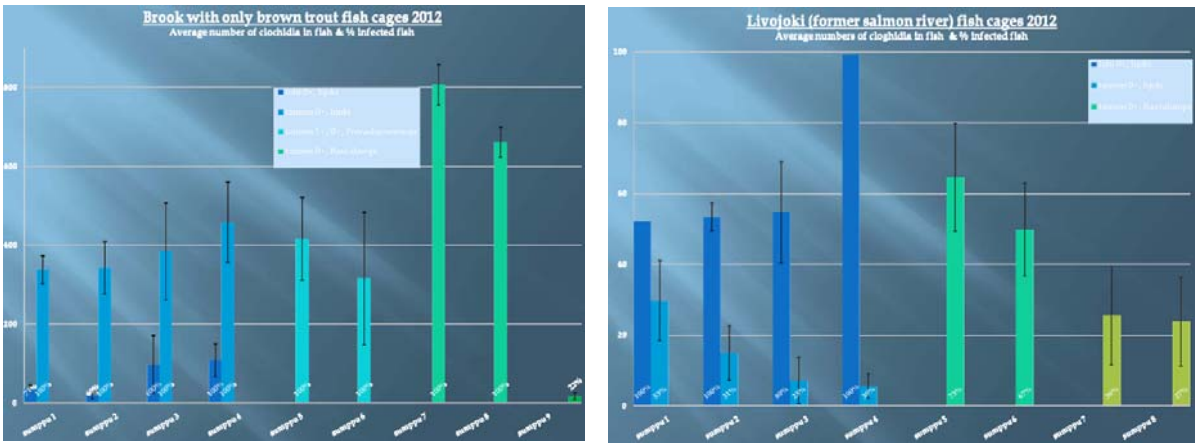

Figure 2. Mean numbers of glochidia on host fish and percentage host fish infected in fish cage experiments in two rivers.

Host Fish. Mussels in the old salmon rivers prefer salmon as a host and in small brooks brown trout (with exceptions!). The local brown trout is not always the best host. Preliminary results suggest that duckmussel infection may cause immunity against FPM infection.

New Populations. Three new FPM rivers were found in the Iijoki river catchment, but no new ones in the Tana and Neiden catchments. Detection of glochidia infection in field is 100% reliable when the number of glochidia is greater than 20. Host fish "always" reveal the presence of a FPM population when the mussel population is big. Testing of the method in scarse populations still ongoing. Electro fishing equipment is heavy to carry in remote areas and therefore angling and other methods to catch host fish will be tested.

Substratum Restoration Measures in Freshwater Mussel Streams

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Stream substratum composition has been identified as playing a key role in the survival and development of juvenile freshwater pearl mussels after their parasitic phase on a host fish, as well as for successful egg and larval development of many freshwater fishes. While the physico-chemical factors which influence survival of juvenile mussels and gravel-spawning fish in the interstices are well understood, there are few systematic studies which compare the effectiveness of different substratum restoration techniques.

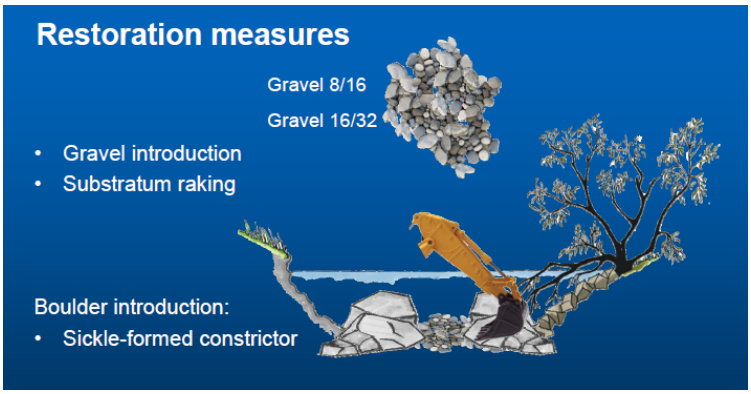

Figure 1. Possible restoration techniques

In Germany, substratum raking and excavation, as well as introductions of different gravel fractions and in-stream structures are all considered appropriate substratum restoration techniques for fishes and mussels. This study compared the effects of some of the most commonly used restoration techniques in different stream ecosystems, considering effects within the treated sites, as well as those on downstream habitats.

Study streams included three systems on calcareous and three on siliceous geologies. Restoration effects were monitored on the abiotic environment including structural habitat characteristics and substratum quality, and on biotic elements including fishes, macroinvertebrates, periphyton and macrophytes.

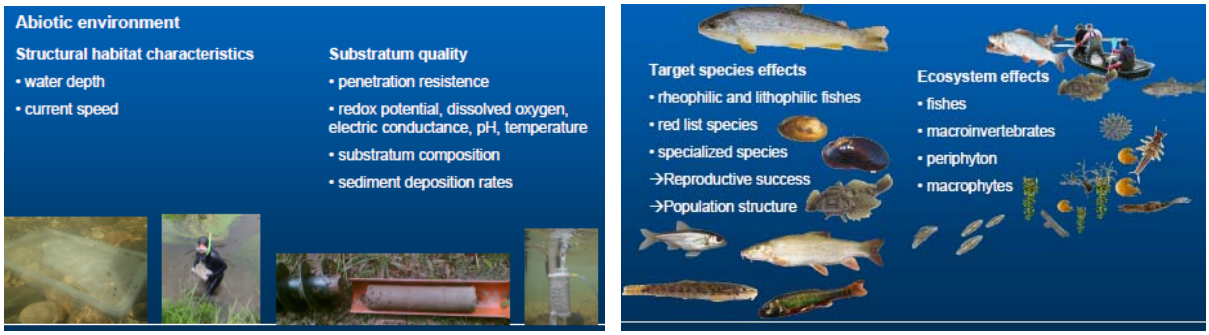

Figure 2. Abiotic and Biotic elements on which effects of restoration were assessed

The results of this study indicate that some measures such as substratum raking are likely to cause more negative than positive effects on stream habitats and aquatic species. In contrast, other measures such as gravel introductions of certain texture compositions were found to have more positive and sustainable effects as evident from improved interstitial water quality parameters and bioindication results.

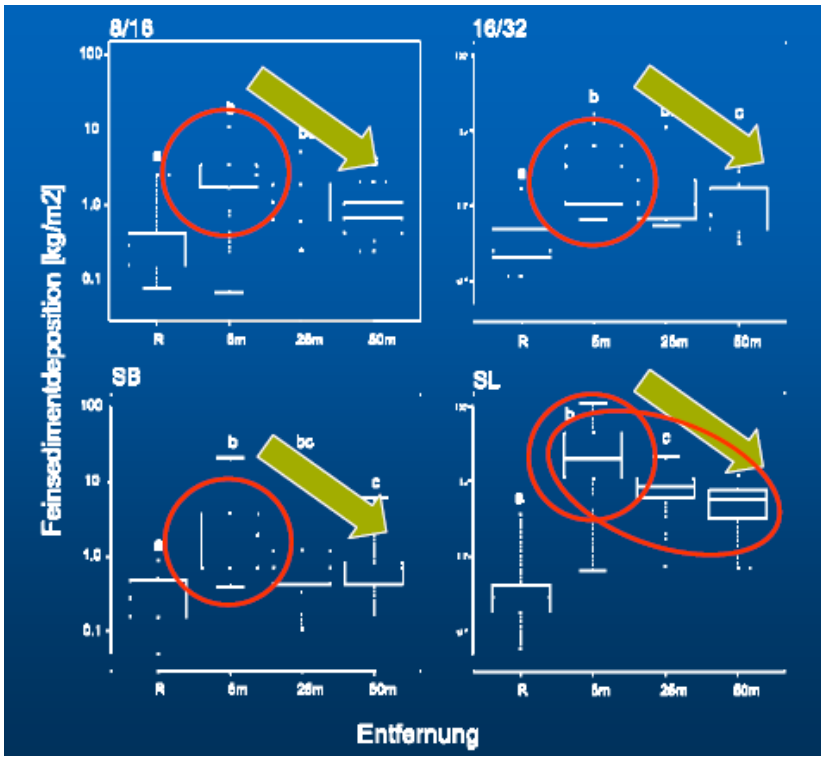

Figure 3. Example of restoration techniques on fine sediment deposition 5m upstream of the treatment site (R) and at sites 5, 25 and 50 metres downstream. The top panels show gravel introduction, and lower panels show boulder placement (left) and substratum raking (right). This latter shows sediment deposition rates up to 12-fold higher than for other measures. Turbidity is also up to 50-fold higher and remains high 50m downstream of treated site.

In general conclusion, improvements due to restoration in interstitial water chemistry in most rivers were only detectable for 3 months. The most marked effects were found for gravel introductions, with less pronounced effects for substratum raking and sickle-formed constrictor. However, results were strongly dependent on the study river and site. Restoration measures did have effects on target species and on ecosystem level, but effects were restricted to species already present at a minimum viable population size prior to restoration. Reproductive success of species depending on long-term improvement of interstitial water quality could not be enhanced. Consequently, in-stream restoration cannot replace proper catchment management and natural river dynamics.

Ultimately, more systematic and rigorous evaluations of restoration measures are needed for identification of the most useful and cost-effective approaches.

Investigations into factors causing pearl mussel decline in the North Tyne catchment, north east England

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The Tyne Freshwater Pearl Mussel Restoration Project commenced in October 2010 and its overall objective is to produce a restoration plan for the North Tyne and Rede catchments (north east England), based upon the requirements of the freshwater pearl mussel, *Margaritifera margaritifera*.

The project aims are to:

- Report on the current environmental conditions and threats to *M. margaritifera* within the catchment;
- investigate the potential reasons for pearl mussel decline;
- recommend and prioritise restoration actions (with delivery timescales).

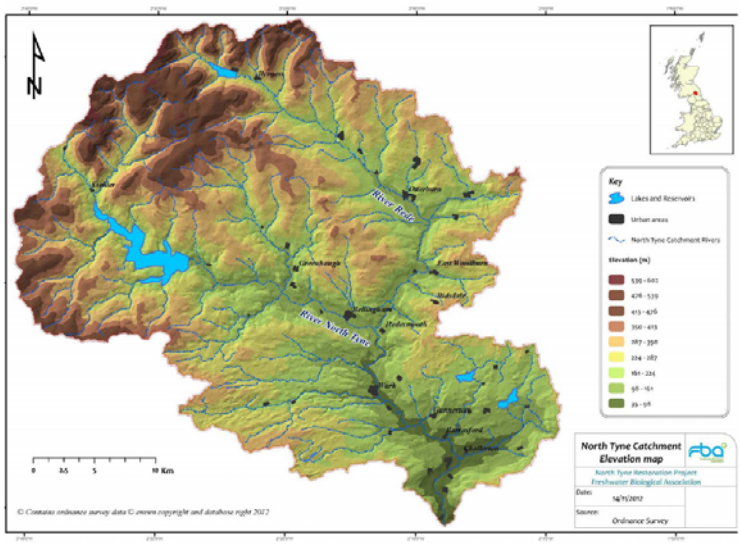

Figure 1. The North Tyne Catchment. Catchment area 1118 Km^2. North Tyne 66 Km long. Rede 58 Km long.

The catchment is relatively large and there are many factors affecting recruitment. Restoration of conditions which able to support functional recruitment is likely to take decades.

The upper reaches of the North Tyne are impounded in Kielder Reservoir with complete regulation of the flow regime. Catcleugh Reservoir is situated in the upper reaches of the Rede.

Issues identified in the catchment include aggravated sediment input and excess nutrients, altered flow regime from Kielder, and high turbidity events. No natural glochidiosis has been observed for several years possibly due to sparsely distributed mussels.

The project has undertaken a range of investigations including analysis of historical water quality data and analysis of substrate characteristics and flows. Data loggers were installed to record water quality parameters every 15 minutes and are supplemented by additional spot samples.

Electrofishing has been undertaken to look for glochidiosis, and captive rearing is ongoing at Kielder (encysted fish release) and at the Freshwater Biological Association (juvenile rearing).

The project has found that activities within the catchment are delivering excess nutrients to the river, especially during rainfall events. There is currently no aspiration to raise water quality to higher than Good Ecological Status under the Water Framework Directive, which is not good enough to support FWPM. Nutrient levels are particularly high in the catchment (where most of the mussels are). HES would mean thresholds of 0.02-0.04 mg/L SRP (MRP).

Fine sediment is being delivered to the river during rainfall events. This degrades pearl mussel habitat and increases turbidity. Redox at 5 cm indicates loss of oxygen at depth that is not suitable for juveniles. There is also an absence of smaller coarse sediment in North Tyne upstream of confluence with Rede due to the impact of Kielder. Flow at siphon level is very low and bears no correlation to flow observed at 60 % of water column height. Both rivers are very 'spatey' and dredged parts of the Rede make the in-stream habitat unsuitable for pearl mussels. Flow regime in the North Tyne is largely controlled by Kielder releases and compensation flow is too low. Long periods of extended releases to service hydroelectric power generation or safety of the reservoir could be stressful to mussels. Flow regime of the North Tyne upstream of the confluence with the Rede makes it unsuitable for pearl mussel restoration in the medium term. Large scale improvements of land-use practices is the only way to save pearl mussels in this catchment. Restoration works are ongoing and some work has been completed.

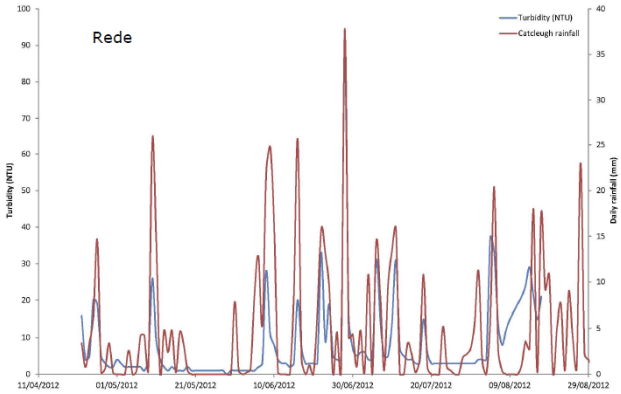

Figure 2. Daily rainfall (red) and turbidity (blue) in River Rede.

Willow weave 2009

Willow weave 2010

Figure 3. Willow spilling restoration works during 2009/2010

The project is now entering its final stage (delivery of findings and final report) including recommendations for short (1-5 years), medium (5-20 years) and long term (20-40 years) restoration measures. Mussels may not survive beyond this time frame.

A view on some practical measures for improvement and restoration of northernmost *Margaritifera* populations.

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There are several possible ways to view improvements and restoration of *Margaritifera* populations; this presentation will just emphasize some practical measures in the northernmost range of the species.

Figure 1. Forestry Drainage (*photo; I. Valovirta, all other photos and illustrations by P.E. Aspholm*) and Slurry Spreading

Impacts

Small creeks may be easily influenced by small environmental and anthropogenic events or activities including forestry, forest fires, fishing, fish stocking, ditch construction, construction of forest roads and embankments, cattle and reindeer herding, just to mention some.
Larger rivers may be influenced more from pollution, eutrophication, toxicity, irrigation, farmland runoff, construction of hydroelectric power plants (dams etc), and channelizing for boating and rafting of timber.

Measures Techniques

In creeks and small rivers the presence of forest protection zones is essential, as revegetation and reforestation provide good protection against several problems. Revegetation with local shrubs and trees is preferred. Road side ditches, and agriculture and forest ditches should include inbuilt ecological and technical sedimentation ponds followed by a wetland filter of local and native species. It is better to make several small systems rather than a few large ones, considering costs and maintenance.

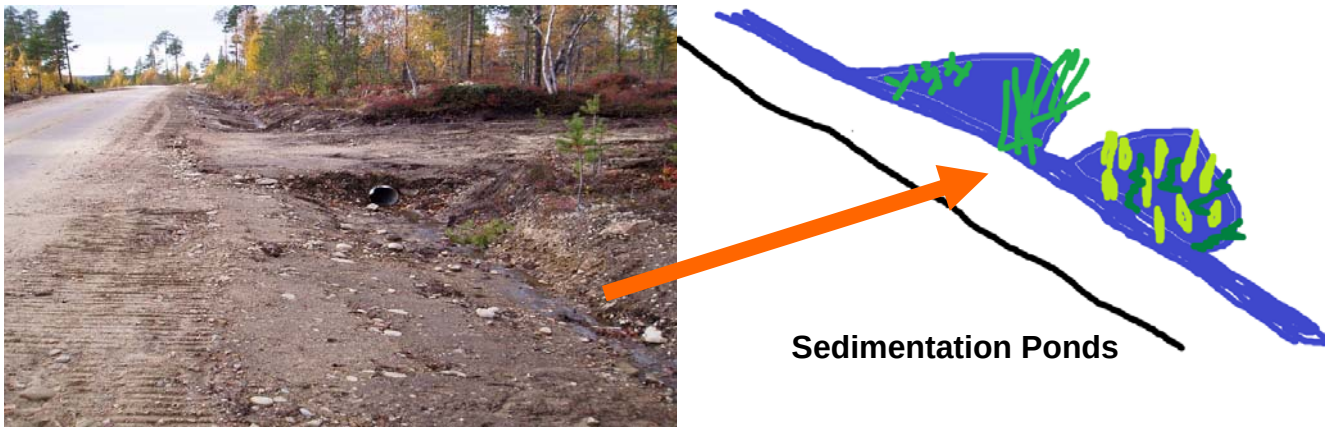

Figure 2. Inclusion of small sedimentation ponds in roadside ditches

Areas covered by debris and sediments may need stone replacement. Restoration of oxygenation is important where it has been impaired. In northern rivers erosion by ice can be a problem, both substrate and mussels can be removed through scouring by ice movement along the river bed.

One important aspect is that water should be able to penetrate sediments from beneath and move up through the substrate. Thus it is important to avoid clogging of surface sediments, and this is essential to allow the recruitment of young *Margaritifera*. Avoiding or at least careful use of heavy machinery on the sides of the creek is also important to avoid moving and compacting the sediment and substratum. Replacement of stones in the stream and rapids could be used to force the water under or into the substrate, so the water will up-well in slower parts of the rapids and stream. These sites might form micro-size improved areas for mussel recruitment.

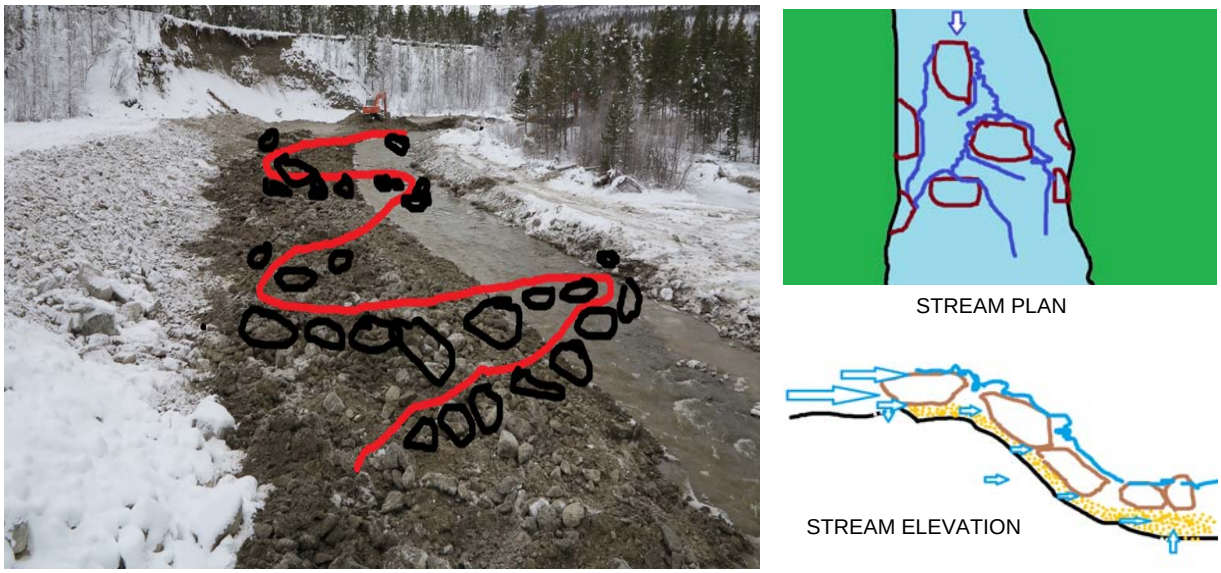

Figure 3. Making micro-niches and ensuring upward flow through sediments through introducing meanders and boulders.

In some cases where remaining mussels are dispersed at low densities (>100m apart) consideration should be given to gathering individuals and placing them in an optimal natural site to maximize the probability of fertilization. Site selection considers fish population, habitat, ice and flow conditions, substrate etc. Mussels to be moved should be placed in several sites rather than all at the same site.

Figure 4. Pearl mussel population

When undertaking various restorations works it is very important to understand that every river and creek has different hydrological, chemical, and biological processes and parameters at work. This means that each river functions and responds differently to climate and restoration activities. All ecological systems are different; therefore knowledge of the individual river is important. One other consideration is to make the measures reversible or removable if future results appear to be negative. Thus small scale measures are more expedient.

However, one of the most important issues is to let local people know of the presence of the sensitive mussels, their important function in the ecosystem and the ecosystem services they provide. Furthermore, courses, education and information for commercial sectors and machine operators are a good precaution and build competence in local environmental managers. Last and not least, it is important to have prepared plans and the logistics necessary to meet threats, especially anthropogenic threats.

Figure 5. Attendees at field course viewing pearl mussel population

This presentation is based on information obtained through the Interreg project: ***Restoration of Margaritifera populations in the north with new methods****.*

Freshwater Pearl Mussel Conservation in the Armorican Massif

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Programme LIFE+ carried on by the association Bretagne Vivante, the Fédération de pêche du Finistère and the CPIE des Collines normandes
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Figure 1. FWPM populations in the Armorican Massif.

Six main pearl mussel populations remain in the Armorican Massif. They are included in the conservation programme and are located in Natura 2000 sites. Their conservation status varies but most consist of old mussels. The Bonne Chère population was estimated at 1900 mussels in 2011 and has the most favourable status of the group. This paper considers practical implementation of measures and focuses in particular on the Bonne Chère stream.

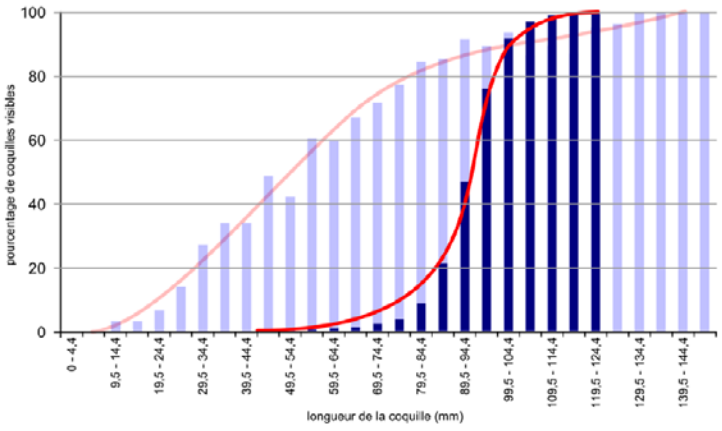

Figure 2. Shell length profile of Bonne Chère population in 2009 (dark bars) based on 900 individuals, compared to functional population (Degerman, 2009).

Three main areas of activity are described below and include Environmental Restoration, Environmental Control and Survey, and Ex-situ Conservation and Reinforcements.

Black spots requiring remediation have been identified using existing data, field observations and catchment surveys. These have been used to produce management plans that contain action lists.

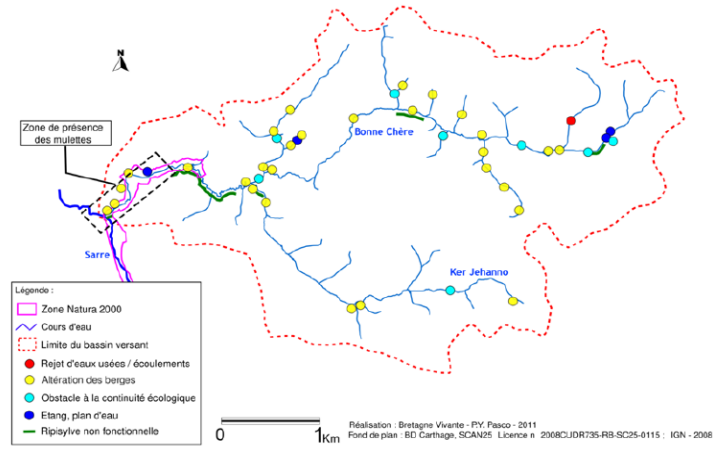

Figure 3. Issues to be resolved for restoration of pearl mussel population in the Bonne Chère catchment, including wastewater discharges (red), bank modifications (yellow), ecological continuity obstacles (pale blue), pond/lakes (dark blue).

Actions that have been carried out include maintenance of riparian woodland, mitigation of migratory barriers, riparian planting and bank protection, fencing of river banks and provision of alternative livestock drinking sources.

Figure 4. Examples of restoration actions including riparian and bank management and removal of barriers to migration.

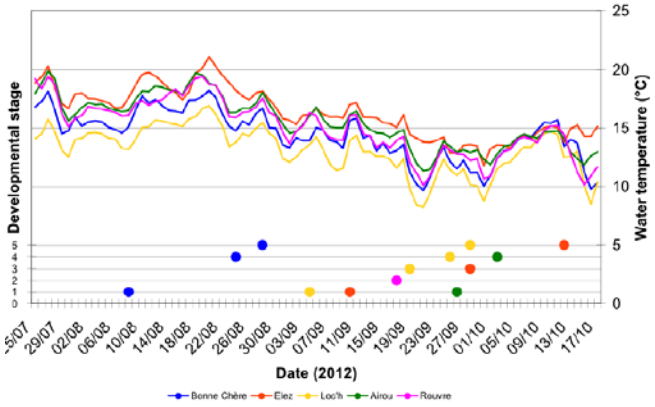

Figure 5. Water temperature monitoring and larval development stage in streams.

Water and sediment quality were assessed over a long time period to characterize status, identify favourable habitats and detect any problems. Redox potential was also measured in sediments.

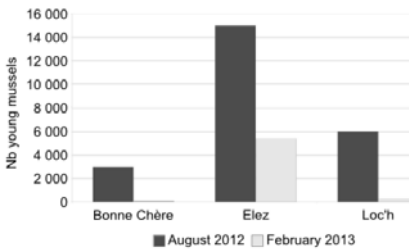

Figure 6. Extrapolation of the number of young mussels based on sorting of a substrate sample in February 2013: 39 for Bonne Chère, 5380 for Elez and 254 for Loc'h.

A breeding programme commenced in 2012 to reinforce existing pearl mussel populations. This activity is carried on by the Fédération de pêche du Finistère (a local fishing federation), partner of the LIFE programme.

Overview of Freshwater Pearl Mussel conservation actions in Sweden

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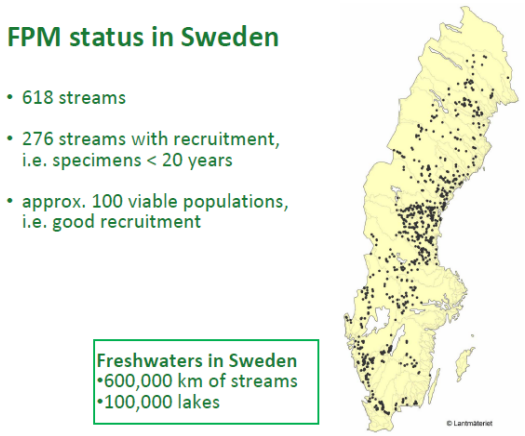

Figure 1. FPM Status in Sweden

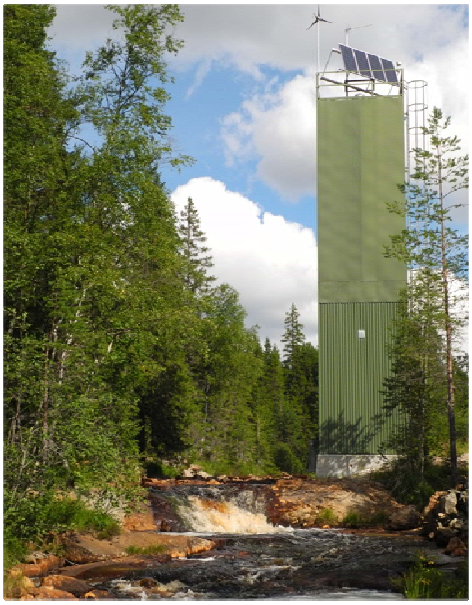

Figure 2. Stream liming by automatic doser

There are more than 600 freshwater pearl mussel (FPM) streams in Sweden (Figure 1). FPM has been protected under fishery legislation since 1994. There are around 100 Natura 2000 sites and 10 – 20 Nature Reserves, while some streams have been "protected" by agreements between the Forest Agency and the land owners.

The most common conservation actions are habitat improvements like liming of acidified streams and elimination of host fish migration obstacles. Anthropogenic acidification leads to toxic water (low pH, high concentration of inorganic aluminium) affecting FPM and host fish. 20,000 lakes and more than 10,000 streams are acidified. Liming (addition of $CaCO_3$) is the only mitigation possible. Around 2,000 km of FPM streams were limed in 2011 (Figure 2).

Figure 3. Replacement of stones in streams

Restoration of connectivity involves removal or modification of barriers to fish migration such as culverts and weirs and installation of fishways. Historically boulders have been removed from streams to facilitate timber floating. Another common conservation action is restoration of bottom structure through replacement of removed stones (Figure 3).

Along some streams the riparian zones have been restored to a more natural structure and tree species composition, often in combination with addition of dead wood (Figure 4). A range of actions are taken to prevent or minimize siltation. This includes a common policy approach in the forestry sector. Ditches are sometimes blocked to stop the transportation of fine particles which may lead to siltation of stream substrate (Figure 5).

Figure 4. Restoration of the riparian zone.

Figure 5. Blocking of ditches to prevent sediment transport.

In some restored streams FPM has been re-introduced, and in some instances FPM individuals have been moved into clusters to increase the probability of reproduction. There are also some pilot projects on infestation and release of brown trout in streams.

There are FPM monitoring programs at national as well as regional levels, and information and training programs are also undertaken.

Figure 6. Monitoring, and Information and Training Programs.

Influences from and management of catchments supporting rivers with mussel populations

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Most often, the restoration of rivers as mussel habitats has to deal with impacts from the surrounding terrestrial areas. Contamination from pollutants and nutrients, siltation of the bottoms of the streams, burial of mussels by loads of moving sediments are the typical restoration issues to be addressed in the river catchment.

Figure 1. Examples of impacts from the catchment on rivers. Left: Road drainage connects soil erosion from arable fields with the river, causing siltation. Middle: Manure spread near ditches and tributaries may easily be washed into the river. Right: Water samples from drainage tubes and springs show increased nitrogen leaching from fertilized arable land.

Since 2004 we have conducted catchment studies on a number of pearl mussel rivers in Germany. Even though in the cultural landscape of Central Europe all rivers face the same detrimental impacts, the significance of the different impairments varies greatly. Thus, each catchment restoration project has an individual agenda.

Figure 2. Sediment erosion and transport. Left: Normally siltation is the main impairment caused by erosion from arable land. In this special river, however, masses of moving gravel, burying potential mussel habitat, are the problem. Middle: natural sources of gravel are scarce. Right: Drainage of forest roads has altered the hydrology of a small tributary, causing severe channel erosion.

Results from the catchment studies illustrate the processes of acute sediment erosion and transport as well as nutrient loading. End-of-pipe measures such as mud collectors in tributaries are critically evaluated.

We argue that restoration has to be done as near to the sources of the impairments as possible. In most cases this means measures have to be distributed and will concern quite a number of landowners and farmers as well as occupants of tributaries and headwaters of the mussel rivers. Thus, catchment restoration needs stamina and some permanent staff.

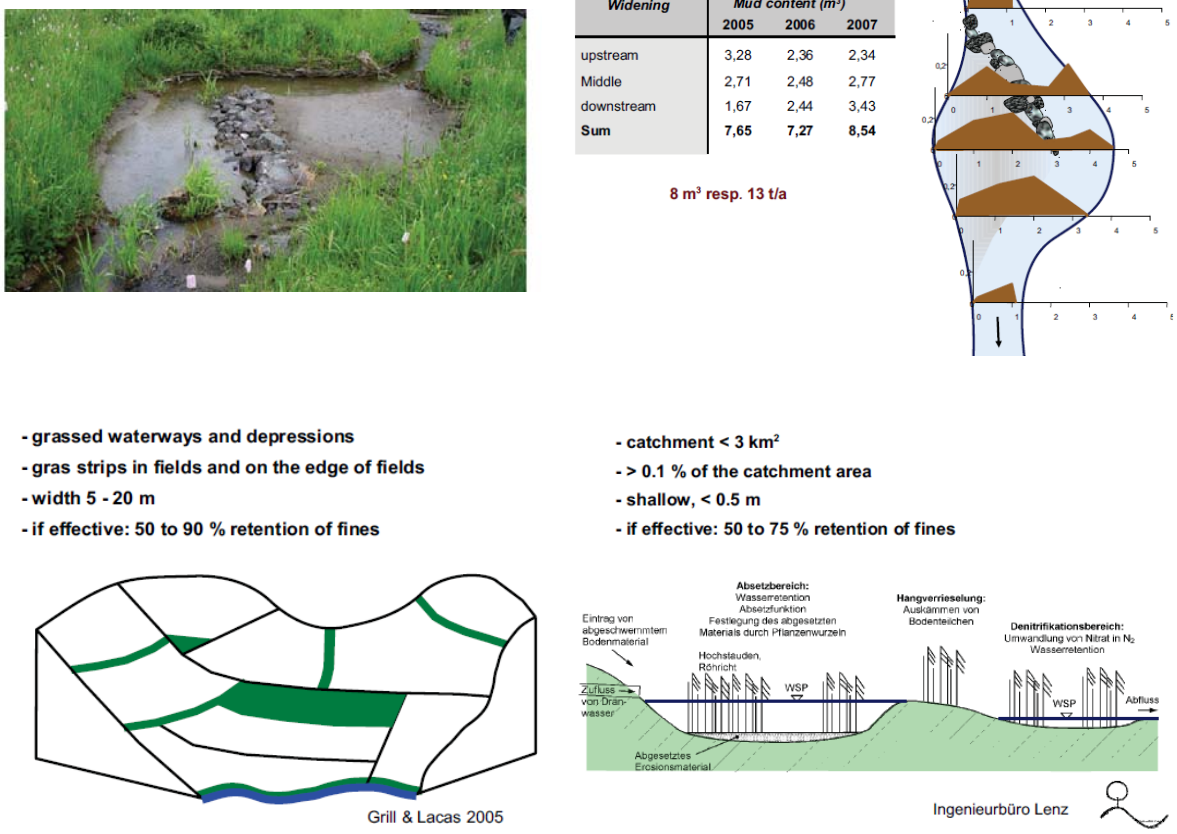

Figure 3. Examples of catchment restoration measures. Sediment traps (top left and right) are only effective if situated at the headwaters, near the source of eroded soils. Buffer zones for pesticide, P- and soil accumulation (bottom left) can effectively reduce the impairment of rivers from the catchments, if they are situated throughout the catchment. However, buffer strips alongside the main river alone have little effect. Constructed wetlands for denitrification, P-, and soil accumulation (bottom right) can be effective, if the conditions given in the picture are met. *Cf.* Syversen 2005; Gril & Lacas in: Braskerud 2005.

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Practical Implementation of Freshwater Pearl Mussel Measures

(http://www.freshwaterpearlmussel.com)

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Letterkenny, Friday 15th February 2013

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