Proceedings from the CONNECT-workshop

"Physical habitat restoration in canalised watercourses – possibilities and constraints"

Edited by Trond Taugbøl and Jan Henning L'Abée-Lund

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"Physical habitat restoration in canalised watercourses - possibilities and contraints"

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Abstract: This report contains the keynote lectures, country status reports and other plenary talks, and a summary of conclusions and recommendations from the CONNECT-workshop held in Lillehammer, Norway, November 2000.

Keywords: Habitat restoration, country status

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Foreword

CONNECT is a European network comprised of national and governmental research and management institutions working in the area of ecology, nature conservation, management of landscape, biodiversity and natural resources. At the CONNECT Directors Meeting in November 1999 it was decided that the Norwegian Institute for Nature Research (NINA) should organize a workshop on habitat restoration. The Norwegian Water Resources and Energy Directorate (NVE), the Ministry of Agriculture (LD) and the Directorate for Nature Management (DN) was asked for collaboration, and comprised the organizing committee together with NINA. Jan Henning L'Abée-Lund (NVE), Eivind Berg (LD), Øyvind Walsø (DN) and Trond Taugbøl (NINA) has been members of the committee.

The workshop was held at Quality Hotel Hafjell, Lillehammer, Norway in November 6-8, 2000 and gathered 27 participants from 8 European countries. This report contains the keynote lectures, country status reports and other plenary talks, and a summary of conclusions and recommendations from the working group established during the workshop. The papers have been printed as received from the authors with only slight editorial adjustments made by the editor.

The Norwegian Water Resources and Energy Directorate, the Directorate for Nature Management, the Ministry of Agriculture and the Norwegian Institute for Nature Research have financed the workshop.

Are Mobæk

Director Water Resources Department

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River habitat restoration in canalised watercourses: possibilities and constraints

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1 Introduction

Natural alluvial rivers, namely those not constrained by bedrock or engineering works are free to adjust their dimension pattern and profile in response to the discharge and bed material load supplied from the catchment, the calibre of the bed material, the nature of the bank sediment and vegetative cover and the valley gradient. Provided that these governing, or boundary, conditions do not change overtime, the river will achieve an equilibrium, or regime, state when there is no net change in the cross sectional dimensions, plan form or longitudinal profile of the river. This does not preclude some erosion, deposition or lateral channel migration during extreme floods provided that subsequent events restore the river to its longer term average condition.

Any change in channel morphology, due to natural events, such as meander cut offs and landslides, or artificial intervention through engineering works, could systematically destabilise the river by locally altering the river's bed material transport capacity and, thereby, its longstream sediment continuity. Similarly, climate and land use changes can destabilise river systems by modifying flow regimes and the frequency of sediment transport.

Rivers vary in their susceptibility to such changes. Those that actively transport bed material load, referred to as *active* ones, are particularly vulnerable and will quickly react to any imposed change. In contrast rivers that no longer transport bed material load can be regarded as *passive* provided that the imposed changes fail to mobilise the bed material.

Attempts have been made to differentiate between the two stream types in terms of a threshold value of stream power. For rivers in Denmark, Brookes (1987) found that those with a stream power at bankfull flow of more than 35 watts m^{-2} were destabilised by river engineering works whereas rivers with a stream power below this threshold essentially remained stable following realignment. Although this method did differentiate between active and passive rivers at the sites studied, it cannot be a general criteria because it ignores the calibre of the bed material. Many rivers in S.E. England have an immobile gravel substrate, which represents a legacy from the last glacial period when meltwaters transported glacial debris. The threshold stream power obtained by Brookes represents that for a particular range of gravel sizes. Its value would be considerably lower for sand-bed rivers.

2 Canalised rivers

2.1 Definition

As a result of engineering works many rivers have been artificially widened, dredged and straightened. To all intents and purpose such rivers have effectively been canalised as all natural habitat features have been destroyed. Canalised is a more appropriate term for describing such rivers than channelised as all water courses are by definition some form of channel.

2.2 Purpose

Rivers have been canalised for several millennia for a variety of reasons. Inevitably the earliest attempts were minor in terms of their impact on the river because they were manually constructed. Mechanisation has resulted in more ambitious projects being carried out with associated wider and more serious impacts. The following review is specific to England and Wales but it is probably typical of many countries in Western Europe. The extent of the problem is illustrated by the fact that 95% of the rivers in S.E. England, south and east of a line between the month of the Humber and Exmouth, have been canalised or severely modified (Brookes *et al*. 1983).

2.2.1 Water power

In order to generate head to power water mills and increase water storage to sustain milling operations during the working day, rivers have been diverted, dredged and widened and weirs and sluices installed. Even at the time of the Doomsday Book (1086), records showed that on many rivers several water mills were operational.

2.2.2 Land drainage

Although there is evidence that rivers had been dredged for many centuries prior to 18th Century, the late 1700s was the golden age of land drainage. In order to improve the agriculture productivity of the river flood plains, it was necessary to lower ground water levels. This was achieved by dredging the bed of the river. Not only were rivers canalised, but drainage resulted in the destruction of adjacent wetlands.

2.2.3 Navigation

To extend the length of navigable channel many rivers were dredged during the early 1800s to increase depths. In addition, locks and dams were often installed to artificially raise depths. Where rivers were straightened, bank protection would often be required to prevent the river remeandering. This would guard against boat wash erosion which, otherwise, would occur on the unprotected banks.

2.2.4 *Flood alleviation*

Urban development of flood plain sites in the early 19th Century resulted in the demand for protection against flooding. Traditionally this was achieved by various combinations of widening, dredging and straightening the river often in association with the construction of flood banks or levees adjacent to it. The former aimed to increase the 'in-bank' discharge capacity of the river and the latter to further constrain the higher flows within a narrow corridor in the flood plain.

2.2.5 *Consolidation of land holding*

There is considerable map evidence to show that rivers were realigned to consolidate land holdings and facilitate cultivation of the flood plain. A comparison of medieval parish boundaries, which on flood plains followed the course of the river, and the current rivers course often indicate that rivers have been relocated in a relatively straight course adjacent to the valley side. Much of this activity probably occurred in the late 18th Century and early 19th Century.

2.2.6 *Railway and highway construction*

To facilitate the development of the railway network in the early to mid 19th Century and, more recently, for highways, rivers have been straightened, realigned and diverted in order in minimise the number of bridge crossing required.

2.3 Methods and Impacts of Stability

On active rivers, the only way to maintain an artificial condition was to prevent the bed and banks from being eroded. This was generally achieved by lining the banks with heavy blockstone revetment and constructing a series of weirs to maintain river gradients. Considerable maintenance work was often required to maintain the revetted banks.

In contrast, on passive rivers erosion rarely occurred as its ability to transport bed material is further reduced by the engineering works. Light maintenance dredging, once every 5 to 10 years, was often required to remove any sand that had been deposited over the gravel bed.

3 River restoration

3.1 Pollution Control v Habitats

In the immediate post-war period, there was considerable concern about the health of many European rivers. Pollution control legislation in the 1950s and '60s generally lead to a slow and progressive improvement in river water quality. However this did not necessarily result in increased biodiversity indicating that water quality was not a sufficient condition and that a river's physical habitat is just as critical if the goal of river restoration is to be achieved.

During the 1970s public concern about the impoverished physical state of many rivers in England and Wales lead to demands for the development and introduction of more environmentally sensitive river engineering practices. In the UK, the Royal Society for the Protection of Birds were in the vanguard of the movement with the publication of the Rivers and Wildlife Handbook in 1984. Since then numerous European guidelines and books have been produced advocating the adoption of better management practices (Eiseltová and Biggs 1995, Hey and Heritage 1993, Kern 1994, Nelsen 1992, Newbury and Gaboury 1993, Patt *et al*. 1998, RSPB/RSNC 1984, RSPB/NRA/RSNC 1994, Tanago and Jalon 1993, Thorne *et al*. 1998). Typically these illustrate a range of procedures that have been implemented but which often remain relatively unproven because there has been little opportunity to evaluate their longer term success or failure or identity their range of application. Inevitably such empirical approaches are specific to the particular circumstances.

The physical processes controlling channel shape and dimensions, which underpin natural channel design and habitat sustainability, are rarely considered in any detail.

3.2 Terminology

The term river restoration is a general one used to describe procedures carried our to improve habitat diversity. Strictly *restoration* implies the recreation of the river condition prior to canalisation. This is possible provided the boundary conditions have not changed over the intervening period. However if they have changed, then the river would not be sustainable following restoration. In these circumstances *naturalisation* is the best option. The new boundary conditions prescribe the sustainable natural configuration for the river.

Restoration or naturalisation imply that there are no other constraints on the design of the restrictions scheme. For example no space constraints to prevent meanders being constructed or financial limitations which would prevent a scheme being fully implemented. Where there are other objectives that need to be maintained, such as flood control, land drainage and navigation, full restoration or naturalisation may not be achievable. To meet these objectives, the only solution would be to *rehabilitate* the river by introducing some natural habitat features within the engineered channel. To avoid semantics, restoration in subsequently used to describe all the above procedures.

4 Restoration and objectives

4.1 Overall Goal

Restore a natural river, given space and financial constraints while, if necessary, maintaining specified river management functions: for example, land drainage and flood alleviation.

4.2 Specific Objections

These can vary depending on constraints or required river functions. Adding inappropriate ecological objectives will guarantee failure. It needs to be recognised that rivers are essentially physical controlled and biological colonised. Not recognising this will result in unsustainable designs particularly on 'active' rivers.

4.2.1 No space of financial constraints or specific river functions to maintain

A number of different options have been adopted and many are not sustainable.

a) Restore original river morphology (dimensions, pattern and profile) and reconnect river with its flood plain

This is the simplest approach which will be successful provided that there are no significant changes in the controlling boundary conditions.

b) Create a natural channel as appropriate for the current climate and catchment conditions which reconnects the river with its flood plain

If the boundary conditions have altered since canalisation, option 4.2.1a is not a feasible solution. The challenge is to design an appropriate sustainable natural channel. The associated habitat diversity represents the maximum potential diversity for that river environment.

c) Construct a channel to maximise biodiversity (species richness)

In order to achieve ecological objectives, there is a danger that totally inappropriate habitats are created which are alien to that river type. Maintaining such a 'wish list' of habitats will not be sustainable even with constant management intervention.

d) Construct a channel to maximise the abundance of a particular species of fish (e.g. trout) either for all stages in their life cycle (self sustaining) or for mature fish (stocked)

This is a specific example of option 4.2.1c where significant management enables a 'Disneyworld' for fish to be created and maintained. It is only feasible on 'passive' rivers. Many of the groundwater fed chalk streams in Hampshire (UK) are in this category. Centuries of management and manipulation have enabled the rivers Test, Itchin and Avon to become classic 'dry fly' trout streams. The recent purchase of a reach of the Itchin by the Hampshire Wildlife Trust with the intention of allowing the river to renaturalise itself is seen as sacrilege by the angling club which previously had the fishing rights.

4.2.2 Space or financial constraints but no specific river function to maintain

a) rehabilitate the river to recreate a more natural dimension and profile (no meandering) given current climate and catchment conditions

In these circumstances, restoration potential is curtailed by the need to maintain the river's alignment and any associated bank stabilisation measures. The challenge is to develop a sustainable solution that maximises the potential habitat diversity of the river.

b) modify the river to maximise biodiversity (species richness)

As for 4.2.1c above.

4.2.3 (No) space and/or financial constraints plus need to maintain flood alleviation, land drainage, navigation etc.

Irrespective of whether or not space or finances are available, the need to maintain some prescribed river function ensures that restoration potential will be somewhat limited. Consequently some form of rehabilitation represents the potential goal as outlined in 4.2.2.

5 Restoration design

5.1 Design Objectives

The discussion on restoration goals and objectives indicates that many are not attainable. Clearly it is necessary to set a design objective that is both achievable and desirable. The objective should be to create a natural sustainable river, as prescribed by local conditions, which maximises the river's potential biodiversity.

5.2 Design Requirements

The minimum requirement in order to proceed with a restoration design is to predict the reach average bankfull cross sectional dimensions (top width, mean depth and maximum depth), bankfull slope and plan form (sinuosity and meander arc length). Constructing a channel to these basic specifications presupposes that the river will carry out its own fine tuning and create appropriately spaced pools, riffles and bar forms. The potential danger with this approach would be bank failures and meander migration as the river adjusted itself. Any failures that did occur would not be reversible.

To avoid these potential problems, particularly in active rivers, it is necessary to predict the variability in channel cross section between pools and riffles and also allow for further variation through meander bends.

Before constructing the scheme it is essential to check the stability of the proposed design to ensure that the bankfull discharge and any associated bed material load correspond to those immediately upstream and downstream. Any discontinuities that occur through the restoration reach need to be rectified by modifying the design if aggradation or degradation are to be avoided. Equally, the factor of safety of the constructed banks needs to be assessed for the most likely mode of failure to ensure that design bank heights, particularly in meander bends, do not exceed critical values for stability (Hey 1994). Failure to prevent differential bank erosion will result in the river adopting a totally different channel pattern and profile and, more significantly, could destabilise the neighbouring reaches. On passive rivers, the requirement is to prevent siltation by sediment finer than that constituting the bed material.

5.3 Design Options

5.3.1 No constraints: space, finance or competing river function

a) Reinstate original river

Provided that the boundary conditions have not changed, re-instatement of the original precanalised river is the simplest option. The former channel acts as a blueprint for the design. This presupposes that the three dimensional morphology of the river can be prescribed. Rarely is this possible. While old maps can provide information on the meander plan form and, indirectly, channel slope, the problem is to determine the original bankfull width and depth and its variation through the reach. Dimensioning the width by scaling up from a map can result in considerable error even when large scale plans are available. If the original river was backfilled with distinctly different material, then careful re-excavation would enable the cross section to be re-established. This type of approach has been successfully applied on passive rivers as, for example, the River Bredel in Denmark. Any attempt to apply this procedure for restoring active rivers would result in failure if there had been changes in boundary conditions post canalisation.

b) Ad hoc design

Many ad hoc designs have been implemented which aim to restore the range of river habitats that are expected to be found in that ‘type’ of river. This begs two fundamental questions. How is the appropriate river type specified and what are its associated habitat features? In most instances it would appear that the design has been based on visual aesthetics and/or a desire to maximise habitat diversity. While this is likely to be an improvement on the initial canalised condition, such trial and error approaches are unlikely to be sustainable even on passive rivers. While reported failures can increase the body of experience, in many instances foresight could have prevented them happening.

The restoration of a reach of the River Cole in Wiltshire, UK, as part of an EU-LIFE demonstration project, is illustrative of this ad hoc design approach. The river had been diverted and impounded several centuries ago to power a water mill. The plan was to re-establish the original course of this passive river past the Mill. This would restore the local continuity of the river and reconnect it with its floodplain. In all the published literature regarding this project, no detailed information was given on how the new channel was dimensioned or what checks were carried out to evaluate the stability of the proposed design (Vivash *et al*. 1998). The main concern appeared to centre around numerical modelling of flood levels in order to ensure that no increase occurred following restoration.

Shortly after construction of the scheme, bank failures started to occur along the restored reach. The resultant increase in sediment supply to the river has caused significant deposition further downstream with associated loss of habitats (Sear *et al*. 1998). This demonstration project can be regarded as a success if the intention was to encourage the river to re-establish its own course. It also illustrates that habitats are only sustainable if they are in harmony with local channel processes. While it has been a useful experience which, if monitored, will guide the design of comparable schemes in the future, the apparent lack of detailed geomorphological and engineering input in either the design or its evaluation is regrettable. Existing knowledge would have provided sufficient foresight to have significantly benefited the scheme.

c) Reference reach

In situations where a reach of passive river has been canalised while adjacent upstream and/or downstream sections have remained stable and natural, the adjacent reach can be used as a reference or blue print to dimension the restoration works. This is very comparable to reinstating the original river (5.3.1a).

More usually there is no obvious reference reach adjacent to the restoration site. In these circumstances it is necessary to locate a suitable stable natural channel that can be used as a reference for scaling the required channel dimensions. This implies that the river used as the reference reach represents the type that is appropriate for the restoration site. River classification is a prerequisite for applying this approach. The classification needs to be both comprehensive, in terms of covering all river types, and comprehensible to ensure that it can be readily and consistently applied.

Although classification forces a continuum to be divided into categories, it is evident from observing rivers in a range of environments, that specific river types can readily be identified. Each type is characterised by a particular range of dimensionless parameters that define their dimensions, pattern and profile and any associated bed material size. The use of dimensionless variables automatically addresses the problem of scale and also explains why rivers of a given type are similar irrespective of size.

As stable channel form reflects the controlling boundary conditions, it follows that identical stable rivers must have the same boundary conditions. Equally any alteration in boundary condition will result in an observable change in channel form. The most comprehensive river classification scheme so far devised is that due to Rosgen (1994).

This classification system enables the stable stream type required for the restoration scheme to be identified. Within the same hydrophysiographic region, a stable reference reach of the same stream type is surveyed to determine its average reach dimensions and local variations between pools and riffles. Once the dimensionless ratios for the various morphological parameters have been established, the design morphology is scaled using the predicted natural bankfull cross sectional area at the restoration site. The latter is obtained from regional curves linking bankfull cross sectional area and catchment area for that hydrophysiographic region (Rosgen 1996).

The method has proved to be very successful for stabilising active rivers in the US across a range of river environments. In a European context the classification system needs to be extended to passive rivers and, in particular, self stabilised canalised ones. Equally it will be vitally important to identify any remnant natural reaches. Both represent potential reference reaches for guiding restoration designs. Such research is in progress.

d) Regime equations

Empirical equations that have been developed for predicting the dimensions of stable alluvial channels are referred to as regime equations. Inevitably they only apply within the bounds of the original data base used to derive them. They attempt to quantify the effect of bankfull discharge, and associated bed material load, bed material size, bank material and vegetation and valley slope on channel dimensions. Most equations fail to include all the controlling variables, thereby the values of the numerical coefficients and exponents in the equations are affected to an unknown degree, and only predict the width, depth and slope of straight channels.

To date equations have been developed for sand-bed and for gravel-bed rivers. These recognise that different transport processes operate in the two types of system, essentially bedload v. suspended load, which result in distinctly different river morphologies. They fail to acknowledge that differences are likely to occur within both sand and gravel-bed rivers given the variations that have been observed between river types.

Assessments of the predictive capabilities of a range of regime equations for gravel-bed rivers indicate that errors in the prediction of bankfull width and depth are, at best, in the range $\pm$ 70% at the ninety five percent confidence level, while for slope the errors are significantly worse, $\pm$ 163% (Hey *et al*. 1990).

e) Rational equations

As rivers are physically determined, it should be possible to define a set of governing equations which prescribe how a river adjusts its morphology to set of controlling variables. For gravel-bed rivers there are seven unknowns and, hence, seven governing equations. Three equations can be defined, namely continuity, flow resistance and sediment transport, which enable three out of width, depth, slope and velocity to be determined given the bankfull discharge, bed material size and load. To achieve a solution either the width, depth or slope must be prescribed and the river must be straight. Although equations are available to predict meander plan form, further refinement of this rational approach for natural channel design awaits the development of equations to define channel width adjustment (Hey 1997).

5.3.2 Constraints: space and/or finance but no competing river function

Often restoration is constrained by lack of space due to flood plain development which precludes the re-instatement of meanders. Even when space is unlimited financial restrictions may not allow the restoration of a truly natural river. In these circumstances consideration has to be given to rehabilitating the river by creating a range of sustainable instream habitats within the confines of a relatively straight channel. On active rivers, the canalised condition would have been artificially maintained through regular dredging and the banks stabilised with some form of heavy engineering works. Any instream measures that are introduced would need to be in harmony with bed material transport processes in order to be sustainable. With passive rivers, the artificial canalised condition would have been maintained with light maintenance dredging to prevent siltation. In these circumstances a sustainable solution can be achieved provided that siltation can be prevented.

a) Re-instate pools and riffles

Prominent pools and riffles develop in active gravel-bed rivers but are essentially absent in sand-bed ones. In meandering channels the riffles occur where gravel bed load crosses the channel at the inflexion point between bends. They connect the zone of preferential transport over the lower part of the point bar on the inside of adjacent meander bends. In straight channels the riffles link the bars which develop on alternate sides of the river.

On passive gravel-bed rivers, it would be appropriate to re-instate riffles, as they would have been relics from a previous active phase, but they would need to be artificially created. As there is no gravel movement, they will not naturally reform once dredging of sand and silt ceases. It has to be recognised that the creation of gravel riffles in sand or clay-bed rivers would be totally artificial.

The riffles aim to increase habitat diversity by creating local variations in flow depth and velocity. This is particularly noticeable at low flow when longstream variations are at a maximum. The effect progressively reduces as bankfull flow is approached. At low discharges, overall water levels are increased by the riffles which produce an associated rise in ground water levels (Hey 1992).

Research is currently being carried out to determine the effect of riffle re-instatement on flood discharge capacities and to quantify their ecological benefits. Preliminary results indicate that naturally formed riffles do not impair the bankfull discharge capacity of the river which implies that their re-instatement will not raise flood levels. Guidelines are being developed to prescribe the appropriate height and profile for riffles. The spacing of riffles is also important. On straightened passive rivers they need to be located at between 6 and 9 times the natural bankfull width of the river.

b) Lateral deflectors

Many canalised rivers have been widened to meet particular engineering objectives. On active rivers, the channel would rapidly narrow once maintenance ceased due to sediment accumulation. With passive rivers the narrowing process is much slower as it principally results from vegetation encroachment.

To speed up the narrowing process, lateral deflectors can be constructed into the river from the bank. These can take the form of a triangular structure with its apex projecting into the river or a simple high vane projecting downstream into the flow at about 30 degrees to the bank (Hey 1992). Not only do these enable a more natural width to be established but, by restricting the flow, they induce increased velocities and bed scouring. Habitat variability is increased as a consequence. To maximise the potential benefits of deflectors, they need to be sequentially located against opposite banks. This immediately creates a more sinuous course to the river. Deposition and vegetation encroachment in the separation zone upstream from the deflector and in the back eddy downstream will extend the length of narrowed river and it also provides excellent marginal habitats. The spacing between alternate deflectors needs to be between 6 and 9 times the natural bankfull width of the river. Should flood risk be a concern, then the height of the deflector and the blockage of the river are key issues. Laboratory tests indicate that deflectors can be designed which do not raise flood flow levels.

The more expensive alternative of physically narrowing the river by backfilling behind some form of retaining structure installed along the river bed is not recommended. It fails to generate the local flow variability that the deflectors produce.

c) Vanes

The installation of simple submerged vane structures on the river bed enables pool habitats to be recreated in passive canalised rivers. Although, in general, there is insufficient energy in the flow to transport bed material and create a scour hole, the vane focuses the available energy to promote local transport and scour during high discharges. Pools can be created in mid channel with twin vanes angled at 30º upstream into the flow (Hey 1992). The low velocity, near bed, flow is directed by the vane towards the bank and the compensating faster overtopping flows converge at the water surface. By inducing twin spiral circulation cells with surface flow convergence, faster flowing water is transferred to the bed which causes erosion and the creation of an extensive scour hole. The eroded sediment produces a shallow bar further downstream.

Pools nearer the bank can be created by installing a single vane angled upstream at 20-30º to the bank and pitching from bankfull level to the bed at a maximum of 7º. The approach flow senses the stagnation created by the vane near the bank and rolls the current over the structure towards mid channel. The downwelling generated by the single spiral current causes bed erosion. By installing vanes on alternate sides of the river spaced 6-9 widths apart, the pools would conform to a natural series. Significantly these structures, and slight variants on them, have been used to protect banks on active rivers from erosion.

Research is nearing completion to define the optimum geometry for the vanes to maximise the extent and depth of the scour hole. Although the paired vanes can slightly increase low flow depths due to their blocking effect, during bankfull flows, they are effectively drowned out and, therefore, have no adverse impact on water levels. The major drawback with vanes is their tendency to trap floating debris. This is most pronounced with paired vanes. They also obstruct weed cutting activity.

5.3.3 No space or financial constraints but competing river function

a) Flood capacity

Where a river has been canalised to increase its flood capacity and that function has to be maintained post restoration, the two objectives clearly have to be compatible. Full restoration is the first priority (5.3.1) and particularly the re-establishment of the natural bankfull capacity of the river. The flood capacity is best created by constructing flood banks set back from the river; usually beyond the belt width of the meandering river. This ensures that the natural in-bank processes in the river are not disrupted by overly confined flood flows and, thereby, the long term stability of the restored river is guaranteed (Hey *et al*. 1990).

b) Maintain low ground water levels and flood capacity

Where a river has been canalised and extensively dredged to increase its flood capacity and lower groundwater levels, a different solution is required. In order to maintain the lowered groundwater table, it is necessary to retain the existing bed level. To create a natural meandering channel corresponding to this bed level (5.3.1), a new lower level flood plain has to be created below the original one. The amount it is lowered is prescribed by the depth the original channel was dredged. The width of the lowered flood plain containing the restored river depends on the required flood capacity. At a minimum it should extend beyond the belt width of the new meandering channel to avoid any localised erosion and deposition due to adverse interactions between in-bank and over-bank flows (Hey 1992).

6 Conclusions

6.1 Success or Failure?

Often river restoration is carried out with the simple objective of increasing species richness by improving habitat diversity. The basic assumption is that increasing the latter will benefit the former and that the scheme will be sustainable.

It poses the question, are the goals of restoration achieved? Ideally pre and post project surveys need to be carried out to establish whether the desired improvements in, for example, fisheries, macro-invertebrates, macrophytes etc. had materialised and been sustained. This would require pre and post project monitoring of the restoration reach in order to quantify any changes. Rarely are such surveys carried out and, thereby, the opportunity to gain valuable experience is lost. For established schemes lacking pre project baseline surveys, a retrospective assessment could be undertaken whereby a control reach, which still exhibits all the features of restored reach prior to canalisation, is used to prescribe the pre project condition. Although space-time substitutions are not ideal, its does ensure that changes in flow or water quality that could adversely affect the interpretation of the results of pre-post project surveys equally influence both reaches.

6.2 Funding Restoration

Although there is considerable public demand for restoring rivers, particularly in urban areas where demand for riverside properties is buoyant, rarely are there public funds available simply to achieve conservation goals. Consequently restoration objectives are generally funded as an adjunct to wider development programmes.

Mitigation and enhancement packages to compensate for any adverse impacts of capital works programmes elsewhere along the river probably provide the best opportunities for funding restoration works. This is particularly the case for flood alleviation schemes, bridge crossings and river training works. Similarly in England and Wales it is now necessary for some form of river restoration works to be carried out in order to obtain a water abstraction licence. Balancing the adverse impacts of the proposed development against the potential benefits of restoration is inevitably rather subjective and does not necessarily guarantee a net improvement.

There are two areas where river restoration could be justified on the basis of quantifiable benefits. First, by creating a buffer zone adjacent to the river, significant improvements in water quality could materialise. Second, by re-establishing the connection between the river and its flood plain, the natural flood storage and conveyance of the valley could result in lowered flood levels downstream. Both could potentially justify river restoration leaving the associated improvement in the conservation, fisheries and amenity value as an unmeasured bonus.

Finally, serious consideration needs to be given to seeking lottery funds to achieve conservation and amenity objectives. This is particularly appropriate for urban areas where there is the opportunity to rehabilitate the riverine environment and provide recreational space for the whole community.

References

Brookes, A. (1987) The distribution and management of channelized streams in Denmark. *Regulated Rivers* **1**, 3-16.

Brookes, A., Gregory, K.J. and Dawson, F.H. (1983) An assessment of river channelization in England and Wales. *Science of the Total Environment* **27**, 97-112.

Eisetová, M. and Briggs, J. (1995) *Restoration of Stream Ecosystems: An Integrated Catchment Approach*, International Waterfowl and Wetlands Research Bureau, Slimbridge, Gloucester, UK, IWRB Publ. 37, 170pp.

Hey, R.D. (1992) River mechanics and habitat creation. In. O'Grady, K.T.O., Butterworth, A.J.B., Spillett, P.B. and Domainiewsky, J.C.J., *Fisheries in the Year 2000*, Institute of Fisheries Management, UK, 271-285.

Hey, R.D. (1994) Restoration of gravel-bed rivers: principles and practice. In. Shrubsole, S., *Natural Channel Design: Perspectives and Practice*, Canadian Water Resources Association, 157-173.
Hey, R.D. (1997) Stable river morphology. In. Thorne, C.R., Hey, R.D. and Newson, M.D., *Applied Fluvial Geomorphology for River Engineers and Managers*, Wiley, Chichester, UK, 221-236.
Hey, R.D. and Heritage, G.L. (1993) *Draft Guidelines for the Design and Restoration of Flood Alleviation Schemes*, National Rivers Authority, R&D Note 154, 98pp.
Hey, R.D., Heritage, G.L. and Patteson, M. (1990) *Design of Flood Alleviation Schemes: Engineering and the Environment*, Ministry of Agriculture, Fisheries and Food, 176pp.
Kern, K. (1994) *Grundlagen Naturnaher Gewässergestaltung*. Spring-Verlag, Berlin, 256pp.
Newbury, R.W. and Gaboury, M.N. (1993) *Stream Analysis and Fish Habitat Design: A field Manual*, 2nd ed. Newbury Hydraulics, Gibson, B.C., 262pp.
Nielsen, M.B. (1992) *Re-creation of Meanders and Other Examples of Stream Restoration in Southern Jutland, Denmark*. Sønderlyllands Amt.
Patt, H., Jürging, P. and Kraus, W. (1998) *Naturnaher Wasserbau*. Springer, Berlin, 358pp.
Rosgen, D.L. (1994) A classification of natural rivers. *Catena* **22**, 169-199.
Rosgen, D.L. (1996) *Applied River Morphology*, Wildland Hydrology, Pagaso Springs, CO., 363pp.
RSPB/RSNC (1984) *The Rivers and Wildlife Handbook*. RSPB, Sandy, Bedfordshire, UK.
RSPB/NRA/RSNC (1994) *The New Rivers and Wildlife Handbook*. Royal Society for the Protection of Birds, Sandy, Bedfordshire, UK, 426pp.
Sear, D.L., Briggs, A. and Brookes, A. (1998) A preliminary analysis of the morphological adjustment within and downstream of a lowland river subject to river restoration. *Aquatic Conservation: Marine and Freshwater Ecosystems* **8**, 167-183.
Tanago, M.G. del and Jabon, D.G. de (1993) *Estudio de Directrices a Seguir en Actuanciones Encaminadas a la Restauracion y Adecuacion de Cances y Riberas Fluviales*. Ministerio de Obras Publicas y Transporte, Madrid, 300pp.
Thorne, C.R., Hey, R.D. and Newson, M.D. (eds.) (1998) *Applied Fluvial Geomorphology for River Engineers and Managers*. Wiley, Chichester, UK, 376pp.
Vivash, R., Ottosen, O., Janes, M. and Sørensen, H.V. (1998) Restoration of the rivers Brede, Cole and Skern: a joint Danish and British EU-LIFE demonstration project, II – The river restoration works and other related practical aspects. *Aquatic Conservation: Marine and Freshwater Ecosystems* **8**, 197-208.

Country status report - Denmark

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There are approximately 30,000 km watercourse of natural origin in Denmark, and an equivalent length of man-made watercourses. The quality of the water in the watercourses has improved year by year during the last decades, largely due to the upgrading of sewage works. This should, all in all, provide good opportunities to enjoy nature, as well as a multitude of habitats for a diverse flora and fauna.

However, the majority of our watercourses have been channelised to drain agricultural land. Channelisation was often accompanied by the construction of weirs and other obstructions at freshwater fish farms, industry and urban areas, and in many cases these effectively hindered the free passage of fish and stream macroinvertebrates. As a result, many of the Danish watercourses lack physical variation and habitats for the flora and fauna are limited in number and quality. Less than 10 % have retained their natural meandering channels. Traditional harsh stream maintenance such as repeated dredging and weed cutting has further contributed to the poor physical conditions found in many present days Danish streams.

The situation is starting to improve, though, partly as a result of changes and improvements in the administration of our watercourses. The water quality of larger Danish stream has improved considerably over the past 20 years. Concentrations of diffuse phosphorous and nitrogen in the Danish streams have declined by 5 per cent over the past 20 years, whereas phosphorus and nitrogen loadings from sewage treatment plants have declined by 86 % and 65 %, respectively, in the same period.

However, considerable work still needs to be done to improve the physical condition of our watercourses. This can be achieved through environmentally sound watercourse maintenance as well as through various types of restoration measure.

The Danish Watercourse Act

Stream restoration activities in Denmark began in 1980 with the restoration of the river Voerå and its tributaries. With the advent of the new Watercourse Act in 1982, it became legally permissible to rehabilitate Danish watercourses. This possibility has been exploited, and over the years, more than 1000 restoration projects have been carried out – ranging from the laying out of spawning gravel to major projects aimed at remeandering watercourses and improving the interplay between watercourses and their river valley.

In the Danish Watercourse Act from 1982 individual restoration measures was described as five simple methods. These allowed the establishment of artificial overhanging banks, current concentrators and spawning grounds, and the laying out of large rocks, logs and the like on the watercourse bed – methods that to present Danish eyes provide extremely limited possibilities to rehabilitate watercourses. Today, introducing unnatural “hardware” into watercourses is considered undesirable in Danish watercourses.

Despite the fact that the five restoration methods mentioned in the Watercourse Act are extremely limited, it has nevertheless been possible to use other and more extensive forms of restoration in practice. All that was needed was to use another clause in the watercourse act dealing with regulation of watercourses. This watercourse regulation provisions in the act were originally formulated with a view to ease water drainage through deepening, straightening and widening of the cross-sectional profile. However, restoration also involves changing the physical form of a watercourse, and from the legal point of view it is therefore to be seen upon as a regulation.

A 1995 amendment to the Watercourse Act added a new provision to the part dealing with restoration. This provision enables the county councils to improve conditions in watercourses in which summer discharge is poor, for example, immediately downstream of intakes to freshwater fish farms. In such cases, the County could limit the amount of water diverted to the fish farm by stipulating a minimum residual discharge in the watercourse.

Stream maintenance

It is not just through physical restoration that the condition and form of watercourses can be improved. This can also be achieved through watercourse maintenance. Maintenance of Danish watercourses has traditionally served the sole purpose of holding in check the natural changes that take place in watercourses so as to ensure that the water could drain away sufficiently effectively. With the advent of the Watercourse Act, traditional maintenance of watercourses has in most cases been replaced by more environmentally sound maintenance. A survey accounting for 1000 km of the largest streams in Denmark revealed that harsh stream maintenance were applied in over 50 % of the watercourses in 1985 compared to only 5 per cent in 1996. Gentle and ordinary stream maintenance had risen from 20 % to 45 % in the same period. The number of watercourses without any maintenance has been constant over the past 15 years.

Both restoration and environmentally sound maintenance improve the physical conditions in watercourses. With environmentally sound maintenance, one can develop a narrow meandering course in a channelised watercourse using the forces at work within the watercourse. The first results can often be seen within 3-5 years, but it will often take a long time, maybe 100 years or more, before the stream are functioning fully naturally.

With physical restoration, the time frame is much shorter. Using an excavator one can rapidly excavate new meanders and reopen culverted reaches. But excavators are expensive to run. It is roughly estimated that the remeandering of one km of stream costs about 500,000 DKr. In contrast, the implementation of environmentally sound maintenance practice has already improved physical conditions in thousands of kilometres of Danish watercourse - and often saves money. Thus in the majority of

Danish watercourses, good physical conditions will have to be ensured by environmentally sound maintenance.

Restoring local watercourse reaches

One of the most widespread restoration activities throughout Denmark has been the re-establishment of salmonid spawning grounds. In these cases it is important to use the correct composition of gravel and to know the specific hydraulic parameters of the stream section to avoid siltation. In many cases, excess sediment transported from upstream reaches to the spawning grounds rapidly renders them useless. A short-term solution is to widen and deepen the stream, thereby reducing flow velocities and trapping the sediment. Although sediment traps may be useful, they are undesirable because they are artificial and require regular maintenance.

Restoring continuity between watercourse reaches

Uniform physical conditions is just one of the problems associated with channelised watercourses. Another is that the watercourse fauna is often hindered from moving freely up- and downstream by dams, weirs, piped road crossings, electrical power plants, fish farms and water mills. A rough estimate states that more than 5000 such obstacles have been present in the Danish streams. Many of the obstacles were established in connection with channelisation, when weirs were built to even out the former gentle fall over the meanders. Right up to the end of the 1970s, closely spaced obstacles were common even in relatively small river systems.

Since the 1980s, the Danish counties have removed or levelled out more than 500 obstacles. Also the municipalities are working purposefully to recreate the continuity in the streams. This year the municipality of Silkeborg, as the first municipality in Denmark, removed the last of its 35 obstacles. However, despite of the concentrated efforts to remove the obstacles, considerable numbers still remain.

Were obstacles or dams cannot be removed because of historical or cultural reasons (e.g. water mills) or for economic or legal reasons (e.g. fish farming, electricity power plants) construction of fish ladders was once the major method to create continuity in the streams. Fish ladders have, however, often shown to be ineffective and hard to maintain. Today, construction of maintenance free bypass riffles are preferred to fish ladders. If constructed correctly these bypass channels work well and monitoring with fish traps has shown that all or most fish species can pass bypass channels that are correctly constructed. Fish ladders are now only constructed as a last alternative, and old fish ladders are now often replaced by bypass channels.

Large-scale restoration projects

There is a growing interest and overall understanding in the Danish people that the ecology of our freshwaters is threatened. Furthermore many cultivated drained wetlands are abandoned because drainage systems are ageing, or because there is little economic incentive in cultivating former wetlands under the present EU agricultural policies. All in all, this has generated a public interest, also amongst some landowners, in restoring the natural hydrology of the wetlands and streams in Denmark. The first larger remeandering project carried out in Denmark was initiated as local interest groups put forward a proposal to restore a more natural river and floodplain of the River Gelså at Bevtoft city.

Re-meandering projects are complex in the way that many factors are altered at the same time. To evaluate the effects of a re-meandering project a monitoring program should be set up. The program, large or small, has to follow some general statistical guidelines otherwise it may be impossible to determine the effects from the natural variations in parameters. Two or a combination of these strategies may be employed: The ”before/after” approach, and the use of control and experimental reaches.

Danish restoration projects are, however, far to seldom followed up by studies of the impact of restoration on biological, chemical and physical conditions in the watercourses and their riparian areas. Similarly, the experience gained from the individual projects is seldom published, and hence is seldom of benefit to others working with watercourse restoration. There is therefore a need to describe the various types of restoration projects and to evaluate their impact.

During the years NERI has been monitoring the effects of some of the remeandering projects carried out in Denmark. Results from the monitoring projects have been reported in several papers (see the literature list below). The most comprehensive project monitoring have been carried out in connection with the remeandering of the three rivers Gudenå, Gelså and Bredeå.

Literature

Biggs, J., Corfield, A., Grøn, P., Hansen, H.O., Walker, D., Whitfield, M. & Williams, P. 1998. Restoration of the Rivers Brede, Cole and Skerne. A Joint Danish and British EU-LIFE Demonstration project, V - Short-Term Impacts on the Conservation Value of Aquatic Macroinvertebrate and Macrophyte Assemblages. - Aquatic Conservation. Marine and Freshwater Ecosystems 8(1):241-255.

Frandsen, S.B. 1996. New meanders of the River Gudenå - A river restoration project. - County of Vejle, Denmark. Video 10 min.

Friberg, N., Kronvang, B., Svendsen, L.M., Hansen, H.O. & Nielsen, M.B. 1994. Restoration of a channelized reach of the River Gelså, Denmark: effects on the macroinvertebrate community. Aquatic Conservation: Marine and Freshwater Ecosystems, vol. 4: 289-296.

Friberg, N., Kronvang, B., Hansen, H.O. & Svendsen, L.M. 1998. Long-Term, Habitat-Specific Response of a Macroinvertebrate Community to River Restoration. - Aquatic Conservation. Marine and Freshwater Ecosystems 8(1): 87-99.

Friberg, N., Hansen, H.O. & Kronvang, B., submitted. Habitat surveys as a tool to assess the benefits of stream rehabilitation II: Macroinvertebrate communities. - Submitted Verh. Internat. Verein. Limnol.

Hansen, H.O. (Ed.) 1996. River restoration - Danish experience and examples. - Ministry of Environment and Energy, National Environmental Research Institute, Denmark. 99 pp. (Downloadable: www.ECRR.org *>Publications >Other ECRR publications*).
Hansen, H. O. 1997. Remeandering of a Danish headwater stream. The River Gudenå demonstration project. Verh. Internat. Verein. Limnol., 26, 879-883.
Hansen, H.O. 1998. Stream Restoration: Rehabilitation of a headwater stream and its riparian areas - Technical Report. - Final technical report from the EU-LIFE project # LIFE94/DK/A25/DK/462/VEJ. March 1998, 29 pp.
Hansen, H.O., Kronvang, B., Rebsdorf, Aa. & Græsbøll, P. 1992. Restoration of the river Gudenå near its spring. – Vand & Miljø 8: 263-266. (In Danish).
Hansen, H.O., Friberg, N. & Baattrup-Pedersen, A. 1999. Remeandering of three Danish streams: Impacts on the biota. – In: Friberg, N. & Carl, J.D. (Eds.) Biodiversity in Benthic Ecology. Proceedings from Nordic Benthological Meeting in Silkeborg, Denmark, 13-14 November 1997. National Environmental Research Institute, Denmark. 142 pp. – NERI Technical Report No. 266.
Hoffmann, C.C., Pedersen, M.L., Kronvang, B. & Øvig, L., 1998. Restoration of the rivers Brede, Cole and Skerne: A joint Danish and British EU-LIFE project, IV - Implications for nitrate and iron transformation. Aquatic Conservation: Marine and Freshwater Ecosystems 8, 223-240.
Hoffmann, C.C., Pedersen, M.L. & Laubel, A.L. 2000. Headwater restoration of the river Gudenå – 2. Implications for nutrients in riparian areas. - Verh. Internat. Verein. Limnol. 27: 602-609.
Kristensen, P. & Hansen, H.O. (Eds.) 1994. European rivers and lakes - Assessment of their environmental state. - European Environment Agency, Copenhagen. 122 pp. Kronvang, B., Svendsen, L.M., Friberg, N. & Dørge, J. 1997. Stream restoration in Denmark: Assessment of the ecological benefits. - Zbl. Geol. Paläont. 1(10): 969-981.
Kronvang, B., Svendsen, L.M., Brookes, A., Fisher, K., Møller, B., Ottosen, O., Newson, M. & Sear, D. 1998. Restoration of the rivers Brede, Cole and Skerne: A joint Danish and British EU-LIFE project, III - Channel morphology, hydrodynamics and transport of sediment and nutrients. Aquatic Conservation: Marine and Freshwater Ecosystems 8, 209-222.
Kronvang, B., Svendsen, L.M., Ottosen, O., Nielsen, M.B. & Johannsen, L., 1998. Remeandering of rivers: short-term implications for sediment and nutrient transport. Verh. Internat. Verein. Limnol 26, 929-934.
Kronvang, B., Hansen, H.O., Friberg, N., Larsen, S.E., Fjordback, C. & Johnsen, R., submitted. Habitat surveys as a tool to assess the benfits of stream rehabilitation I: The physical dimension. - Submitted Verh. Internat. Verein. Limnol.
Madsen, B.L. 1995. Danish Watercourses - Ten years with the new watercourse act. - Ministry of Environment and Energy, Danish EPA. Miljønyt no. 11. 208 pp.
Madsen, B.L. 1995. Rehabilitating Danish Streams - Miljø-Tema no. 11. Ministry of Environment and Energy, Danish EPA. 28 pp.
Madsen, B.L. 1996. Freedom regained - A film on stream restoration in Denmark. - Ministry of Environment and Energy, Denmark. Video, 24 min.
Pedersen, M.L., Hoffmann. C.C. & Svendsen, L.M. 2000. Headwater restoration of the river Gudenå - 1. Implications for nitrate transport. - Verh. Internat. Verein. Limnol. 27: 593-597.

Country status report - Germany

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Introduction

Germany is a federal republic of 16 seperate states – "Länder". In water policy the federal government in Berlin only has the competence of frame-rules. Each of the "Länder" has to fulfill this frame for its own, as well in laws and decrees as in organisation, technical guidelines etc.

I come from Bavaria and I am working there. So Bavarian conditions are my background. But for more than two decades I have been member of different working groups of the German Association of Watershed Management – DVWK – and the German Institute for Standardization - DIN -. So I can give a Country Status Report of Germany. For details please add in brackets Bavaria.

From my background I am engineer not ecologist. So my stress would be perhaps a technical point of view.

Legal frame in Germany

Legal frame in Germany is the federal law to order the waterbalance – Gesetz zur Ordnung des Wasserhaushalts (WHG) [1]. There are given rules and goals for watercourses also in our points of view. § 28 defines the maintenance including the needs of eco system which are to be observed. Aspect and recreational value of fluvial landscapes are to be taken into consideration too. Maintenance includes the watercourse itsself and the banks. It is not written where there is the limit towards the land.

Very important is § 1 a "principle":

(1) Waterbodies have to be protected as component of ecosystems and habitat for animals and plants Those are to be managed in a way that .... avoidable impacts of their ecological functions will not happen.

(2) Everybody is obliged .... to avoid pollution of the water or other detrimental changes of its capacity .... to preserve the ability of waterbalance and to avoid an increase and an accelleration of water effluent.

New since 1996 and very helpful too, is § 32 dealing with flooded areas. Flood plains are to be preserved in their function as natural retention areas. Former flood plains should be reactivated as far as possible. Theese are good weapons in our fight against developing settlements or roads etc in flood plains or river meadows.

Guidelines and rules

Laws always come along behind public opinion. The first practical step into direction of ecological management of watercourses have been the attempts to construct rough ramps instead of vertical weirs in the 70 s. In those days the first ecologists came into technical working groups of engineers. And the first mutual publication in Germany was the leaflet Nr. 204 of the German association of Watershed Management – DVWK – from 1984: “Ecological aspects in training and maintenance of watercourses” [2].

Detailed points of view followed in this red series, e.g.
- Ecological aspects to dead waters (1991) [3].
- Methods and ecological effects of mechanical maintenance of watercourses (1992) [4]
- Aspects of landscape – ecology of river dikes (1993) [5]
- Fishpasses – calculation, design and control of function (1996) [6]
- Riparian strips along watercourses – function, shaping and maintenance (1997) [7]
- Musk, beaver, nutria – marks of identification and way of living – shaping and protection of endangered banks, dikes and dams (1997) [8]
- Shaping and maintenance of watercourses in urban areas (2000) [9].

Following or parrallel to these guidelines almost each of the “Länder”, worked out its own rule, very intensively and good in my opinion is Baden-Württemberg.

Till today there is only one complete textbook to this topic on the German market “Naturnaher Wasserbau” by Springer, which I wrote together with two friends of mine, Heinz Patt and Peter Jürging [10].

So we can say: principles and ideas to see rivers as compartiments of ecological units are up to date in Germany. I see our topic here – habitat restoration in canalised rivers – to cut off those parts of the entire vision you can realize in your special case. And I must mention that there are of course different visions for different rivers if you are working e.g. in mountain area, midlands or flat plains.

Three essential goals

The essential goals of ecological based visions we can summerize in three points of view:

- Fluvial dynamics which means changing of erosion and sedimentation as well in riverbed as banks.
- Migration within watercourses which means there should be gateways along the river continuum and from the mean river into tributaries.
- Riparian meadows and strips, natural components of riverlandscapes.

In the following I will list some keywords and verify these by examples of our work in Rosenheim.

Fluvial dynamics

Open floor of river bed
No pavement or concrete should make tight the floor of riverbed. The possibility of erosion during and sedimentation after respective higher discharges should be given thus transportation and restorage of sediment. So the interstitial will be habitat of Zoobenthos.

If necessary protection against vertical erosion could be produced by sills of stones or boulders protecting by their wheight only. The parts between those sills should be open.

Installation of stimulating blocks creating turbulent and calmed sections of runoff with local erosion and sedimentation will cause wider diversification in physical and biological habitat conditions.

No bank revetment
Give the rivers space for lateral erosion. Usually you have to buy the land. If you can take away longitudinal bank protection.

With enough land asides the river the best solution will be "Zero-Construction". In riverrestoration you must have patience to observe what the river is doing.

If necessary take into consideration bank protection by vegetation only, willow, ash, alder; fas- cine, wattle, anchored trees etc. Or replace longitudinal bank protection by dikes or spurs built by stone, trunks or hurdle, perhaps a combination of stone and timber.

If bunding is necessary a dry wall of stone without mortar or concrete by ecological means is better than a concrete wall.

Dynamics in river meadows
To improve this goal the following measures should be taken into consideration: Reactivate flooding of river meadows by taking away old dikes protecting only agricultural land; excavating river meadows or raising riverbed thus creating wetlands; giving the oppertumity to erode channels etc.

Migration within watercourses

Replace weirs by ramps
Vertical weirs more than 1,00 – 1,20 m high cannot be passed even by trouts. Other species are stopped by an heigth of 0,40 or only 0,20 m. So replace vertical weirs to enable migration of aquatic animals not by technical ramps but by "cataracts" which means open ramps: This construction we developped in Rosenheim imitating natural conditions. Prof. Bechteler of the University of the German Armed Forces is just now testing the limits in a physical model with movable bed [11].

If the weir cannot be replaced perhaps a by-pass channel is helpful: You need a minimum discharged in your channel, often it's hard to get it.

In diverted river sections a minimum discharge in the watercourse is necessary to enable migration. We have a leaflet to solve these questions [12]. Usual we carry out an experiment in nature to find the optimal minimum discharge, optimal by economical and ecological means; but the negotiations are longlasting and often hard. Of course the water quality has to be good or sufficient to recreate gateways of low discharge.

Also the semiaquatic and amphibic section of a river can be improved for migration in a watercourse by installing a very small bank e.g. along a wall. It could be sufficient for a connection of
upstream and downstream parts of the river system.

Riparian strips

One essential goal is to have flood plains and natural river meadows along our rivers. And we know their functions or effects: flood absorption, habitat of amphibious living spezies, space for longitutinal migration of a lot of spezies as well as migration from the watercourse to the land, factor of local climate, recreational area etc.

Along canalised rivers usually we don’t have river meadows. But perhaps there is a chance to buy land in one point. There you can create a local river meadow even with dynamics I mentioned above.

Riparian strips along water courses can improve essentially the amphibious habitat of canalised rivers. They are slim substitutes of river meadows. Usually 5,0 – 10,0 m are sufficient. Along river Murn we had ecological investigations by the Technical University Munich-Weihenstephan [13]. They found by diversification of individuals and spezies that a riparian strip of 5,0 m along the upward border of the bank-rim is enough. And the management of this strip is important. Intensive agricultural use cutting the grass five times a year is not good of course. And wilderness is not good too. Best management by ecological means was cutting the grass once a year or once in two years. The landward border of such a riparian strip could be a little way for hiking, biking and for our river maintenance works.

Summary

In Germany our vision is an entire ecologically functional unit of river, riparian meadow, flood plain and valley. You must know the different components of your river-ecosystem, their functions and their interactions. In canalised rivers where there is no space e.g. for dynamics in riparian meadows you have to take those parts you can realize in your case to improve the physical habitat.

I think that should and could be especially
- open floor of river bed
- dynamics of bedload
- diversification of effluent conditions
- enabling migration in watercourses

- replacing weirs by cataracts
- creating by-pass gateways around weirs
- minimum discharge in diverted river sections
- installation of riparian strips.

References

[1] Gesetz zur Ordnung des Wasserhaushalts (Wasserhaushaltsgesetz – WHG) vom 12. November 1996, (BGBl. I S. 1695).

[2] DVWK (1991a): Ökologische Aspekte bei Ausbau und Unterhaltung von Fließgewässern. – DVWK Merkblätter zur Wasserwirtschaft, Heft 204, 2. Auflage (unveränderter Nachdruck von 1984), Bonn.

[3] DVWK (1991b): Ökologische Aspekte zu Altgewässern. – DVWK Merkblätter zur Wasserwirtschaft, Heft 219, Bonn.

[4] DVWK (1992): Methoden und ökologische Auswirkungen der maschinellen Gewässerunterhaltung. – DVWK Merkblätter zur Wasserwirtschaft, Heft 224, Bonn.

[5] DVWK (1993): Landschaftsökologische Gesichtspunkte bei Flussdeichen. – DVWK Merkblätter zur Wasserwirtschaft, Heft 226, Bonn.

[6] DVWK (1996): Fischaufstiegsanlagen – Bemessung, Gestaltung, Funktionskontrolle. – DVWK Merkblätter zur Wasserwirtschaft, Heft 232, Bonn

[7] DVWK (1997): Uferstreifen an Fließgewässern – Funktion, Gestaltung und Pflege. – DVWK Merkblätter zur Wasserwirtschaft, Heft 244, Bonn.

[8] DVWK (1997): Bisam, Biber, Nutria – Erkennungsmerkmale und Lebensweise, Gestaltung und Sicherung gefährdeter Ufer, Deiche und Dämme. – DVWK Merkblätter zur Wasserwirtschaft, Heft 247, Bonn.

[9] DVWK (2000): Gestaltung und Pflege von Wasserläufen in urbanen Gebieten. – DVWK Merkblätter zur Wasserwirtschaft, Heft 252, Hennef.

[10] PATT, H., JÜRGING, P. & KRAUS, W. (1998): Naturnaher Wasserbau – Entwicklung und Gestaltung von Fließgewässern. – Springer-Verlag, Berlin, Heidelberg, New York

[11] VOGEL, S. & BECHTELER, W. (1999): Darstellung und Auswertung der Versuche am Modell Leitzach-Rampe. – Universität der Bundeswehr München, 2. Zwischenbericht 12/1999 (nicht veröffentlicht).

[12] BayMLU (Bayer. Staatsministerium für Landesentwicklung und Umweltfragen) (1999): Restwasserleitfaden. – 2. überarbeitete Auflage 1999.

[13] KRAUS, W.: Uferstreifen – unverzichtbare Bestandteile von Tallandschaften. – Z. f. Kulturtechnik und Landentwicklung 35, S. 130 – 139.

Country status report – Stream rehabilitation in The Netherlands*

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**This paper is a compilation of the publication of Driessen et al., 1998.*

Introduction

The Netherlands is a flat country, half of which is below sea level. The highest point in the most southern part of the country is about 200 m above sealevel. The climate is atlantic and there is a precipitation surplus of 200 to 400 mm a year. This surplus is stored in the predominantly sandy bottom of the Plistocene and discharged by lowland streams, fed by helokrene springs and seepage.

These streams have been adapted to agricultural, domestic and industrial needs, resulting in chanallized and otherwise modified watercourses. Around the eighties of the last century, only about 4% of all streams still had a natural morphology and a more or less natural hydrology. Since then, many projects to rehabilitate (parts of) streams have been carried out. In 1995 a country-wide survey has been performed to evaluate the rehabilitation projects (Driessen et al., 1998). The ascending line of the number of projects and kilometers under rehabilitation has continued to rise in the last years of the century.

Rehabiliation projects

A total of 159 projects has been evaluated, comprising some 300 km of stream length. More than 65% of the projects date from 1990 onwards (Fig. 1). For 82 projects, data on restored reaches are given in Table 1.

Table 1 *Average length of restored reach per project*

Period	Number of projects	Average length of restored reach (km)
1985-1989	13	2.7
1990-1992	28	3.8
1993-1995	41	3.9

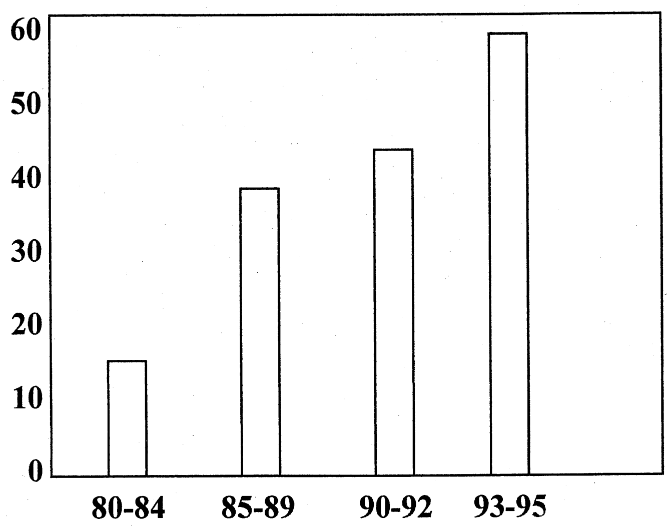

Figure 1 *Number of stream rehabilitation projects per time period over the years 1980-1995.*

In 71 cases, the costs per project have been indicated. Table 2 gives these figures in American Dollars.

Table 2 *Average costs of stream rehabiliation projects*

Period	**Number of projects**	**$ per project**
1985-1989	12	290,735
1990-1992	26	908,846
1993-1995	33	1,032,049

Registration of the financial contributors has been performed for 102 projects. Both national government and regional water authorities contribute in more than 70% of the projects (Table 3).

Table 3 *Financial contribution in 102 stream rehabilitation projects*

National Government	75%
Regional Government	32%
Regional Water Authorities	70%
Nature Conservation	11%
Others	11%

Rehabilitation measures

The measures have been divided into four groups:
- hydrological measures: increasing (ground)water level and (ground)water supply in the catchment area are equally applied
- morphological measures: creating riparian zones and riverbanks is most frequently conducted, followed by meandering
- water quality measures: direct reduction of input of substances is far more used than the indirect reduction by the use of bufferzones
- biological measures: species directed management by habitat adjustment and planting bank vegetation are equally applied, but introduction of species is hardly used.

Of all measures together, the most applied one is creation of riparian zones and river banks, followed by adjustment of stream maintenance (Table 4).

Table 4 *Percentage of rehabilitation measures in the described categories* (n = 810)

Hydrology	**%**	**Morphology**	**%**	**Water quality**	**%**	**Biology**	**%**
Increasing (ground)-water level	4	Removal of dams and embankments	6	Direct reduction of input of substances	7	Planting bank vegetation	11
Increasing (ground)-water supply	3	Meandering	7	Creating bufferzones	3	Adjustment of stream maintenance	16
		Creating riparian zones and river banks	25	Removing sediment	1	Introduction of species	2
		In-channel features like pools and riffles	5			Species directed management	10
Total	**7**		**43**		**11**		**39**

Monitoring techniques

Data about 91 rehabilitation projects have been collected and only 46 provided a monitoring or evaluation program. Abiotic and biotic data have been measured before the project starts to be able to compare these with post-project data. The check-list in Figure 2 may function as a guideline (Verdonschot, 1995).

Table 5 indicates the parameters measured in 9 different regions. Water quality and biological parameters are more often measured than hydrological and morphological ones. In most regions a period of ten years of monitoring will be taken into account. Monitoring methods are generally similar in all regions. Vegetation is measured by the Tansley method, diatoms are collected by scraping of vegetation or other substrata, macroinvertebrates are collected by using a pond net and fish by electro-fishing or nets. All organisms are being identified to species level.

ANALYSIS OF THE PROBLEM

1. Recognision of the problem
2. Data Collection
3. Formulation of goals
4. Analysis of bottle necks
5. Enlargement of acceptance by stakeholders

DESIGN

6. Composition of the list of participants
7. Formulation of possible measures and alternatives
8. Judgement of attainability
9. Program of requirements and planning procedure

EXECUTION

10. Preparation of execution
11. Realisation
12. Monitoring

EVALUATION

13. Test/refinement/readjustment of goals and feed-back

AFTERWARDS

14. Optimization of management and maintenance

Figure 2 *Check-list of procedure for rehabilitation projects*

Table 5 *Monitoring techniques: parameters and number of regions where used*

	Parameter	Number of regions
HYDROLOGY	Ground water level	3
	Water level	4
	Discharge	3
	Current velocity	5
MORPHOLOGY	Longitudinal profile	4
	Transversal profile	5
	Substrate mosaics	3
WATER QUALITY	Oxygen	9
	Nutrients	9
	Major ions	7
	Toxic substances	4
BIOLOGY	Riparian vegetation	8
	Water vegetation	8
	Diatoms	1
	Macroinvertebrates	9
	Fish	6
	Others	6

Discussion

Most rehabilitation projects comprise short stream stretches and not whole streams and catchments. This is certainly due to the high costs, different ownerships of stream stretches and the lack of space in an overcrowded country. Hydrological measures that should be the primary task in the rehabilitation of streams form a minor part of measures performed. It is therefore questionable if the results of many projects are as successful as expected. If at least there was an expectation! Rehabilitation goals should be defined in terms of qualitative and quantitative, abiotic and biotic parameters. This definition can only be made with knowledge of the major controlling factors in a whole stream system. Monitoring should then focus on the goals, taking into account the recovery time of the stream in relation to the measures taken and should be efficient in effort and costs. Controlling factors have been summarized in an hierarchical system, the so-called 5-S model (Verdonschot, 1995). This system has been illustrated in Figure 3. It is composed of 5 main groups of controlling factors:

- *System conditions* are the ultimate controlling factors, acting at a high spatial and temporal scale level in the catchment. The conditions are a given in certain areas and cannot be changed by management.
- *Stream hydrology* comprises the controlling factors related to water quantity.
- *Structures* concern the morphological characteristics of the catchment, the stream corridor and stream.

- *Substances* comprise water quality gradients from catchment boundary to stream and from source to mouth. These three last groups of controlling factors can be influenced by management and they constitute the tools for rehabilitation of streams.
- *Species* (communities) finally form the biological response to the four abiotic groups of factors.

The 5-S model can be filled with data for each specific situation. There are numerous interactions between the components of the model, many of which can be manipulated by management measures. The knowledge of controlling factors and their interactions is growing and the 5-S model is being applied successfully in different case studies recently.

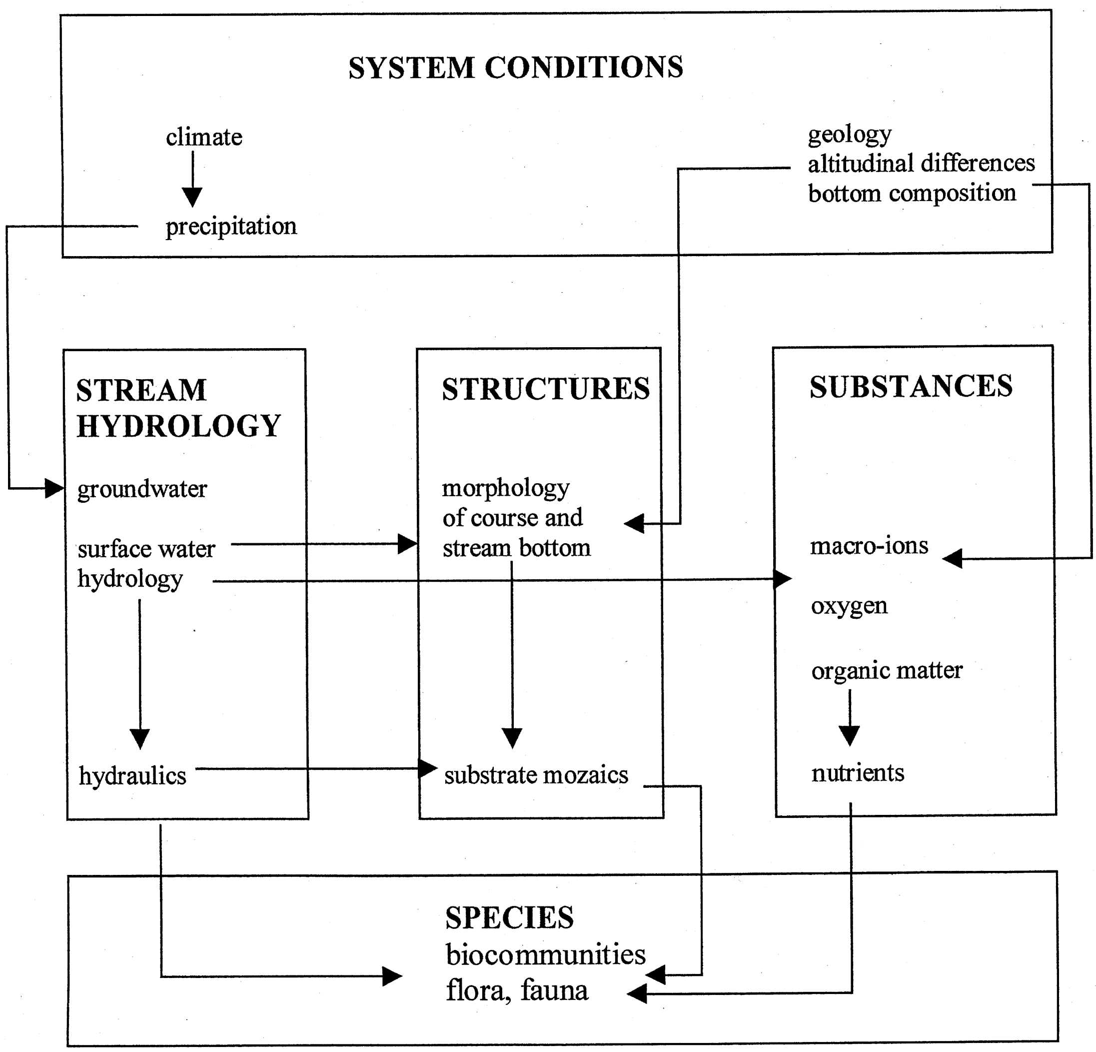

Figure 3 *The 5-S model*

References

Driessen, J.M.C., Verdonschot, P.F.M & Schot, J.A. 1998. Stream rehabilitation in The Netherlands: Present status and future developments. In Hansen, H.O. & Madsen, B.L. (eds.) River Restoration '96 Session lectures Proceedings. International Conference arranged by the European Centre for River Restoration. National Environmental Research Institute. Ministry of Environment and Energy, Denmark.

Verdonschot, P. (Ed.) 1995. Beken stromen. Leidraad voor ecologisch beekherstel. Publication of STOWA (95-03) and Werkgroep Ecologisch Waterbeheer (WEW-06).

Country status report - Flanders, Belgium

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Overview of the Flemish watercourses

Physically spoken, one can consider four major types of watercourses:

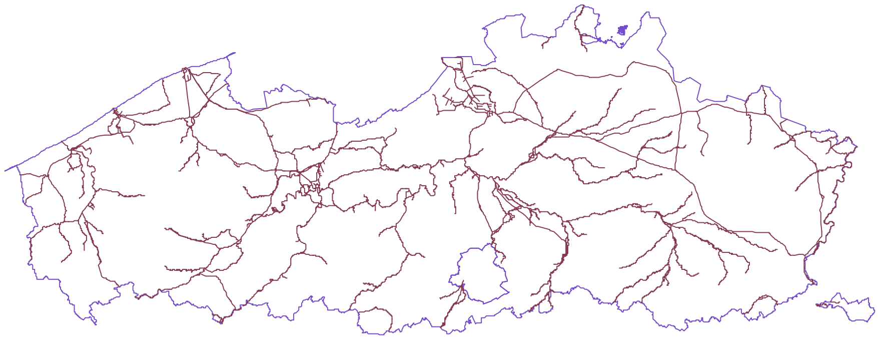
- *Lowland brooks and rivers*, that have predominantly a silty or sandy substrate, often with an important sediment load in slow flowing currents with a more or less constant dry weather discharge and marked peak discharges. The catchments are generally deforested (less then 10% tree cover)
- *Tidal rivers*: some 250 km; the river Scheldt and tributaries (s.a. Durme).
- *Gravel river*: a short stretch of the left bank river Meuse, forming the border with the Netherlands
- *Canals*: artificial watercourses dug out for shipping

Administratively spoken one can consider 4 different categories:

Responsibility for the different watercourses are regionalised in Belgium, meaning that it is not a Belgian but a Flemish and Walloon matter. The administrative subdivision is the same for the two regions.

- *Navigable watercourses*: responsibility of Flemish government, comprising all major rivers and canals, as a rule they are or can be used for shipping
- *Category 1 rivers*: responsibility of Flemish Government, all rivers that cross a province border.
- *Category 2 rivers*: responsibility of the five provinces, all rivers that cross a province border.
- *Category 3 rivers*: responsibility of the municipalities

The category 1 to 3 rivers are the so-called “non-navigable watercourses.



Map with the navigable and category 1 watercourses

River canalisation - what preceded…

Along almost all major rivers there were local, small-scale initiatives involving river canalisation; most frequent were the construction of modest embankments along tidal sections of the rivers that started somewhere around the years 900-1200 and onwards. These embankments along tidal sections are called “inpoldering” (a specific term used in Flanders region and The Netherlands).

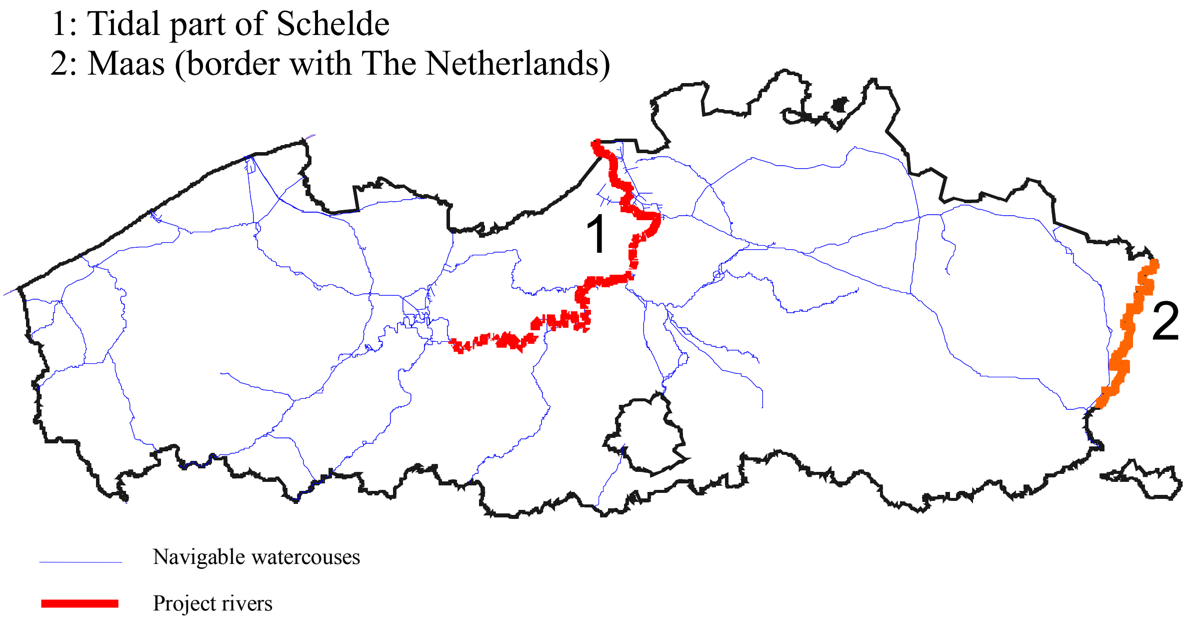
The major wave of river canalisation started just after and as a result of the big inundations in 1976, this canalisation and embankment plan is called SIGMA-plan. In The Netherlands this process (the so-called DELTA-plan) started two decennia earlier after the major inundations of 1953.

Till only very recently there was (and in some areas there still is) a tendency of canalising and “normalising” stretches of rivers as a result of the planning after the 1976 inundations. This led to the following status of the Flemish rivers:
- All navigable and all category 1 watercourses are firmly “ameliorated” in Flanders.
- The majority of the category 2 and 3 rivers are ameliorated but to a lesser extend.

Amelioration means section enlargement, lowering of the drainage level, cutting of corners and meanders, fixing and paving of the river banks and construction of artificial levees. The driving forces behind these processes were flood prevention and predominant agricultural land use.

Meanwhile in the field, things were changing, at least locally since approximately 1990. Below are 4 restoration projects that helped us change the way of looking at our rivers.

Tidal part of the River Scheldt (specific info: tom.ysebaert@instnat.be)



The elongated estuary of the River Scheldt has a total length of 160 kilometre, covering an area of 35000 ha. This stretch comprises a complete salinity gradient (< 0.7 to >15 psu). The mean discharge of the Scheldt is approx. 100 m³/sec, and the tidal amplitude of the river ranges from 2 meter at the river mouth to as much as 5 meter land inward. Although the river Scheldt has been heavily regulated and canalised in the past and the predominant economical function of the river, it still has a very high ecological value (f.i. thousands of hectares of tidal marshes, possibility of free migration of organisms in the river). Within the boundaries of its economical function and within the flood prevention security guidelines, a lot of projects are conceived and carried out in order to increase and restore the ecological function of the river.

This project can be summarised in two area's of special attention:

- MARS-project (Marsh Amelioration along the Rivers Scheldt) is a partly EC-Life funded project aiming to:
  - land inward relocation of embankments (dykes) in 6 locations, involving approx. 7-800 ha)
  - removal of historical, artificial sediment deposits, originating from dredging activities or waste dumps along the river course.
- Adjusting the shape and paving of embankments to create ecological possibilities of (semi-) terrestric, aquatic and bentic communities at different locations along the tidal part of the river

In conducting this project, at least two points of view are confronted with one another: The water manager is focusing on increasing the floodwater storage capacity. That way the safety levels increase, while the ecologist is aiming for the enlargement of the estuarine ecosystem. In doing so, biodiversity is increasing and is buffered in a better way. This is a good example of a win-win situation, at least compared to the 1990 situation.

Status of the project: in execution
This is a huge project with important scale problems. Shipping capacity and a very bad urbanisation (directly linked to flood-prevention needs) are over-dominant factors in project related discussions.

The river Meuse (gravel river) (specific info: kris.van.looy@instnat.be)

The Meuse river is also a heavily regulated and canalised river. Three main aims are distinguished in this project:

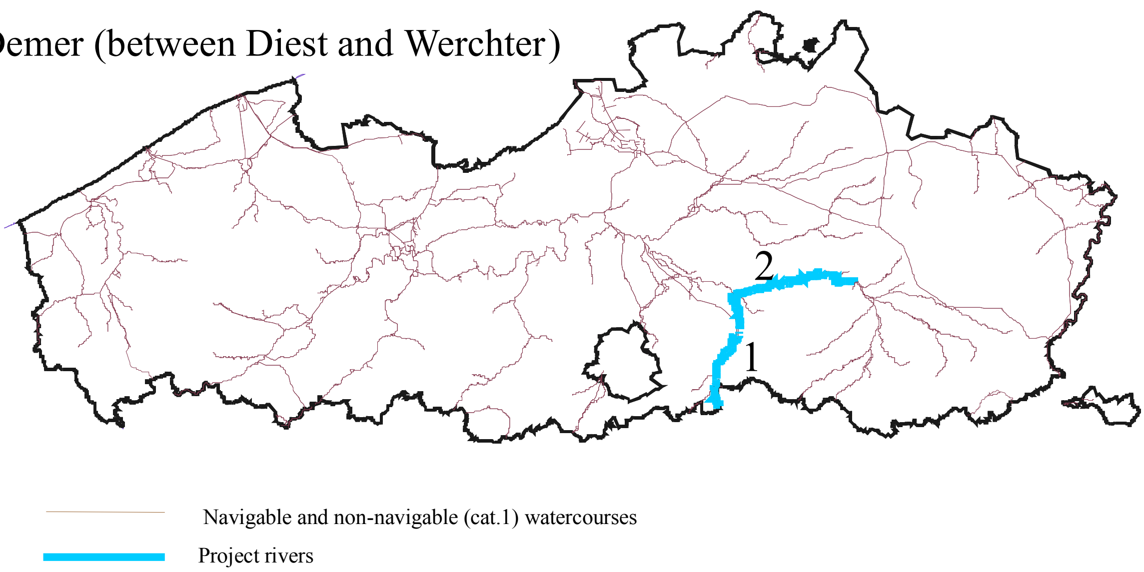
- Land inward relocation of embankments e.g. the partial restoration of the winterbed
- reconnection of previously cut-off oxbow lakes
- releasing (spontaneous process) and eventually enlargement of the summerbed so that gravel deposits become tolerable

Status of this project: planning phase, execution imminent

The river Dijle (specific info: piet.de.becker@instnat.be)

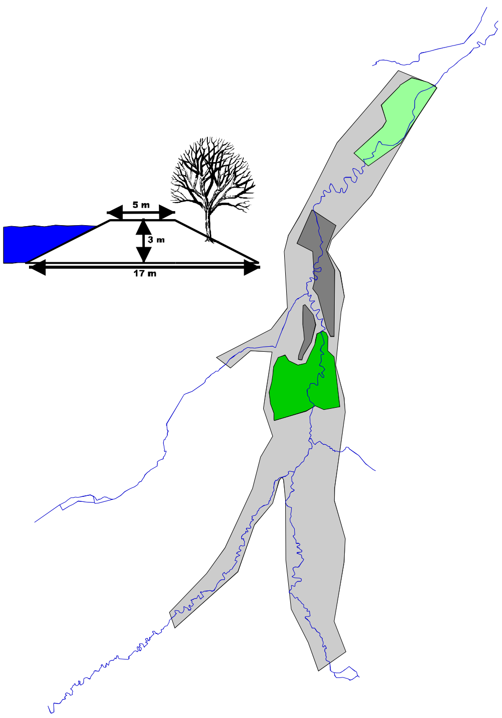
1: Dijle (upstream Leuven)

2: Demer (between Diest and Werchter)



This restoration project is about 17 kilometre of a middle course of a silty, alluvial valley with floodplain mires. The river has a mean dry weather discharge of 4-5 m³/s and is a rare exception on the general river canalisation rule in Flanders. There is a safety (flooding) problem for the university town of Leuven, downstream the project area.

At first a traditional solution was proposed involving the construction of several detention reservoirs. This solution has major ecological disadvantages such as:
- the reduction of the river to a mere evacuation channel
- no connection between the river and the floodplain
- storage of large amounts of water on a small area results in massive sedimentation
- the artificial dykes around the detention reservoirs cause visual disturbance



Retention reservoirs of the Dijle river

After long discussions the project philosophy was altered toward an ecological sound solution involving the restoration of the alluvial floodplain ecosystem by:
- limiting the human interference in the floodplain as much as possible and instead rely on hydrological processes and spontaneous recovery of river course.
- enhance natural storage without infrastructure
- distribute floodwater over the entire floodplain surface
- no more sediment dredging or riverbank mowing, instead no maintenance works on the river canal and a natural evolution of meanders
- restoring the drainage channel network and reconnection to the river so that natural inundation increase compared with the actual situation

Status of this project: in execution

The major point in the discussion was met when the safety level with respect to avoiding flood damage in the downstream city of Leuven was met for a return period of 1/100 years. Seen the dramatic decline of agricultural land use in the river valley, an ecologically sound solution became possible. This is another example of a win-win situation for river managers and ecologists.

The Demer river - a lot more complicated! (specific info: bart.aubroek@instnat.be)

Compared to the Dijle, the problems in the valley of the Demer are a lot more complicated. The river is completely canalised and the river bed has been deepened significantly (1-2 meter). The floodplain is partly in agricultural use (60 %) and used for industrial activity. The remaining surface is partly forested and a nature reserve. There are two major cities along the river experiencing regular flooding damage. Last but not least there is a poor river water quality.

The aim of this project is to provide flood protection for the two cities (1/100 years), a partial restoration of the alluvial floodplain ecosystem including the restoration of the historical drainage level and the reconnection of previously cut-off meanders is wanted by the ecologists. However, there is also important agricultural land-use in the floodplain.

Status of this project: end of planning phase.

There is a hydraulic model with spatial distribution and retour periods of flood events. The ecological constraints for restoration of the nature reserves in the floodplain are known. Now coming up is the confrontation with other land users such as farmers, the two cities, and industry.

The present water management situation in Flanders

In the last decades there is a declining weight given to agricultural land-use in river valleys. This gives river managers more room to discuss a new integrated water management scheme. However, due to river canalisation in the past, flooding occurs only sporadically. Urban and industrial development in natural floodplains increased due to the (false) sense of safety. This causes a lot of problems when floodplain restoration is under discussion. Flooding risks and possible economic damages has risen and are still rising steeply. The result is that the different river managers are evaluating and rethinking (par force) their water management approach.

Some recent initiatives

Catchment committees for all river catchments have been established. In these committees all actors and stakeholders involved in land-use in a certain river catchment are united to report and discuss water management matters relevant to the catchment in question.

River function plans for navigable watercourses. (Specific info: kris.decleer@instnat.be). Prior to new river management plans, the multifunctional use and the weight given to the different groups of land-users in the floodplain in question has to be determined. Such plans can vary a lot between different river valleys.

Buffer strips along category 1 watercourses. (Specific info: enny.van.der.welle@instnat.be).
The aim is to establish a 10 meter riparian zone on both banks of the category 1 rivers. These buffer strips are supposed to function as ecological corridors, bank stabilisation against erosion, nutrient-, pesticide and sediment traps.

Country status report - River habitat restoration of channels in the UK

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Introduction

Physical habitat restoration should consider the extent of the changes that have occurred in British streams over the centuries and recently and more intensively in recent decades, in the context of the types of direct, indirect and consequential actions. Mans interaction with rivers has ranged from simple effects such as the increased access by or for cattle, through the removal of excess bank or aquatic vegetation to the re-sectioning and re-alignment of lengths of watercourse or the construction of new channels. But should also include other effects such as the removal or addition of water and discharge of water containing dissolved or solid materials.

Traditionally, channel modification has emphasised a simplicity of form in combination with the ability to produce channels by intensive labour or heavy machinery. The basic concept seems to have been that water flows in a straight line and speed of removal is enhanced by the shortest route. However sediments are deposited, water flow is be reduced by bed and bank material and both lead to on-going dredging and 'weed' removal.

Each intervention has its own series of direct and consequential change mainly on the section modified but also for a distance downstream but also to an extent upstream. Indirect intervention may include modification of the volume, intensity, periodicity or seasonality of water flow, each bringing a wide range of scenarios for change. Changes in the chemical or physical quality of water also create changes in the development of biota which may influence the sustainability of normal cycling of animals or plants. Indeed the combination of elevated nutrients may inhibit plant growth. Combinations of these perturbations may directly lead to excessive, erratic or catastrophic changes to the expected condition of the physical environment and may lead to less successful or failure in restoration schemes

Assessment which encapsulates/captures these changes and which can be used in comparisons against natural standards which determine the diversity of habitats in terms of flow, substrate and erosion/deposition features, and the presence type and extent of vegetation, is as important as understanding the basic geomorphology principles to ensure a reasonable degree of stability for planning, development and implementation of a rehabilitation scheme.

Restoration may take many decades to return to a truly natural state although it may appear almost indistinguishable and like land substitution for development, it should be discouraged before considered a pragmatic alternative.

The objectives of this paper on physical habitat restoration in channelised watercourses of the UK are to:

1. give a context to the situation in the UK by quantifying the existing types & extent of modifying factors in the context of the original channel requirements and to determine the various stages of management which lead to these significant physical modification of channels;
2. give an overview of recent river restoration schemes with their objectives, choices, status and constraints;
3. suggest guidance framework on sustainable restoration by considering mechanisms to determine the appropriateness of materials by contrasting the habitats of near-natural channels ie semi-natural and pristine with modified channels in terms of flow, substrate and erosion/deposition features, and the presence type and extent of vegetation; and emerging consequential effects on channels water flow and biota; and to consider the role of experience which though effective locally can be counter productive if applied at the broader scale.

Extent of channelisation

As in much of Europe, watercourses in agricultural and urban areas of the UK are to a large extent managed or often channelised but there is growing awareness of this and of the need to consider restoration towards a natural conditions or to a practical compromise. Perversely in some areas the conditions established over many centuries have become to be considered the 'norm' and local requirements may not consider the apparently extreme proposal of conservationists to be relevant to 'the natural countryside'. The focus on restoration varies with country and the focus varies over a wide range. The need to restore needs to be seriously considered and resolved, on e result may be the transformation of examples of whole river systems or merely a series of sections of representative parts of several rivers of a type or group.

Historically, changes in the UK over the centuries have ranged from small agricultural modifications to allow the greater seasonal use of flood plains or for water supply to for example the formal modification of valley plain as 'water meadows' for grazing by using the river water to keep the meadows free of frost or 'flood meadows' to capture the rich supplies of rich silt made available during floods (Vaughan 1610). In the last century, the intensity with which fallen or even maturing trees were removed and channel enlargement, gravel and sand bar removal, re-sectioning and straightening, intensified from the 1930s until, by the mid-1980, it was estimated that between 1930 and 1980 8500 km of major or 'capital works' had been undertaken with a further 35,500 km being maintained ie the defined 'main river' in England and Wales (Brookes et al 1983). The latter maintenance included the alleviation of flooding both in summer and in winter, improved drainage of agricultural land, reduction and prevention of erosion or even improvements for navigation. This survey did not include the remainder of the estimated

156,000 km of river in England and Wales or the smaller and agricultural channels which may total as much again. A survey of the management of aquatic weeds confirms the range of the figure for other maintenance and gives a value of 9000 km subjected to regular weed removal but points out that light dredging to remove weed together with a considerable amount of silt was also undertaken periodically in other major lengths of river as part of river maintenance (Dawson 1987). Thus it would appear that the regular or 'little and often' approach can over long periods lead to changes which may be equivalent to major works.

Recently the River Habitat Survey which has systematically surveyed the UK with up to three surveys in each 10 x 10 km square which involved a general and 10 transect to assess the physical habitat features in 500m sections, revealed that 70% of lowland sites (<200 m) and 40% of upland sites were modified to some degree (Raven *et al.* 1998). The survey has itemised the range of modifying factors of river channels thus for example when calculated for all the flow-categorised streams and rivers of England and Wales, shows that an estimated 11 000 km have been straightened, 71 000 km have re-sectioned, based on the RHS estimates of at least on third of one or both banks of the 500 m sample lengths, and that 52 000 km have been extensively re-sectioned.

Concurrent with these modifications of the physical habitat to the riverine habitat of the UK, has been the increase in the loadings of nutrient. This now results in near critical levels for aquatic vegetation which may now have reach such levels that they not only reduce diversity but may limit the growth of aquatic plant and favour algae. Formerly enhanced levels increased their growth leading to an need to remove excessive growth in about a quarter of the UK at a annual cost estimated at £100-200M for multi-owner watercourses.

Overview of recent River Restoration, Rehabilitation and Re-engineering and their objectives

Currently, 700 schemes have been registered on the database at The River Restoration Centre at Silsoe, UK., but as yet little detail is available to give an overview (November 2000, www.qest.demon.co.uk/rrc/rrc.htm). Currently the only data available is main river or catchment and site names, locations, county main focus and contact and details of project.

Analysis of data from the mid 1990s on selected examples from a recent survey from the UK comes mainly from England and Wales although there are examples from Scotland and Northern Ireland (Holmes 1998). A total number of 1790 major activities were recorded and they were divided 1. rehabilitation, 2. restoration of free passage between reaches > 1 km benefit, and 3. flood plain restoration. These activities were distributed throughout the country except for Scotland which was either under-recorded or proportionally fewer schemes have been implemented (Figure 1). Further analysis indicates that the most frequent activities in the three above divisions include provision of habitats for single species, current deflectors etc, bank re-profiling or cross-sectional enhancement and tree planting although no details are available on the extent of the schemes (Figures 2, 3 & 4). Conversely, these lists also contain examples of such techniques which are claimed as restoration such as fencing, control of alien species, increased tree shade which undoubtedly tackle specific problems but are only stages on the way to full restoration. Overall whilst these changes may enhance the habitat for species, provide an aesthetically improved vision of the river or assist in developing more natural communities, little evidence is provided to show that they are based on geo-morphologically or ecologically-sustainable principles and can be expected in most cases to require on-going maintenance.

The total cost of these schemes is not available but analysis of the some 40 examples (6%) for in-channel and marginal or floodplain projects selected by Holmes (1998), indicates that for an average length of 5.3 km with a mean area of benefit of 104 ha and the mean cost per scheme of £238 000 which gives a mean cost per kilometer of channel or riparian area of £46 000 to £130 000 depending upon the benefit; the cost per kilometer of only the channel schemes was £39 000 although the cost for other different objectives was not available. Thus, although the objectives and methods of schemes have changed with time and undoubtedly vary with cost, no details have yet been recorded centrally (by RRC). Despite this, however, the few costs available equate to a total cost of £90M – 170M or £10M per year for the 700 sites which have been restored over the past decade or about one tenth of the annual spend on general inland flood defence of £120M; in addition annual maintenance costs about £60M (Bramley, pers comm.).

Although a few schemes, particularly the demonstration projects, have been reported in the scientific literature (eg Hansen et al. 1998), most schemes did not have either a good pre- or post-project appraisal at a suitable interval after implimentation which makes it is difficult to assess the success of the various schemes, or are set in the context of basic analysis of geomorphological driver factors such as energy or geology of the riparian area or the upstream catchment.

Data collection for national databases for use in future planning, prediction and advice, should be specified based upon the general experience of success and failure and also with reasonable consultation with relevant disciplines and requirements of river ecology, geomorphology and engineering.

Suitable survey techniques which encapsulate the sufficient detail for collection of comparative data from equivalent or suitable adjacent sites for relevant and contextual planning, and for pre- and post-construction survey should be developed or adopted and used. The River Habitat Survey (RHS) currently in use in the UK and some other European catchments, is available and may meet many of the needs of a methodology. RHS is a rapid, and thus inexpensive, non-subjective survey technique allowing the standardising the recording of a range of predominant physical features of channels and their surroundings. This survey could be considered less detailed than required for river restoration or for other specialised disciplines would wish under ideal conditions but which does provide a common framework for many studies on a national basis which would not otherwise be acceptable to an individual project with a current database of some 17,000 surveys.

Surveys should also extended to schemes in which lakes and ponds, if adjacent, have been established, and account for aspects such as naturalness and time to naturalization.

Detailed consideration should be given in re-naturalisation to the issue of promoting fish habitats for all life stages. Thus niches of habitat and prey-interaction change throught the life cycle of fish species and may be quite rapid or of short duration but without the necessary habitat the life cycle may not be completed and allow a community to develop which is sustainable in the reach of the scheme. In comparisons of the key habitat requirements for fish and it has been concluded that, in general, availability of suitable spawning sites is the most important factor (see Gozlan, this volume).

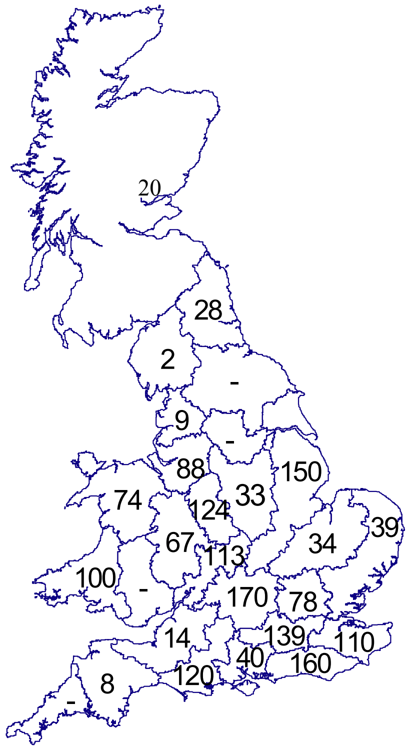

Figure 1 *Summary distribution of the rehabilitation work undertaken in watercourse reaches by area of the Environment Agency in England and Wales and for Scotland (After Holmes 1998).*

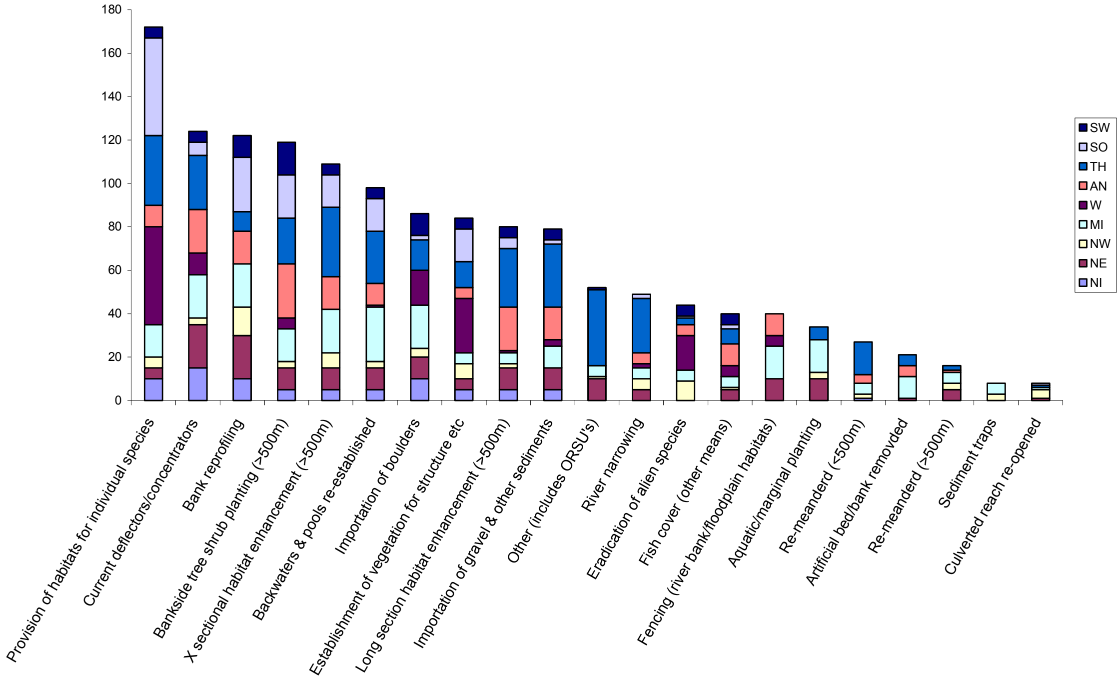

Figure 2 *Summary of the main types of rehabilitation work – 1. Rehabilitation of Water course reaches by area of the Environment Agency in England and Wales and for Northern Ireland (After Holmes 1998). [Key to Environment Agency regions : SW, South West; SO, Southern; TH, Thames; AN, Anglian; W, Welsh; MI, Midlands; NW Northwest; NE, Northeast; NI, Northern Ireland)]*

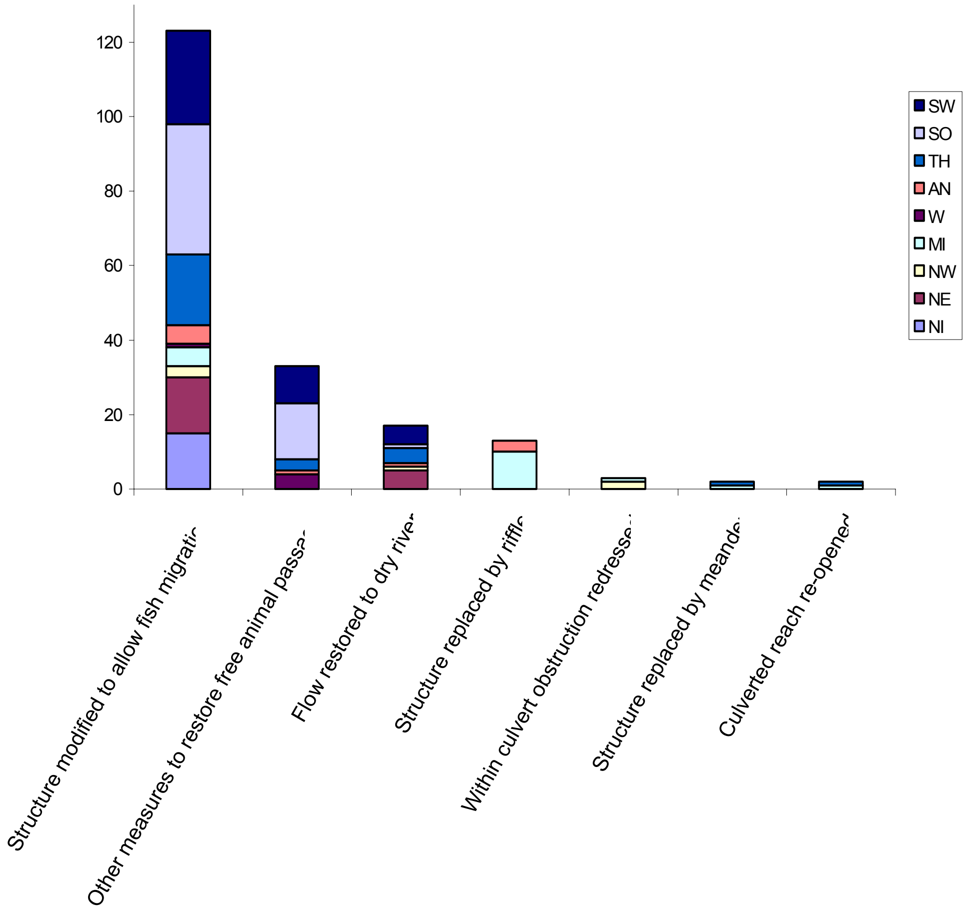

Figure 3 *Summary of the main types of rehabilitation work – 2. Restoration of free passage between reaches benefiting at least 1 km upstream for water course reaches by area of the Environment Agency in England and Wales and for Northern Ireland (After Holmes 1998). [Key to Environment Agency regions see Figure 2.]*

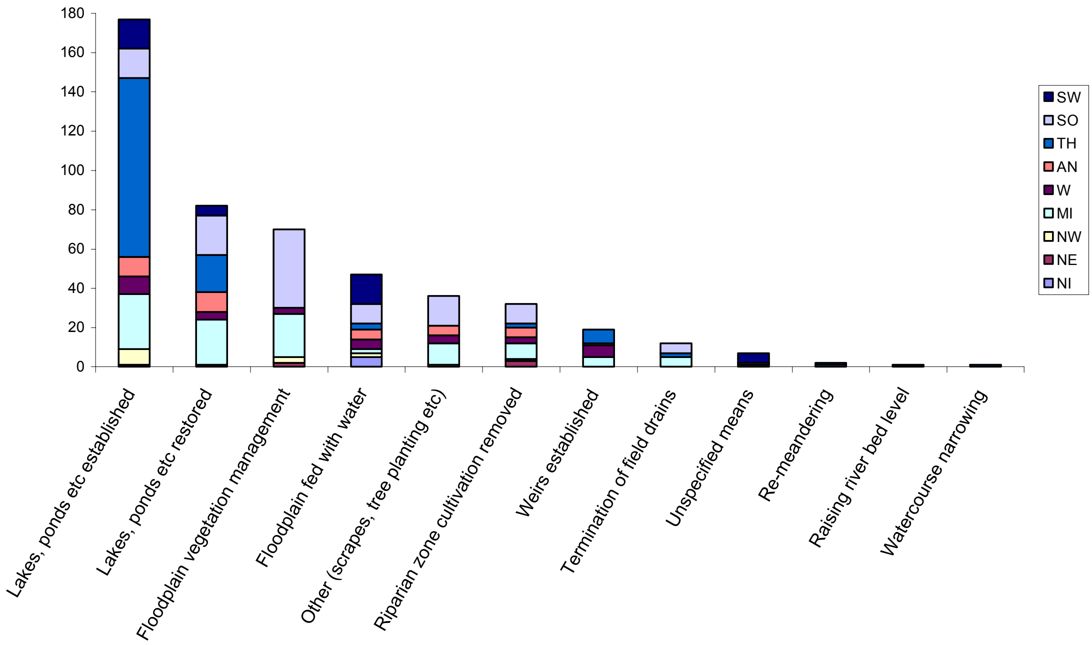

Figure 4 *Summary of the main types of Rehabilitation work – 3. Flood plain restoration by area of the Environment Agency in England and Wales and for Northern Ireland (After Holmes 1998). [Key to Environment Agency regions see Figure 2.]*

Natural variation in channel planform and its modification

Proposed changes should be put into context by, for example, comparison with adjacent, and hopefully unmodified, sections of river as proposed by Rosgen or by comparison with the general pattern of variation expected from geomorphological principles or from some general data set such as that of the semi-natural or pristine sites of the River Habitat Survey (Raven at al 1998). The latter gives the physical habitat of rivers by contrasting stable and unstable regimes by comparison of unmodified or semi-natural rivers with a range of modification and the consequential changes over a range of substrate, flow and erosion-deposition regimes over a range of local and general bed energy gradients.

Analysis of the River Habitat Dataset on the basis of one survey per 10 by 10 km square for the UK shows for the river channels that the representative and demonstration sites selected for the assessment by Holmes (1998) were predominantly in the lowland and coastal levels of the UK and a such were predicted to have fine predominantly sandy and finer sediments although some gravel and pebble substrates were probable in some sections based on the analysis of the RHS reference data set by Jeffers (1998, Figure 5). This analysis were based upon the PCA ordination analysis of map-based data to create a characterisation system for river habitats based on the UK reference dataset (5,600 sites) by using the logarithm the altitude of the site, its slope at the site, the distance to source, and the square root - height of source, and then ‘standardised’ by subtracting mean dividing by standard deviation which gave for the first two of four components:

I = 0.599 altitude + 0.598 slope – 0.265 distance + 0.462 height of source
(montane decreasing in altitude to coastal - variability = 54%)

II = 0.098 altitude – 0.205 slope + 0.779 distance + 0.585 height of source
(low energy to high energy - variability = 32%)

Further analysis of the RHS data allows analysis and probabilistic prediction of, for example, the predominant substrate, flow type or erosion deposition conditions, to be undertaken from the map-based variable for a proposed river scheme. Other relationships to be investigate may allow prediction of the planform of channels or similar factors by comparison with benchmark or pristine channel or even the semi-natural channels of the main RHS reference dataset, although as yet such detail does not appear to have been published even for the most studied rivers.

The most appropriate materials or substrates for use may also be derived from such relationships and thus such as materials which may need to slightly 'harder' or larger than the typical substrate expected for un-modified types of this watercourse ie substrate than slope to seasonal flow dynamics BUT not so hard or large as to become a more permanent or immovable feature and create new features or major diversions in the channel form. Thus, gravel or pebbles in a sand-bed stream or cobbles in a gravel-bed stream are likely to acceptable whereas boulders in a sand stream are not and may cause direct or consequential adverse changes. Conversely, however the removal on pseudo-armouring especially for example the surface flint layer in southern English chalkstreams must be thoughtfully replaced if long-term stability is to be achieved.

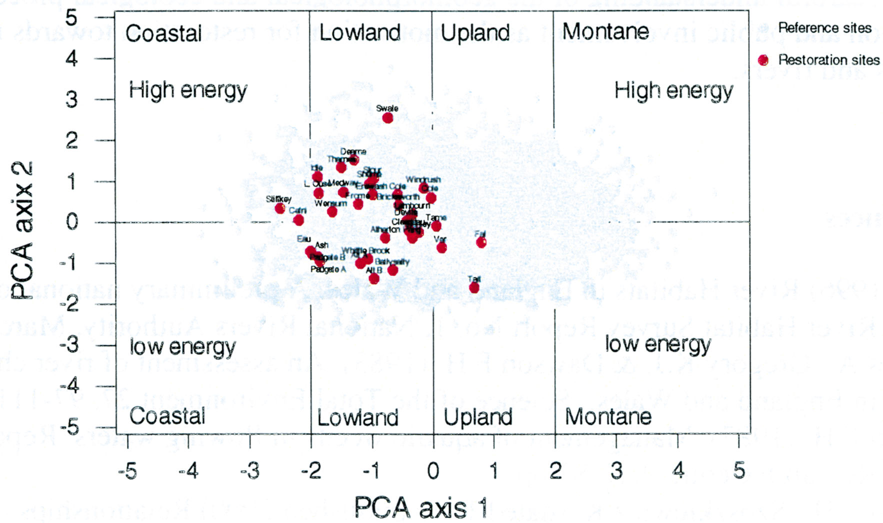

Figure 5 *The distribution of the restoration schemes selected by Holmes (1998) (in red) on the sites of the PCA ordination analysis (gray) of map-based data based on the UK reference dataset.*

Summary and Conclusion.

River restoration in the UK is varied and responds to the varying types and extent of river channelisation undertaken over the last decades and centuries. This review of restoration and its objectives and choices has shown the background to original channel modifications, the perceived requirements and consequential effects on channels, flow and biota. The continuing needs of users, pro-environment and legal requirements several of which may limit the choices, type and scope for further restoration. Thus, in the UK, some 5% or 9,000 km of channels were greatly modified in the 1930-80s with a further quarter of all channels subject to regular maintenance and now over the past 20 years progressively more apparently-appropriate restoration schemes currently totalling 700 together with several demonstration schemes have been implemented but still only represent a minute proportion of those prior modifications. Although several aspects of the latter have been reported in scientific journals, pre- or post-assessment surveys need to be undertaken to show the success of particular schemes and appropriate survey techniques need to be agreed for general use (Hansen et al 1998). There are options for the background information to be obtained to assist in the design stage of restoration schemes but there is, in addition, the need to solve the problems of the constraints from the different demands on channel functions, regional policies in environment, agriculture, water supply, perceived requirements and a range of specific problems especially stakeholder involvement ie resource use versus conservation which should be tackled through careful understanding of the geomorphological and ecological processes, education and public involvement as the motivation for restoration towards natural streams and rivers.

References

Anon (1996) River Habitats in England and Wales. A preliminary national overview. River Habitat Survey Report No. 1, National Rivers Authority, March 1996.

Brookes A., Gregory K.J. & Dawson F.H. (1983) An assessment of river channelization in England and Wales. Science of the Total Environment 27, 97-111.

Dawson F.H. (1987) Management of aquatic weeds in flowing waters. Report to Water Research Centre, UK. 83 pp.

Dawson F.H., Szoszkiewicz K. (dated 1999 published 2000) Relationships of some ecological factors with the associations of vegetation in British rivers. Hydrobiologia 415: 117-122.

Dawson F.H., P.J. Raven and Gravelle M.G. (dated 1999 published 2000) Distribution of the morphological groups of aquatic plants for rivers in the UK. Hydrobiologia 415: 123-130.

Dawson F.H., & Holland D. (dated 1999 published 2000) The distribution in bankside habitats of three alien invasive plants in the UK in relation to the development of control strategies. Hydrobiologia 415: 193-201.

Dawson, F.H., Raven, P.J. & Gravelle, M.J. (dated 1999 published 2000) Distribution of the morphological groups of aquatic plants for rivers in the U.K. Hydrobiologia 415: 123-130.

Hansen, H. O., Boon P.J., Madsen B.L. and Iversen T.M. (1998) River restoration. The Physical dimension. Aquatic Conservation Marine & Freshwater Ecosystems 8 (1) 1-264.

Holmes NTH (1998) A review of River Rehabilitation in the UK, 1990-1996. R & D Technical Report W175, Environment Agency, Bristol, England, 150pp.

Raven P.J., Fox P., Everard M., Holmes H.T.H., & Dawson F.H. (1997) River Habitat Survey: a new system to classify rivers according to their habitat quality. *Freshwater Quality: Defining the indefinable.* Scottish Natural Heritage, Univ. of Sterling, 5-7 September 1995. (ed. P.J. Boon) 215-234pp., HMSO, London.

Raven P.J., Holmes, H.T.H., Dawson F.H., Fox P.J.A., Everard M., Fozzard, I. & Rouen K.J. (1998) River Habitat Quality The physical character of rivers and stream in the UK and Isle of Man. River Habitat Survey Report No. 2. Environment Agency, 86 + 4pp.

Raven, P.J., Boon, P.J., Dawson F.H. & Ferguson A.J.D. (1998) Towards an integrated approach to classifying and evaluating rivers in the UK. Special issue : The application of classification and assessment methods to river management in the UK Aquatic Conservation: Marine & Freshwater Ecosystems 8 (4) 383-393.

Raven, P.J., Holmes N.T.H., Dawson F.H. & Everard M. (1998) Quality assessment using River Habitat Survey data. Special issue : The application of classification and assessment methods to river management in the UK. Aquatic Conservation: Marine & Freshwater Ecosystems 8 (4) 477-499.

Raven, P.J., Holmes N.T.H., Naura M. & Dawson F.H. (2000) Using river habitat survey for environmental assessment and catchment planning in the UK. Hydrobiologia 422/423: 359-367.

Raven, P.J., Naura M., Holmes N.T.H. & Dawson F.H. (2000) Healthy river habitats fit for wildlife: deriving the physical dimension. J. CIWEM 14 (4) 235-239.

Sear D. Armitage P.D. & Dawson F.H. (1999) Groundwater dominated rivers. Hydrological Processes 13, 255-277.

Vaughan R. (1610) Most approved and long experienced water-workes. Theatrum Orbis Terrarum, (reprinted 1977), Amsterdam

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Country status report - Sweden

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Introduction

Sweden has over time used a lot of effort and money to canalise rivers and watercourses for agricultural reasons, for log driving and for flood control. Moreover, rivers are fragmented by hydropower, logging dams and by culverts (e.g for timber roads).

Nature protection of physical habitats in watercourses has not been given high priority on a national level in Sweden while large efforts have been made to improve water quality. From the 1960-ies and on point source treatment has been improved, in the 70-ies a large-scale liming program started and since the 90-ies efforts are put into reduction of agricultural leaching.

Existing local and regional restoration programs have been promoted mainly by the National Board of Fisheries or by local actors.

National strategy

A change in attitude and focus is observable on a national level. Recently a new official report on environmental quality objectives, assigned by the Swedish government, was presented (The Future Environment- The Responsibility of all, SOU 2000:52). The report states that in order to reach the goal "Sustainable lakes and watercourses", protection and restoration is needed concerning natural water-flows, biotopes and species. Different sectors have produced background documents to the report, among which the Swedish Environmental Protection Agency and the National Board of Fisheries.

Moreover, the Swedish Environmental Protection Agency is developing a strategy for protection and restoration of physical habitats in streams and lakes. Key-biotopes are identified and measures for protection or concern are presented. The strategy will be a guidance document for e.g. regional nature protection, local planning (municipalities), forestry and agricultural concern for land-use in connection to streams and lakes.

Another sign of awareness of the value of stream habitats are the statements of concern to surface waters within forestry, as well as the agro-environmental support towards buffer-zones within agriculture.

Restoration activities

There is no national program present for river restoration in Sweden, but fishery or nature conservation authorities, municipalities and others have initiated local and regional activities. The largest regional projects have been implemented in the north of Sweden. In the most northern county the fishery authority has the responsibility for restoration of rivers cleared for log driving. The same actor is planning a program for restoration of two “National rivers” (Pite älv and Vindelälven), unaffected by hydropower exploitation. Power companies are involved in local projects with the aim to mitigate effects on salmon production e.g. planned restoration of the rivers Mörrumsån and Gullspångsälven.

The National Board of Fishery (NBF) has also initiated a monitoring program of different restoration measures in rivers cleared for log driving.

Within the liming program the Swedish Environmental Protection Agency (EPA) support physical restoration activities in selected, limed streams.

Results from a research project on the impact of forestry in small watercourses (SILVA-project) have promoted development of forestry concern to watercourses.

In agricultural areas, large-scale restoration projects of in-stream physical habitats are absent. However, implementation of wetlands and establishment of buffer-strips within agriculturally dominated watersheds are fulfilled by a number of projects in the south of Sweden. The main aims of these projects are often to reduce nutrient transport to inland and coastal waters and to improve the conditions for plants and animals in the agricultural landscape.

Buffer-strips along watercourses are also promoted by the agro-environmental support system within the EU-program.

The first (?) re-meandering project in the agricultural landscape is planned in a tributary to Kävlinge river in Skåne, S Sweden. The plan is to restore a 2,5 km canalised stretch to a 3,2 km meandering stream and to increase the ground-water level by increasing the bottom level in the stream.

Co-operation within watersheds

- Wetlands in agricultural areas - projects fulfilled as co-operations between local and regional authorities and farmers in the region.
- Co-operation in the Emå river catchment area (SE Sweden) - a project to promote environmentally sustainable development in the catchment area of the river. Working groups deal with various opportunities and problems in various sectors, e.g, fish and fishing, agriculture and forestry, water- management, nature and cultural history. So far mostly discussions and paperwork.
- Research co-operation in the Ammerå river system – a project promoting research on aspects concerning fishing and forestry in a river system.

Financing

Projects have been financed by:
- Local tax money
- Local / regional fishing interests
- State investment money (directed to municipalities)
- The National Board of Fisheries
- The National Board of Forestry
- The Swedish Environmental Protection Agency
- EU-funds
- Power companies

Problems and bottlenecks

The strong focus on water quality aspects of rivers may be one explanation to the relatively low activity of habitat restoration in canalised watercourses in Sweden. Another explanation may be the amount of fresh waters available, there is no national overview of what and where restoration activities should be prioritised.

The water legislation is very strict and the rights of all waters are on private ground. In the agricultural landscape, management of watercourses is organised through local co-operations prescribed by law. The owners of the waters have the right and responsibility to manage the watercourse in accordance to what was decided 10, 50 or 150 years ago. It is very difficult to change this against the will of the landowners. Major restoration measures in watercourses may need a trial in the environmental court, a time-consuming and costly process.

The landowners have the right to carry on forestry or agriculture in close connection to the streams and may claim for compensation for all activities that hinder normal land-use, a fact that increases the costs of stream corridor restoration.

The aim to manipulate water flow is still outspoken. We need an acceptance of the natural processes of waters and a planning of the land-use in respect to that. Parallel to restoration of canalised watercourses protection of the most valuable biotopes must be conducted as well as improvement of the general consideration of surface waters in the landscape.

Country status report - Finland

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Abstract

Most of the Finnish rivers have been modified for timber floating, flood control, drainage or hydro-power. Also the northern climate, lowland, cohesive sediments, lakes and marshes have their influence on the status of Finnish rivers. Restoration of floating channels began in 1970's and since then many in-stream restoration projects both in rivers and brooks have come true. However, large-scale actions like restoration of meanders, river corridors and floodplains have been rare. By now, there has been only a couple of meander restoration projects and they have all been brooks located mostly in state-owned forests. Obstacles and bottlenecks have been caused mostly by private landownership, slow water-court process, financing of restoration projects, inadequate monitoring and risk and uncertainty in projects. Development and research of the field are active and little by little also landowners are going to change their attitudes towards restoration.

Conditions in Finland

Total length of Finnish rivers is 20 000 km, if brooks are not included. Number of lakes, bigger than 0,01 km^2, is 56 000. The average altitude of Finland is only 154 metres. Instead of mountainous brooks, the upper reaches of the rivers can be farmland or forest ditching area. Low gradients of rivers together with cohesive sediments, mostly clay, accomplish that fluvial processes in Finnish rivers are slow. The eroded material which is mostly clay or silt, causes a certain problem for water quality.

The northern climate with six months ice and snow causes problems for river restoration. Thick ice blocks floating with the spring floods created by suddenly melting snow mean flood danger but also stress for strand vegetation and instream structures.

Finland has a low population density of 17 persons per square kilometre. Although settlement is concentrated on coastal areas and river valleys, there are more natural or near-natural watercourses in Finland than e.g. in Central-Europe. However, there are not long, natural river or brook sections.

Finland is the world's most forested country. Finnish rivers and streams have been widely engineered for forestry use, in particular for timber floating in 1920-50's. The length of floating channels has been 40 000 km. Timber floating has caused severe damage especially for small rivers in northen forest areas.

Streams have been also deepened and straightened for agricultural and forest land drainage. Flood protection in the lowland areas is still of great importance especially for settlement. A specific problem in Western Finland is the width of floodplains. Due to extremely mild valley slopes flood water may easily spread far away from the channel. The situation is further worsened by the higher rate of post-glacial uplift along the flow direction towards the Gulf of Bothnia. Flood protection and land drainage improvements are nowadays still planned in Western Finland.

The 20th century has been an era of construction of hydro-power plants. Most drastic river engineering works were carried out in Northern Finland in the postwar time of 1940's, when energy demand was the most important objective. This development ended up in the situation where almost all major rivers are regulated, graded with dams and impassable for fish. The vanishing of salmon was compensated by artificial fish breeding. Fish passes are being planned into some big rivers (like Kemijoki).

River banks and bottoms have rarely been reinforced in Finland. This means that even if a river has been straightened and dredged, vegetation structure in river banks can be quite complex. The problem is that interaction between the channel and the riparian zone has decreased: diversity of river corridors and floodplains in constructed rivers are small because of missing of flood areas, meadows, side channels and old meanders.

Rehabilitation of rivers

Active river rehabilitation began in the 1970's as a consequence of the significant decline in timber floating - nowadays most of the wood is transported by land. Orders to restore floating channels have been given to Environmental Administration. At the beginning, restoration was mostly removing structures and it was aimed at fisheries, aesthetics and recreational use. Besides this, many rivers and brooks have been restored by fishery authorities.

Restoring methods have mostly been putting stones back into the rapids, construction of low weirs of stones or wood, widening the streams and creating fish habitats. The most important target has been increasing shelter for fish. There have been 223 river restoration projects in Finland by 1998. Projects included 1651 rapid restorations, together 1062 hectares. Spawning areas constructed number by now 638 and fish passes 53.

In the recent years broader ecological and conservational issues have achieved more importance. Conserving and restoring biodiversity and flow dynamics are presently notable objectives. Besides habitats for salmonids, new methods have been developed to create habitats for crayfish and lamprey (Lampetra fluviatilis).

Even if most of the rivers and brooks canalised for timber floating have been restored, there are still many rivers poor of habitats. It has been estimated that there are 500 rivers, altogether 4200 km, in the need of restoration. The problems of rivers are connected with silting, shallowing of pools and eutrophication.

Problems, obstacles and bottlenecks

Even if there have been many instream habitat improvements in Finland, measures in river corridors and floodplains have been rare. There have been a couple of meander restoration projects in Finland, but they have been brooks located mostly in state-owned forests. However, family forestry is the cornerstone of Finland's forestry. The State owns about a quarter of the country's land area, i.e. some nine million hectares, the rest being private forests.

There are not many methods available to establish greenways along rivers (river corridors), because the areas are private-owned. Earlier the only way was to buy them by State. Nowadays however, with the help of the EU's support schemes (the Supplementary Protection Scheme) it is possible to get financing for preserving the biodiversity and the agricultural landscape, for broader protection zones and for constructed wetlands, including also flood areas and restoration of canalised rivers.

Water court process in Finland has been very slow. At the moment some projects under construction were planned already in 1980's. That means that even if ideas and planning methods have changed, it is not always possible to carry out them, because measures are fixed in the court decree. All modifications must be agreed by both parties, the administration and the landowners.

It is difficult to get financing for pure restoration projects in Finland. Most of the projects are financed by the Ministry of Agriculture and Forestry, and their conditions are that besides restoration there must always be also "a real target", like flood control or drainage. Only exceptions are restoration projects of floating channels. Also Ministry of the Environment finances restoration projects, but because lakes have often more recreational value than rivers, recent financing has been mostly directed at lake restoration. It has been estimated, that there are still 1474 lakes in need of restoration.

Monitoring of projects is often inadequate. Many restoration projects are small and cheap, and financing ends when the construction work is over. This means that same mistakes can be done in various parts of the country.

As a consequence of low gradients and cohesive sediments the rate of natural recovery is notably lower in Finland when compared for example to Central Europe. That means that signs of canalisation are visible after ten or twenty years. This indicates also that the associated risk and uncertainty in rehabilitation projects may be higher.

Projects, case studies

Myllypuro-brook
A part of Myllypuro-brook in Nuuksio National Park in Southern Finland was straightened and widened in 1950's and 1960's to drain fields. The aim of the restoration project was to recreate the natural values of the flooded brook valley. About two kilometres of Myllypuro and its tributaries were rehabilitated in 1997-2000. The course of

the former meandering stream was mostly seen in the field which favoured the "historical approach" for restoration.

The biggest problem was estimating the proper dimensions a new stream cross-section should have. The soil type of this area is mainly clay, which means that natural recovery of the brook is very slow. A new, just excavated channel is without vegetation and its conveyance capacity may be even bigger than in a straight, vegetated, old channel. Some parts of the brook seem to have recovered rapidly after work, but in some parts it was obvious that natural recovery is so slow, that it is reasonable to help it. This was done by wooden deflectors to diverse flowing conditions and also to make habitats for invertebrates and fish.

Lauttaoja-brook
Lauttaoja-brook is located in North Ostrobothnia. The aim of its rehabilitation was to test different restoration methods in this canalised brook and in its catchment. The project included plugging up ditches and constructing retention areas for surface runoff. The bed of the brook was rehabilitated by stones and wooden deflectors and also in certain sections the flow was conducted into the historical meandering channel.

Development and research

"The biodiversity, ecological management and restoration methods of northern water systems (BEMARES)"
An extensive co-operative project was started in June 2000 to study the biodiversity of the northern constructed water systems and the possibility to restore them in environmentally friendly ways. The participants in this *Luomujoki* ('ecological river') -project include research and development institutes, power companies, regional environmental centres and universities.

The project consists of five subprojects, which are:
1. Development of water system typologies and classifications, which are required in EU's Water Framework Directive (WFD)
2. Development of ecological restoration methods
   - methods of environmental river engineering and restoration
   - restoration of alluvial areas and small brooks
   - ecological methods of littoral protection
   - the generation of computerised habitat models for fish and plants
   - the translocation of endangered plant species and the construction of suitable habitats for such species.
3. The maintenance of birdlife diversity in regulated rivers
4. Legal perspective to environmental restoration
5. Promotion of co-operation and familiarity with the methods of interaction

The project of Environmental River Engineering was started in 1997. The most important target is to find out how feasible ways of management practises used abroad can be applicable for Finnish flow waters changed by flood control and drainage works.

http://www.vyh.fi/hoito/luomurak/luomu.htm (at present only in Finnish)
http://www.water.hut.fi/wr/research/luomu/index_in_english.html (Helsinki University of Technology)

Country status report - Norway

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Background

Physical habitat restoration in canalised watercourses has a history of more than 20 years in Norway. But it has been mostly isolated projects and with a low volume.

In a historical perspective log driving is one of the main reasons for canalising rivers. This was large-scale business and Europe needed timber for construction. As an example, after London burned in 1666 a significant part of the timber used for reconstruction came from Norway. Later on agricultural activity on floodplains focused on rivers to achieve increased efficiency. The result was straightened rivers.
The last factor affecting river has been flood defence of urban areas. In this contexts canalising and flood protection has severely affected. Irrespectively of the purpose, the canalised rivers have reduced their rivers. The main purpose has been to increase the capacity of the river bed heterogeneity offering the aquatic organisms a different environment to live in. We find these canalised watercourses all over Norway but the highest concentration is in the southeastern parts

Habitat restoration - examples

The first example is restoration in one of our former large log driving watercourses, River Femundselva. In this river we have a master plan for restoration. One or two projects from this plan are being realised every year. The project River Femundselva by Sølenstua was finished in September 2000. Boulders were deployed in a random pattern instream.

River Flisa is also a large former log-driving watercourse. This is a more comprehensive project and stretches for about 12 km in total. A number of large, but low groynes were made of boulders covered with gravel. This to create a meandering pattern instream. In addition a set of current concentrators was built to form riffles and pools and lots of boulders were deployed instream.

Most of the projects are in medium sized rivers such as River Letjenna and River Tannåa. In this type of watercourse the restoration plan normally concentrates on making pools and riffles. Looking into the pools you will find rocks deployed in the deeper parts

Then we have the large channels in agricultural areas. These are normally systems with less energy than the log driving rivers. This means slow flow and lots of sand. There has been some activity in these systems during the last 15 years but no big successes as far as

I know. It is like working in flowing oceans of water and sand. One year the rock piles are on dry land, after the following flood the rock piles is buried in sand.

The small channels in agricultural areas are easier than the big ones. But there is a difference to log driving watercourses. Log driving has ceased whereas agriculture is still ongoing. Our restoration has to take this into account. The interests and conflicts are more obvious in rivers and streams connected with agricultural activity than in rivers in forested areas used for log driving. Thus the are more possibilities in the latter group and we have more degrees of freedom working in the log driving channels.

A general problem with restoration in the channels in agricultural areas is the fact that the new bottom of the channel is situated several meters below the surrounding terrain. Remeandering these rivers will be very extensive. Normally the ditching is based upon this low situated channel. If we raise the water level the farmland may turn into wetland.

In 1995 a major flood hit eastern Norway. The rebuilding of flood defence took place in 1995-98. This resulted in a lot of channels. We have waited this two years to let these channels stabilise, but from 2001 we will start working with restoration plans.

Many of these channels are high-energy systems. We have to see what is possible to do instream. Due to heavy bed load transport several restoration/rehabilitation techniques may be ruled out. In these cases we can look at constructing side-channels or may be the cost-benefit analysis will give the result: no measures. River Våla is an example of a high energy system with limited possibilities for restoration.

Where are we?

Deployment of rocks and building of rock and gravel groynes are the traditional methods. They are creating flow variation and meandering within the channel. In the future we want to try combinations of timber and rock/gravel in selected rivers. We also want more focus on biodiversity, not only salmon, trout and crayfish.

We have worked with criteria for evaluating this kind of projects. Its positive if:

- Natural processes are re-established
- Restoration is a part of a larger plan
- The project is near to dense populated areas
- Increased habitat diversity implies increased biodiversity
- The measures are long lasting with low maintenance

We have used the criteria to make a master plan for biotope adjustment measures for Hedmark county

In the future I think we'll focus on the use of timber, log jams, large woody debris, combinations of timber and rock/gravel in our biotope work. We also need to focus more on biodiversity not only fish and fishing. Especially in some high-energy systems - the use of side-channels is interesting. And may be - as agriculture changes we'll be allowed to think of remeandering some rivers.

Main obstacles

The water resource management is split geographical, rivers crosses borders between counties and between local governments. We also have a split between different parts of the management: Directorate for nature management, Norwegian Water Resources and Energy directorate and County governors.

Another problem is that the riverbed belongs to the landowners - and we usually have many landowners along our rivers. A problem in conducting improvements in manipulated rivers occurs when one of landowners is negative. To increase the possibility of success we can:

- form partnerships with other actors
- focus on co-operation with the Ministry for agriculture.
- use media to focus this as “Healthy-nature-projects”

Identifying functionally descriptive fish species to assess rivers integrity

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Introduction

Both ichthyologists and river managers are often concerned by the impact of the environment on the recruitment of the populations studied (Curry 1994). The presence or absence of certain fish species in a river can be used as an indictor of certain habitat characteristics (Gozlan *et al.* 1999). For example, some species are indicators of good connectivity within the river system, others indicate the presence of upwelling ground water, good vegetation cover, natural seasonality offlooding or even the type of substratum (sand, pebbles, cobbles). Some species, more sensitive to the human impact on rivers than others, can therefore act as an indicator of the relative integrity of the ecosystem (Gozlan 1998). However, the mosaics of habitat needs at both intraspecific and interspecific levels must be taken into account for physical habitat restoration.

Implication for habitat restoration

Intraspecific level: The life history perspective.
The life history traits of each species will highlight the complexity of habitat restoration needed for a particular species. The more complex the life history traits of a fish species is, the more diverse its habitat needs will be. For example, a fish species with indirect development will have many more environmental requirements (see Fig 1) than one with direct development (Balon 1990). A fish species need for a certain habitat type (e.g. sand, low velocities, plants etc) may only require a few weeks per year, however this habitat is indispensable for the effective recruitment and survival of the population. The flexibility of habitat choice for a fish species depends on the biological function associated with this choice. For example, a fish species may have less flexibility for its choice of spawning habitat than for its feeding habitats (Fig. 2). The implications for habitat restoration will therefore be different according to which phase of the species life history needs to be restored (Fig. 3) and according to the type of functional diversity of the fish community in the section of river to be restored.

Interspecific level: The functional diversity perspective
The diversity and complexity of community structures vary according to the type of river to be restored (floodplain vs upland river). Although the species biodiversity needs to be taken into account, the functional biodiversity needs to be restored. The increasing complexity from upstream to downstream reflects the increasing diversity of ecological

niche and consequently the functional diversity of the system (Guégan et al. 1998). The variation of diversity in a functional group of the food chain can have strong consequences on the production of other functional groups (Naeem & Li 1997). The monitoring of changes in the ecosystem's functional diversity will thus enable the impact of physical habitat restoration to be highlighted as composition of ecological groups are affected more than the overall number of species.

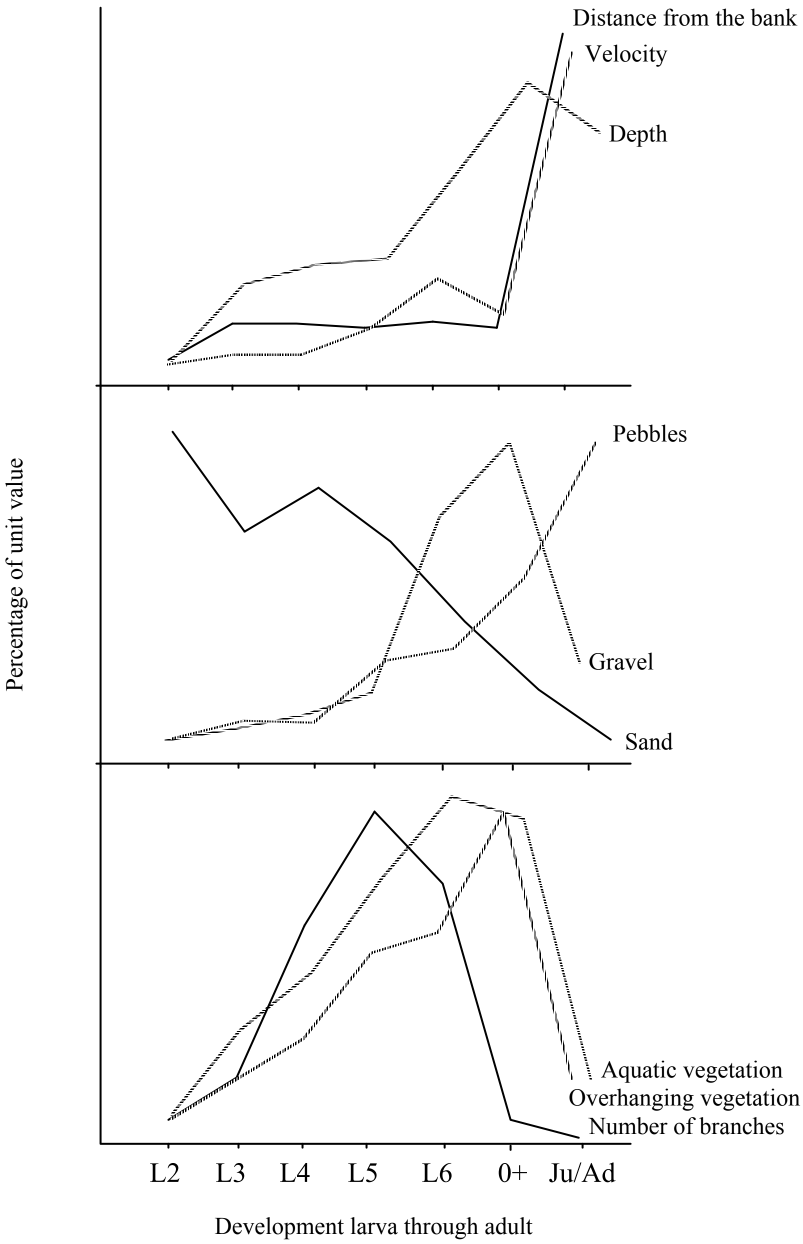

***Figure 1** Cycle of habitat for a endangered species with indirect development, Chondrostoma toxostoma. L2-L6 correspond to the 6 larval developmental steps, 0+ are the young-of-the-year and Ju/Ad correspond to the juveniles and adults.*

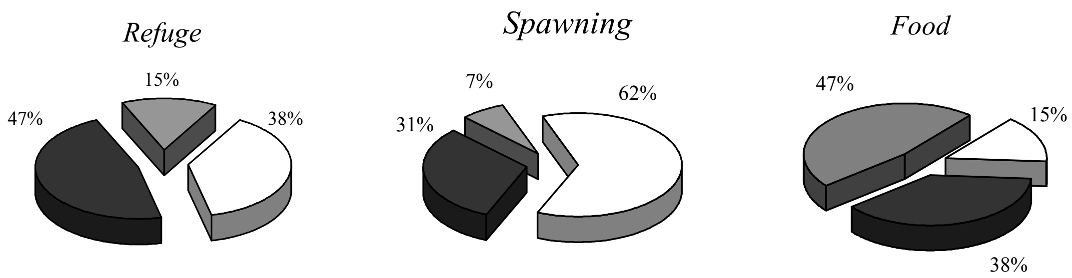

Figure 2 *Percentage of UK freshwater fish species having very strict habitat requirements (white cheese), strict habitat requirements (black cheese) and flexible habitat requirements (grey cheese).*

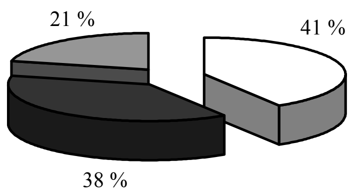

Figure 3 *Physical habitat degradation responsible for a threat to half of British fish species, loss of spawning grounds (white cheese), straightening of river (black cheese) and loss of connectivity (grey cheese). Data from Mann et al. 1984 and Leleck 1989.*

Conclusion

In England, as far as fish are concerned, habitat restoration should focus mainly on the restoration of spawning sites and could often consist of free access to suitable sites. If we wish to restore a canalised watercourse, prior to any restoration, we need to define the ecological goals that need to be achieved for this specific portion of river. There is no point in replacing one engineered structure by another one even if it makes the watercourse look nicer. This sort of structural change should only be carried out if it will help us to restore the ecological system and the life history traits of the species in place (Stearns 1993). In some places, engineering works will not significantly affect the ecosystem, in other cases a minor weir can stop species migrating to a suitable habitat. Finally, in order to estimate the quality of habitat restoration, ecological monitoring of the changes in functional groups must be done and functionally descriptive fish species should be found to assess river integrity.

References

Balon, E.K. 1990. Epigenesis of an epigeneticist: the development of some alternative concepts of the early ontogeny and evolution of fishes. Guelph Ichtyol. Rev. 1: 50 pp.

Curry, P. 1994. Obstinate nature: an ecology of individuals. Thoughts on reproduction behavior and biodiversity. Can. J. Fish. Aquat. Sci. 51: 1664-1670.

Gozlan, R.E., Mastrorillo, S., Copp, G.H. & Lek S. 1999. Predicting the structure and diversity of young of the year fish assemblages in large rivers. Freshwater Biology.41: 809-820.

Gozlan, R.E. 1998. Environmental biology and morphodynamics of the sofie *Chondrostoma toxostoma* (Cyprinidae), with emphasis on early development. PhD thesis, University of Hertfordshire, England. 220pp.

Guégan, J. F., Lek, S. & Oberdorff, T. 1998. Energy availability and habitat heterogeneity predict global riverine fish diversity. Nature. 391: 382-384.

Hatcher, C.O., Nester, R.T. & Muth, K.M. 1991. Using larval fish abundance in the St. Clair and Detroit rivers to predict year-class strength of forage fish in Lakes Huron and Erie. J. Great Lakes Res. 17: 74-84.

Lelek, A. 1987. Threatened fishes of Europe. The freshwater fishes of Europe. Wiesbaden. Aula-Verlag. 9.

Mann R. H. K., Mills, C. A. & Crisp, D. T. 1984. Geographical variation in the life-history tactics of some species of freshwater fish. pp. 170-186. *In*: R. J. Wootton (ed.), Fish reproduction: strategies and tactics, Academic Press. Symp. Fish. Soc. Br. Isles, London.

Naeem, S. &. Li, S.B 1997. Biodiversity enhances ecosystem reliability. Nature. 390: 507-509.

Stearns, S.C. 1993. The evolution of life histories. Oxford Univ. Press, Oxford, 249pp.

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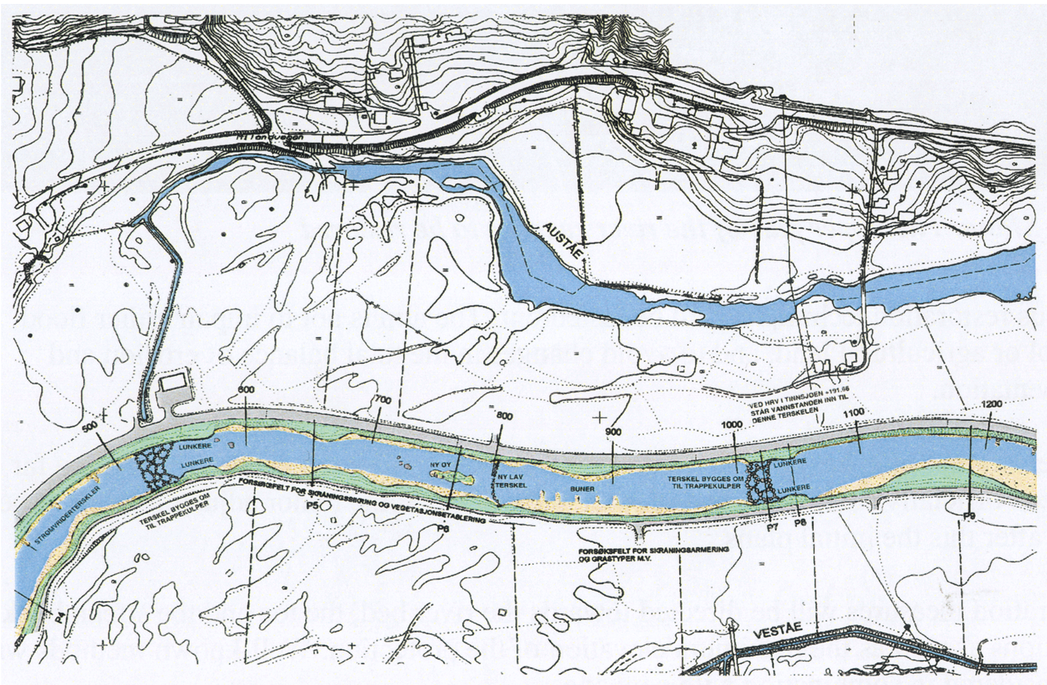
Through the major research programmes, the Weir Project and the Biotope Adjustment Programme, that were carried out by the Norwegian Water Resources and Energy Directorate (NVE) during the seventies and eighties, a large amount of new knowledge on remedial measures in regulated rivers has been obtained. At present, there is a growing international focus on river restoration techniques, some of which are different from those traditionally used in Norway. The aim of the Måna restoration project is to evaluate methods and techniques for river restoration, and to assess how these can be utilised under Norwegian conditions, particularly in rivers that have been channelised or where the banks have been extensively protected against erosion.

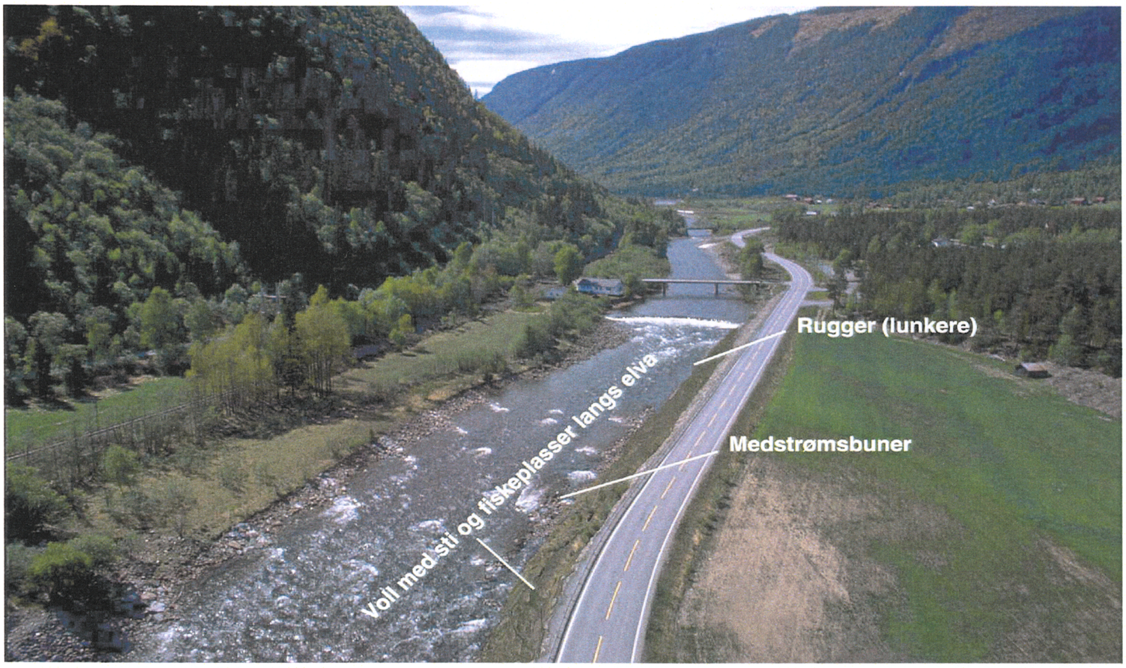
In order to gain practical experience both from planning and carrying out a set of biotechnical applications, a section of River Måna in Telemark County has been selected. This will serve as a test reach and a showcase for the applications involved. This particular river reach is about 2 km long, and embodies a stone armoured channel with a section of a main road on top of the left stream embankment. The visual impression is sterile and monotonous, and the road forms a barrier between the river and its surroundings. Natural vegetation is sparse.



River Måna. A section of the restoration plan

The original scope of the project included an option of remeandering the river or at least dismantling a section of the channel to regain a larger riparian zone. It soon turned out that vital interests opposed these ideas. Such interests comprised landowners as well as decision-makers inside authority bodies. The scope became mainly restricted to adjustments inside the channel itself, though some adjustments will be made to partly restore the two old main river beds.

Adjustments in the channel itself need to be made to the present streambank stabilisation works due to erosion and gradual lowering of the riverbed. As a result of hydropower development there is a low residual water flow. A statutory minimum flow will soon be decided on to improve water quality and conditions for aquatic organisms, and to give a more pleasing visual appearance. A major research programme on fish habitat requirements has been carried out in recent years.



River Måna. The upper part of the river reaches to be restored

Various restoration techniques will be tested out. The aim is not to impair either flood control or agricultural land, and to avoid changes in the total balance of erosion and sedimentation.

The restoration plan has been presented to important parties and experts, but has so far not been officially considered by the local authorities. Some minor adjustments have been made after this the initial plans.

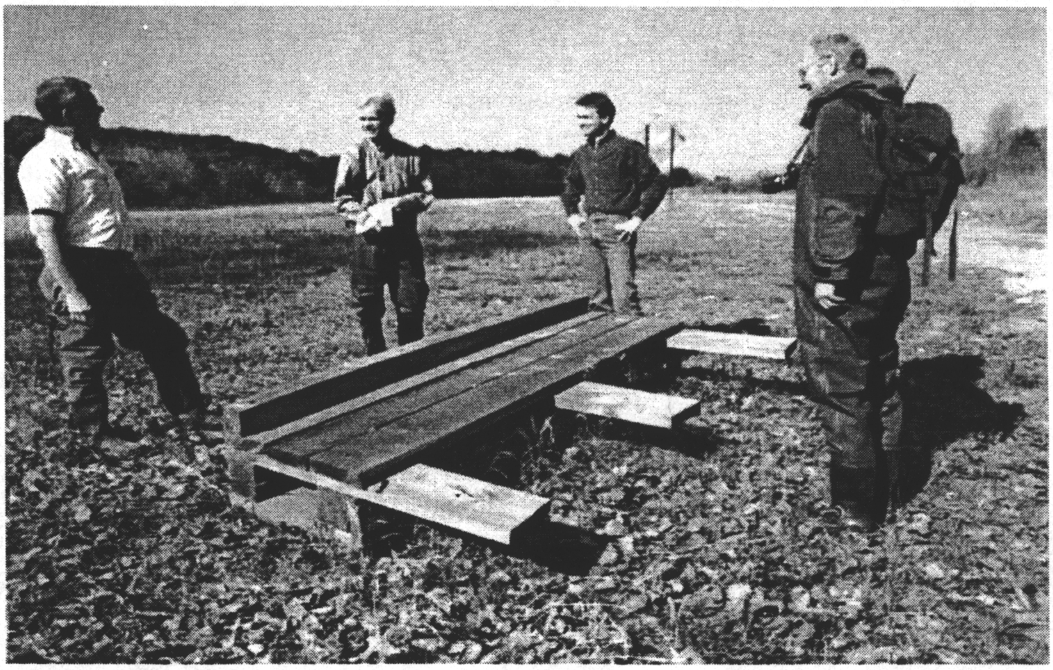
Restoration measures will be directed towards the river bed, the toe and the streambank elevations as well as the maximum elevation of the protection. Well-known methods will be considered in combination with new ones.
The river bed itself will be furnished with various types of weirs, deflectors, bendway weirs, cobble riffles, pools etc. Providing the river bed with boulder clusters, small islands

and spawning grounds are other conceivable techniques. The toe and the lower river banks are particularly susceptible to physical stress from flow impacts. The necessity for scour prevention may restrict the types and extent of the restoration techniques that will be applied. There will be a demand for robust and stable solutions in this zone. Convenient biotechnical protection measures include lunkers, fibre rolls, anchored tree logs and other kinds of streamside buffers and sediment retaining measures.

Furnishing the marginal and lower bank zones with vegetation requires use of plants with a good rooting system. This usually means herbaceous plants like reeds, rushes, sedges and other semi-aquatic plants. Use of larger species of trees and shrubs will be limited, and one will strive to select species with flexible stems that will bend under pressure from flood forces. Vegetation will be implanted by the use of fibre rolls, or by sprigging and sodding techniques when conditions are favourable.

The slopes of the stream bed elevation are steep, monotonous and sterile. By levelling off the slope, conditions for plant life will improve. However, there is also a need to bring in soil and to increase stabilisation by use of geotextiles, etc. To succeed in developing an appropriate cover of trees, shrubs and herbaceous plants a combination of miscellaneous methods is recommended. Shrub-like tree species such as willows (*Salix* sp.) with a good rooting system may be introduced in several ways like willow cuttings, posts, stakes and mats. Conventional plantings may enhance the variety. The area should then be enriched with a ground cover of moss, sedges and herbaceous plants. In recent years, the supply of grass mixtures in the Norwegian market has improved considerably with regard to the variety.

The estimated cost of the restoration project is approximately NOK 6.3 mill.



Lunker construction shown before being submerged and installed in a river bed

Numerical Modelling Tools for Predicting Physical Habitat Adjustments

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Introduction

Hydro power plants and installations highly affect the water discharge schemes in a large number of Norwegian watercourses. This again influence on the physical habitat for animals and plants in rivers and lakes. Various consequences of physical habitat changes for fish have been studied and monitored, and power companies usually have to implement efforts to mitigate negative impacts on fish. Such efforts are minimum in-stream residual discharge, artificial floods, and physical habitat changes, such as weirs, fish ladders and other types of constructions. The traditional way to assess such mitigations has been to use general biological and engineering knowledge to make qualitative plans for habitat adjustments.

The development of powerful computer programmes, and improved understanding of quantitative habitat conditions, show that it is possible to use computer models to predict physical habitat adjustments. This gives the possibility for optimised solutions, as the physical changes can be combined with computational fluid dynamics (CFD), in order to see how physical changes of the river bed affect the water flow and sediment transport. This paper will give some examples from Norwegian rivers where computer models have been used extensively as a tool for habitat adjustments.

The river Bøvra, Mid-Norway

Bøvra is a small river (middle flood: 0.41 $m^3/s\ km^2$ or 9.0 m^3/s) which runs in to a lake with various species of fish and benthos. The lower 200 metres were staightened and chanalised in1960 by the land owner in order to prevent flood and ice damages. SINTEF has been engaged by the Norwegian Water Resources and Energy Directorate (NVE) to look at possibilities to get the river back to its original water course. The aim was to improve the environmental aspects, while maintaining flood control and to be able to utilise the areas adjacent to the channelised river more intensively

Three different alternatives where studied:

1) Homogenous water flow in a wide course.
2) River stretch with current restrictions with pools downstream each restriction.
3) River stretch with biotope current deflectors, ref "Vassdragshåndboka" Handbook handeling physical problems in rivers, Norwegian Water Resources and Energy Directorate

All alternatives used the same trace.

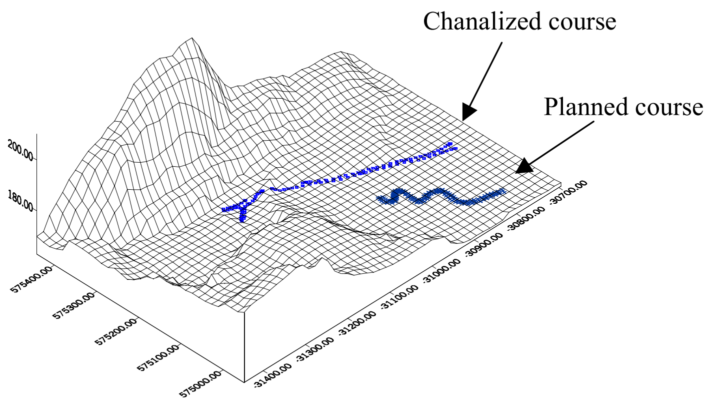

Figure 1 *Old and new trace of lower Bøvra (Alfredsen 1997)*

The next figure shows a few results from the study. On a workstation these pictures are of course shown in colours, and can be manipulated in numerous ways.

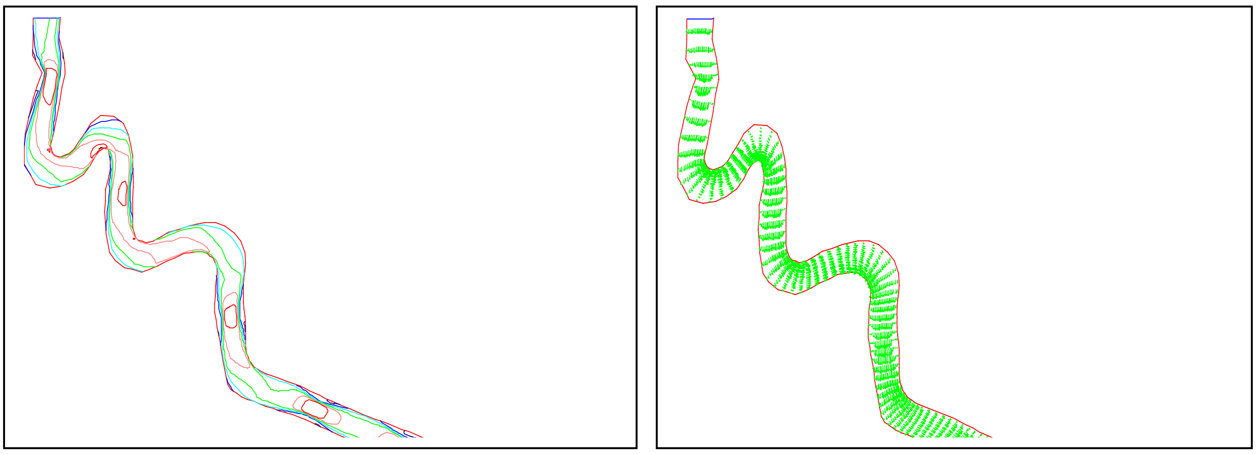

Figure 2 *The river stretch modelled as alternativ 3. The left picture shows the calculated water velocity iso lines, with highest water velocities at consentrations. The right picture showes the modelled velocity vectors in the computational grid (Alfredsen 1997)*

All three alternatives have been studied in the same way after the following procedure:

- ✓ Define new canal with help from CAD/GIS programmes
- ✓ Digitise the canal and generate grid
- ✓ Hydraulic simulation

This ends with the following optimising process:

Analysis of simulation results - > do changes - > new simulation

This process has been repeated until the conditions in the new channel has been considered to be satisfying. This project is now in the planning fase, and as a result we can not compare computed results with the real changes so far.

Mandal River in South Norway

Mandal River is a large watercourse in southern Norway, regulated for hydropower production through different reservoirs and power plants. The river was among the most important Atlantic salmon rivers in Norway until the middle of the previous century, when acid rain ruined the stock of fish. Liming of the river have now brought the salmon back to the river, but parts of the river are still severely regulated. One of the problems for salmon has been to pass artificial weirs on their way up to the spawning areas. This problem is especially connected to the fact that the weirs in general are constructed on river reaches where the discharge is reduced to a minimum in-stream flow because of power production.

Different solutions have been tried out in order to motivate the salmon to pass these stretches, among them to use artificial floods and to construct fish ladders. As a part of this work SINTEF has been engaged to suggest solutions for physical habitat adjustments for migrating adult salmon. Biological assistance has been given from NINA (Norwegian Institute for Nature Research). First of all we have looked at the weirs, and suggested that these are intersected in order to reduce the water drop. This is based on general hydraulic knowledge, and biological observations that show that salmon hesitate to climb the weirs. The areas between the weirs are characterized by large amount of shallow water with small water velocities, and the next step has been to restore these areas into acceptable migration stretches.

Around 1000 geometrical points have been measured with a total station as input for the creation of a surface model of the riverbed of a 270 metres river stretch between to weirs. This stretch has so been simulated in the numerical model SSIIM (Olsen & Stokseth 1995) to describe the water velocity distribution of the stretch before a change of the riverbed. The model has been calibrated to fit the real hydraulic situation. One idea has been to create a “ditch” in the middle of the river as a more attractive migration habitat for adult salmon, with larger depth and larger water velocities. To investigate the hydraulic conditions after a geometrical change of the riverbed, we have tried to change the surface model to represent the changed riverbed. Figure 3 shows the water depth in the model of the manipulated bed.

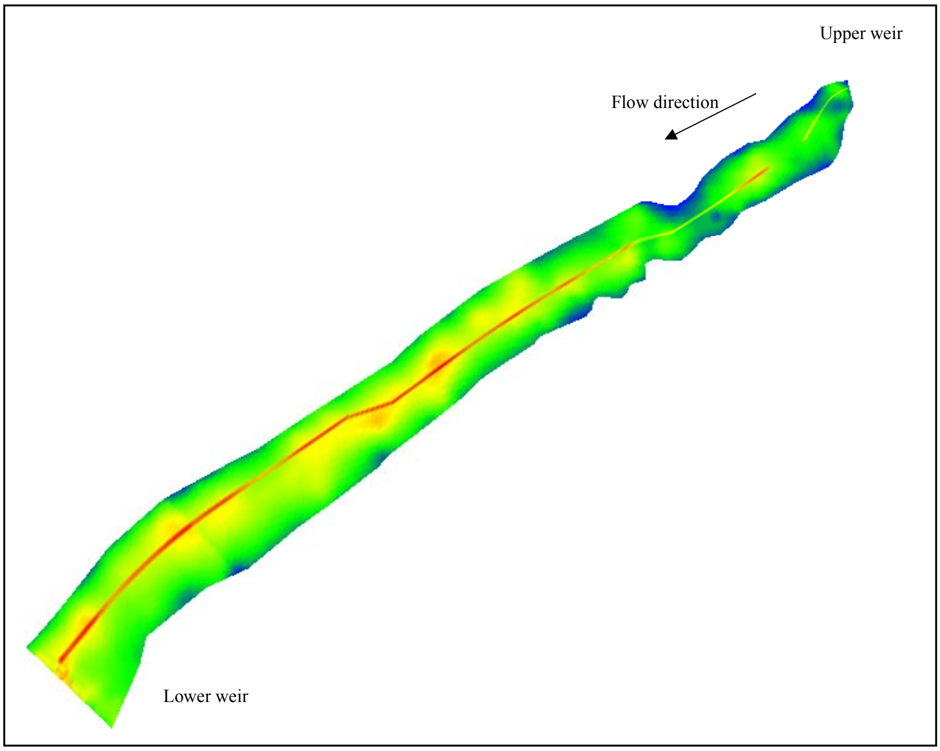

Figure 3 *Water depth of a 270 metres river reach in Mandal river. The riverbed surface model has been adjusted to create a deep midriverchannel as a means for attracting adult salmon to migrate upstream to their spawning areas*.

The hydraulic situation has been simulated after the change in geometry, and figure 4 shows the water velocity distribution before and after the adjustments. Figure 5 indicate how we have managed to increase the water velocities in the created midriverchannel in the middle of the river.

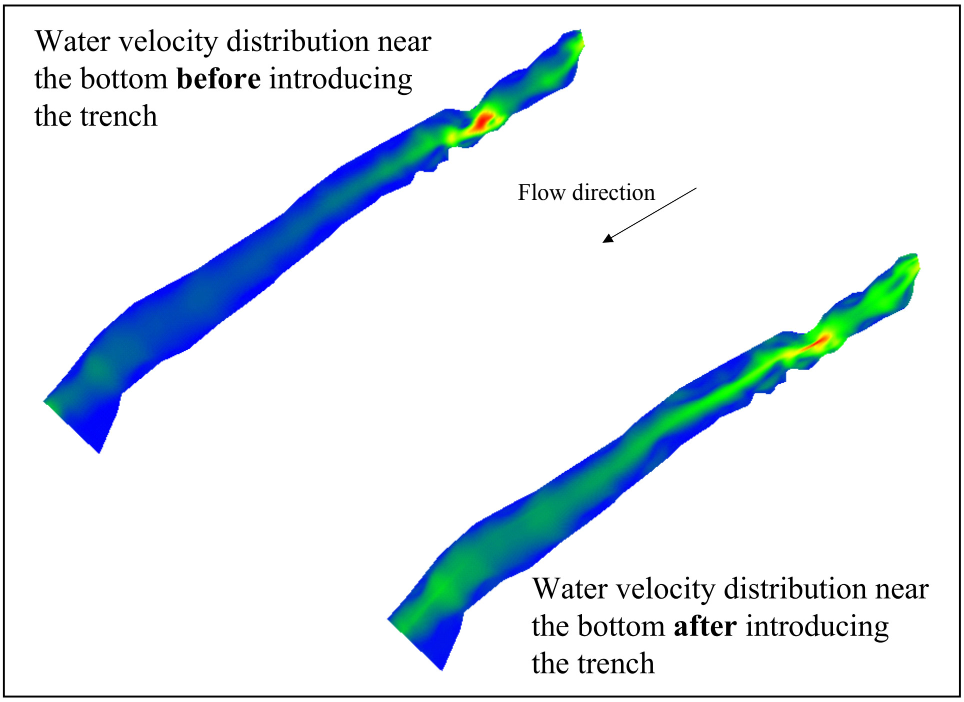

Figure 4 *Calculated water velocity distribution before and after the geometrical changes presented in figure 3. Note how water velocities have increased (light areas) in the modelled "ditch" in the middle of the river.*

The calculated values show clearly that the water velocities will increase in the midriverchannel. The next figure show that the changes is largest in the upper part of the calculated river reach, while the velocities do not increase significantly in the cross section 60-100. This project shows how numerical tools can help us to visualise how physical changes will change the hydraulic habitat for fish.

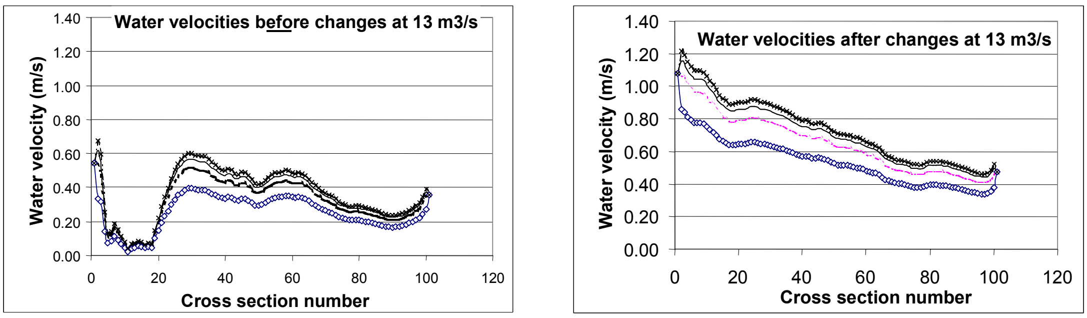

Figure 5 *Water velocities in four different depths in the middle of the midriverchannel in each of 100 cross section. Cross section 1 is the upper part, and cross section 100 is the lowermost section, near the lower weir. The lower curve is water velocities close to the bottom, and the curve with the highest values are surface velocities.*

River Dalåa in Mid Norway

Dalåa River is a tributary to River Stjørdalselva, an important river for Atlantic salmon with an annual catch of 5-15 000 kg. Investigations were carried out by the local power company, Nord-Trøndelag Energiverk (NTE), to see the consequences of utilising the water in Dalåa for power production. Because of the regulation the water discharge was severely decreased, and the natural river bed was not any longer serving as "natural" for the new water regime, as the water flow turned to be homogenous and shallow. A part of the river was chosen to monitor effects of physical habitat adjustments on fish. SINTEF and LFI Trondheim were asked to collaborate with NTE to run the project. Results from such studies are valuable for analysing changes as mitigation for loss of in-stream water. This study was done with the idea that hydraulic variability is positive for the fish habitat. As input to further analyse the chosen river stretch was mapped with a large number of geometrical points, as shown in figure 6.

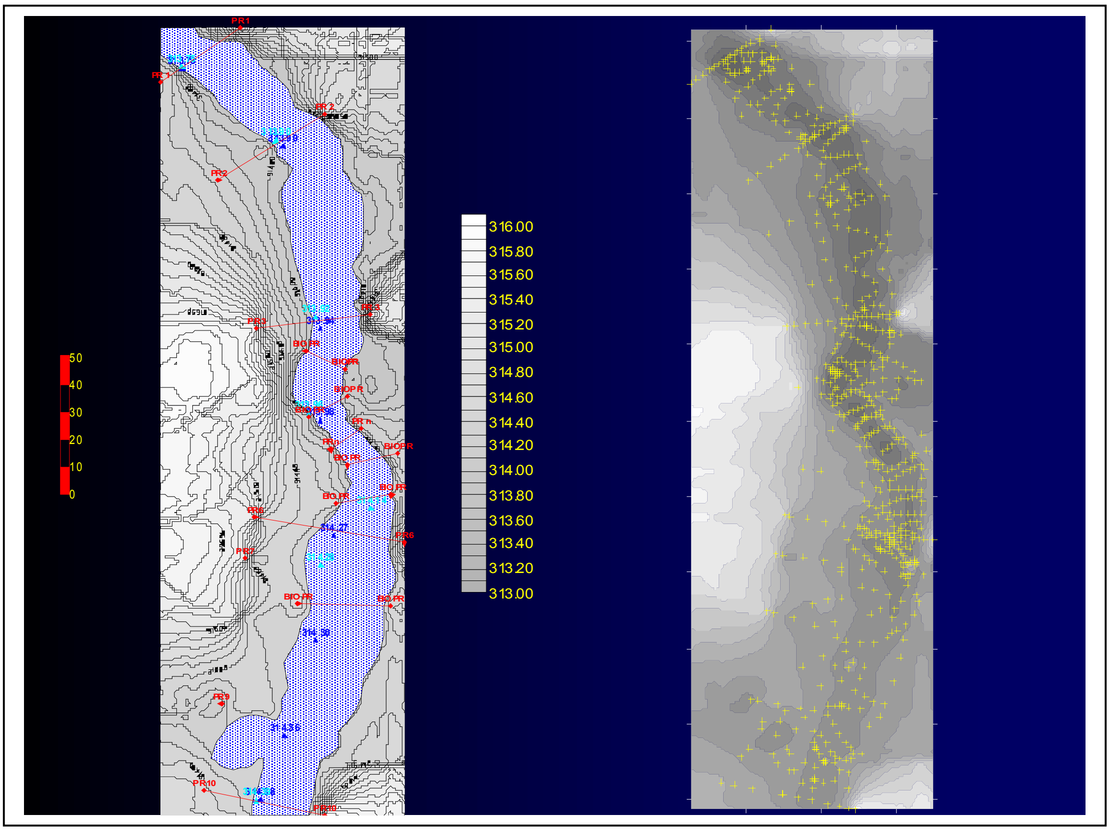

Figure 6 *The right picture shows the measured geometrical points while the left picture indicates wetted area on the study site in Dalåa. The scale in the middle shows the elevation of the area in metres above sea level (Wolf).*

The next step was to adjust the riverbed to the new water regime in order to increase the hydraulic variety by adding current deflectors and pools. This was done by using the one dimensional HEC-2 model (US Corps of Engineers 1982). Habitat assessments were done by using the numerical FBV-model (Vaskinn 1985). In this way we where able to say something about the future physical habitat.

The adjustments are shown in figure 7.

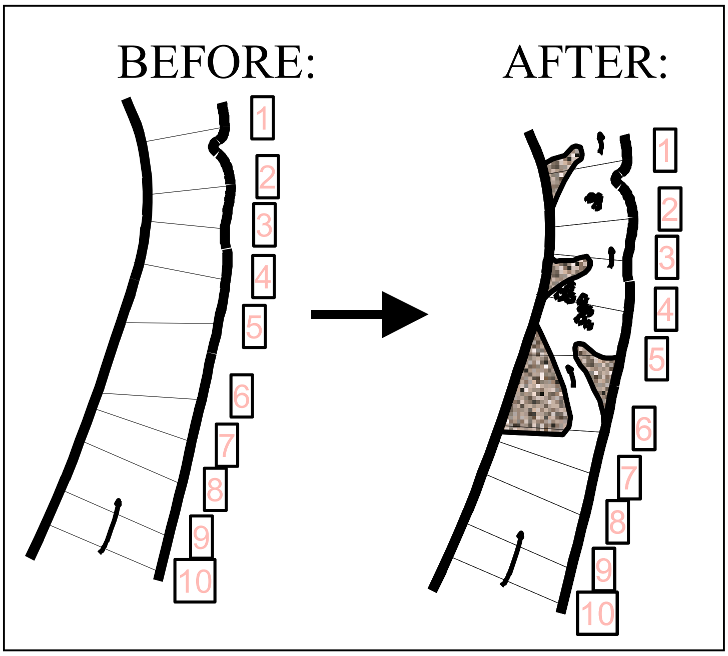

***Figure** 7 Plan view of the study site showing the river stretch in Dalåa with transects and indicated habitat adjustments (Harby).*

Later the adjustments have been numerically verified with the 3D-model SSIIM and the HABITAT-model (figure 8).

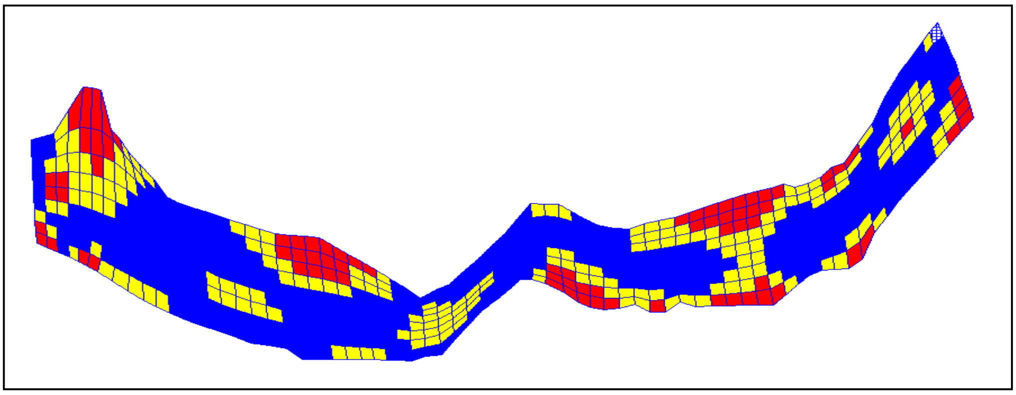

***Figure 8** Habitat map from HABITAT showing the calculated quality of the physical habitat for juvenile Atlantic salmon (Alfredsen 1997).*

The habitat adjustments done in Dalåa have been monitored since 1994 to see how juvenile atlantic salmon utilise the study site compared with the upstream reference site. Results from this work are shown in figure 9, and indicate significant higher fish densities in areas with adjusted habitat.

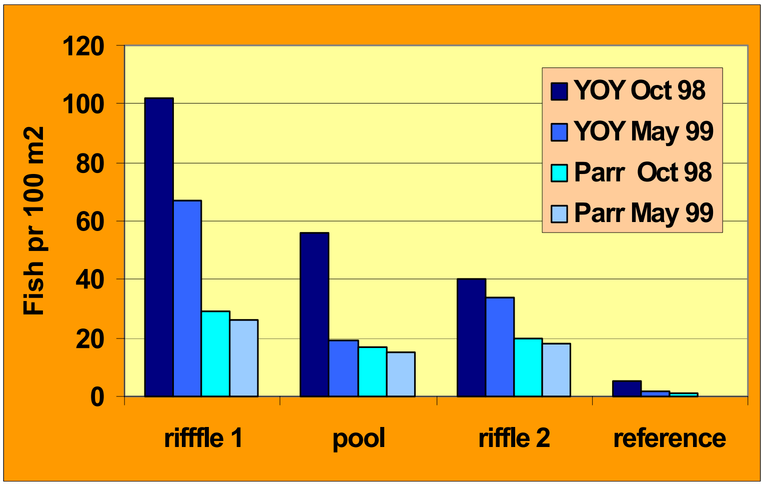

Figure 8 *Density of juvenile atlantic salmon on riffle 1 and 2 and one pool on the adjusted river reach, compared with a reference strech (Harby & Arnekleiv 1994).*

Acknowledgment

All the work presented in this paper is carried out by a group of people in SINTEF and collaborating institutions. The work in River Bøvra is performed by The SINTEF scientists Knut Alfredsen and Per Ludvig Bjerke and the project was funded by Norwegian Water Resources and Energy Directorate (NVE). Hans-Petter Fjeldstad and Atle Harby from SINTEF have done the studies in River Mandal, with funding from Mandal River Multi Purpose Planning Group. The River Dalåa project was funded by Nord Trøndelag Energiverk, and scientific work was performed by Harby and Alfredsen from SINTEF and Jo Vegard Arnekleiv and Wolf Marchand from the University in Trondheim. I would like to acknowledge my colleges in SINTEF and collaborating institutions, and especially thank the funders who make physical habitat studies possible.

References

Alfredsen, K., Marchand, W., Bakken, T.H. and Harby, A. 1997. Application and comparison of computer models for quantifying impacts of river regulation on fish habitat. Proceedings of Hydropower-97, Trondheim.

Alfredsen, K. 1997. A modelling system for estimation of impacts on fish habitat. Proceedings from the 27th Congress of International Association for Hydraulic research, p. 883-888. San Fransisco.

Bjerke, P.L. 2001. Restaurering av Bøvra. SINTEF- rapport (in prep.). Trondheim.

Halleraker, J.H., Daae,T. and Fjeldstad, H.P. 2000. Økologisk optimalisert vannføring i regulerte vassdrag. SINTEF-rapport STF22A00411, Trondheim.

Harby A. og Arnekleiv J.V. 1994. Biotope improvement analysis in the river Dalåa with the River System Simulator. Proceedings, IAHR 1st International Symposium on Habitat Hydraulics, Trondheim 18-20 August 1994: 513-520.

Harby, A., Alfredsen, K., Erlandsen, A.H., Halleraker, J.H., Heggenes, J., Killingtveit, A., Lingaas, O., Saltveit, S.J. and Vaskinn, K.A. 1999. Methods and applications of fish habitat modelling in Norway. Presented at 3rd International Symposium on Ecohydraulics, Salt Lake City, USA.

Harby, A., Alfredsen, K.T., Arnekleiv, J.V., Berger, H.M., Fjeldstad, H.P., Halleraker, J.H. and Haugland, S. 2000. Predicting fish habitat restoration and improvements by the use of new habitat-hydraulic simulation tools. Presented at EISORS, Toulouse, France.

Marchand,W. 1996. Fish Habitat Modelling. Diploma thesis, Norwegian Institute of Science and Technology.

Olsen, N. R. B. and Stokseth, S. 1995. Three-dimensional numerical modeling of water flow in a river with large bed roughness. IAHR Journal of Hydraulic Research, Diploma thesis, Vol. 33, No. 4.

US Corps of Engineers 1982. HEC-2 Water Surface Profiles. Users Manual. US Corps of Engineers. Davis, California.

Vaskinn, K.A. 1985. Fysisk Beskrivende Vassdragsmodell. NTNF`s Forskningsprogram:Miljøvirkninger av vassdragsutbygginger.

A Danish classification system and database for river restoration projects

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To obtain a useful overview of river restoration projects undertaken in order to guide future projects in the right direction it is important to continuously undertake systematic collection of project statistic and information. Therefore, the Danish Centre for River Restoration in co-operation with the Danish counties, have developed a river restoration classification system and created a database on Danish river restoration projects.

Classification system

The database is based on a classification system, which differentiates between **'Types'** and '**Methods'**. Each restoration project is divided into one of three types according to the overall objectives of the project based on the extent of restoration within the river system (Figure 1).

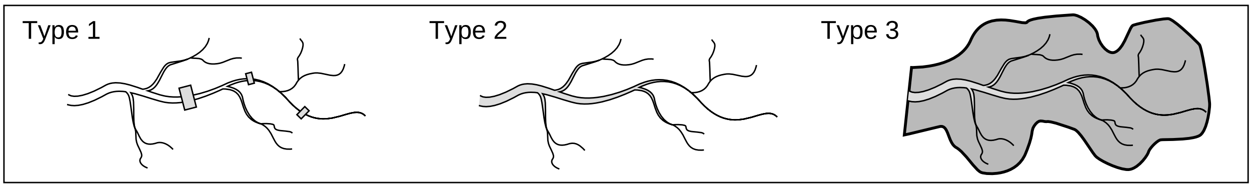

Figure 1 *Schematic definition of the three types of restoration projects describing the primary objective of the project.*

Type 1: Restoration of watercourse reaches; encompasses projects whose objective is local improvement of shorter reaches, typically resulting in *better habitats* locally, both in the river and in its nearest surroundings.

Type 2: Restoration of continuity between watercourse reaches; encompasses projects aimed at ensuring free passage along river systems, reconnecting reaches and restoring *free passage* and continuity.

Type 3: Restoration of river valleys; encompasses projects affecting both the watercourse and its whole river valley ensuring an *ecological and hydrological entity*.

Each 'type' encompasses a number of 'methods' that have been used to achieve the objective of the project.

The classification system and database is further described and explained in Hansen (1996).

Database

The database contains the following information on all projects: name of the stream and stream system, UTM – co-ordinates, restoration code according to the systematic, year of conclusion. Furthermore, the price of the project, the discharge, the catchment area and other information are included for some of the projects.

According to the database a total of 1068 river restoration projects have been carried out throughout the Danish counties up to and including 1998 (Figure 2). In addition the Danish municipalities and private organisations have carried out a substantial number of restoration projects.

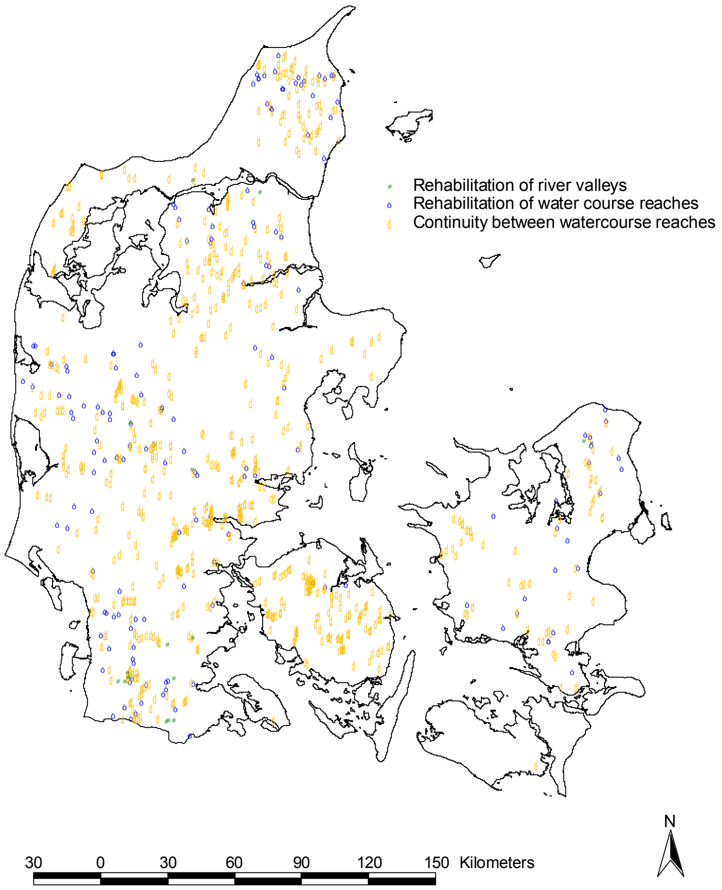

Figure 2 *Positions of restoration projects carried out by the Danish counties up to and including 1998. Please note that a number of projects are missing on the maps as no UTM co-ordinates have been given.*

Of the 1068 projects carried out, 227 locally restored watercourse (type 1), 807 restored the continuity between watercourse reaches (type 2), and 34 included restoration of the adjacent river valleys (type 3) (Figure 3).

The priority of the projects have changed over the years (Figure 3). Creating continuity between river reaches (type 2) has, always been the most important measure, but as more obstacles have been removed or otherwise overcome, the creating of better physical river reaches have gained more attention. In addition, large-scale restoration projects including the environment of the whole river valley (type 3) are often prioritised today and have grown in number. As each of these projects is of course more expensive, the total number of other river restoration projects has therefore decreased.

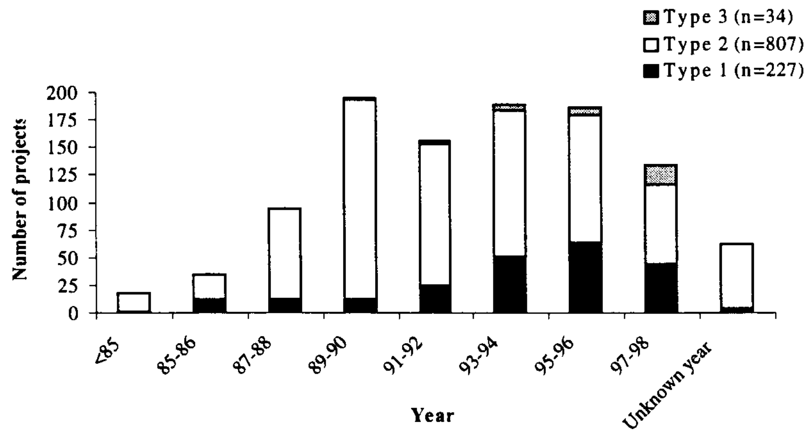

Figure 3 *Number of restoration projects carried out in the Danish counties.*

Construction of fish ladders was once the major method to create continuity in the streams (Figure 4). Today, construction of maintenance free bypass riffles are preferred and fish ladders are now only constructed as a last alternative. However, totally removing the obstacles are the most consequent and effective measure to restore the continuity and this measure has indeed been the type of restoration projects carried out most frequently.

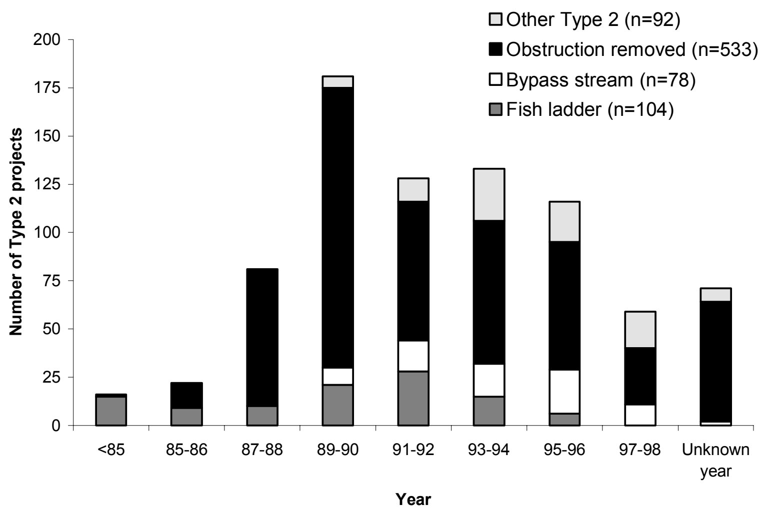

Figure 4 *Number of type 2 projects carried out in the Danish counties.*

The database also reveals some indications on the costs of the projects during the years. The total expenses on half of the 1068 projects included in the database amounts to more than 110 million DKr. (Figure 5). That again is about half of the amount the Danish State are presently using on the restoration of the River Skjern... the presently largest river restoration project in Europe including 2200 ha wetlands.

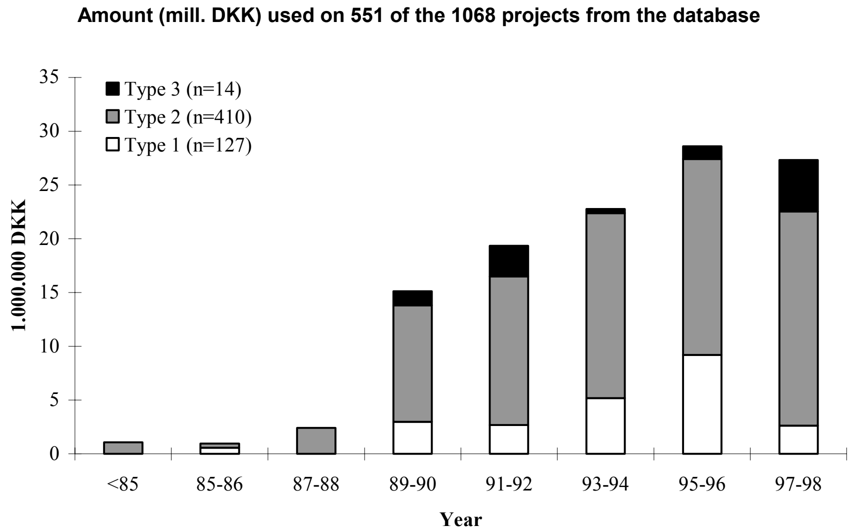

Figure 5 *Amount used on 551 of the 1068 restoration projects included in the database.*

References

Hansen, H.O. (Ed.) 1996: River restoration - Danish experience and examples. - National Environmental Research Institute, Denmark. 99 pp. (Downloadable from: www.ECRR.org >*Publications* >*Other ECRR publications*).

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River regulation results in poor physical river conditions, and poor physical conditions have a negative impact on water quality. At the same time the uniformity of channelised and deepened rivers provides poor conditions for aquatic life. One way to restore the physical variation of the rivers is by an active programme of river restoration.

Today, the EU has acknowledged restoration of rivers and their floodplains as necessary, and EU has already funded a number of river restoration projects. However, to benefit most from the knowledge and experience gained from the past on river restoration there is a need for national organisations as well as an international organisation to collect and disseminate such information.

For this purpose five institutions met in 1997 to bring about a centre for river restoration. This was amongst other things done by successfully applying the EU LIFE programme for funds to establish and run a secretariat for the centre. In 1999 the official constituting meeting of the European Centre for River Restoration (ECRR) was held in Denmark with 55 participants representing 22 European countries. At the meeting the centre was officially established, a management board was set up and the first steps towards a European network on river restoration was taken.

Objectives and goals

The key objective of the ECRR is to support the development of river restoration as an integral part of sustainable water management throughout Europe. This is done through the network consisting of participants of individual people, institutions and national centres. By facilitating the exchange of information through newsletters, the Internet, meetings and conferences the centre helps to identify and understand the benefits of river restoration.

The goals for the Centre are to:
- Exchange information on river restoration; (through newsletters, home pages, workshops, conferences etc.);
- Gain greater benefits from river restoration projects;
- Increase the cost-benefit of river restoration works;
- Obtain greater biodiversity, and better water quality and flood management;
- Improve confidence in promoting and implementing river restoration;
- Bring about changes in policy and practice on river restoration;
- Improve European access to world-wide experience.

ECRR network

The goals are to be achieved through the network of the centre. It should be stressed that all participants of the network not only have the opportunity but also the responsibility to make the centre work.

A close contact between participants, both nationally and internationally, should be established and participants are encouraged to build up national networks.

Ideally, the participants in each country should appoint one institution as national river restoration centre, which should have the prime contact to the ECRR at the national level.

The national centres are intended to establish and run a national network, and it should act on a national basis and allow all interested parties to participate. It should be noted that anybody wishing to contact the ECRR or other participating institutions directly, are encouraged to do so and need not go through the national centres, and there should be no limits as to the number of participating institutions in the national network.

It is anticipated that each national centre will set up a national network and a homepage, publish newsletters and arrange national workshops etc. The ECRR secretariat are in the process of producing a 'manual' for national ECRR centres in which the expectations from, and obligations to the ECRR will be described.

Progress

The establishment of the ECRR participant's network was initiated in 1999. By November 2000 the ECRR has 275 participants from 31 European and 11 non-European countries. National river restoration centres have been established in Denmark, Germany, Italy, the Netherlands, Romania, Russia, Spain and UK.

An Internet homepage has been established with the URL-address www.ECRR.org and a number of newsletters have been issued (available from the home-page).

A database on ECRR participants has been established.

A prototype on a database on river restoration projects has been established on Danish projects. At present more than 1000 Danish projects have been included in the database.

The centre has hosted two international conferences. The first was held in Silkeborg, Denmark in 1996 with focus on the ecological effects of various restoration measures in small lowland rivers, especially physical modification of watercourses and the consequent effects this has on habitats and biota. Papers presented at the conference have been issued in Hansen *et al.* 1998; Hansen & Madsen 1997 and Hansen & Madsen 1998.

The second international conference hosted by the ECRR was held in Wageningen, the Netherlands in May 2000. The conference focused on the practical approaches in river restoration, and provided information on many aspects of river restoration, and contributed to the further development of the ECRR pan-European network. More than 100 participants from 24 European countries, USA, China, Turkmenistan and Australia attended the conference. Proceedings from the conference are expected during spring 2001.

Funding

The operational development of the ECRR requires external funding. As mentioned, EU's LIFE-programme granted funds for the running of the ECRR secretariat until 2002. The management board is presently investigating future possibilities for funding of the secretariat and the work of the ECRR – most likely through EU. One way will be to seek support through the COST programme, which funds expenses on travel and subsistence.

Participants of the network should seek national funding for their own internal activities as the ECRR cannot provide grants or fund them.

Future

During the remaining period of LIFE support, the centre will primarily work on the further expansion of the network and establishment of national centres in as many European countries as possible.

Subsequent the termination of the LIFE funding period in 2002 it is anticipated that funding will be found elsewhere. The short-term plans of the ECRR after the LIFE period are to:

- Accelerate actions and disseminate information;
- Improve value and awareness of demonstration projects - Technical, environmental, economic, social etc.;
- Extent databases on people, institutions, projects;
- Promote:
  - Research and monitoring;
  - Funding opportunities;
  - Project partnerships;
  - Assessment of needs;
  - Training.

References

Hansen, H.O., Boon, P.J., Madsen, B.L. & Iversen, T.M. (Eds.) 1998: River Restoration. The Physical Dimension. A Series of Papers Presented at the International Conference River Restoration '96, organised by the European Centre for River Restoration, Silkeborg, Denmark. - Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1), 264 pp.

Hansen, H.O. & Madsen, B.L. (Eds.) 1997: River Restoration '96 - Plenary Lectures. International Conference arranged by the European Centre for River Restoration. - National Environmental Research Institute, Denmark. 151 pp. (Downloadable from: http://www.dmu.dk/1_viden/2_Publikationer/3_Ovrige/rapporter/87-7772-317-1.pdf).

Hansen, H.O. & Madsen, B.L. (Eds.) 1998: River Restoration ’96 - Session lectures proceedings. International Conference arranged by the European Centre for River Restoration. - National Environmental Research Institute, Denmark. 294 pp. (Downloadable from: http://www.dmu.dk/1_viden/2_Publikationer/3_Ovrige/rapporter/87-7772-374-0.pdf).

Conclusions and recommendations from the groupwork

The workshop participants were divided into four discussion groups with presentation back to plenary session. Discussion guidelines were provided. Key issues for discussion were: 1) Habitat assessment procedures, 2) Restoration design, 3) Significance of the riparian zone, 4) Project organisation, finance and stakeholder involvement and 5) New EU-proposals.

Below is a summary of the main conclusions and recommendations.

Habitat assessment procedures

Purpose and aims

- Habitat assessment important for:
  - definition of pristine conditions and setting habitat goals for restoration
  - prioritisation of sites for restoration
  - pre- and post-monitoring programmes (reference and control sites)
  - EU's Water Framework Directive – countries are obliged to quantify water resources.
- Habitat assessments are useful but should not be a constraint to practical restoration.

Methodology

- Great variation between countries in classification methods.
- The need for a standardised system and different assessment levels depending on purpose, should be further discussed.
- Important to consider impact of seasonality.

Habitat goals

- Habitat goals for restoration vary greatly and may include:
  - improved conditions for endangered or ”important” species like salmon, crayfish, otter, etc.
  - incresead biodiversity in general
  - aestethical values
  - water quality improvement
  - pre-encroachment conditions.

Restoration design

Principle

- Should be based on hydrology, hydraulic flow and geomorphology with a major role also for ecologists. Need for better collaboration/communication between different professions. Holistic approach.
- Whatever the goals are: design for equilibrium conditions. Sustainability, i.e. no maintenance should be needed. Have a long term aspect.
- Minimize multiple-use conflicts. For instance flooding capacity should not be impaired.

Methodology

- Measures depends on the goals for restoration and areas available. Clear distinction between: a) areas where the stream can be unconfined and b) areas where infrastructure must be protected.
- There is a great potential for computer modelling.
- Post-installation monitoring of effects should normally be performed. Adjustments may be necessary.
- Reporting of failures. Many lessons can be learnt from failures provided they are reported.
- Restocking of species may be necessary in order to speed up recovery.

Significance of the riparian zone

Bank vegetation

- Essential for bank stabilistaiton.
- Increases aquatic and terrestrial biodiversity.
- Shading influences temperature and macrophyte growth.
- Should be replanted with local species/ecotypes.

Buffer zone

- Width not prescriptive.
- Play a role (although debated) in control of nutrient fluxes.
- Important living place and migration corridors,”green veins”, for vertebrates/invertebrates.
- Valuable as a landscape element.
- May influence local climate (eg create frost pockets).
- May need management.
- Need for public education regarding conservation/amenity value.

Project organisation, finance and stakeholders

Opportunism/Finance

- Ecology alone is normally not enough for ”selling” a restoration project.
- Restoration measures can be incorporated in projects on flood control, fisheries, erosion combat, and highway and other infrastructure construction.
- Important to link research money to practical projects, i.e. there must be good contact between researchers and managers responsible for the practical projects.
- Land-owner benefits and goodwill often a prerequisite for finance and accomplishment of the project.
- In some countries: set-aside schemes and countryside stewardship promotes restoration projects.

Legislation
- Varies markedly across Europe.
- International obligations (eg Water Framework Directive).
- Need for ecological restoration to be better reflected in the legislation.

Project organisation/composition/information
- Should be an increased international as well as national collaboration. Especially important is collaboration between agriculture and environmental interests.
- Project planning should include scientists, planners, socio-economists, land-owners, and other watercourse stakeholders.
- Consultation and dissemination of results to all relevant groups at all stages.
- Dissemination of results to the public and politicians.
- Good information on positive results, especially on species that can be harvested, will positively influence the attitude towards restoration projects.

New EU-proposals

The following subjects were identified as possible EU-proposals.
1. River response to climate change.
2. Effect of bank vegetation on lateral erosion processes and natural channel morphology.
3. Monitoring techniques and the role of indicator species.
4. Restoration of spawning sites for anadromous brown trout (*Salmo trutta*) in Northern Europe.
5. Guidelines for good (best) practise in river restoration.
6. Common Assessment Program (CAP) for river restoration projects.

The subjects have been further outlined by appointed persons. A memo dated January 8th 2001, containing the proposal outlines and suggestions on the proposal progression, has been e-mailed all participants and CONNECT-institutes/contact persons.

CONNECT Workshop, Lillehammer, Norway, November 6-8, 2000

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