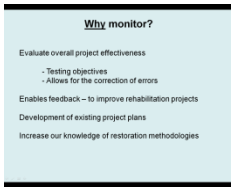
Presentation 1 – Angelopoulos, Natalie

Although the need for monitoring has been acknowledged in recent years the majority of river rehabilitation schemes are still poorly monitored; this reduces the opportunity to evaluate restoration projects making it impossible to identify whether projects are achieving their objectives and therefore, constrains future progression of river rehabilitation practice.

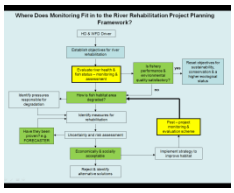
Monitoring outputs from restoration and rehabilitation projects should intend to help practitioners by presenting experiences about success or failure of the application of different measures.



Monitoring is imperative to all river rehabilitation project planning frameworks as it facilitates the evaluation of overall project effectiveness by testing objectives against results.

The application of monitoring and evaluation should be promoted within river rehabilitation project planning as it assists the EU Water Framework Directive's aim to ensure rivers reach good ecological status or potential by the year 2015.

Effective monitoring should follow a strategic listing of questions, such as what? when? and how? should we monitor, to identify the appropriate monitoring method suitable for each individual restoration projects.



An adaptive management framework for river restoration project planning involves a sequence of steps and feedback loops designed to cover the planning, action, monitoring and evaluation components of a project framework. The framework should be transferable to individual rehabilitation projects by drawing on commonalities in objectives and techniques

Objectives should work towards benefiting fish communities whilst enhancing our understanding of how communities respond to changes in habitat over time, taking in to account the needs of individual fish species and size classes, to recognise the 'missing' habitat and identify the habitat enhancement technique needed.

Monitoring is a vital stage in adaptive management as it influences the decisions made to continue, modify or discontinue management actions (Bash & Ryan 2002)

Pre-monitoring and assessment should be the next step to evaluate current river health and fish status to decide if the fishery performance and environmental quality of the river are satisfactory.

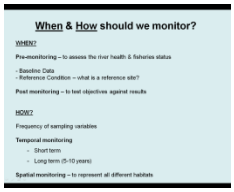
Post-project monitoring after implementation is essential to assess the success of restoration works. It is difficult to have consistent measures for project success, but the use of objectives in the project framework allows managers to know when they have reached their goal.

The feedback loop within an adaptive management framework provides managers with the ability to overcome uncertainties through the collection of monitoring data.

The majority of restoration schemes result in habitat manipulation, for this reason it is imperative to monitor habitat change but also fish populations as response variables because they represent one of the best opportunities to test hypotheses within a river rehabilitation project (Roni et al. 2005). It is important to monitor entire community structures, but at a single species level fisheries assessment should be completed through the study of fish population dynamics, density, recruitment, mortality, age and growth determination. Measuring population response is perhaps the most direct way to understand outcomes of restoration (White et al. 1999).

Indicator species can be used as the main interest of study and can be selected in two ways: firstly by using a sensitive species that will be the first to show a response to restoration works, or secondly, by selecting the fish species that had poor status in the pre-monitoring assessment. This species can be used as an indicator to assess if restoration work has benefited the fisheries status.

Basic habitat variables such as reach dimensions, substrate, flow and percentage cover must be collected regularly to assess the changes that have occurred to the morphology of the river through restoration actions. A more detailed collection of habitat variables will enable the use of habitat models such as PHABSIM and MesoHABSIM within the analysis of river rehabilitation projects.

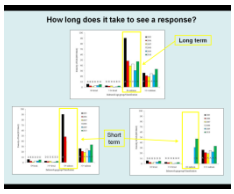


When?
Both pre and post monitoring is essential within a river rehabilitation project planning framework. Pre-monitoring includes the collection of baseline data to assess the status of river health and fisheries health.

Post-monitoring is an essential phase that is needed to assess the success of restoration works, and long-term, post-monitoring will provide a more valuable data source for evaluation purposes (Kondolf & Micheli 1995).

How?
Both spatial and temporal monitoring is required when monitoring restoration schemes.

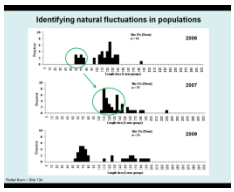
Successful monitoring requires multiple reference sites and frequent sampling of variables to overcome patch dynamics and to identify trends, thus improving understanding of the natural variability that occurs within a river ecosystem.



The data presented in this slide is taken from the fisheries assessment of the introduction of a hydropower scheme. The scheme became operational in May 2010 – monitoring was in September of each year including 2010 – the results are within the influence of the hydropower scheme so in 2010 the reach survey would have had water abstracted. The data shows the high variability in salmonid populations before the scheme was operational and suggests even though the scheme was operational in 2010, there was no obvious impact BUT this is just one year follow up of monitoring and it needs monitoring for a number of years after.

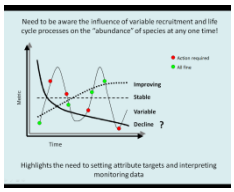
This slide also highlights the importance of not only long-term monitoring, but long-term pre-monitoring.

The longer the period of monitoring the more valuable the data source.

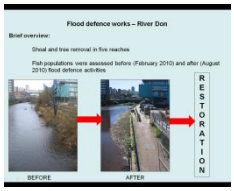


The data presented across the next 2 slides are from the fisheries assessment of a different hydropower introduction than the one previously mentioned. The scheme was put in place 2008 and was operational by 2009, monitoring was in September of each year, with the exception of 2008.

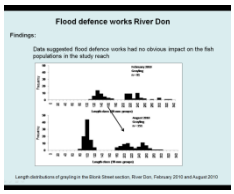
Site 13c is a control site (this slide), above the hydropower scheme so would not have been directly influenced by water abstraction down stream. This can be used as a comparison to site 13d (next slide) which is a site below the hydropower scheme. By comparing the length frequency histograms it is possible to identify trends and natural fluctuations with in populations (highlighted by coloured circles). Both sites show similar growth and recruitment within the brown trout stocks and also show similar variability of brown trout recruitment. Brown trout recruitment in 2006 at both sites is good and growth is also good, shown by the frequency in 2007. However, missing data from 2008 is like missing an important piece of the puzzle. It means that the poor number of 1+ trout found in 2009 surveys cannot be explained as poor recruitment without the collection of fisheries data in 2008.



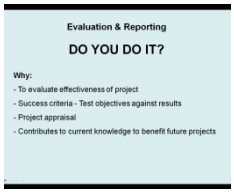
Successful monitoring requires multiple reference sites and frequent sampling of variables to overcome patch dynamics and to identify trends, thus improving understanding of the natural variability that occurs within a river ecosystem. Monitoring will account for this natural variability in fish population dynamics as illustrated in this figure.



The main aims of this project were to carry out fish population surveys prior to and following flood defence works where shoal and tree removal took place in five reaches of the River Don between Nursery Street and Meadowhall Way road bridge. The analysis and interpretation of the data from the surveys aimed to inform on the status of fish populations in these. It must be stressed that the photographs are taken part way through the project and restoration works have been incorporated into the project plans and are currently being undertaken.



Overall, the greater number of fish and similar or higher species diversity in the Nursery Street, Blonk Street and Effingham sections in August 2010 compared to February 2010 suggest the flood defence works have had no obvious impact on the fish populations in the study reaches. However, long term monitoring is important and it is recommended that monitoring continues in all sections following flood defence works to identify any changes in fish populations in response to habitat modifications.



Incorporating monitoring and evaluation into a well defined project framework will help overcome the question of 'how much is enough?' Evaluating the effectiveness of restoration projects by testing objectives against outcomes should enable success to be measured. Reporting results for dissemination is an important step and will enable us to learn from success or failures, and thus improve river restoration and management tools.

One possible mechanism for reporting the outcomes of rehabilitation actions is uploading the reports onto the FORECASTER (Facilitating the Application of Output from Research and Case Studies on Ecological Responses to Hydromorphological Degradation and Rehabilitation) website that is a knowledge and information system designed as a reference tool for those seeking to formulate a suitable rehabilitation programme to improve ecological status of degraded river.

REFORM is thus a partnership between hydrologists, geomorphologists and hydraulicians, ecologists, and social and economic scientists, who together participate in each work package.

WISER (lead UDE) and FORECASTER (lead UHULL) are the first two European projects where restoration experiences are compiled and evaluated from multiple European countries, both REFORM and RESTORE (lead EA) will significantly increase the exchange of experiences across EUROPE.

ASSESSING THE IMPACT OF RIVER REHABILITATION SCHEMES – A MISSING DIMENSION OR UNNECESSARY PROCEDURE?

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Abstract
Developing environmentally acceptable methods for river rehabilitation is now a fundamental requirement to meet objectives under the EU Water Framework Directive (WFD) and Habitats Directive. Although literature on restoration ecology is extensive, it remains fragmented and rarely is the success, or other outcomes of projects assessed to determine the efficacy of the projects to meet these objectives. One of the reasons for this failure is lack of clearly defined end-points against which to measure success. This lack of understanding is a serious impediment for managers who have to make decisions on the most cost-effective restoration measures to address hydrogeomorphological degradation in different river types. The objective of this contribution is to establish a procedure to assess the efficacy of rehabilitation schemes and enable managers to choose the most cost effective measures for various scenarios.

The paper provides an integrated approach to project planning that deals with both the variability of river rehabilitation activities and complexity of river ecosystems. Restoration projects should not be selected at random and therefore, it is essential that any future rehabilitation scheme must follow a framework that firstly prioritises projects and secondly identifies multiple objectives. These objectives should work towards benefiting fish communities, taking in to account the needs of individual fish species and size classes, to recognise the 'missing' habitat and identify the habitat enhancement action needed. Measuring project success can be challenging but nevertheless it is imperative to include pre-assessment, short-term and long-term monitoring in to the framework. The challenges for future monitoring are examined with ideas to overcome the difficulties of comparing rehabilitation effectiveness across rivers.

Keywords: adaptive management, evaluation, flood defence, monitoring, restoration, recruitment, Water Framework Directive.

1. Introduction

River rehabilitation should seek to improve the ecological integrity of rivers (Angermeier 1997) to provide the necessary ecosystem goods and services (Baron *et al*. 2002; Richter & Postel 2003) through the application of adaptive management in conjunction with a comprehensive project framework. Rehabilitation methods provide a mechanism that should lead to long-term sustainable development where remedial action should focus on the underlying cause(s), with a primary objective of restoring the system to an acceptable state, ultimately leading to a self-sustaining resource (Cowx 1994). Monitoring is imperative to all river rehabilitation project planning frameworks as it facilitates the evaluation of overall project effectiveness by testing objectives against results. It is a vital stage in adaptive management as it influences the decisions made to continue, modify or discontinue management actions (Bash & Ryan 2002). Although the need for monitoring has been acknowledged in recent years the majority of river rehabilitation schemes are still poorly monitored; this reduces the opportunity to evaluate restoration projects making it impossible to identify whether projects are achieving their objectives and therefore, constrains future progression of river rehabilitation practice. The application of monitoring and evaluation should be promoted within river rehabilitation project planning as it assists the EU Water Framework Directive's aim to ensure rivers reach good ecological status or potential by the year 2015.

There are a number of challenges and uncertainties to account for when attempting to understand the intricacy of how ecosystem networks respond to river rehabilitation. Challenges and uncertainties can be seen as a hindrance but can be overcome by increasing the efficiency of monitoring and evaluation through an adaptive management framework. Effective monitoring should follow a strategic listing of questions, such as what? when? and how? should we monitor, to identify the appropriate monitoring method suitable for each individual restoration projects.

2. Adaptive management for river restoration project planning

An adaptive management framework for river restoration project planning (Figure 1) involves a sequence of steps and feedback loops designed to cover the planning, action, monitoring and evaluation components of a project framework. The framework should be transferable to individual rehabilitation projects by drawing on commonalities in objectives and techniques. An adaptive management framework (Figure 1) allows each of the stages of project management to be easily visualised and highlights where monitoring fits in to the framework. Establishing objectives that relate to the functional aspect of the ecosystem is crucial (Dewberry 1996 *cited in* Downs & Kondolf 2002) for successful river rehabilitation and should be the first step within the framework. Objectives should work towards benefiting fish communities whilst enhancing our understanding of how communities respond to changes in habitat over time, taking in to account the needs of individual fish species and size classes, to recognise the 'missing' habitat and identify the habitat enhancement technique needed. Goals and objectives of individual restoration projects can vary because the particular ecological process of concern can differ between projects (Wohl *et al*. 2005). Selecting objectives allows science to guide rehabilitation management and enables evaluation of the overall project effectiveness by having objectives to test against outcomes. Pre-monitoring and assessment should be the next step to evaluate current river health and fish status to decide if the fishery performance and environmental quality of the river are satisfactory. If so then objectives need to be re-set, away from rehabilitation measures and towards sustainability and conservation for rivers to reach a higher ecological status. However, if the fishery performance and environmental quality of the river is unsatisfactory, the question of how the area is degraded needs to be evaluated by identifying pressures responsible and their impacts. Once these pressures have been identified, suitable measures for rehabilitation can be selected and evaluated through a risk and uncertainty assessment. Many agencies now insist on such Environmental Impact Assessments before permission to proceed or grant funding (Cowx 1994). If proven to be economically and socially acceptable,

rehabilitation measures can then be implemented. Post-project monitoring after implementation is essential to assess the success of restoration works. It is difficult to have consistent measures for project success, but the use of objectives in the project framework allows managers to know when they have reached their goal. The feedback loop within an adaptive management framework provides managers with the ability to overcome uncertainties through the collection of monitoring data, to facilitate improvements by the correction of errors through adjusted developments (Bash & Ryan 2002; Wohl *et al*. 2005) and to support management in the decision to curtail rehabilitation practices once objectives have been reached.

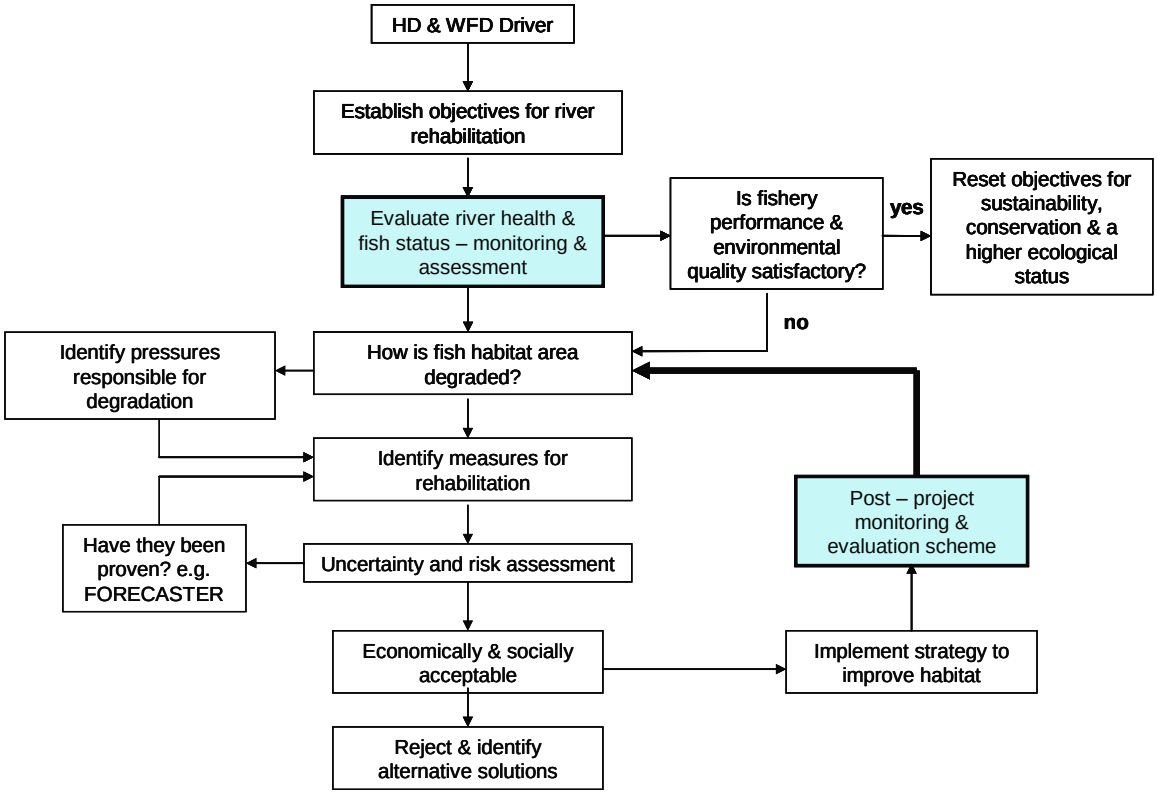

Fig 1. An adaptive management framework flow diagram for river rehabilitation project planning

3. Importance of monitoring & evaluation within a project framework

3.1 Fish monitoring and habitat assessment methods

The question of 'what' to monitor is challenging yet still imperative and ought to be used to standardise monitoring methods and make them transferable across rivers. The majority of restoration schemes result in habitat manipulation, for this reason it is imperative to monitor habitat change but also fish populations as response variables because they represent one of the best opportunities to test hypotheses within a river rehabilitation project (Roni *et al*. 2005). It is important to monitor entire community structures, but at a single species level fisheries assessment should be completed through the study of fish population dynamics, density, recruitment, mortality, age and growth determination. Measuring population response is perhaps the most direct way to understand outcomes of restoration (White *et al*. 1999). Indicator species can be used as the main interest of study and can be selected in two ways: firstly by using a sensitive species that will be the first to show a response to restoration works, or secondly, by selecting the fish species that had poor status in the pre-monitoring assessment. This species can be used as an indicator to assess if restoration

work has benefited the fisheries status. When studying species response to habitat modification it is vital that all life stages are considered. Invertebrates are also an ideal indicator species to monitor change within restoration projects.

Basic habitat variables such as reach dimensions, substrate, flow and percentage cover must be collected regularly to assess the changes that have occurred to the morphology of the river through restoration actions. A more detailed collection of habitat variables will enable the use of habitat models such as PHABSIM and MesoHABSIM within the analysis of river rehabilitation projects. The use of mathematical models within an adaptive management framework for river restoration allows for uncertainties to be identified and enables management decisions to be altered as new information is collected (Wieringa & Morton 1996 *cited in* Downs & Kondolf 2002).

3.2. Importance of long-term monitoring

Few ecosystems have been studied comprehensively in terms of their abiotic parameters, species composition, community structure, functional attributes, and responses to natural disturbance (Clewell & Rigour 1997). Recognising when monitoring should take place is vital to increase the accuracy and understanding of the success level of each restoration project. Both pre and post monitoring is essential within a river rehabilitation project planning framework. Pre-monitoring includes the collection of baseline data to assess the status of river health and fisheries health, and assist in the identification of river rehabilitation objectives (Kondolf & Downs 1996). Baseline data (or pre-monitoring data) can be used within river rehabilitation assessment to compare the habitat and fishery statues of the river between pre and post monitoring of the restoration works. Evaluating multiple reference sites (control sites) will allow for the success level of restoration projects to be measured by taking in to account patch dynamics (Clegwell & Rigour 1997) to give a comprehensive review of the biota local to that river. Post-monitoring is an essential phase that is needed to assess the success of restoration works, and long-term, post-monitoring will provide a more valuable data source for evaluation purposes (Kondolf & Micheli 1995).

3.3. Spatial and temporal monitoring

Both spatial and temporal monitoring is required when monitoring restoration schemes. Ecosystems exhibit natural fluctuations from patch dynamics that differs between sites (Clewell & Rigour 1997) and hence, a single reference site does not necessarily represent the habitat across the whole river, and therefore, cannot accurately assess the efficiency of a restoration scheme. Successful monitoring requires multiple reference sites and frequent sampling of variables to overcome patch dynamics and to identify trends, thus improving understanding of the natural variability that occurs within a river ecosystem. Monitoring will account for this natural variability in fish population dynamics as illustrated by Figure 2. A number of factors (weather, predation, disease *etc*.) are known to depress populations even when the habitat can support a larger population (Block *et al*. 2001). These factors can influence natural fluctuations within populations that only frequent monitoring can identify. Therefore, the timeframe over which monitoring is completed is fundamental when it comes to overcoming the complex interactions within an ecosystem and understanding the lag time associated with restoration activities (Cairns 1990; Beechie *et al*. 2000, 2005, 2009). Long-term monitoring of restoration works is essential to ensure that the population has time to adjust to time-dependent changes (Block *et al*. 2001) so accurate evaluation of the restoration scheme can be made, whereas short-term monitoring would be inadequate.

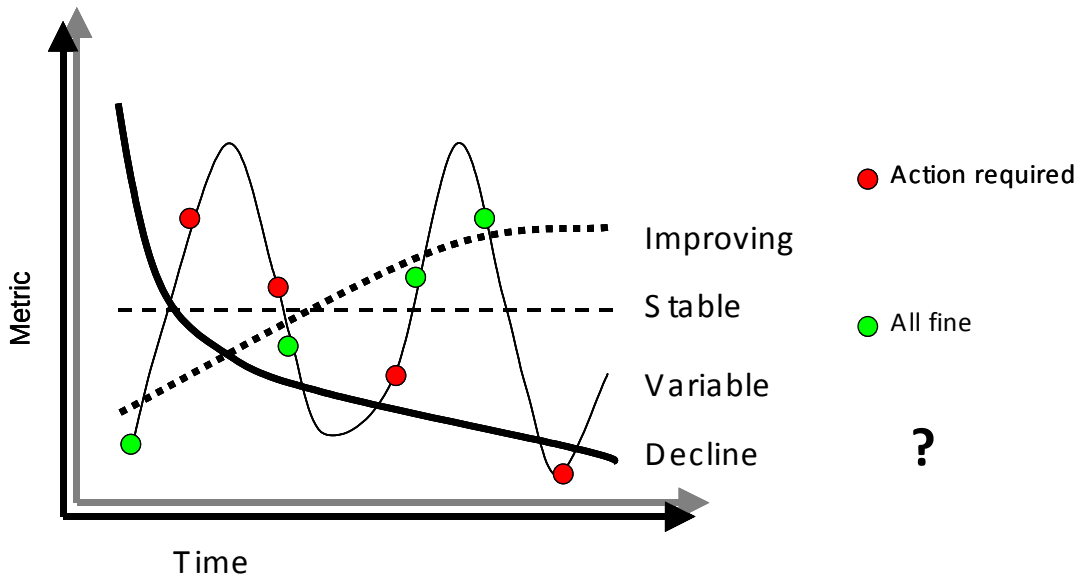

Fig 2. Demonstrates the influence of variable recruitment and life cycle processes on the abundance of species at any one time

3.4. Importance of evaluation within a project framework

Assessing restoration success can be challenging, nevertheless, it is essential to advance our understanding of river rehabilitation. Incorporating monitoring and evaluation into a well defined project framework, where performance standards and monitoring protocols are outlined prior to project installation (Clewell & Rigour 1997) will help overcome the question of 'how much is enough?' Evaluating the effectiveness of restoration projects by testing objectives against outcomes should enable success to be measured. Reporting results for dissemination is an important step and will enable us to learn from success or failures, and thus improve river restoration and management tools.

4. Conclusions

One of the problems faced with monitoring the success of rehabilitation activities is whom should fund the assessment. In reality, it should be the obligation of the proponent of the rehabilitation scheme to fund the monitoring and fundamentally to also report the outcomes. It is essential that successful projects are reported together with failures so others can learn from the problems encountered. One possible mechanism for reporting the outcomes of rehabilitation actions is uploading the reports onto the FORECASTER (Facilitating the Application of Output from Research and Case Studies on Ecological Responses to Hydromorphological Degradation and Rehabilitation) website that is a knowledge and information system designed as a reference tool for those seeking to formulate a suitable rehabilitation programme to improve ecological status of degraded river (http://forecaster.deltares.nl). The system is set up as a Geo-wiki where case studies describe the output from restoration and rehabilitation projects and intends to help practitioners by presenting experiences about success or failure of the application of different measures.

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