Outputs from a Monitoring Seminar

12th – 13th December 2006

The Forest Lodge Hotel, Lyndhurst, New Forest

‘THE NEED FOR RIVER RESTORATION MONITORING TO ESTABLISH THE TRUE POTENTIAL (AND CONSTRAINTS) TO DELIVERING GOOD ECOLOGICAL STATUS’

the River Restoration Centre
Working to restore and enhance our rivers

Environment Agency

Scottish Natural Heritage

SEPA
Scottish Environment Protection Agency

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Contents

1. Executive Summary

Overview

Restoration is seen increasingly as a means of attaining ecological integrity and habitat heterogeneity in river systems. However, current evidence suggests that restoration schemes are poorly appraised on the basis of integrated ecological and fluvial geomorphology criterion. Understanding of the appropriateness of river restoration techniques for different river systems and project objectives therefore remains limited. Thus it is generally recognised that there is now a need to provide good integrated pre- and post-project appraisal and monitoring of river restoration efforts.

This seminar brought together people from a range of natural science disciplines and included academics, practitioners and consultants, with the aim of working towards agreeing a river restoration monitoring framework capable of providing guidance about the range of monitoring methodologies available and the level of monitoring needed for a given project size and set of objectives.

Key findings

It was agreed that developing an integrated monitoring approach that provides scientifically sound answers to a range of river restoration objectives is not a straight forward task. Methodologies within specific disciplines tend to vary and those chosen are often dependent on whether the monitoring is being designed from an academic point of view or where a more pragmatic approach is required/necessary. Furthermore, whilst there was some overlap between disciplines in terms of methods used, often different terminology, together with temporal and spatial differences in data collection mean that data interpretation can become problematic. This was emphasised by the results collected from pre-seminar questionnaires that clearly indicated that current monitoring generally uses industry standard methodologies. Yet, despite the collection of much quantitative data, through the use of these methods, our confidence about river restoration projects remains limited quite possibly because of the lack of an integrated approach to monitoring and the setting of clear project objectives.

The discussions led to a series of questions which included:

- Do existing techniques (and perhaps more specifically, how they are executed) need to be adapted to answer river restoration project objectives?
- How do we address the scale of monitoring? (i.e. do we want to know about catchment scale influences or local patch scale ecological and hydrological interactions?).
- Are there sufficient funds available to ensure monitoring outputs will increase confidence in river restoration technique success and applicability?

It was generally agreed that:

- Whilst there is still some way to go to achieve integrated monitoring, one way forward would be to ensure that a 'project coordinator' is included in any restoration project to steer research findings and ensure that project objectives remain central to the appraisal outputs.
- Restoration monitoring or adaptive management appraisal must be included as part of initial project costs.
- Sufficient budget should be provided to ensure that good analysis is carried out as well as the data collection.
- Both pre- and post-project appraisal and monitoring are essential if robust scientific conclusions about the success or failure of river restoration projects are to be achieved.

This discussion was an important aspect in agreeing a way forward for developing a monitoring framework to help guide people towards carrying out 'best practice' monitoring. The seminar provided the first steps towards developing this concept and provided a good way of bringing together people who were committed to forwarding the idea of implementing an industry standard 'handbook' (perhaps similar to the fluvial geomorphology handbook, for example) for monitoring river restoration projects.

Part of the ethos of the framework was to try to determine the level of monitoring that should be applied to projects and what percentage of overall cost should be used for data collection and analysis. Views on this varied between delegates with suggestions ranging from between 5-40% of the total project budget being allocated to monitoring which demonstrates some of the difficulty in balancing academic-based detailed monitoring with the more pragmatic consultant's approach. Many delegates did however feel that there was value in ensuring that, in the case of small, low cost projects, there should be a higher percentage of the overall cost (in the region of 20% of the total project budget) dedicated to the project appraisal, since low cost projects often provide an opportunity to cost effectively answer project success and management questions.

The need to test the scientific rigour of integrated monitoring and restoration techniques led to the conclusion that funding was urgently required for a large scale integrated catchment research project(s) geared towards testing a monitoring protocol specifically designed for evaluating river restoration techniques.

Overall, the seminar provided a good starting point for considering the way forward to designing an integrated monitoring protocol. It clearly identified the need to pull together a team of interested parties to deliver this and the need to also embark on a research and development programme to determine best practice river restoration.

2. Introduction

River restoration is increasingly seen as one way to achieve ecologically improved species richness and diversity in aquatic systems. There is however, much debate over whether or not getting the hydromorphological dynamics correct will automatically lead to ecological enhancement even when water and sediment quality is good.

Many researchers have hypothesised that there are two types of processes that determine the success or failure of a river restoration or enhancement project in terms of ecological gain. These are:

1. Deterministic processes that operate by increasing the spatial heterogeneity (or geomorphological patchiness) within a reach.
2. Stochastic processes where potential for ecological improvements are controlled by the local conditions in terms of 'supply' of species.

In most river restoration projects it has generally been assumed that getting the hydromorphology correct (point 1) will automatically lead to ecological improvement. However, there is growing concern that project success may be limited by local species supply (point 2) although evidence for this remains limited.

With the requirement of the Water Framework Directive (WFD) to increase river habitat quality there is an urgent need to increase confidence regarding the success of river restoration projects for a given set of techniques where project objectives are specifically aimed at ecological gain. The only way to increase confidence is to ensure that, wherever possible, monitoring is included as a core activity of the restoration process.

Currently though, there is no integrated, trans-disciplinary, scientifically sound, monitoring protocol that takes account of project scale, cost and initial objectives to define a suitable level of pre- and post-project appraisal.

2.1 Seminar Aim

To bring together key people from a range of natural science disciplines (e.g. fisheries, ecologists, geomorphologists, hydrologists, water and sediment quality experts) and backgrounds (e.g. statutory authorities, academics, consultants, NGOs) with a view to agreeing a monitoring protocol that is underpinned by sound science but critically is feasible to carry out in view of inevitable cost constraints.

2.2 Envisaged objectives

- Agree a monitoring/appraisal framework (matrix) which defines the most appropriate level of monitoring necessary on the basis of project size, sensitivity and cost.

- Enhance understanding of each discipline's rationale for monitoring and through this agree a trans-discipline monitoring protocol.

- Identify a range of sites (both completed and imminently proposed projects) that could be used as case studies to test the scientific rigour to the new framework/protocol.

3. Responses to questionnaires completed prior to the seminar

The following provides a summary of the questionnaires completed by the delegates. The content of the questionnaire was devised to help the River Restoration Centre formulate the workshop format and highlight the wide range of views likely to be voiced between different disciplines.

A more detailed assessment of the questionnaires may be completed at a later date. These responses are the outputs of a pilot project and it should be stressed that they are based on a small sample (34 respondents). However, these responses are from people who have a strong track record in river restoration and therefore felt to be reasonable reflection of the current position of river restoration monitoring and post project appraisal within the UK.

The bold titles (1-15) in this section are the questions asked in the questionnaire.

1. Main area of expertise (defined for the purposes of this seminar)

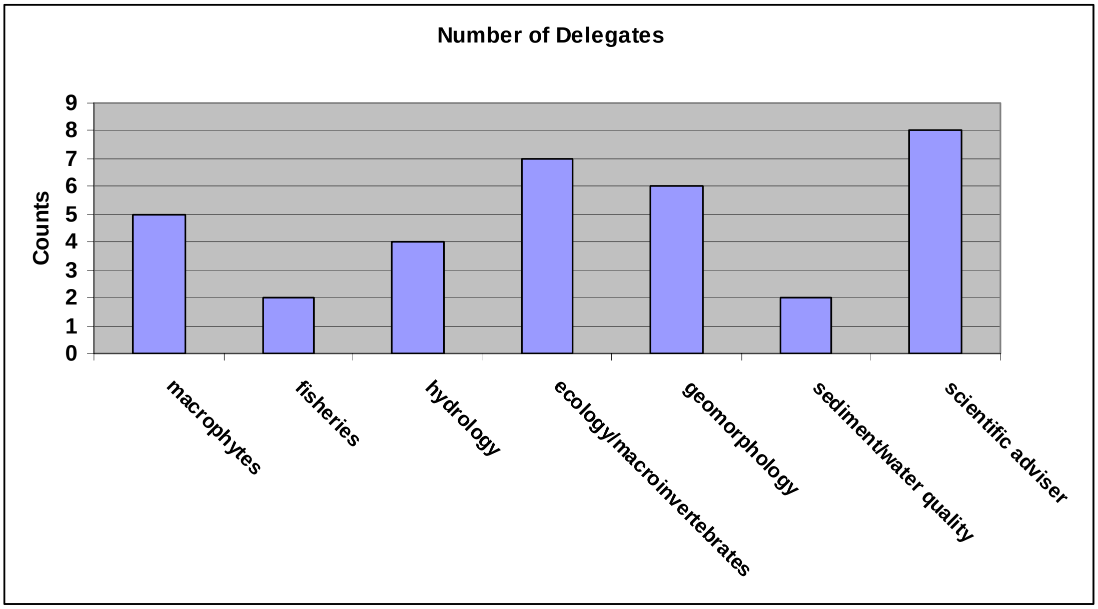


Figure 3.1 Delegates' main areas of expertise

2. Are you completing this form on the basis of monitoring experience or what you feel are the most appropriate methods for river restoration post project appraisal.

Of the 34 responses approximately 70% had direct experience of undertaking monitoring programmes.

3. Name the main monitoring methodologies you use. (Note: questionnaire suggested up to six options)

The main reason for this question was to enable delegates to start thinking about the different methodologies they may apply to river restoration projects to later populate the framework proposed by England, Skinner and Carter in their presentation (pages 21-23).

In total 47 methodologies were suggested from the key areas of expertise (Marcrophytes (M), Fisheries (F), Hydrology (H), Ecology (E), Geomorphology (G), Sediment/Water quality (S)). For the purposes of summarising the answers to this question the Scientific Adviser's information has been amalgamated with the other data from the appropriate disciplines.

Although 47 methodologies were highlighted these were specified 105 times in all. However, only 6 methodologies were suggested by more than 4 individuals, as highlighted in the table below. The raw data indicates that there is a wide range of different methodologies being used. However, there was some ambiguity over terminology. For example, whilst remote monitoring was classed as a methodology by ecologists, it was stated as airborne photography by geomorphologists. This suggests that there is a need to tighten the technical language so it is more easily transferred across disciplines. A glossary of terms may be one way to address this.

Nonetheless, it is interesting to note from the table below that River Habitat Survey (RHS) is the methodology that has been adopted by a range of disciplines. How it is used and whether or not the Environment Agency's database is interrogated routinely as part of the methodology assessment process is not known.

Methodology	**Disciplines using the methodologies and number of counts per discipline**	**Total counts**
River Habitat Survey (RHS)	Macrophyte (3) Ecology (3) Geomorphology (2)	8
Fixed Point Photography	Macrophytes (3) Geomorphology (4)	7
Mean Trophic Rank (MTR)	Macrophytes (5) Fisheries (1)	6
Fluvial Audits	Geomorphology (3) Ecology (1) Fisheries (1)	5
Fish Netting	Fisheries (4)	4
Electro-fishing	Fisheries (4)	4

Figure 3.2 The main type of methodologies used between different groups

4. For what purpose do you use each of the monitoring methodologies specified in question 3? Examples might include: to evaluate spawning habitat success, quantify the spatial and temporal scale of geomorphic adjustment following project disturbance, or analyse species richness and abundance.

The purposes for using each monitoring method were almost as wide, in terms of terminology, as the methods defined with 41 different responses given. Even where the same method had been highlighted, the rationale for using that method often varied between disciplines. To provide an example of the variation in method usage, the 'purpose' comments stated for the 4 most commonly used methods are shown below.

Note: the letters after the comment referred to the area of expertise associated with the comment. See page 6 for description of coding.

RHS

- Quantity changes from baseline (M)
- EIA (M)
- Quantify moderate to major changes in habitat structure at reach, catchment, regional or national scale (M)
- To determine how the structure (flow, morphology and macrophytes) of a restored reach has changed (G)
- Record key features habitats and flow types (G)
- Assess habitat modification and current habitat (E)

Fixed point photography

- Species colonisation and vegetation community establishment (M)
- Species abundance and hydromorphic adjustment (M)
- Changes in communities affected by climate, abstraction, physical manipulation etc and observe the aesthetic character and changes of the river (M)
- Back up visual inspection of erosion or deposition (G)
- Visual changes to deposition and erosion at a particular cross-section (G)
- Rapidly evaluate morphology changes (G)
- Record of form and desk based analysis of change (G)
- Record quantitative change of channel and floodplain format and key parameters such as width, depth and slope (G)

MTR

- Abundance of species and some hydromorphic information (M)
- Changes in communities affected by climate, abstraction, physical manipulation etc (M)
- Trophic status of rivers (M)
- Pollution/low flow assessment and river restoration (M)

Fluvial audit

- Spatial and temporal scale of geomorphic adjustment (G)
- Scale/nature of geomorphic Adjustment (G)
- Identify reaches best suitable of restoration and quantity changes after works take place (E)
- Evaluate channel stability (G)
- Use in conjunction with other methods to help explain pre- and post restoration changes (F)

5. Describe the main points of each methodology and what it achieves in one or two simple sentences (for the benefit of those who work in different disciplines) e.g. River Habitat Survey – a 500m length walkover river survey, data collected provides a habitat quality index and information is stored on a national database.

Below is a summary of the main methodologies highlighted within the questionnaires that perhaps are not known to other disciplines. Many other methods were also described but are considered more widely known (e.g. cross-sections and fixed point photography) so are not included within the figure below.

Methodology	**Over all description**
JNCC	500m survey of macrophytes with maps describing links between plants and hydro-morphology
MTR	100m survey of macrophytes with maps describing links between plants and hydro-morphology
RHS	500m length walkover river survey. Data collected provides a habitat quality index and information is stored on a national database.
Site condition monitoring	Based on JNCC for SSSI's and SACs can include various other methods.
Macrophyte sampling	Macrophytes recorded in 1km reach using standard checklist. Abundance and cover recorded
River Corridor Survey	Walk over survey 500m lengths. Field maps to characterises structure and vegetation. Highlights issues such as pollution etc.
Hydraulic Engineering Centre River Analysis System (HEC RAS)	1-D flow model – output used for sediment transport calculations
River energy audit scheme	Budgets specific stream power through reaches of the channel network to give indication of channel potential for erosion or deposition.
Continuous water level measurement	Water level information collected every 15 minutes

Spot flow gauging	Water depth and velocity measures in section s across river to produce average velocity across the cross-section.
Cross- section surveys	Spaces about every 1000m along the river with spacing about every 1m from bank to bank
Kick sampling	3 minute kick/ sweep samples. invertebrates collected using a net
Before-After Control Impact (BACI) Surveillance	Similar to a baseline ecological survey but incorporate spatial and temporal bases difference either at site or between site.
Baseline ecological survey	Discrete point/zone sampling of biological community required to compare communities within different habitats of a river and for pre-restoration baseline assessment
Fluvial audit	Provides information on sources and sinks of sediment and channel stability/instability.
Physical biotope mapping	Measurement and mapping of biotopes
Morphological Impact ASsessment Tool (MImAS)	500m or water body scale assessment of conditions. Looks at pressure on morphology to likely ecological status.

Figure 3.3 Summarising the descriptions of the less well known monitoring methodologies

6. **As briefly as you can state the main variables measured for each methodology (for example diversity, richness, biomass, cross-sectional variation, etc). Also state whether of not these methods are qualitative or quantitative.**

The response to this question revealed that the variables measured were very diverse. Making good sense of this data requires more detailed analysis. There was however, a clear trend towards measuring richness/diversity and abundance and this measure was consistently noted within ALL groups. Vegetation cover was also identified by the macrophyte, sediment/water quality and scientific advisers groups as a variable that needs to be measured to help assess river restoration project success.

Many of the approaches are quantitative which may suggest that the current methodologies are robust in themselves. However, integration between disciplines is perhaps, still limited which would go some way to explaining the current call for more robust scientific evidence to support restoration efforts (i.e. data is available but interpretation must relate to key objectives to provide answers to river restoration questions).

	Quantitative	**Qualitative**	**Both**
macrophytes	8	3	3
fisheries		4	2
hydrology	9	1	
ecology/macroinvertebrates	8	3	4
geomorphology	8	4	3
sediment/water quality	7		
scientific adviser	6	2	8
	46	**18**	**29**

Figure 3.4 Showing that many monitoring methodologies are quantitative in approach giving rise to speculation that it is the interpretation (and integration) of results with respect to river restoration objectives that needs to be addressed.

7. From the drop down boxes describe the main reasons for selecting the methodologies you have described

The following figure shows that much of the data collection is completed as part of industry standard methods which may not have necessarily been adapted for river restoration purposes. Similarly there is a strong focus on using relatively simple methodologies (in term of data collection). Perhaps the most revealing information is that testing new methods specifically designed for river restoration assessment is very low and cost limitations did not figure highly as a limiting factor. It is not however known if this is a function of monitoring being primarily completed at fixed statutory agency points as part of the overall stream process assessment rather than a monitoring protocol being designed and completed specifically to address restoration objectives.

	Industry standard method	**Testing of new method**	**Simplicity/ easily repeatable**	**Cost**	**Other**	**No response**
macrophytes	10	0	0	0	7	0
fisheries	2	1	4	3	3	6
hydrology	7	0	1	0	0	0
ecology/macro-invertebrates	7	1	4	0	6	0
geomorphology	1	1	3	2	4	3
sediment/water quality	1	2	4	0	0	0
scientific adviser	3	1	5	0	7	0
other	2	0	7	2	2	0
Counts	**33**	**6**	**28**	**7**	**29**	**9**
%	**29.5**	**5.35**	**25**	**6.25**	**25.9**	**8**

Figure 3.5 Showing split of types of methodologies used and why

8. **Give an estimate of the cost of each methodology per unit size. Please, specify the length and width of the unit size. Don't spend ages searching for this information – indicative/best guess costs and size will be fine.**

As with some of the other questions, the range of results was very varied and need further discussion and assessment to provide clear answers. In brief, as shown in Figure 3.6, the cost of completing a specific method varied considerably from anywhere between less than £100 per 100m reach to over £1000.

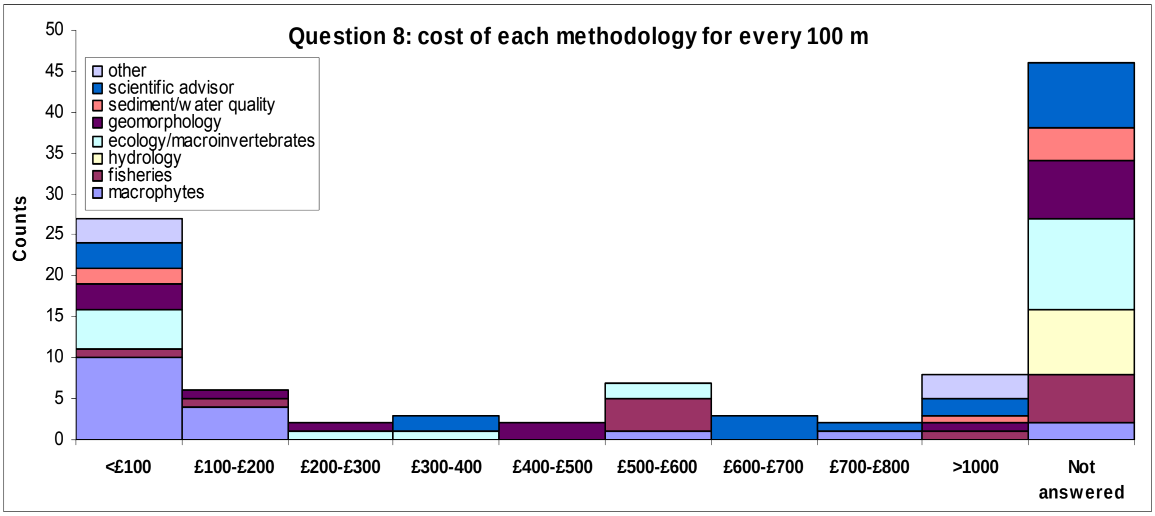


Figure 3.6 Large range of costs associated with different types of methods

9. **<u>Ideally</u> how often would you repeat your methodologies at a site? For consistency imagine you are monitoring a 500m reach in a river that is 5m wide.**

There was some misunderstanding of the question (e.g. hydrology requirements were more to do with gauge information rather than monitoring site).

Overall however, times varied from every 6 months to every 6 years. 25% of the answers indicated that monitoring should be completed on a yearly basis.

10. **Is this repeat pattern of the methodologies expected to change for different lengths/widths of reaches (i.e. is the approach flexible)?**

In all cases, with the exception of hydrology, there was a higher proportion of responses stating that the methods did not change for different lengths/widths of reaches suggesting that approaches may not in themselves be flexible to achieve an integrated river restoration methodology.

	Yes	**No**	**No response**
macrophytes	7	10	
fisheries		13	
hydrology	2	6	
ecology/macroinvertebrates	6	10	3
geomorphology	6	7	
sediment/water quality	6	1	
scientific adviser	8	11	
other	4	2	
Total	**32**	**60**	**3**

Figure 3.7 Flexibility of methodologies according to discipline

11. If yes, is it length/width or a combination of both that are likely to be the critical factor?

Answers varied with many respondents unwilling to make a commitment to either length or width or a combination of both as summarised below

Length	9.6%
Width	6.4%
Both	40.5%
No response	43.5%

12. What do you feel are the limitations of the methodologies that you use (or you are aware of) when applied to post-project appraisal of river restoration schemes? Please give examples if you can.

31 different suggestions were provided with 108 responses in all. Those that were stated 5 or more times are listed below with cost, time and subjectivity being the key limitations of methodologies.

Subjective/limited detail	22
Cost	14
Time consuming	13
Not easy to replicate	6
Fish not a good subject to monitor	5

13. What do you think is the minimum pre-project data requirement (spatial and temporal) to complete successful post-project appraisal/ monitoring?

There was no clear consensus to this question with almost 20% of participants not answering the question. Ecologists, geomorphologists, hydrologists and scientific advisers generally felt that 1-2 years of pre-project data was required and that a control site should be a pre-requisite of a monitoring protocol.

14. Are you involved with the development of any new monitoring tools? – Please specify

It has already been highlighted in previous questions that development of new tools and techniques is limited. This question sought to identify which groups may be developing tools above and beyond others. The table below is a summary of the responses which may tentiatively suggest that the ecology and geomorphology groups are leading the way in terms of trying to address the specific requirements of river restoration monitoring.

	Yes	**No**
macrophytes	1	1
fisheries		2
hydrology	2	1
ecology/macroinvertebrates	4	5
geomorphology	3	1
sediment/water quality	2	
scientific advisers	1	2
	13	12

Figure 3.8 Showing which groups are aware of new tools being developed

15. Brief details of any integrated monitoring of restoration projects

Delegates were asked to provide information on projects they had been involved with to give some idea of what was monitored as part of these projects.

Comments are summarised in Appendix B of this document (pages 59-61).

16. Generic comments were also asked for about the framework regarding monitoring costs

The following framework was given for guidance and respondents were asked to make comments.

15%	15-20%	20%
5%	10%	15-20%
(minimal cost)	5%	15%

Risk ↑

Scale →

The following summarises most of the comments made:

1. Concern was expressed about the notion of risk of the project as a way of defining monitoring budgets.
2. Suggestions were made that sometimes simple, cost effective methods could be widely applied and hence may need more monitoring budget to show this for greater gain. Therefore, there may be a case for increasing the percentage figure for small projects.
3. Statements were made that there is no point doing post project monitoring without any post project appraisal and therefore this would need to be included in any framework.
4. It was mentioned that the RRC database could be used to define what has been successful and what has not to tie up figures.

4. Seminar Programme

Day 1

9.00	Registration
9.30	Introduction - Martin Janes (RRC)
9.40	Monitoring criteria, duration and predicting consequences? - Terry Langford (University of Southampton)
10.00	Discussion
10.10	Can we use sediment and hydrology based models to predict physical habitat? – Nick Wallerstein (University of Nottingham)
10.30	Discussion
10.40	TEA & COFFEE
11.10	An update - lessons learnt from the “habitat description measurement and assessment in rivers” workshop (HDMAR) - Alistair Maltby (ART)
11.30	Discussion
11.40	Monitoring and appraisal of River Restoration Projects - Kevin Skinner (Jacobs), Judy England (Environment Agency) & Matt Carter (Environment Agency)
12.00	Discussion
12.30	LUNCH
13.45	Introduction to workshops – Jenny Mant (RRC)
13.55	Workshops - To agree appropriate monitoring and appraisal methodologies depending on cost/risk and uncertainity of restoration projects, for each discipline
15.40	TEA AND COFFEE
16.10	An agency’s perspective on river restoration appraisal and monitoring - Mark Diamond (Environment Agency)
16.30	Discussion
16.40	Reporting on the outputs from the workshops (RRC)
17.25	Discussion and agreement of framework
18.10	Close

Day 2

8.55	Introduction – Martin Janes (RRC)
9.10	Towards an integrated approach to monitoring and adaptive management: perspectives from a geomorphologist and a fisheries ecologist - David Sear (University of Southampton) & Andy Gill (Cranfield University)
9.40	Discussion
9.50	TEA & COFFEE
10.20	Site visit - David Sear (University of Southampton) and Maxine Elliot (Environment Agency)
12.50	LUNCH
13.50	Introduction to workshops – Jenny Mant (RRC)
14.00	Workshops - Towards integrated monitoring and appraisal, dependant on cost / risk / timescales / objectives and uncertainty
15.00	TEA & COFFEE
15.30	Reporting on the outputs from the workshops (RRC)
16.00	Discussion
16.30	Suggestions for ways forward, outputs and offers of involvement
17.00	Close

Seminar – Day 1

5. Summary of Presentations

5.1 Introduction - Martin Janes

Refer to Appendix C of this document for presentation slides

This seminar was organised by the River Restoration Centre and supported and funded by Environment Agency (EA), Scottish Environmental Protection Agency (SEPA) and Scottish Natural Heritage (SNH).

Martin Janes provided an introduction to the seminar by explaining the motivations for organising the event. These were:
- To further the discussion and outcomes of a workshop held in 2001
- To focus on monitoring and its application to river restoration

Martin also outlined the aims and objectives of the two day seminar, which were:
- To design a best practice approach to monitoring, which is based on sound science, but also feasible to implement given the inevitable cost constraints
- To focus on agreeing a monitoring framework
- To enhance integration between disciplines
- To identify a range of test sites that can be used as monitoring case studies

Before the start of the seminar attendees were asked to complete and return a questionnaire. Martin used data from the attendee's completed questionnaires as a means of identifying some of the problems that are currently faced.

5.2 Monitoring Criteria, Duration and Predicting Consequences – Terry Langford

Refer to Appendix C of this document for presentation slides

Terry Langford was asked to give a presentation to address monitoring of river restoration projects from an ecological perspective.

Terry raised questions over how we establish whether a restoration project has been successful when the targets are often not clearly defined or fully transparent; for example he questioned how, if targets are not quantitative, the success of a technique can be measured.

Terry highlighted that there are always unintended ecological consequences of restoration, that restoration to benefit one species may have disadvantages for another.

Terry also addressed the issue of scale, drawing attention to the fact that restoration is largely carried out at the reach scale with the hope that benefits will occur on a larger scale. However he questioned how, since monitoring still focuses on the reach scale, can any conclusions be drawn about the wider benefits of restoration?

Terry proposed the theory that restoration should be treated as a disturbance: 'Restoration is a disturbance that alters the effects of a previous disturbance' (Langford 2007). He commented that if we regard restoration in this light and refer to research on disturbance ecology then it would help establish an improved approach to ecological monitoring.

Finally, Terry brought attendees attention to the prediction of impacts. His feeling was that restoration projects are currently being viewed as experimental and urged that with appropriate pre restoration data and consultation of published literature it should however be possible to make reasonable predictions. Terry questioned why such predictions are not being made.

To conclude he highlighted a statement made by the late Lord Kelvin: "When you can measure what you are talking about and express it in numbers, you know something about it. When you cannot express it in numbers your knowledge is of a meagre and unsatisfactory kind."

Discussion. Discussion following Terry Langford's presentation focused primarily on the ecological theory that is available and how this might be used to inform a monitoring framework.

5.3 Can we use sediment & hydrology based models to predict physical habitat? – Nick Wallerstein

Refer to Appendix C of this document for presentation slides

Nick Wallerstein was asked to give a presentation to address the geomorphological and hydrological aspects of monitoring river restoration projects.

Nick started his presentation by posing three questions, which formed the basis of the rest of his presentation. These questions were:

1. Can channel stability models be used to help predict habitat status?
2. Can the data required for such models be used in pre-existing habitat models?
3. Can channel stability models be used to direct post project monitoring efforts?

Points raised with regard to channel stability models:

- Dis-equilibrium (degradation or aggredation) in sediment transport is regarded as bad since degradation results in loss of substrate vital for feeding / spawning / habitat, loss of diverse bed morphology, flashier flows due to confinement and loss of aquatic plants; whilst aggredation results in smothering of substrate vital for feeding / spawning / habitat, loss of morphological diversity, loss of flow depth, fines choking fauna, and increases in water temperature.

- Dynamic equilibrium is regarded as good since it results in ordered but variable bed morphology, which enables diversity of habitat thus increasing species diversity and its adjustment to morphology - enabling sustainable flora & fauna migration.

Nick focused on four channel stability models: 1. stream power screening tool, 2. river energy audit scheme (REAS), 3. HEC RAS SIAM and 4. ISIS Sediment. He described the applicability of each model.

Points raised with regard to habitat models:

- Nick proposed the idea that habitats could be related to specific stream power thresholds. He hypothesised that if the mean velocity, depth and substrate size range for a species is know, then literature can be used to establish the slope at which this data was obtained and thus the habitat can be related to the stream power. This was exemplified using data on fry, par and adult brown trout
- Nick commented that if we are to establish the level of stress in terms of aggredation or degradation potential that a species can stand then there is much need for relevant data to be collected.

In response to his final question posed at the start of his presentation, can channel stability models be used to direct post project monitoring, Nick commented:

- “We must remember that rivers are dynamic in terms of sediment transport, and therefore morphology, both: spatially and temporally. Therefore habitat status for difference plants / animals varies with time and space in any dynamic system and it makes sense therefore to use a sediment modelling tool which predicts locations of change to highlight reaches that should be selected for special attention on post-project monitoring”
- He emphasised that “It does not make sense for monitoring to be spatially static”

Discussion. Discussion following Nick Wallerstein’s presentation focused on the complexity of ecological interactions between organisms and the habitat and questioned whether the models proposed were multifaceted enough to take into account the many factors associated with community composition.

5.4 An update: lessons learnt from the “habitat description measurement and assessment in rivers” (HDMAR) workshop - Alistair Maltby

Refer to Appendix C of this document for presentation slides

Alistair Maltby was asked to give a presentation based on the findings and lessons learnt from the “habitat description measurement and assessment in rivers” (HDMAR) workshop held in March 2006.

The ‘Restoring Eden’ project was undertaken by the Eden Rivers Trust; the catchment was monitored using an early version of RHS, catchment-wide electrofishing surveys, in addition to statutory monitoring. During the course of the project it was identified that there was a need to develop a ‘matrix’ or ‘toolbox’ of methodologies appropriate for targeting and monitoring River Trust activity. This was the motivation behind the HDMAR workshop.

The workshop was attended by attendees from government bodies, River Trusts, NGOs, research institutions and academic institutions. There were five aims of the workshop, these were:

1. To identify principle applications and their scales
2. To identify and describe current methods.
3. To propose a toolbox of methodologies and good practice
4. Data storage, access and management
5. To summarise current research and recommend future work

The expected outcomes were:

- Better awareness of the issues surrounding the description, assessment and application of habitat surveys;
- Collation and dissemination of good practice that will bring more consistency to the activity, enabling easier sharing of results and a common language across workers in the field. Various media options, to be discussed at the workshop;
- A framework for future development – through for example a standing group on habitat assessment, e-discussion group or repeat workshops; and
- A prioritised programme of key future research needs and benefits to put to potential funding bodies

Discussion around the idea of a monitoring matrix lead to the scale of sites being divided into catchment, reach, site or micro. Other attributes such as the objective, the methods, and the key variables were taken into account. The following methodologies were focused on: RIVPACS, SERCON, EFI / FAME, FCS, HABSCORE, PHABSIM, aerial survey, walkover survey, RFHI, RHS, fluvial audit.

Alistair described some of the problems and issues that arose from the discussion. These included how to compare such a diverse range of methodologies that were designed with very different purposes in mind; concerns over the validity of some methodologies to meet their intended purpose and discussion over the advantages and disadvantages of both RHS and fluvial audit tools.

Before the workshop began it was hoped that a matrix would be agreed that could be published in the Atlantic Salmon Trust Blue book and on an updateable website (IFM). However this was not achieved as a consensus of opinion could not be reached!

Discussion. Discussion following Alastair's presentation raised questions over why it was so difficult for a consensus of opinion to be reached in the HDMAR workshop. Attendees suggested that perhaps when tackling physical restoration monitoring there is a lot that can be learnt from past experience of water quality monitoring. The question was also raised over what is good ecological status – this is what the WFD is aiming to achieve but how do we know when this status has been reached, rivers have been modified for so long it is probably impossible to get back to a natural state. It was suggested that perhaps we can look at paleoecological records to provide evidence of historical form and function, but is this relevant or have systems changed too much?

5.5 Monitoring and Appraisal of River Restoration Schemes - Judy England, Kevin Skinner, Matt Carter

Refer to Appendix C of this document for presentation slides

Judy and Kevin began their presentation by outlining what Monitoring and Post Project Appraisal are – that is a procedure that seeks to determine whether a technique has worked effectively. They stressed that it should be an integral component of any project yet is often not undertaken due to an assumption that restoration is a good thing so a scheme "will work", poor planning or time and money constraints.

PPA is needed since it allows us to:

- assess a scheme's success & achievement of its aims
- identify which restoration techniques work best in different situations
- explain what is happening in the river, what works, what doesn't and what are the unforeseen consequences of our actions
- by understanding this we can then amend the scheme to ensure a project achieves its objectives
- monitoring allows us to learn more about aquatic systems by testing scientific hypotheses – the more we know about the systems we work with the better we can become at predicting what will happen.
- the outcomes can then help prioritise future programs of investment.

Best Practice:

Judy and Kevin explained some of the basic principles that should be followed when undertaking PPA:

- **Objectives**: Each scheme should have clear objectives or expectations. Without these it is impossible know what the scheme is trying to achieve. In addition to monitoring the achievement of the objectives the wider impacts also need to be considered. In this way we will be able to better predict the wider consequences of a scheme and ensure that one element of an ecosystem does not benefit at the expense of another that may have an equal or greater ecological value.

- **Baseline data:** Key to all monitoring is the need for adequate baseline information. This should be collected prior to the finalisation of the objectives so that they can be refined as necessary. Without understanding the current situation it is not possible to either measure what changes occur or what restoration to plan.
- **Control sites:** Control sites are needed in order to help distinguish between background changes and those attributable to the restoration scheme. Where possible the control site should also provide the reference conditions that are the target of the restoration scheme.
- **Timescale**: The timing of the appraisal is a balance between the time taken for a system to recover and the need to gain useful information. Ecological recovery is dependent upon a variety of factors ranging from the extent of the disturbance (channel restoration), proximity of sources of colonists and ecological processes of colonisation. Where ecological restoration is dependent upon physical processes that are slower to respond, recovery will take longer. As more schemes are evaluated and reported the better we will be able to estimate the recovery timescales.
- **Reporting**: The effective communication and the dissemination of the results is essential. The lessons learnt from monitoring are important in the identification of which restoration schemes are successful in producing the desired outcomes.
- **Science:** Basic scientific principles should be followed – such as Before-After Control Impact (BACI) and replicated surveys. Scientifically based monitoring and assessment ensures that statistical examination of the changes is possible and the success of a scheme can be proven. The more that is learnt about what happens as the result of a restoration scheme the better we can understand the interactions between ecology and supporting physical and chemical processes, predict the ecological outcomes and refine expectations.

Which schemes to monitor?

When choosing which scheme to monitor there is balance between scale, uncertainty and risk that need to be taken into account. Judy and Kevin examined how a more strategic approach might be achieved.

To enable this more strategic approach a model has been developed to ensure that limited resources can be targeted to where there is the most environmental risk and potential to learn. The philosophy behind the model is that small-scale projects using established techniques are predictable and therefore present a low risk so need less monitoring. Whilst large-scale projects using new or novel techniques present the greatest risk and therefore warrant a higher degree of monitoring and appraisal of their impacts.

Project scale can be defined as the length of river affected or even the frequency with which the technique is applied.

Novel techniques can refer to new designs, new methods of construction, innovative ideas, combinations of techniques or the application of techniques within new types of river systems such as moving from rural to urban situations. The ability to distinguish how novel a technique is will rely on knowing what schemes and techniques have been appraised in the past.

The grid reference of scale against the novelty of the project is used to identify a square within the model to indicate the level of risk and effort of monitoring required. The model is overlain with different ecological and geomorphology methodologies to give an idea of the types of monitoring that could be applied to the various levels of risk. The suggested methodologies have been selected based upon their ability to monitor short sections or more extensive areas of channel. Those techniques targeted at more detailed monitoring will allow scientific and statistical comparisons between sites and provide additional information about the habitat relationships and preferences of the taxon assessed.

The draft model presented by Judy and Kevin formed the basis of the workshop discussions.

Discussion. Discussion following Judy & Kevin's presentation focused on the axes of the matrix – primarily the y-axis: 'Established to New Technique'. It was felt by many attendees that perhaps a risk scale on the y-axis would better account for the factors being considered. A number of attendees suggested that perhaps a third axis should be added. There was also a considerable amount of discussion around the way that monitoring was prioritised as a number of attendees had concerns that small scale projects, which are by far the most common scale of project and can have large cumulative impacts, might not be monitored.

As a result of this discussion the y-axis of the matrix was modified from 'Established to New Technique' to 'Low to High Risk'. The x-axis was maintained as 'Small to Large Scale'.

5.6 An agency's perspective on river restoration appraisal and monitoring - Mark Diamond

Refer to Appendix C of this document for presentation slides

Mark Diamond, from the Environment Agency, focused his presentation on why we should monitor river restoration projects. Mark started by stating that 50% of water bodies are at risk because of morphological change (e.g. impassable barriers). Actions within the WFD are seeking to address this but they must be seen to be cost-effective, so evidence from monitoring is required to show that river restoration can make a measurable difference.

Mark stated the importance of objective setting in terms of:

- Clear stating point
- Clear objective
- Clear required effect

He also drew attention to an article by Pretty *et al* (2003), Journal of Applied Ecology and stated that “From this substantial sample of lowland rivers, there is little evidence of any general benefit to fish of small-scale instream structures in river rehabilitation.” Mark went on to question whether in-stream devices do actually increase salmonid abundance and made reference to the Centre for Evidence-Based Conservation (CEBC) at University of Birmingham who have examined this question through a systematic review of existing data and found that adding woody debris significantly increases salmonid abundance and there is a large effect size, but that traditional in-stream devices are significant but have negligible effect size. Mark highlighted that there is hardly any published evidence on the effectiveness of riparian fencing yet this method of riparian restoration has been widely implemented.

Mark’s final point identified a forthcoming review by Steve Ormerod *et al* which is likely to conclude that the links between ecology and the physical structure of rivers are insufficiently quantified to support key policies and legislation.

Mark closed by raising some priority questions:

- Do the most frequently used reach scale measures work?
- What are their unintended consequences?
- How extensively should they be applied?
- How should we take into account the catchment context?
- How should we analyse river systems to decide where interventions will be most efficient and effective?

6. Summary of workshops

Prior to attending the seminar each attendee was asked to complete a questionnaire, the main driver behind this was to set the scene for the seminar and to get the attendees thinking about the subject areas that would be discussed during the course of the seminar. The outputs of the questionnaire were used to help inform discussion in the workshops.

On the first day of the seminar attendees were divided, according to their area of expertise, into six groups. Each group included consultants, practitioners, academics and representatives from government agencies. The groups' areas of expertise were:

1. Scientific Adviser
2. Ecology
3. Fisheries
4. Geomorphology
5. Hydrology / Sedimentology
6. Macrophytes

The aim of the workshop was to agree a monitoring framework for each discipline to help ensure that both academics and practitioners could agree on the appropriate level of monitoring for different types / sizes / novelty of river restoration projects / techniques. The framework was based on a 'risk to scale matrix' as proposed by Judy England, Kevin Skinner and Matt Carter in their presentation.

Each group was given a list of questions to discuss and was asked for the purposes of the workshop to assume that clear objectives had been set for any given project and that they were monitoring the aspects that related to their area of expertise.

The questions for group 1 focused on 5 main areas:

- The Framework
- Data collection (time and scale)
- Funding
- Policy
- R&D

The questions for groups 2-6 focused on 4 main areas:

- The Framework
- Fit for purpose
- Data collection (time and scale)
- Costs

6.1 Discussion and conclusions from Scientific Advisers

The information below summarises the questions that were asked and the responses that the Scientific Advisers (group 1) gave.

The Framework

Under the title of ‘The Framework’ the following questions were provided to facilitate discussion:

A. Given that there is currently no protocol set for monitoring river restoration projects, how ‘fit for purpose’ do you consider this risk-scale matrix framework?
B. Are there any methodologies that should be added to the framework? (The group were provided with a summary of the questionnaire responses around which to base their discussion).
C. What do you think are the key limitations for any of the methodologies?
D. What scale of monitoring should we be doing for different scales of projects?

These responses relate to questions A to D as detailed above. It has not been possible to provide details of the response to every question. The questions were provided to help facilitate discussion but not all of the questions were covered.

Group	Main conclusions
Scientific Advisers	A) YES (but check other protocols such as those developed by P. Downs) Scale: Scale of impact (site, reach, catchment) Risk: risk of project failure, external risks Note. Must have really good definitions of scale and risk for the framework to be effective and understandable, could apply each objective separately to the framework In time the restoration techniques will reduce in risk with use

Figure 6.1.1 Scientific adviser responses to questions A to D above regarding the framework.

Data collection (time and scale)

Under the title of ‘Data collect’ the following questions were provided to facilitate discussion:

A. What is the minimum pre-project information that you feel is needed (time & scale)?
B. Post-project, how long ideally do you need to monitor to be confident that a project has reached its full potential.

These responses relate to questions A and B as detailed above.

Group	**Main conclusions**
Scientific Advisers	A) Pre: Generally, need enough data to adequately diagnose the problem and propose an appropriate project design. The rest is methodology specific. B) Post: Depends upon the targets set and time to realisation. Perhaps longer if wishing to check equilibrium. Could the monitoring methodologies suggest resource per period following works completion? (3 yrs, 5, 10 – reducing?)

Figure 6.1.2 Scientific adviser responses to questions A to B above regarding data collection.

Funding

Under the title of 'Funding' the following questions were provided to facilitate discussion:

A. You have been given an outline framework with suggested % costs that should be used for project monitoring – do you agree with these, are they realistic from your perspective?
B. Where is the money likely to come from for project monitoring?

The outline framework that each group was provided with was:

15%	15-20%	20%
5%	10%	15-20%
(minimal cost)	5%	15%

Risk ↑

Scale →

These responses relate to questions A and B as detailed above.

Group	**Main conclusions**
Scientific Advisers	A) Suggest 20% minimum cost for low cost/low risk projects (due to small available budget) with prioritised list of essential to desirable monitoring methodologies. Up to 5% of budget for large scale/high cost projects (assuming this is a large budget of £5m or more). This 5% expenditure would be the minimum and could be exceeded by

	B) R&D funding. Money sources include ‘the project’, Water Framework Directive (WFD), River Basin Plans (RBPs) and R&D

Figure 6.1.3 Scientific adviser responses to questions A to B above regarding funding.

Policy

Under the title of ‘Policy’ the following questions were provided to facilitate discussion:

A. What is your Agency’s current approach to monitoring river restoration; is it likely to change in the future?
B. From a policy point of view what do you need to support river restoration and increase confidence in its potential importance in helping to deliver WFD objectives
C. Could the framework form part of the statutory consenting process?

These responses relate to questions A - C as detailed above.

Group	Main conclusions
Scientific Advisers	A) SEPA: Controlled Activities Regulations (CARs) – requirement for up to 5 years post project monitoring (as a minimum). Would use this framework as ‘best practice’ resource. EA Policy being drafted, this will mean that internal and partnership spend projects must have monitoring. Details still to be finalised. May well suggest that not all projects be monitored, but some be more intensively monitored (see R&D) B) Need more complete evidence base for restoration techniques if they are to be applied as ‘mitigation measures’

Figure 6.1.4 Scientific adviser responses to questions A to C above regarding policy.

R&D

Under the title of ‘R&D’ the following questions were provided to facilitate discussion:

A. What R&D do we need?

These responses relate to question A as detailed above.

Group	Main conclusions
Scientific Advisers	A) Reference to Freshwater Collaborative Research Partnership. Need for a central repository for data (ConsEvidence.com), could be an academic institution who would be willing to manage and 'work' the data. A co-ordinated partnership approach. Hydromorphology – Practical techniques, 'focus sites' with which to demonstrate & develop core science (in hydromorphology, pressures and responses). Research Council funding and Agencies funding for research into the R&D is needed. Need a strong consortium to take forward what is needed. R&D surcharge to project ~ 2% into a pot for experiments?

Figure 6.1.5 Scientific adviser responses to question A above regarding R&D.

6.2 Discussion and conclusions from technical groups

The information below summarises the questions that were asked to the technical groups (groups 2-6), the responses that each group gave, and highlights where similar discussions arose and common agreements were reached.

The Framework

Under the title of 'The Framework' the following questions were provided to facilitate discussion:

A. Specific methodologies: their applicability for river restoration monitoring – what are the techniques; how applicable are they to river restoration; and what are their limitations?
B. Project scale and risk – when and where would you apply the techniques; what are their estimated costs; where do the methodologies fit within the matrix; are there any gaps?
C. Agree the framework for your group's area of expertise – do the methods fit; if a consensus cannot be reached what are the concerns and variations in views?

Outcomes from this discussion that were common to more than one group include:

- In response to question C, several groups stated that it was difficult or impossible to assign specific methodologies to the framework as the methodology used will be so dependant upon the river, project and the location.

- Common monitoring methodologies that were chosen include: Physical biotope mapping, cross sections and aerial photography.

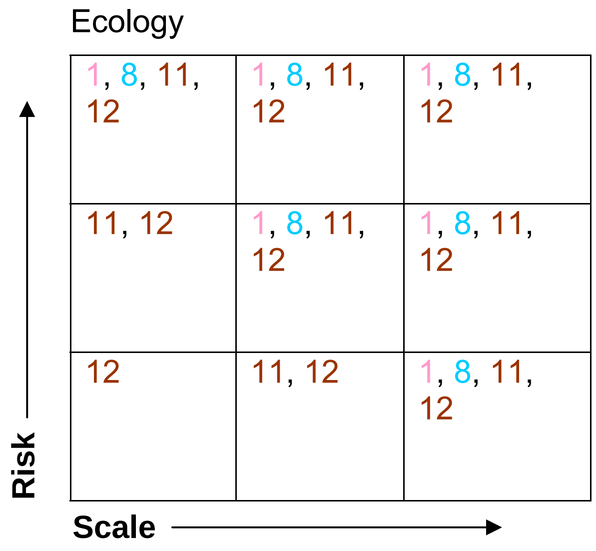
A more detailed output from each technical group.
These responses relate to questions A and B as detailed above. It has not been possible to provide details of the responses of each group to every question. The questions were provided to help facilitate discussion but in some instances not all of the questions were covered.

Technical group	**Main conclusions**
Ecology	A) The monitoring methods identified were qualitative, quantitative, photos and biotope mapping. The group concluded that it is not possible to be more precise about the recommended techniques as the most appropriate technique will be so dependant upon the river, project and the location. B) Monitoring should ideally cover spring, summer and autumn seasons.
Fisheries	A) The monitoring methods identified were: Eectrofishing (qualitative, semi-quantitative, quantitative) Angler Catch Data (active, passive) Hydroacoustic (fixed, mobile) Netting Trapping (eg. fyke, emergence) Counters Observation (eg. redd counts, spawning, RoV, diving) Tracking
Geomorphology	A) Methodologies used are for the most part adaptable and could be applied to restoration projects since they can take account of spatial and temporal variability. B) Estimated costs of methodologies: Airborne photography £2000 per hour – 10km Physical biotope mapping £500-£1000 - (reach based – 500m in-channel) Topographic survey £500-£1000 - 250m Fixed point photographs £300-£500 - 50 to 60 repeats per day Fluvial audits up to £1000 per day - 6km Cross-section survey £1000-£2000 - 18 sections over 1km Erosion pins £300-£500 - 50 repeats

Hydrology / Sedimentology	A) The monitoring methods identified were: Water level/flow - continuous Water quality Vegetation – riparian/floodplain Invert sampling Slope (river bed/energy) X-section/long-section Flood extent - Aerial photos, trash lines, anecdotal evidence Water table level Sediment deposition on floodplains LIDAR data B) Applicability of methodologies to monitor river restoration projects is dependant upon the size and risk of project Estimated cost of each methodology is too difficult to assess as it is very project dependant
Macrophytes	A) Potential methodologies identified for the framework are: Taxa mapping / transects based methodologies Taxa based methodologies Remote sampling based methodolgies.

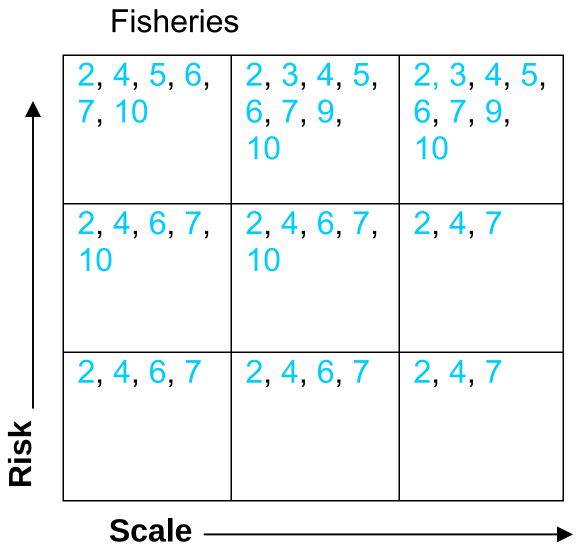
Figure 6.2.1 Groups' 2-6 responses to questions A and B above regarding the framework.

In response to question C each group discussed and agreed a framework of monitoring methodologies:



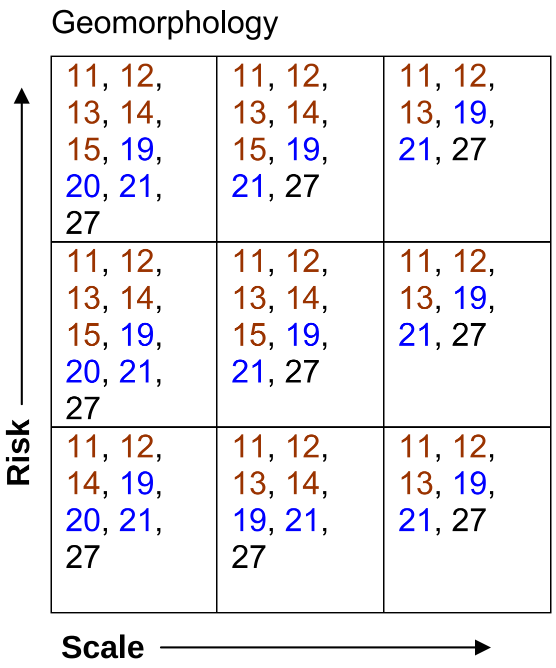
1, 8, 11, 12	1, 8, 11, 12	1, 8, 11, 12
11, 12	1, 8, 11, 12	1, 8, 11, 12
12	11, 12	1, 8, 11, 12

Figure 6.2.2 Agreed ecology framework



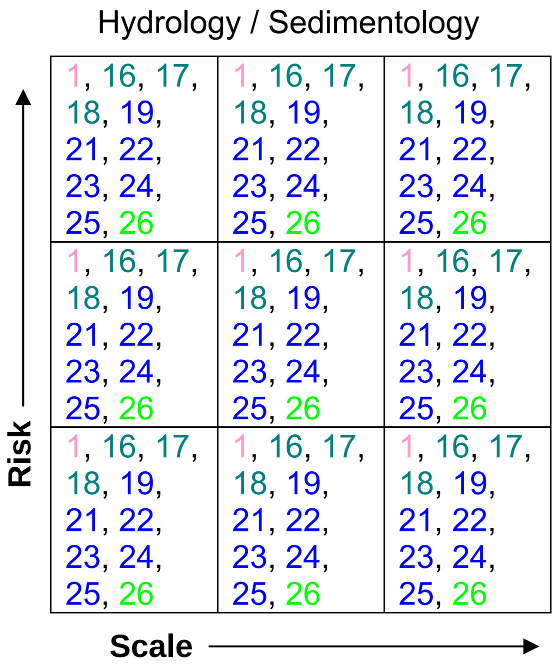
2, 4, 5, 6, 7, 10	2, 3, 4, 5, 6, 7, 9, 10	2, 3, 4, 5, 6, 7, 9, 10
2, 4, 6, 7, 10	2, 4, 6, 7, 10	2, 4, 7
2, 4, 6, 7	2, 4, 6, 7	2, 4, 7

Figure 6.2.3 Agreed fisheries framework



11, 12, 13, 14, 15, 19, 20, 21, 27	11, 12, 13, 14, 15, 19, 21, 27	11, 12, 13, 19, 21, 27
11, 12, 13, 14, 15, 19, 20, 21, 27	11, 12, 13, 14, 15, 19, 21, 27	11, 12, 13, 19, 21, 27
11, 12, 14, 19, 20, 21, 27	11, 12, 13, 14, 19, 21, 27	11, 12, 13, 19, 21, 27

Figure 6.2.4 Agreed geomorphology framework



1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26	1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26	1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26
1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26	1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26	1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26
1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26	1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26	1, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26

Figure 6.2.5 Agreed hydrology / sedimentology framework

Figure 6.2.6 provides a key to the monitoring methodologies featured in figures 6.2.2 – 6.2.5. The methodologies have been grouped according to the main discipline to which they apply e.g. Invertebrate sampling is widely considered as a method used to monitor the ecology of rivers whereas water level/flow monitoring is considered to be a method used to monitor the Hydrology / Sedimentology of a river. Some methodologies are applicable to more than one key discipline so have been grouped under multiple disciplines.

Ecology Methodologies
1. Invertebrate sampling (qualitative or quantitative)

Fisheries Methodologies

* Qualitative
▪ Quantitative

2. Angler Catch Data *
3. Counters ▪
4. Electrofishing ▪
5. Hydroacoustic ▪
6. Netting ▪
7. Observation *
8. Fisheries Sampling (Qualitative or Quanitative)
9. Tracking ▪
10. Trapping ▪

Geomorphology Methodologies
11. Habitat mapping (Biotype & RCS)
12. Fixed point photography
13. Fluvial audits
14. Geomorphological mapping
15. Topographic surveys

Hydrology / Sedimentology Methodologies
16. Water level/flow – continuous
17. Water quality
18. Water table level

Geomorphology & Hydrology / Sedimentology Methodologies
19. Airborne photography (digital, remote sensing & traditional aerial photography)
20. Bank erosion
21. Cross-sections
22. Long-section
23. Sediment deposition on floodplains
24. Slope (river bed/energy)
25. Trash lines

Macrophyte Methodologies
26. Vegetation – riparian/floodplain

Geomorphology, Hydrology / Sedimentology & Macrophyte Methodologies
27. Geo RHS

Figure 6.2.6 Key to monitoring methodologies grouped according to the main discipline to which they apply.

Macrophytes

Unfortunately the Macrophyte technical group were unable to agree on a framework of monitoring methodologies. The group considered the framework to be limited for macrophytes as they felt that methodologies should be selected according to the objective of the project, and not the risk or scale. There were many discrepancies within the group on when and how the methodologies and techniques should be applied.

Overview of group responses to questions regarding 'The Framework'

This summary includes the responses from the scientific advisers group and all technical groups. All groups agreed the idea of the Framework in principal and saw it as a good step forward. However, populating the Framework with methodologies proved to be a far more difficult process, with very few methodologies overlapping between groups. This illustrates the current lack of an integrated approach to monitoring and emphasises the need to establish a list of methodologies for monitoring river restoration projects that are applicable and accepted by all the relevant disciplines.

Fit for purpose

Under the title of ‘Fit for purpose’ the following questions were provided to facilitate discussion:

A. Does the suit of methodologies in the matrix you have agreed cover everything that you currently monitor; what variables are monitored and why
B. What other variables might you need from other disciplines to interpret your results?

Output from each technical group.
These responses relate to questions A and B as detailed above. It has not been possible to provide details of the responses of each group to every question. The questions were provided to help facilitate discussion but in some instances not all of the questions were covered.

Technical group	**Main conclusions**
Ecology	B) Variables required from other disciplines include: Habitat physiogoraphy / Hydromorphology Water quantity Water quality Macrophytes (architecture) Colonisation sources
Fisheries	A) Other methodologies that link to fisheries: habitat preference curves HABSCORE PHABSIM LIFE FCS EFI RFHI RHS These are useful but are <u>NOT</u> substitutes B) Other variables Depth, velocity, substratum (ie. fluvial audit info) Water quality
Geomorphology	A) Methods are generally flexible so can adapt to cover all geomorphological objectives B) Main variables required from other disciplines are from the hydrology and sediment parameters (e.g. velocity, bedload plus vegetation cover in terms of strength parameters afforded).

Hydrology / Sedimentology	A) Driven by objectives of scheme rather than the size and risk of scheme B) Links with other areas – can use data from macrophytes, geomorphology
Macrophytes	The group did not have time to discuss this section or any of the following sections as they spent a lot of time trying to come to an agreement about the framework!

Figure 6.2.7 Groups' 2-6 responses to questions A and B above regarding fit for purpose.

Overview of group responses to questions regarding 'Fit for Purpose'

This summary includes the responses from the technical groups only. The responses to this section were fairly broad. Most groups suggested that monitoring methodologies from other disciplines are required in order to interpret results, again re-emphasising the need for an integrated approach to monitoring.

Data collection (time and scale)

Under the title of 'Data collection' the following questions were provided to facilitate discussion:

A. What pre-project information do you need (time & scale)?
B. Post-project, how long ideally do you need to monitor to be confident that a project has reached its full potential.

Output from each technical group.

These responses relate to questions A and B as detailed above. It has not been possible to provide details of the responses of each group to every question. The questions were provided to help facilitate discussion but in some instances not all of the questions were covered.

Technical group	**Main conclusions**
Ecology	A) Monitoring for as long a time frame as possible ideally with a minimum of 2 years before B) Minimum of 2 years after at regular internals and then repeat during the 5th and 10th year.
Fisheries	A) Pre-project Fish Issue spotting - objective setting (w.r.t. drivers e.g. WFD) Habitat Limiting factor analysis (eg, water quality and quantity)

Geomorphology	A) Pre-project data – two fold issues a) reference condition need as much data as possible (spatial and temporal) b) base line information of project to define initial geomorphological conditions. B) Post-project – ideally up to 10 years at variable frequency
Hydrology / Sedimentology	Depends on objectives of scheme A) Minimum of one year pre-project monitoring, but preferably more, to pick up seasonal variations and range of flows Upstream and downstream boundary conditions need to be monitored to understand the complexities and interactions of the system. B) Post project monitoring: Floodplain vegetation should be carried out annually for 5 years then once every 3 years up to 20 years Substrate should initially be carried out more frequently (few times a year) and then tail off Flows should be monitored to gain as full a range of flows as possible – intelligent monitoring Fixed point photography noting flood levels and marking in flood flows Surface flows in flood – “pooh sticks”
Macrophytes	As already mentioned this group did not have time to discuss this section.

Figure 6.2.8 Groups’ 2-6 responses to questions A and B above regarding data collection.

Overview of group responses to questions regarding ‘Data Collection’

This summary includes the responses from the scientific advisers group and all technical groups. With regard to pre-project information all groups stated that enough information needed to be collected prior to restoration in order to be able to adequately diagnose the problem and propose an appropriate design. The geomorphology group highlighted the need have pre project information for a reference site as well as baseline data for the restoration site. In terms of how long data should be collected for prior to restoration, this varied from a minimum of 1 to 2 years. In terms of post-project monitoring there was a unanimous consensus that monitoring should be carried out for as long as possible post restoration in order to establish the effectiveness of the restoration works. In terms of time the groups suggested between 3 and 20 years worth of data was required – a fairly wide spectrum of opinion.

Costs

Under the title of 'Costs' the following questions were provided to facilitate discussion:

A. You have been given an outline framework with suggested % costs that should be used for project monitoring – do you agree with these, are they realistic from your perspective?

The outline framework that each technical group was provided with is the same as that provided to the Scientific Advisers (as shown on page 27 of this document).

Output from each technical group.
These responses relate to question A as detailed above. It has not been possible to provide details of the responses of each group to every question. The questions were provided to help facilitate discussion but in some instances not all of the questions were covered.

Technical group	**Main conclusions**
Ecology	It is possible to learn a lot from monitoring small scale, low risk projects. If the resources are available to intensely monitor such projects then they should be utilised. A) Flagship projects might have a monitoring budget beyond the scale of the matrix: 30% in order to carry out R&D and PhDs to give highly detailed, intense, focused monitoring.
Fisheries	A) No limit - interactive process as appropriate within decision process Cost guidelines: < £500: Observation, Angler catch £500- £1000: Electric fishing, Netting, Trapping >1000: Hydroacoustic, Counters, Tracking
Geomorphology	A) Suggest a change in framework in terms of % cost – keep much the same (10-15%) for each position in the matrix. In some cases monitoring costs might actually be higher in terms of % for smaller low risk projects.

<table>
<tr><td>Hydrology / Sedimentology</td><td>A)
Risk ↑<table>
<tr><td>15 - 50%</td><td></td><td>10 - 30%</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>5 – 40%</td><td></td><td>2 - 20%</td></tr>
</table>Scale →</td></tr>
<tr><td>Macrophytes</td><td>As already mentioned this group did not have time to discuss this section.</td></tr>
</table>

Figure 6.2.9 Groups' 2-6 responses to question A above regarding costs.

Overview of group responses to questions regarding 'Costs'

This summary includes the responses from the scientific advisers group and all technical groups. The conclusions from the groups with regard to cost were very varied, some stated that small scale - low risk projects should have 20% of their budget allocated to monitoring whilst others suggested a scale of 5-40% of the budget. For large scale – high risk projects the suggested percentages varied from 5–30%. Whilst other groups suggested that all projects, regardless of scale or risk should have a monitoring budget of 10-15%. The variation in suggestions is perhaps a result of differing ideas between academics and practitioners – demonstrating the difficulty in balancing a purely academic point of view with a more pragmatic approach.

Seminar – Day 2

7. Summary of Presentations

7.1 Towards an integrated approach to monitoring and adaptive management: perspectives from a geomorphologist and fisheries ecologist - David Sear & Andrew Gill

Refer to Appendix C of this document for presentation slides

David Sear's key message was that we need to think about how we go about monitoring. There needs to be a method that considers how best to integrate different approaches from the various physical and ecological disciplines. It also needs to take into account what spatial and temporal scales are most appropriate for the level of monitoring being completed. A nested approach would be one way forward which considers river features at the patch, reach, segment and catchment scales. David highlighted that research on the New Forest restoration site had already shown that understanding what scale to monitor at was essential to being able to adequately answer initial questions. For example, where data was collected at the catchment scale, the reach scale restoration signal was lost in terms of identifying project success. Instead, it was necessary to ensure that data collection and analysis focused on the patch scale; restoration success could then be detected.

It is also essential to think about where and when we monitor. David showed a slide based on work completed by Rutherford *et al* (2000) that posed questions about how to reduce uncertainity in monitoring outputs. To achieve this it was suggested that monitoring must have repeatable measurable data collection points, a control site, and sampling before and after. Clearly this has a cost implication and therefore, perhaps full scale monitoring for research needs to be limited to some key restoration sites.

One way of dealing with monitoring is to consider why we are monitoring (i.e. is it to improve scientific evidence of scheme success or as part of an adaptive management approach to identify when future management is needed)?

What is therefore, needed is a baseline monitoring evaluation. David made reference to a set of monitoring protocols completed in the Pacific north-west, USA (Roni 2005) which could provide a basis for a similar protocol in the UK.

He suggested some ways in which a monitoring protocol could be set up. In summary this included:

- Improving and increased dialogue between disciplines.
- Establishing knowledge gaps and fill through R&D Projects.
- New use of existing datasets.
- Trialling of monitoring methods & techniques.

- Defining monitoring schemes for specific management requirements (not just WFD!).
- Disseminating the knowledge via a monitoring handbook

Andrew Gill followed on from David Sear by identifying practical steps that can be taken towards adapting an integrated monitoring approach. Andrew emphasised that in order to meet the need for an integrated approach to monitoring and adaptive management, river restoration should bring together the many natural and human related components that characterise the river as it is now. By bringing these components together a whole system integrated approach to conserving, enhancing and promoting the riverine and associated ecosystem processes & functions can be adapted.

The components that are used to characterise the river should encompass all of the following: the physical properties and attributes of the water and the channel; the chemical properties of the water; the biology (from flora to fauna); temporal and spatial aspects and most importantly the ecology (i.e. the interaction between the biological components and the environment that they are present within). In order to achieve the coverage of the components it is necessary first to have a well defined objective and then scope out the main components that have to be taken into account to meet the objective.

Scoping out the characteristics of a project is a fundamental feature of Environmental Impact Assessments (EIA) hence there is a toolkit of methodologies that already exist that can be applied in a river restoration project to identify the components that should be included for integrated management. The EIA methods ensure that each component is looked at and either included or excluded from the components that need to be quantified and assessed. Furthermore they can highlight the need for more data collection that crosses over the boundary between existing topics, thereby requiring separate disciplines to work together.

To truly integrate monitoring and adaptive management for river restoration we need to ensure that the methods used actually utilise integrated methodologies.

8. Site Visit

For the purposes of the second day of the seminar, attendees were divided into multi-disciplinary groups. The second day provided an opportunity to think laterally and to consider how, as a group, we could formulate a structured and integrated way of monitoring to help solve some of the current concerns over the usefulness of monitoring results for river restoration.

To encourage the groups to develop an applied approach to integrated monitoring a site visit was arranged to the Highland Water restoration project. This site was restored as part of the Life 3 Project - an EU LIFE-Nature funded restoration project in the New Forest.

Key information on the Highland Water Project

Background

Headward erosion, induced by downstream activities, had lowered the bed and removed much of the natural gravel substrate, exposing the deeper clays. This has resulted in a channel with little native bed material, 1m+ deeper than expected, reduced over bank frequency, and poor habitat for spawning Sea Trout, Bullhead and Lamprey. There was little evidence of active processes and no opportunity for self-repair.

Objectives:

- To restore the natural hydrological processes necessary to re-instate connectivity between the river & the floodplain & support seasonal inundation. This action should lead to conditions suitable for the development of wet woodland and analogous with those found in other wet woodland sites within the catchment
- To restore geomorphological processes both in-stream & on the floodplain analogous with those found in other wet woodland sites within the catchment
- To conduct the restoration works in such a way that there is no net increase in flood risk to people & property.
- To provide an environment capable of supporting the appropriate balance of invertebrate & fish populations indicative of this catchment.
- To restore environmental conditions required by the Natura 2000 priority habitats.

Based on the background information and objectives, as stated above, whilst on site each group of attendees were presented with a scenario - if they were asked to monitor this site how would they go about it?

The following questions were provided to help facilitate discussion:
- Which methodologies would you employ?
- Where would you locate your monitoring points?
- What would be your sampling density? (Time and space)
- Will these methods be compatible with each other?
- Does this matter; will it add value to the results and appraisal or not?

Each group was provided with a site map and asked to discuss their methodologies, location of points and sampling strategy as a whole. Attendees were asked to consider whether the sampling protocols for each methodology could be overlapped, or are some methodologies less adaptable than others?

The groups were given approximately one hour on site to discuss their ideas.

Overview of sit visit

The time spent on site proved to be very worthwhile, it gave delegates the opportunity to think about how they might go about devising an integrated monitoring project.

A number of delegates commented that at present most monitoring schemes are designed without much cross disciplinary discussion, resulting in a very unintegrated approach. By discussing their approaches to monitoring delegates were able to see how an integrated approach can successfully be achieved. Whilst discussing the finer point of their monitoring schemes on site, such as sampling location points, it was evident that if each discipline is involved in the monitoring design process then it is possible for the same sampling points to be used to collect different variables, and that many methodologies are fairly flexible in this respect.

Many delegates said that this theoretical exercise provided good demonstration of how to develop an integrated approach and suggested that they would seriously consider using this approach in the future.

9. Summary of Workshops

For the afternoon workshops the attendees remained in the same multi-disciplinary groups that they were in for the site visit. The focus of the afternoon workshops was to further discuss how an integrated approach to monitoring could be adopted. It was felt that this was important in order to provide information on the physical and biological changes occurring on a restoration site, with each discipline feeding into the results of others.

Each group was given a list of questions to discuss and was asked, for the purposes of the workshop, to base their discussion around the Highland Water restoration site, but to, at the same time, also consider wider issues related to integrated monitoring.

Discussion and conclusions

The main discussion points focused on 'Integrated Monitoring' and 'The Framework'. Under the title of 'Integrated Monitoring' the groups were asked to consider how integrated their monitoring approaches were, based on their onsite discussion; whether there is potential to adapt methodologies to develop a more integrated approach; and should monitoring be confined or adapt to changes in the physical processes. Under the title of 'The Framework' the groups were asked to decide where the Highland Water restoration site fell within the framework (discussed on the first day), and to consider whether the monitoring methodologies proposed for that position in the framework tie up with the methodologies discussed on site: does the framework work in practice.

These discussion points lead into three key questions that each group was asked to directly respond to. The questions were:

A. Is there a need for a more integrated approach to monitoring?
B. Should one person from a specific discipline coordinate the compilation of results? Is this dependent on the key objective(s) of the restoration project? How will the role vary between different cells of the framework?
C. Refer back to the framework with % costs for each cell (page 27 of this document). Is this sufficient for data collection AND analysis? Should 'analysis' top-slice the funds available (10% of the 10%)?

The information below summarises the responses that the groups gave to questions A-D above.

Group	Main conclusions in response to Question A
1	Yes
2	Dependant on objectives, but if all disciplines are involved then co-ordination is essential.

3	Yes, an integrated approach to river restoration and to monitoring is required. This is a key component in helping people to understand other disciplines.
4	Yes
5	Yes, there is a need to ensure that monitoring is integrated between the disciplines involved.
6	Yes, methodologies are there but they need to be integrated better.

Figure 9.1 Groups' responses to question A above regarding the need for a more integrated approach to monitoring.

Group	Main conclusions in response to Question B
1	Need someone with overview to pull together information. This person should have a good knowledge of statistics. It is important to have a central place to keep the information.
2	Can be a non-expert but if it was an expert than a geomorphologist would be well placed to undertake this work. Disciplines need to be co-ordinated.
3	Yes, a project coordinator / manager
4	Definitely need one person as a lead. It does not matter which discipline but the person needs to be able to draw together the different disciplines, it is more the skills of management rather than the skills of a discipline. The effectiveness of this role is highly dependant upon the individual person. It might be a good idea to have a technical manager and a project manager. There should be a manager that just manages the monitoring in order to remain better focused.
5	There is a need for a central individual to coordinate a monitoring programme; to lead, compile, receive data and deliver conclusions. It was felt that a good generalist was preferable to a specialist, to reduce the temptation to concentrate on one perspective.
6	Yes, someone with an overview, does not need to be discipline specific. Role will vary again depends on objectives and who is available and capable of doing it (size of team, disciplines etc).

Figure 9.2 Groups' responses to question B above regarding coordination of the monitoring by one person from a specific discipline.

Group	Main conclusions in response to Question C
1	*No conclusions reached with regard to this question*
2	There was a suggestion that in the top right the budget for monitoring should be more like 25%.
3	The percentages could be a bit bigger – as much time should be spent analysing the data as collecting it, if data is not properly stored and referenced then it becomes worthless.
4	The objectives determine the analysis, but the cost of this process was largely overlooked in the discussions on the first day. Greater percentages should be given the high risk, large scale area of the matrix. We could give a range of percentages, this range will be small at the bottom left and wider at the top right. The level of analysis, on the same data set, can be very different depending on the desired outputs.
5	As a concept, the group were supportive of top-slicing 10% of the monitoring budget to cover the analysis period. This might be the project manager or, as discussed above, a coordinator for the monitoring only.
6	Intensively monitored, flag ship (gold medal) projects need more investment – analysis should be integral to monitoring, showing an ongoing commitment (i.e. iterative process). 10% of 10% not sufficient for analysis.

Figure 9.3 Groups' responses to question C above regarding % costs within the framework.

Overview of group responses to questions regarding 'an Integrated Monitoring Approach' and 'The Framework'

All of the groups were in agreement that a more integrated approach to monitoring is required and this is perhaps best achieved through having one person coordinating the monitoring scheme. However, a consensus of opinion was not reached over which discipline this person should be from. Some groups suggested that the discipline would depend upon the objectives of the projects whilst others felt that a generalist would be best placed in this position, another group identified that knowledge of statistics was an important criteria.

With regard to the cost and consideration of analysis as well as data collection, most groups felt that the percentage costs for each cell should be increased to allow adequate resources for analysis, although the level of analysis required will depend upon the desired outcomes of the monitoring scheme and hence the project objectives.

Finally the groups were asked if is there was anything else they would like to highlight that had not been covered in the seminar.

The key points highlighted were:

Monitoring methodologies, techniques and analysis
- We now need to think about how methods are applied to specific objectives?
- Can we develop existing tools such as RHS?
- Need some standards for monitoring and methods
- Should we consider more extensive monitoring at a lower intensively as a way forward?
- We need to think about the potential of large scale integrated catchment projects to test monitoring methodologies and techniques
- When do we leave rivers alone – managed retreat and do nothing options – does this need monitoring as well?
- Why we are monitoring – scientific gain or adaptive management?
- How do we disseminate and store data?

Further seminars and courses
- A further seminar needs to be organised that takes account of socio-economic issues
- We need to further address floodplain restoration and monitoring as this was not dealt with adequately within the two days
- Needs to be more courses on integrated science in relation to river management for students

Overview of other points not covered in the seminar

The points above provide an indicator of the next steps that might be taken to progress the development of designing a best practice approach to monitoring. As you can see, there are still a lot of questions being raised and a lot of work that needs to be done. However, the RRC feels that this seminar was an important step forwards and that it has been effective in achieving its original objectives.

Further work and steps will be taken in order to continue the process towards developing a best practice approach to monitoring, which is based on sound science, but is also feasible to implement given inevitable cost constraints.

10. Feedback Forms

The main aim of the feedback forms was to provide the RRC with an assessment of:

1. Whether of not delegates were prepared to sign up to the framework and if not why
2. Suggestions for ways forwards and future seminars
3. Suggestions to improve the framework
4. Suggestions for finding and collating missing data
5. A list of delegates prepared to help with the delivery of a monitoring manual/handbook

Of the 41 delegates who attended the conference responses were received from 33 (80% of total attendees).

1. Agreement to sign up to Framework:

The graph below shows the make of responses. For additional responses and provisos however, please read the text below.

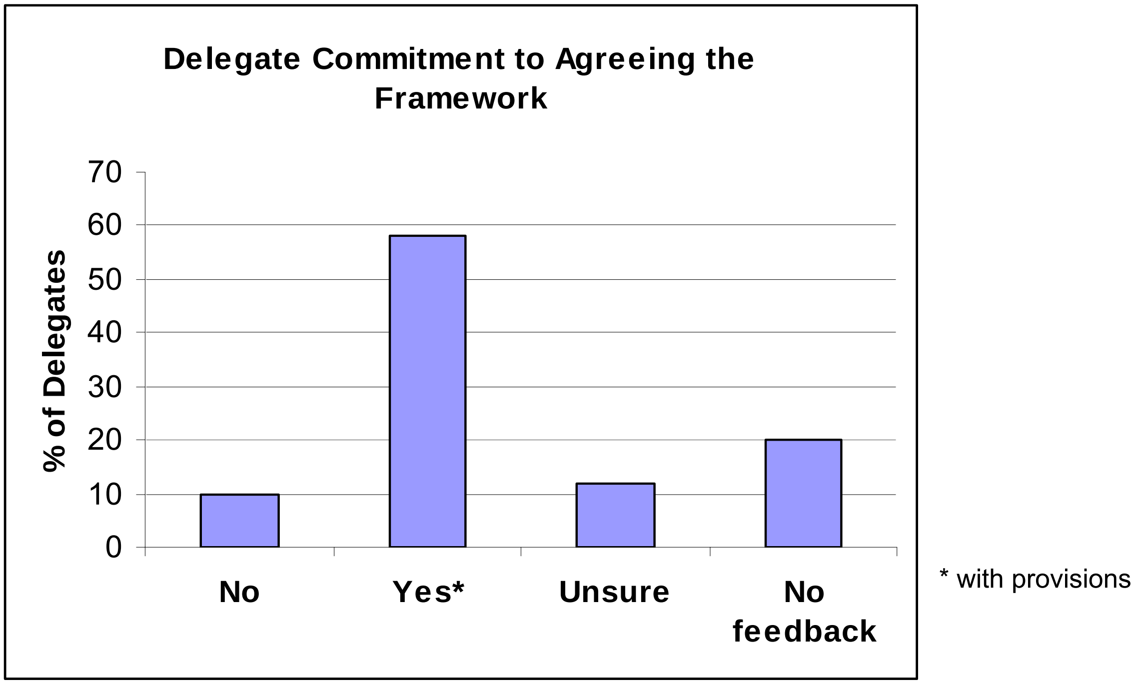


Figure 10.1 Commitment to framework

4 delegates (10% of total attendees) said No to signing up to the framework

Of those that said No, the main concerns were:

- Any framework needs to be embedded with an understanding of the project objects and without this information within an overall protocol a framework of this nature may be subject to misuse or misinterpretation.
- There needs to be a clear distinction made between the need for R&D type monitoring and the need for project appraisal for the purposes of adaptive management (i.e. what can be delivered and how this affects the monitoring protocol).
- Floodplain issues were poorly represented and this needs to be resolved before a true representation of monitoring protocol can be delivered.
- The framework could be useful but needs to be set in the context of a wider framework.
- There is still concern that the methods themselves are unsuitable for restoration assessment and there needs to be more opportunity to discuss these points.

24 delegates (58% of total attendees) said Yes to signing up to the framework. However, there were some reservations amongst these that included:

- Provides a good way forward and potentially a useful guide but should be used with the cautionary note that it is recommended that expert advice be sought.
- Any manual or recommendations must include an explanation about how to design your experiment and how to tie this in with project targets (i.e. why are you monitoring). Within this context it also needs to be clear about when there is no point to monitor and thus some value limits need to be expressed.
- The framework needs to sit within a wider package of decision making tools and take account of the needs of the WFD.
- This is only the first step, but could have value as a driver for further R&D work.
- Any follow on output from the seminar needs to clearly state that any monitoring must be related to clear objectives which then define how you complete you experimental design.
- Need to define what can be considered as minimum acceptable practices for river restoration monitoring (e.g. even if this is repeat photography for all projects).
- Need to highlight concerns about methodology replicability (this may be part of future research design).
- This provides the basis for a bio-physical framework but needs to be balanced with social and planning aspects.

5 delegates (12% of total attendees) remained unsure are to whether or not they were prepared to agree with the framework.

From those who were unsure concerns were expressed that there needed to be more thought about how to interpret the framework. What was needed was to extend the framework to enable guidance on which technique to use and when and explain how to set up the methods and which ones to choose. Amongst this group there was also a feeling that there would need to be more definition on risk.

2. Future seminar suggestions

Suggestions included:

- Repeat the seminar for social impacts and planning.
- How does it fit with the WFD? – Need to think about protocol for large scale projects where there is the need to measure the effectiveness of measures applied extensively.
- Smaller evaluation protocol group to complete handbook/manual.

3. Frameworks suggestions

Suggestions included:

- The cost of projects might be a better axis with a list of methods based on scheme objectives.
- Need to think more clearly about risk and scale issues.

4. Those happy to be involved in developing a handbook/manual:

Delegates were asked to indicate if they were interested in being involved in developing a handbook/manual. Delegates who responded positively included:

Kathy Dale
Helen Dangerfield
Stuart Downward
Maxine Elliot
Judy England
Karen Fisher
Nicolai Friberg
Andrew Gill
Terry Langford
Richard Lansdown
David Sear
Kevin Skinner
Angus Tree
Jenny Wheeldon

11. Discussion

The seminar confirmed the need for an integrated monitoring protocol which could help practitioners evaluate what type/level of monitoring is required for a given river restoration project objective. It was generally envisaged that the framework put forward as an option at this seminar, based on work completed by England *et al* (in press), could form part of a more encompassing protocol. As such, it provided a useful initial step towards achieving a more integrated approach to monitoring. Generally, it was agreed that there in now an urgent need to address questions about what constitutes success in terms of habitat enhancement criteria since river restoration is now high on the agenda as a potential way forward to achieving good ecological status as required by the Water Framework Directive.

Whilst most delegates agreed that a monitoring framework to help guide people towards carrying out 'best practice' monitoring was a good idea, there remained reservations and questions about how best to tackle this. As such this seminar was seen as a good way of bringing together people who were committed to forwarding the idea of implementing an industry standard 'handbook' (perhaps similar to the fluvial geomorphology handbook for example).

There was a positive approach to the seminar agenda and what it was trying to accomplish. It did however, highlight variability in approaches between disciplines which clearly needs to be given more consideration before any integrated protocol can be achieved. For example, ecological sampling is generally viewed *initially* in terms of qualitative or quantitative data collection approaches, whilst geomorphologists' main concerns tend to focus on temporal and spatial variability. Even though both disciplines may take account of all these parameters, the way in which they approach data collection varies and therefore this may make agreeing an integrated protocol more difficult. Variation between disciplines most clearly manifested itself through the variation in terminology used for what is essentially the same method; similarly, how outputs are analysed may be very different.

Another positive output from the seminar was that although some new methods were being developed as part of research and design there was also recognition that perhaps a more cost effective and pragmatic way of approaching river restoration and management monitoring, was to look for ways to adapt current methodologies to answer the specific questions posed as part of restoration objectives.

There was much discussion about the level of monitoring that should be applied to projects and what % of overall cost should be used for data collection and analysis. On the one hand a view was expressed that there should be large scale integrated catchment research projects to test monitoring; conversely, in the case of small low cost projects it was felt that there should be a higher % of the overall cost dedicated to the project appraisal since often simple low cost techniques can adequately answer questions posed.

Differentiating between answering research questions as opposed to identifying future adaptive management needs was highlighted as one way forward to help decide on what level on monitoring is required. Along side this it was felt that there was already a lot of pre- and post-project data available but that this was not readily accessible to the scientific community and as such there was a need for data collation and central storage to enable more efficient dissemination.

It was recognised that much monitoring currently being carried out (although not all) is via agency standard data collection methods and protocols. Whether this data is then analysed in terms of restoration objectives remains questionable. This then poses questions about methods and techniques being ‘fit for purpose’ (i.e. are existing techniques adequately designed to answer river restoration projects objectives or is the design robust but the application of the techniques not sufficiently related to specific river restoration objectives to answer questions)?

Relating initial objectives to the restoration protocol was a theme that ran throughout the two days and culminated in the suggestion that, if we are to work within a framework such as the one posed, we should consider applying it to each objective. Equally important was the notion that we need to think about river restoration monitoring in the context of re-establishing a new equilibrium of post-disturbance state. If river restoration monitoring is approached in this context then it should become more feasible to improve understanding of where a restoration may be successful and its limitations and therefore, reduce project risk and uncertainty.

12. Conclusions and next steps

The seminar provided a good starting point for considering the way forward to design an integrated monitoring protocol. It clearly identified the need to pull together a team of interested parties to deliver this, whilst at the same time embarking on a research and development programme to determine the degree of uncertainity that should be applied to different methodologies when trying to assess restoration objectives and whether or not their adaptation for specific restoration objectives could reduce uncertainty levels.

Any future protocol will need to ask questions about how well it fits in with the Water Framework Directive requirements where there is a need to measure the effectiveness of measures applied more extensively.

As such the next steps fall into 4 key categories:

1. Disseminate the information from this seminar to a wider audience.
2. Use the information collected during this seminar and other feedback mechanisms to help develop the way forward for developing an integrated monitoring protocol/handbook.
3. Consider how best to test existing monitoring tools through a research and development programme.
4. Undertake a ‘data mining’ activity to collate current available data and determine its usefulness in terms of increasing scientific evidence for the value of implementing river and floodplain restoration.

Appendix A

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Appendix B

Delegate List and List of Projects where Monitoring has been carried out

Delegate List

	First name	Surname	Organisation
1	Colin	Bean	Scottish Natural Heritage
2	Andrew	Brookes	Jacobs Babtie
3	Matt	Carter	Environment Agency - Thames Region
4	David	Corbelli	Environment Agency - North West Region
5	Kathy	Dale	Northern Ecological Services
6	Helen	Dangerfield	Haskoning UK Ltd
7	Mark	Diamond	Environment Agency - Head Office
8	Stuart	Downward	Kingston University
9	Maxine	Elliott	EA - Southern Region
10	Judy	England	Environment Agency - Thames Region
11	Alice	Fellick	River Restoration Centre
12	Karen	Fisher	KR Fisher Consultancy Ltd
13	Allan	Frake	Environment Agency - South West Region
14	Nikolai	Friberg	Macaulay land use research institute
15	Andy	Gill	Cranfield University Silsoe
16	Dave	Gilvear	University of Stirling
17	David	Gowing	Open University
18	Stuart	Grieg	Scottish Environmental Protection Agency
19	Di	Hammond	Entec
20	Nigel	Holmes	Alconbury Environmental Consultants
21	Martin	Janes	River Restoration Centre
22	Terry	Langford	Prof T E L Langford
23	Richard	Lansdown	Ardeola Environmental Services
24	Vaughan	Lewis	Windrush AEC
25	Chris	Mainstone	English Nature
26	Alistair	Maltby	Association of Rivers Trusts
27	Jenny	Mant	River Restoration Centre
28	Marc	Naura	Geo Data
29	Matty	O'Hare	Centre for Ecology and Hydrology
30	Steve	Ormerod	Cardiff University
31	Graeme	Peirson	Environment Agency
32	James	Pretty	Queen Mary - University of London
33	Neil	Punchard	Wessex Water
34	Roy	Richardson	Scottish Environmental Protection Agency
35	Monica	Rivas - Casado	River Restoration Centre
36	Dave	Sear	Southampton University
37	Iain	Sime	Scottish Natural Heritage
38	Kevin	Skinner	Jacobs Babtie
39	Fran	Southgate	Sussex Otters and Rivers Project Officer
40	Angus	Tree	Scottish Natural Heritage
41	Rebecca	Wade	University of Abertay - Dundee
42	Nick	Wallerstein	Nottingham University
43	Jenny	Wheeldon	Natural England
44	Sue	White	Cranfield University

Projects

In the questionnaires completed prior to the seminar delegates were asked to provide information on projects they had been involved with to give some idea of what was monitored as part of these projects. Comments are summarised.

Project name	**What was monitored?**	**Project scale l=length w=width**	**Pre-project data?**	**How long was monitoring carried out for?**	**Project cost/ monitoring budget?**	**Project risk in terms of technique 1=low 3=new**
Amesbury	Fixed point photos, RCS and fluvial audit and RRC	800m (L) 20m (W)				2
Brent, Tokyngton Park	Invertebrates, RHS, RCS and many other aspects	150m (L) 5-10m (W)	Y	5 years		2
Cole at Coleshill	Many aspects	2km (L) 3-10m (W)	Y	Ongoing for 11 years	200k/250k	3
Crane	Invertebrates	100m (L) 5m (w)	Y	4 times a year for 3 years prior to restoration and 5 years after	1M/7K	1
Crickdale, North meadow	Water tables and macrophytes	1km (L) 200m (W)	Y	9 years with macrophytes annually and water levels continuously	Research cost/3K	1
Darent	Visual, fish, invertebrates	350m (L)	Y	On going	1.5K/in house	2
Dockens Water	Fixed point photos and RRC assessment	100m (L) 3m (W)				1
East Chisenbury R Avon	Macrophytes, depth, velocity	100m (L) 12m (W)	Y	Twice a year for 3 years	12K/2K	1
East Cottingwith	Macrophytes, water table and sediment deposition	1km (L) 500m (W)	Y	3 years post completion	30K/10K	2

Project name	**What was monitored?**	**Project scale l=length w=width**	**Pre-project data?**	**How long was monitoring carried out for?**	**Project cost/ monitoring budget?**	**Project risk in terms of technique 1=low 3=new**
Fovant	Fixed point photos, RCS and RRC assessment of techniques	800m (L) 15-20m (W)		2 years post		3
Hale	Fixed point photos and RRC assessment	750m (L) 25-30m (W)				2
Hawkcombe Stream	Channel geometry, sediment loads	4500m (L) 15m (W)	N			3
Highland water	Invertebrates	2km (L) 305m (W)	Y	Once per year		1
Kennet- Oxford	Many aspects	6 sites up to 700m (L)	Y	Variable but up to 3 times after completion	Approx 500K/100K	2
Laeca Burn, Aberdeenshire	Macrophytes, physical condition and fish counts	500m (L) 1m (W)	Y	Once – 2 years after scheme		2
Llyn Brianne	Ecological		Y	3-6 years pre, 20 years post		2
Mimram, Archers Green	Invertebrates, gravel interactions	100m (L) 10m (W)	Y	3 years		1
Nith	Cross sections, habitat indicies	3km (L) 8m (W)	Y	3 times a year, 3 years intensively and then for 15 years	1.5m/5-10k per annum	2
Quaggy	Geomorphology	2km (L)	Y	4 times a year		2
Rib Gatesbury, Hertfordshire	Invertebrates, habitat, macrophytes	20m (L) 6-10m (W)	Y	3+ years		2
Shopham Loop	Many aspects	2km (L) 10m (W)	Y	Water levels over 3 years		1
Skerne, Darlington	Many aspects	2km (L) 7m (W)	Y	Up to 3 years	400k/100k	3

Project name	**What was monitored?**	**Project scale L=length W=width**	**Pre-project data?**	**How long was monitoring carried out for?**	**Project cost/ monitoring budget?**	**Project risk in terms of technique 1=low 3=new**
Sinderland Brook	Topographic and fixed point photos	1.3km (L) 0.5m (W)	Y	As built and after 8 months. Photos monthly		2
South Woodford	Fish, macrophytes, geomorphology, RHS, photos, and RRC assessment of techniques	800m (L) 20-30m (W)	Y	2 years post		3
Tilmore Brook	Morphological adjustment	600m (L) 10m (W)	Y (limited)	3 times per year post construction	300K/5K	3
Waverley	Integrated various aspects	40km (L)	Y	Under review		1
Wensum, Bintree, Norfolk	Fish and invertebrates	500m (L) 7-10m (W)	Y	Just post completion and then 4 visits within first year.		2
Wetland project, New Forest	Geomorphology, hydrology, fish, invertebrates, macrophytes, topography	10km (L)	Y	3-4 years after completion	2.5M/?	3
Woodford and Seven hatches, Wiltshire	Fish, macrophytes, geomorphology, RHS, photos, cross sections, Depth-Velocity-Slope (DVS) and RRC assessment of techniques	1.5km (L) 10-15m (W)	Y	Pre and post – once each	190k/40K	3
Wye and Usk Foundation	Ecology and salmonids		Y	3 years post		2
Wye habitat improvement project	Salmonids	5km^2	Y			2

Appendix C

PowerPoint slides for presentations on day one and two of the Monitoring Seminar

Monitoring Workshop
12th – 13th September

the River Restoration Centre
Working to restore and enhance our rivers

SCOTTISH NATURAL HERITAGE

ENVIRONMENT AGENCY

SEPA
Scottish Environment Protection Agency

River Restoration Centre

- Information and Advice centre
- Supporting project and linking to science

- Themed Workshops
  - RR and Sustainable Land Management (1999)
  - RR and Chalk Streams (2001)
  - RR and Geomorphology (2001)
  - RR and Post Project Appraisal (2002)
  - RR funding (2003 & 2004)

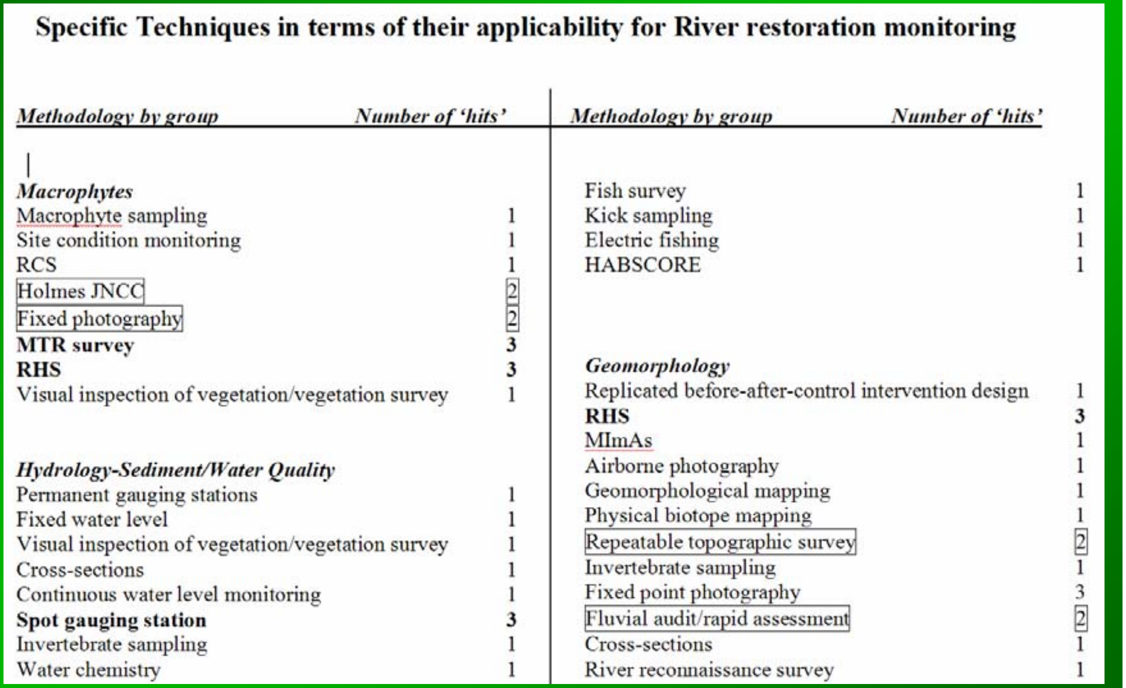
This workshop

- Monitoring – application to river restoration
  - Conceptual: what we aspire to
  - Practical: what is being undertaken
- What should be best-practice?

(at its simplest: can it be used by everyone?)

- Consensus – framework, detail, integration
- How to disseminate it?

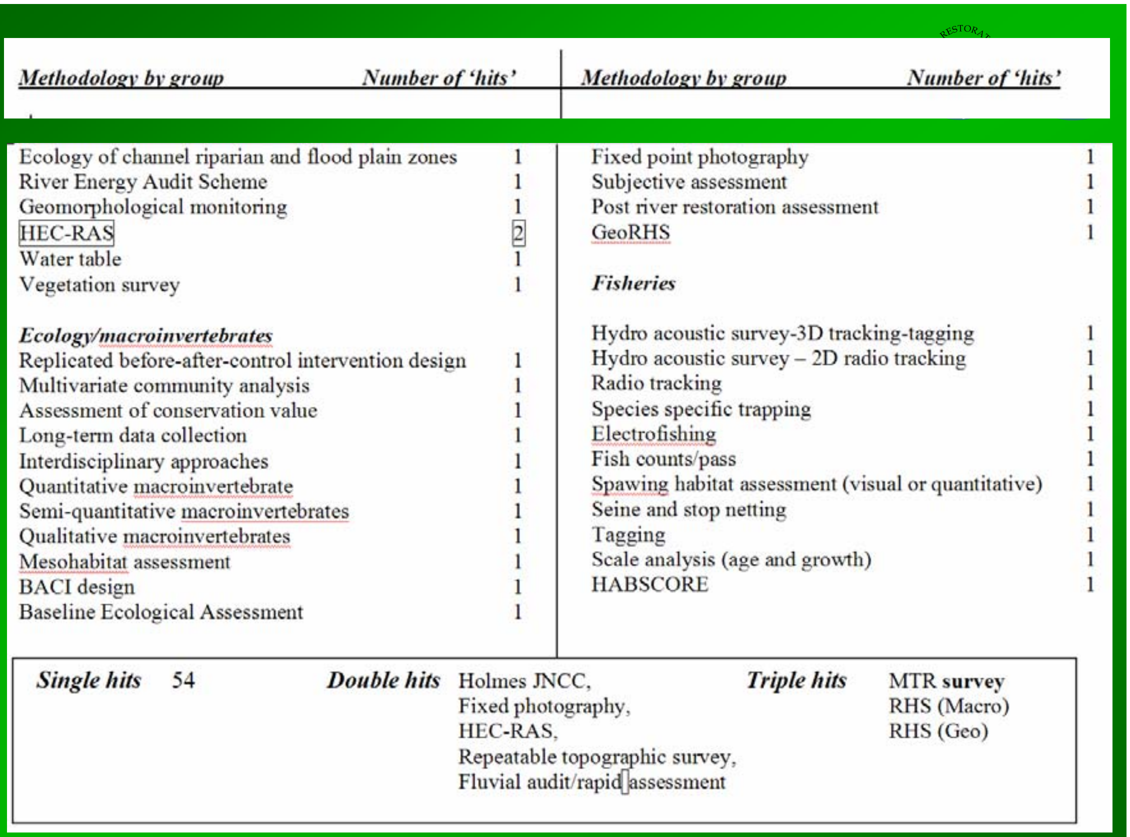
Questionnaires



Specific Techniques in terms of their applicability for River restoration monitoring

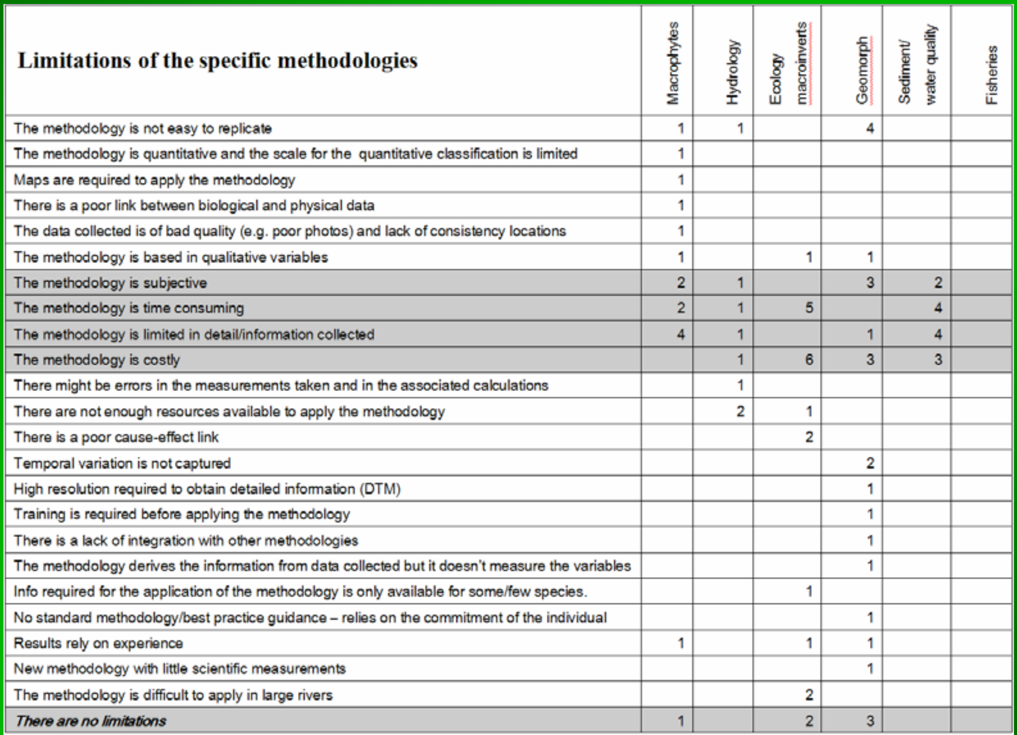
Methodology by group	*Number of 'hits'*
Macrophytes	
Macrophyte sampling	1
Site condition monitoring	1
RCS	1
Holmes JNCC	2
Fixed photography	2
MTR survey	**3**
RHS	**3**
Visual inspection of vegetation/vegetation survey	1
Hydrology-Sediment/Water Quality	
Permanent gauging stations	1
Fixed water level	1
Visual inspection of vegetation/vegetation survey	1
Cross-sections	1
Continuous water level monitoring	1
Spot gauging station	**3**
Invertebrate sampling	1
Water chemistry	1

Methodology by group	*Number of 'hits'*
Fish survey	1
Kick sampling	1
Electric fishing	1
HABSCORE	1
Geomorphology	
Replicated before-after-control intervention design	1
RHS	**3**
MImAs	1
Airborne photography	1
Geomorphological mapping	1
Physical biotope mapping	1
Repeatable topographic survey	2
Invertebrate sampling	1
Fixed point photography	3
Fluvial audit/rapid assessment	2
Cross-sections	1
River reconnaissance survey	1



Methodology by group	Number of 'hits'	Methodology by group	Number of 'hits'
Ecology of channel riparian and flood plain zones	1	Fixed point photography	1
River Energy Audit Scheme	1	Subjective assessment	1
Geomorphological monitoring	1	Post river restoration assessment	1
HEC-RAS	2	GeoRHS	1
Water table	1		
Vegetation survey	1	***Fisheries***	
Ecology/macroinvertebrates		Hydro acoustic survey-3D tracking-tagging	1
Replicated before-after-control intervention design	1	Hydro acoustic survey – 2D radio tracking	1
Multivariate community analysis	1	Radio tracking	1
Assessment of conservation value	1	Species specific trapping	1
Long-term data collection	1	Electrofishing	1
Interdisciplinary approaches	1	Fish counts/pass	1
Quantitative macroinvertebrate	1	Spawing habitat assessment (visual or quantitative)	1
Semi-quantitative macroinvertebrates	1	Seine and stop netting	1
Qualitative macroinvertebrates	1	Tagging	1
Mesohabitat assessment	1	Scale analysis (age and growth)	1
BACI design	1	HABSCORE	1
Baseline Ecological Assessment	1		

Single hits	54	***Double hits***	Holmes JNCC, Fixed photography, HEC-RAS, Repeatable topographic survey, Fluvial audit/rapid assessment	***Triple hits***	MTR **survey** RHS (Macro) RHS (Geo)



Limitations of the specific methodologies	Macrophytes	Hydrology	Ecology macroinverts	Geomorph	Sediment/ water quality	Fisheries
The methodology is not easy to replicate	1	1		4		
The methodology is quantitative and the scale for the quantitative classification is limited	1					
Maps are required to apply the methodology	1					
There is a poor link between biological and physical data	1					
The data collected is of bad quality (e.g. poor photos) and lack of consistency locations	1					
The methodology is based in qualitative variables	1		1	1		
The methodology is subjective	2	1		3	2	
The methodology is time consuming	2	1	5		4	
The methodology is limited in detail/information collected	4	1		1	4	
The methodology is costly		1	6	3	3	
There might be errors in the measurements taken and in the associated calculations		1				
There are not enough resources available to apply the methodology		2	1			
There is a poor cause-effect link			2			
Temporal variation is not captured				2		
High resolution required to obtain detailed information (DTM)				1		
Training is required before applying the methodology				1		
There is a lack of integration with other methodologies				1		
The methodology derives the information from data collected but it doesn't measure the variables				1		
Info required for the application of the methodology is only available for some/few species.			1			
No standard methodology/best practice guidance – relies on the commitment of the individual				1		
Results rely on experience	1		1	1		
New methodology with little scientific measurements				1		
The methodology is difficult to apply in large rivers			2			
There are no limitations	1		2	3		

Costs for 100 m reach

	Macrophytes	Hdrology	Ecology macroinvertebrates	Geomorphology	Sediment / water quality	Fisheries
<£100	7			6	2	
£100-£199	3	2	1	2		
£200-£299				2		
£300-£399						
£400-£499				2		1
£500-£599	1		2			
£600-£699						
£700-£1000	1					
>£1000			1	1	1	
Not answered	3	8	8	12	4	2

Aim and objectives

Aim

To bring together *key people from a range of natural science disciplines* (e.g. fisheries, ecologists, geomorphologists, hydrologists, water and sediment quality experts) *and backgrounds* (e.g. statutory authorities, academics, consultants, NGO) with a view to *agreeing a monitoring protocol* that is *underpinned by sound science* but critically *is feasible* to carry out in view of inevitable *cost constraints*.

Objectives

Agree a *monitoring/ appraisal framework* (matrix) which defines the most appropriate level of monitoring necessary on the basis of project size, sensitivity and cost.

Enhance understanding of each discipline's rationale for monitoring and through this agree *a trans-discipline monitoring protocol*.

Identify a range of sites (both completed and imminently proposed projects) that could be used as *case studies* to test the scientific rigour to the new framework/protocol.

Assumptions

Clear objectives and measurable targets have been set

Outputs

- Results from the questionnaires (all)
- Notes from discussions
- Any agreed consensus
- Ways forward
- Others (as they emerge)

- RRC website, RRC conference, plus….

RRC Workshop Lyndhurst December 2006

MONITORING CRITERIA, DURATION AND PREDICTING CONSEQUENCES

Broad reasons for restoration

<u>Ecological, societal, aesthetic, financial, political</u>

(eg. bio-diversity, flood alleviation, flow restoration, fisheries, water supply, or multi-functional)

<u>Evaluation concepts for rivers</u>

ecosystem health, ecological integrity, ecological architecture, ecological function, geo-morphological processes, structural diversity, ecosystem services, the normative ecosystem, ecological status, stakeholder satisfaction, socio-economic satisfaction,…

<u>SO MANY ALTERNATIVE CRITERIA THAT IT IS IMPOSSIBLE TO JUDGE WHETHER A PROJECT IS SUCCESSFUL OR NOT .</u>

Evaluation

Simple in principle:- Has the project reached its set target whether it be flood alleviation, conservation, fishery improvement, stakeholder satisfaction or multiple targets

Problem is that targets are often not clearly defined, quantitative or fully transparent….

Therefore evaluation using whatever criteria may be impossible.

EVALUATION CRITERIA

Clearly must be related to the target (s)

ECOLOGICAL CRITERIA

Diversity, richness, abundance (of a species), ontogenic enhancement, distribution of a target species, stable functioning ecosystem,

NATURALNESS????   (SERCON)

Don't forget unintended consequences:- disturbing a habitat for the "benefit" of one species/community, may cause disadvantages to another. (Even reducing pollution has adverse consequences on the "pollution fauna").

SCALE (Spatial and temporal)

River restoration is usually implemented at the reach scale for “results” (benefits?) at the larger scale.

Ecological monitoring/evaluation usually at same scale as

restoration activity…. Should it be larger????

Ecological evaluation at larger scales is expensive unless monitoring is automated and /or selective

Temporal scale is more dictated by funding than actual requirement of knowledge

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FROM THE “ORGANISMS EYE-VIEW “(Hidrew & Giller 1994)

Restoration is a disturbance that alters the effects of a previous disturbance

(Langford, 2007)

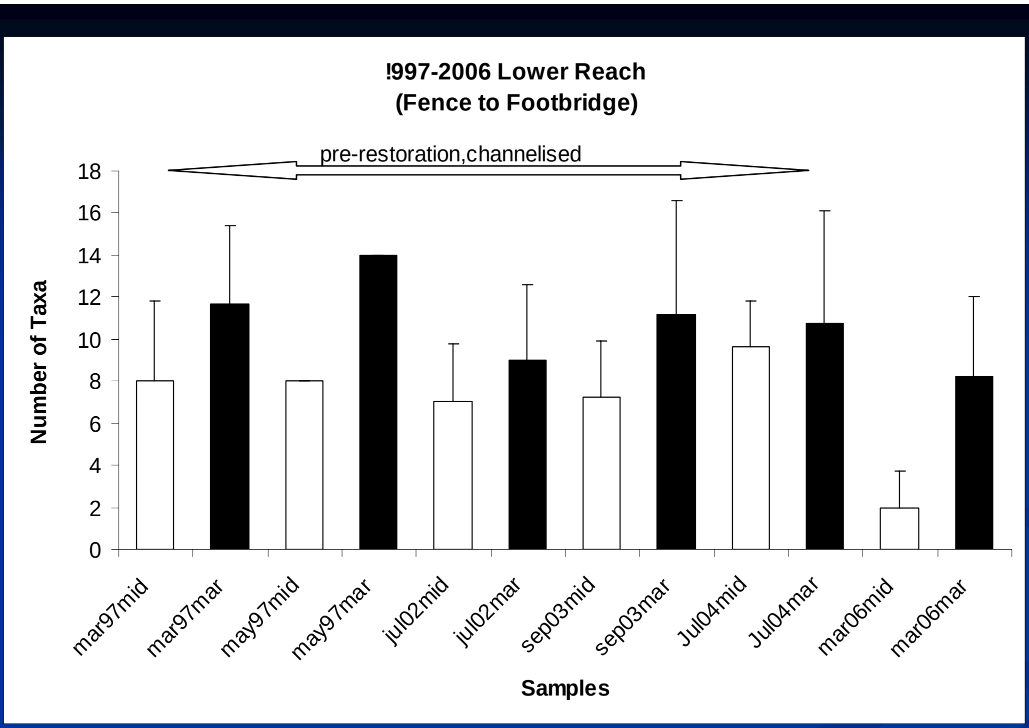
From the human eye-view restoration implies some kind of correction or return to a previous state often undefined.

Factors affecting recovery from disturbance:-

Magnitude of disturbance, resistance and resilience of the flora and fauna.

<u>Resistance</u> can depend on:- the part of habitat disturbed (restored) eg. River margins or midstream habitats or both. Avoidance by species/mobility

<u>Resilience</u> can depend on:- mobility of species, (dispersal mechansims), availability of inocula (eg. from upstream, downstream or adjacent habitat)



<u>Resistance.</u> Midstream and marginal taxon richness in restored reach of a low resistance stream

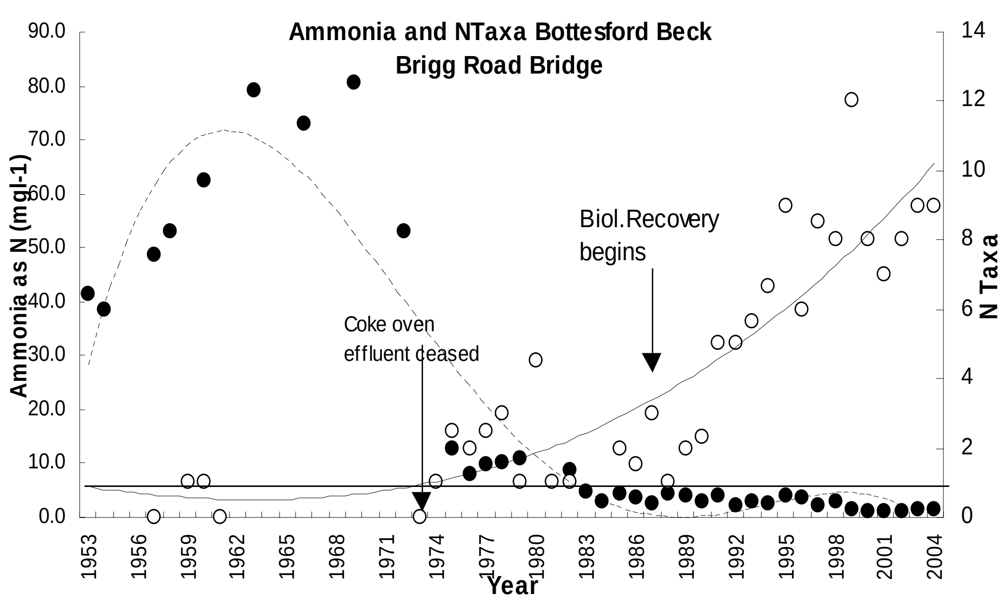
Duration of evaluation programme:-

Resilience

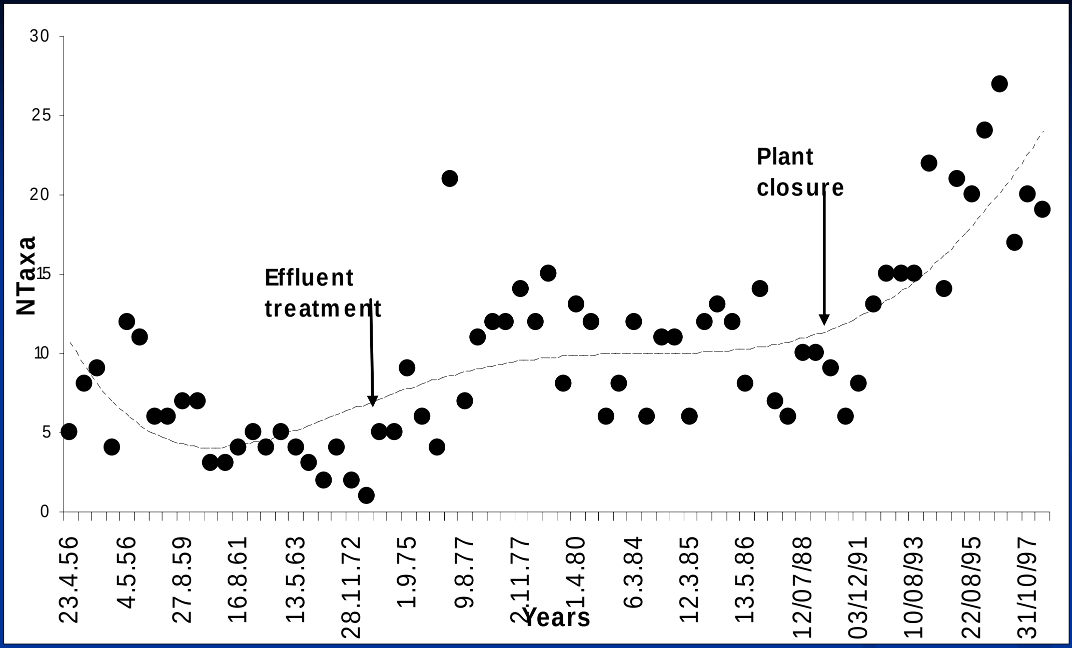
Main stages of recovery:- Colonisation, succession, stabilisation. Probably optimal monitoring should provide some information on the attainment of the last…but this might be hugely variable depending on ecosystem and the extent of the disturbance.

Disturbance and post-disturbance literature extensive, methods, frequencies of sampling, duration of programmes, data analysis. Lots of background. Firm scientific basis.

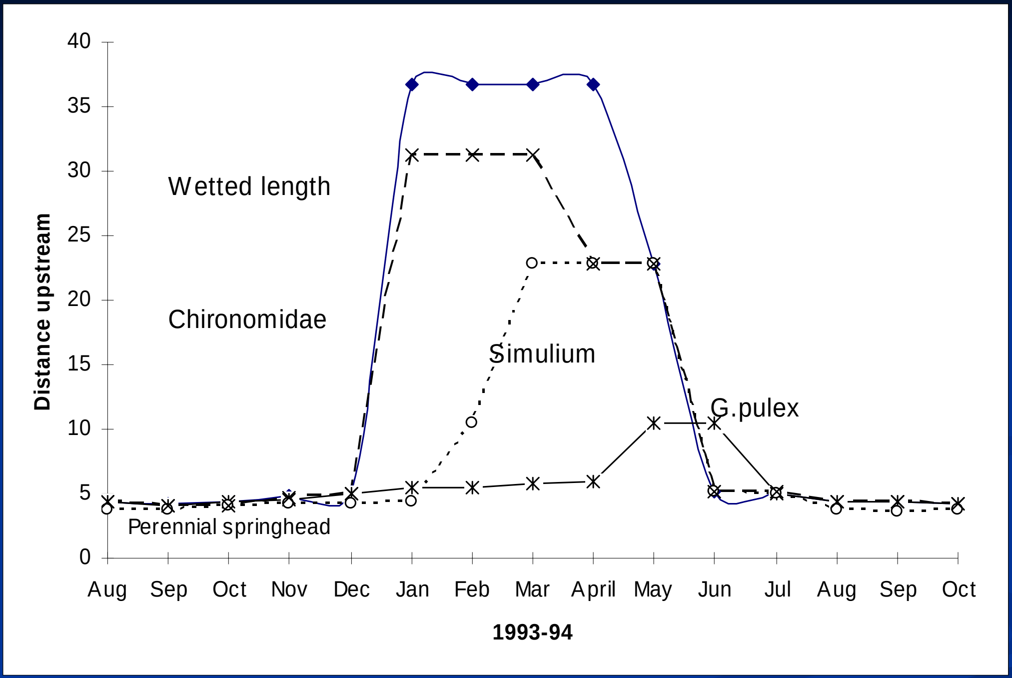
Programme duration can be estimated from published data and "before" surveys.



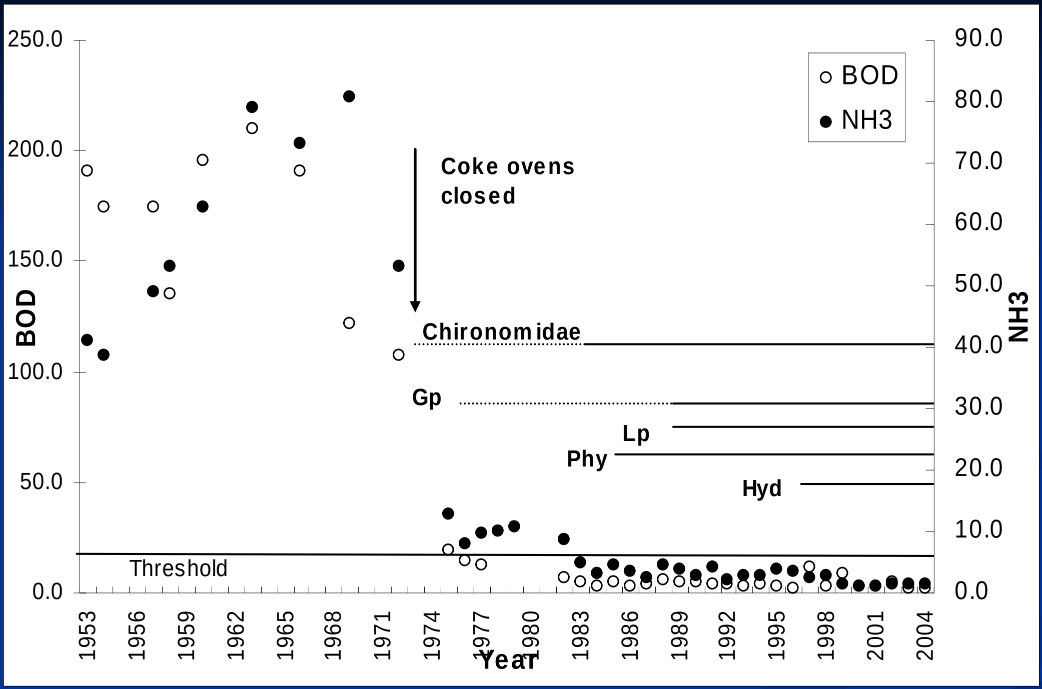
Poor resilience. Delayed recovery after steelworks closure. No clean-water fauna upstream



Good resilience. Recovery of macro-invertebrate richness following closure of a paper mill. Clean river fauna upstream



Mobility of species. Rates of colonisation of various taxa as flows varied seasonally in a winterbourne. The River Bourne. Wiltshire. Until December the stream was dry upstream of the SH



Relative colonisation rates from downstream or non-stream sources. (Total pollution)No instream fauna upstream

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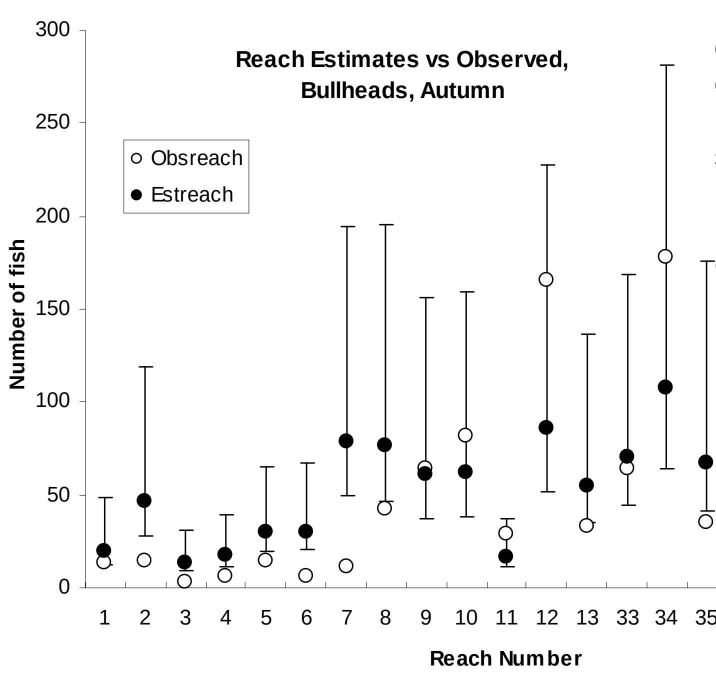
FEASIBILITY OF ECOLOCICAL TARGETS, (PREDICTING CONSEQUENCES)

Although each restoration project may be regarded as a new “experiment” in terms of disturbance ecology the basic theory is well documented.

<u>From “before” studies and published literature</u> it should be possible to make reasonable predictions of target feasibility either qualitatively or quantitatively. This is rarely (if ever) done.

Use habitat preference data for prediction (models????)



Median and quartiles/Estimates of bullhead pops.in reaches. Est from seasonal median. Densities in riffles,pools and CWD

Predicting consequences (models):- Estimated numbers of bullheads in reaches in relation to observed numbers. Data used were areas of riffle, pool and cwd matrices in each reach and median densities of fish from all habitat unit samples.

General principles for predicting consequences

In-channel/riparian structural changes unlikely to increase diversity other than at the reach scale…redistribution of species.

Primary factors determining species occurrence at stream scale:-

Biogeography, water chemistry

Largest changes in diversity from improvements in water quality

Cost benefit for ecological improvement alone by channel alteration…….disastrous

DEVILS BROOK.DORSET

Unintended consequences

Eight species of riparian plants were missing from the restored reaches

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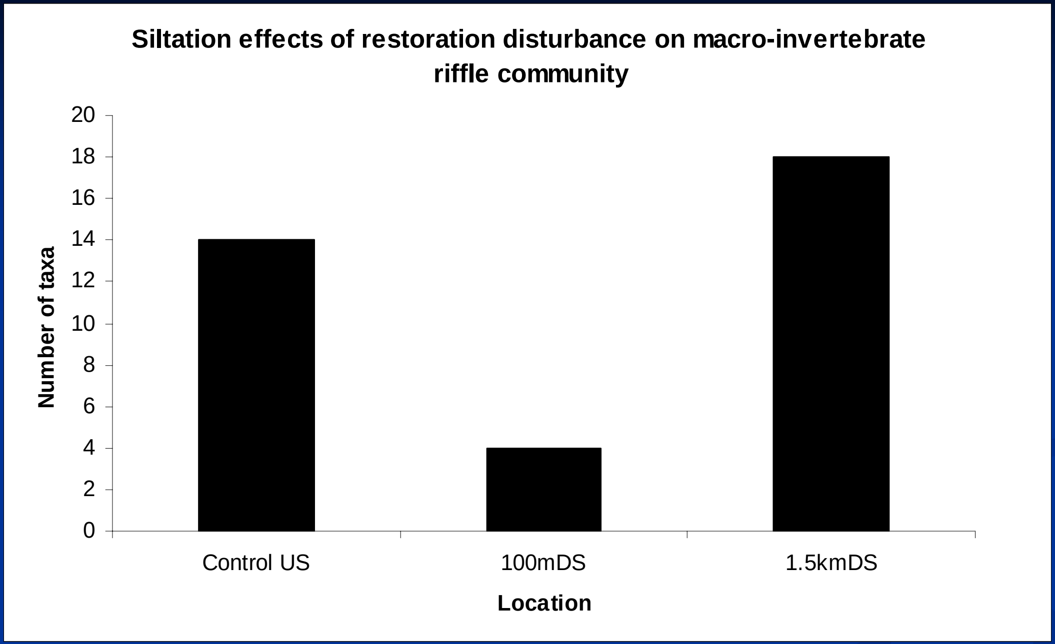
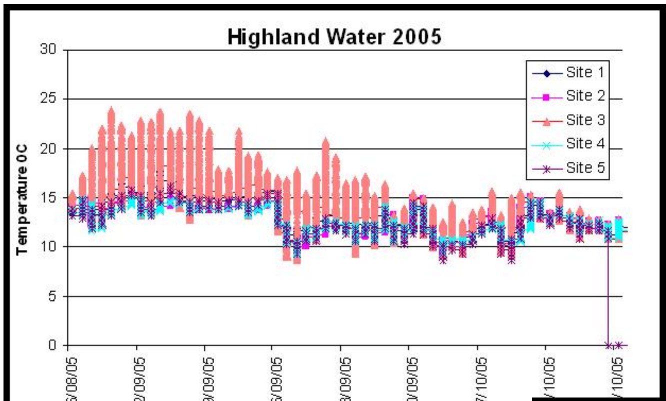
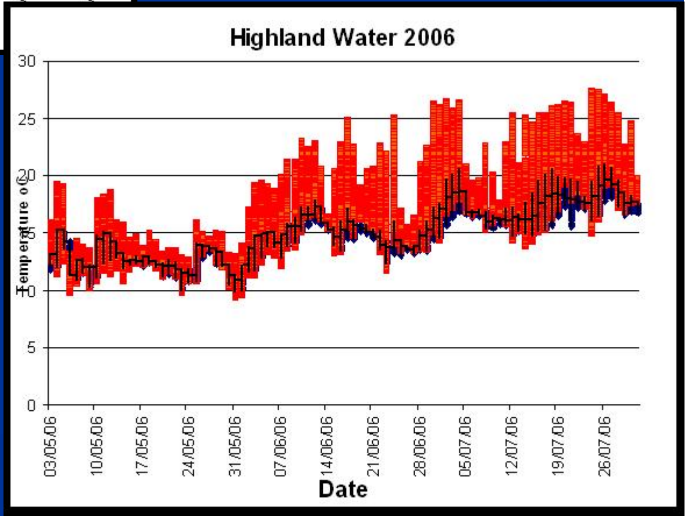

Siltation effects of restoration disturbance on macro-invertebrate riffle community

Unintended circumstances. Displaced silt (fine sediments) “stifle” the invertebrate community in a riffle downstream of the restored reaches.



UNINTENDED CONSEQUENCES

WATER TEMPERATURES LOGGED OVER 2 SUMMERS IN CLEARFELLED AND SHADED REACHES



Maximum daily temperatures could be 8-10°C higher in unshaded than shaded reaches, at times exceeding "comfort zones" for trout and bullheads.

PREDICTING CONSEQUENCES OF RESTORATION DISTURBANCE

For each proposed project can we:-

Devise a "recovery index" for streams and rivers based on categories of disturbance intensity and colonisation strategies and rates of flora and fauna.

Devise a recovery index for substrates, channel morphology and physical diversity

and combine the two.

Based on both spatial and temporal data

“When you can measure what you are talking about and express it in numbers, you know something about it. When you cannot express it in numbers your knowledge is of a meagre and unsatisfactory kind”

Lord Kelvin (died 1907)

Can models which predict sediment *dynamics* be used to aid prediction of physical habitat status?

Questions

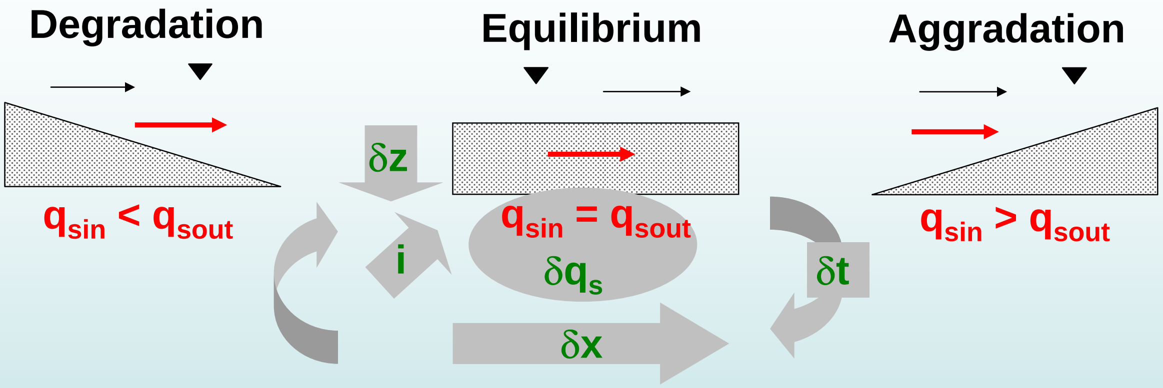
Can channel stability models be used to help predict habitat status?

Can the data required for such models be used in pre-existing habitat models?

Can channel stability models be used to direct post project monitoring efforts?

Channel Stability

In essence channel vertical stability involves a continuum of ….



Degradation

Equilibrium

Aggradation

$q_{sin} < q_{sout}$

$q_{sin} = q_{sout}$

$q_{sin} > q_{sout}$

δz

i

δq_s

δt

δx

and in essence sediment dynamics models solve ……

$$\frac{\delta z}{\delta t} = -\frac{\delta q_s}{\delta x} + i$$

What assumptions are being made when considering channel dynamics and habitat?

- Dis-equilibrium in sediment transport is **bad**

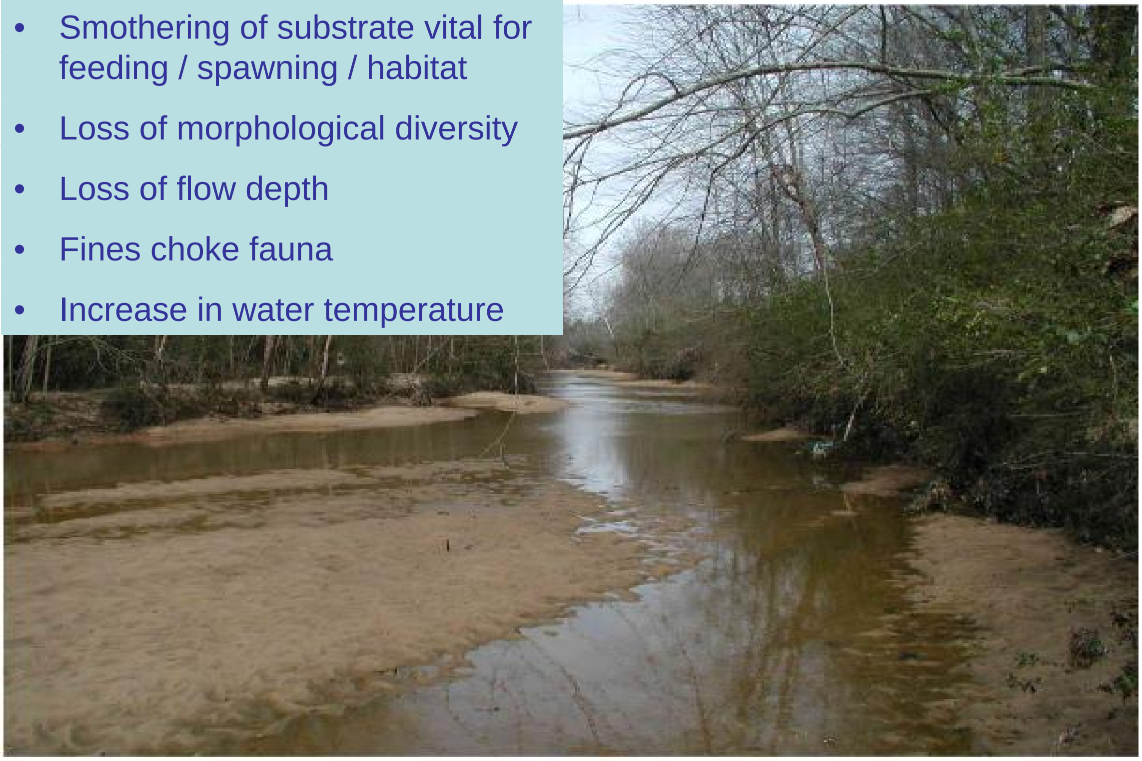
Why ?

DEGRADATION

- Loss of substrate vital for feeding / spawning / habitat
- Loss of diverse bed morphology
- Flashier flows due to confinement
- Loss of aquatic plants

Aggradation

- Smothering of substrate vital for feeding / spawning / habitat
- Loss of morphological diversity
- Loss of flow depth
- Fines choke fauna
- Increase in water temperature



What assumptions are being made when considering channel dynamics and habitat?

- *DYNAMIC* equilibrium is **good**

Why ?

Dynamic Equilibrium

- Ordered but variable bed morphology – Species diversity
- Channel is *dynamic* – There is change but this enables diversity of habitat
- Adjustment of morphology (vertically *and* laterally) is gradual enabling sustainable flora & fauna migration with the physical system and habitat succession
- Varied range of flows within limited extremes and thus limited extreme sediment transport

Sample of Channel Stability Models

Stream Power Screening Tool

(A. Brookes)

River Energy Auditing Scheme (REAS)

(N. Wallersetin & P. Soar)

HEC RAS Sediment Impact Assessment Model (SIAM)

USACE HEC

ISIS Sediments

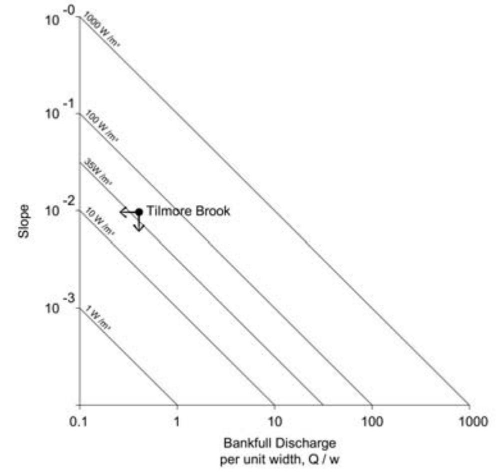
HR Wallingford

Stream Power Screening Tool

Based on Specific Stream Power (ω)

$$\omega = \frac{\gamma Q S_{(e/b)}}{W}$$

γ = bulk unit weight of water, Q = representative discharge, S = slope (e = energy slope – preferable: b = bed slope), W = channel top width.



Continuity:

< 15 – 25 Wm^{-2}: Failure - Deposition

> 25 – 35 Wm^{-2}: Failure - Erosion

River Energy Audit Scheme

Measure of channel stability through continuity of Excess Specific Stream Power - integrated over range of flows found in the channel

$$\Delta\omega_{e(r=n+1)} = \omega_{e(r=n)} - \omega_{e(r=n+1)}$$

$\Delta\omega_e$ = Specific Power differential for reach n + 1. r = reach, (n is from upstream to downstream), ω_e =

$$\omega_e = \omega - \omega_c$$

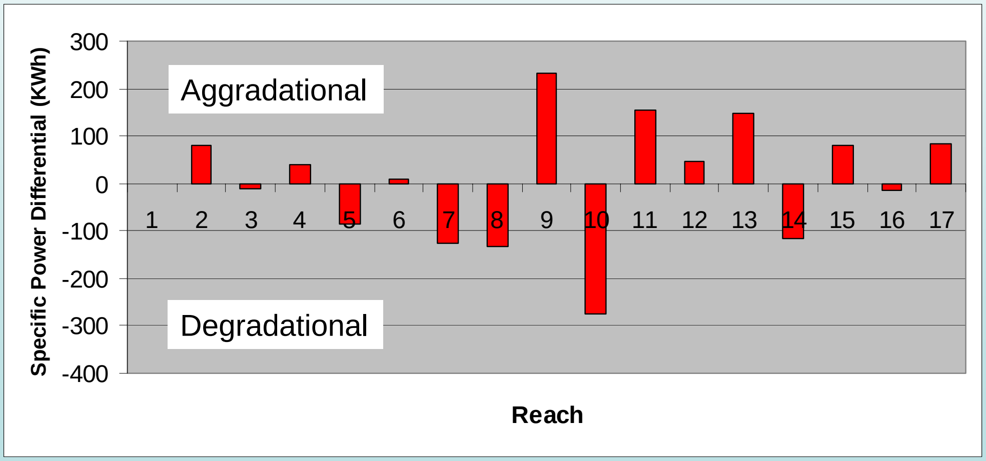
ω_e = excess specific stream power for a given discharge , ω = total specific stream power for a given discharge, and ω_c, critical specific stream power =

$$\omega_c = 290D_m^{1.5}\log\left[\frac{(12d)}{D_m}\right]$$

D_m = grainsize m in the grainsize distribution, d = critical flow depth for that grainsize.

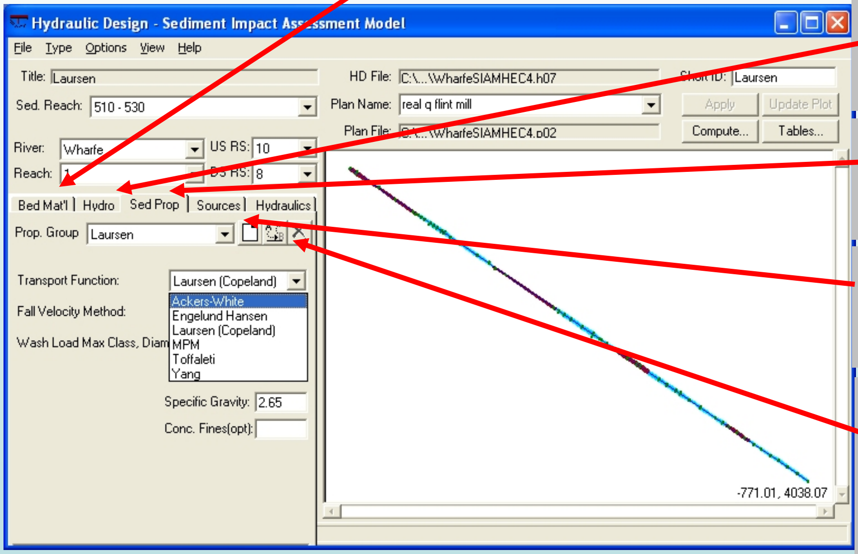
REAS Output

Aggradational / Degradational *tendency* in terms of channel ability to perform work (note that this work may also be performed in lateral adjustment)



HEC RAS SIAM

- 1-D steady state flows run for a river based upon flow duration curve.
- River divided up into geomorphologically consistent reaches (User defined).
- Hydraulics passed to SIAM.



Hydraulic Design - Sediment Impact Assessment Model

Title: Laursen
Sed. Reach: 510 - 530
River: Wharfe
Reach: 1
US RS: 10
DS RS: 8
HD File: C:\...\WharfeSIAMHEC4.h07
Short ID: Laursen
Plan Name: real q flint mill
Plan File: C:\...\WharfeSIAMHEC4.p02
Prop. Group: Laursen
Transport Function: Laursen (Copeland)
Specific Gravity: 2.65
Conc. Fines(opt):

Reach bed material gradation record

Flow Duration record (days.yr^{-1})

Sediment Transport Function

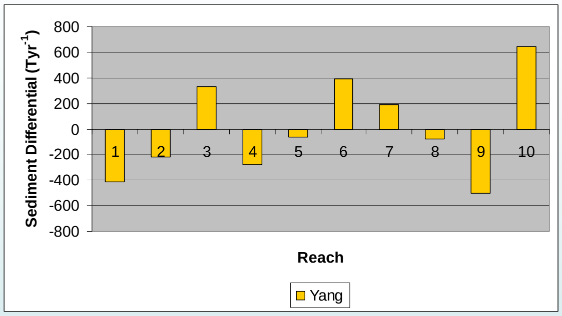
Bank material sediment sources (T)

Hydraulics from RAS require to compute sediment transport loads

- Sediment transport capacity for each reach subtracted from the incoming supply to give a tonnage budget…………..

SIAM OUTPUT

Sediment tonnage differential in T.yr^{-1} – indicating aggradation or degradation



REAS / SIAM CAVEATS

1. Models assume prior knowledge of geomorphologically consistent reach limits.
2. SIAM uses sediment transport formulae which are highly difficult to calibrate.
3. Neither model routes sediment they are purely reach-by-reach balances and result are therefore time invariant – indicative of long term potentials.

ISIS Sediments

1 - D fully unsteady flow routing model coupled with sediment routing model. Aggradation - degradation model – through events.

Solves St. Venent Equations and Exner Equation

$$\frac{\partial Q}{\partial x} = \frac{\partial A}{\partial t} = 0$$

Conservation of mass

$$S_o - S_f = \frac{d(d)}{dx} + \frac{1}{gA}\frac{d}{dx}\left(\frac{Q^2}{dx}\right) + \frac{1}{gA}\frac{dQ}{dt}$$

Conservation of momentum

$$\frac{\delta z}{\delta t} = -\frac{\delta q_s}{\delta x} + i$$

sediment continuity

Advantage

- Time variant – can model events and therefore temporal change in bed elevation

---

What can we do with the results from these models to aid physical habitat status prediction?..............

So how about relating habitat to specific stream power thresholds?

Many habitat thresholds (e.g. fish) are based in part upon $\overline{V}$, $\overline{d}$ & D_x

Now………

$$\omega = (\gamma QS)/w \quad = \quad \tau_o \overline{V} \quad = \gamma \overline{d} S \overline{V}$$

And……....

$$\omega_e = \omega - \omega_c \quad \& \quad \omega_c = f\,(\gamma, S, \rho_s, g, \theta, d, D_x)$$

So, if we know a mean velocity, depth and substrate size range for a species, obtain from the literature the slope at which this data was obtained and assume: $\rho_s = 2650$, $g = 9.81$, $\gamma = 9810$, $\theta = 0.047$

We can calculate a Excess Specific Power Range for an animal ($\omega_{e(species)}$)

Thus if we know that ω_e for a river reach commonly lies within the range $\omega_{e(species)}$ the reach hydraulics are favourable for the species.

Example – Brown Trout

Rearing habitat variables. Data: Raleigh et al., 1984

Life Stage	*Depth (m)*	*Velocity (m)*	*Substrate (m)*
Fry	0.10 - 0.40	0.00 - 0.30	0.065
Parr	0.10 - 0.60	0.05 - 0.50	0.065
Adult	0.12 - 0.91	0.50 - 0.70	0.065

S = 0.001

Associated Specific Stream Power Variables

Life Stage	ω	ω_c	ω_e
Fry	1.1	15.2	-14.0
Parr	2.9	15.2	-12.3
Adult	5.3	15.2	-9.9

Seems to make no sense? – actually it does – these values are in effect zero so these fish don't operate in channels where there is active adjustment although the older and more robust the animal there closer to the active threshold it can live

Correlate these values with known local and reach averaged (γQS)/w – locate in your catchment where these species / life stages are likely to reside

Example – Brown Trout

Rearing habitat variables. Data: Raleigh et al., 1984

Life Stage	*Depth (m)*	*Velocity (m)*	*Substrate (m)*
Fry	0.10 - 0.40	0.00 - 0.30	0.065
Parr	0.10 - 0.60	0.05 - 0.50	0.065

WHY USE POWER:

S = 0.001

- We may not have actual surveyed values of d and v but are much more likely to be able to obtain Q, S, and W from secondary data.
- Change the paradigm of thinking about species from individual hydraulic variables to a measure which is in line with channel morphological adjustment

Adult	5.3	15.2	-9.9

there is active adjustment although the older and more robust the animal there closer to the active threshold it can live

Correlate these values with known local and reach averaged (γQS)/w – locate in your catchment where these species / life stages are likely to reside

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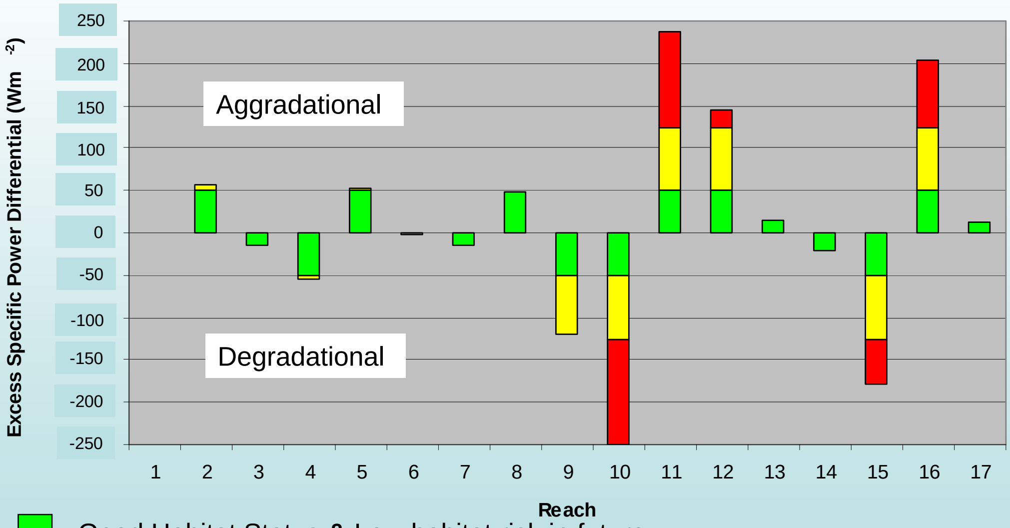
As we (assume) habitat is strongly controlled by channel stability why not relate habitat to specific power balance?

An Aggradation - Degradation Based Habitat Status Indicator



🟩 Good Habitat Status **&** Low habitat risk in future

🟨 Moderate Habitat Status **&** Moderate habitat risk in future

🟥 Poor Habitat Status **&** High habitat risk in future

We Need Data to Calibrate such a model

i.e. in the UK what are the limits for certain species in terms of good, moderate and poor differentials.

In other words what level of stress in terms aggradation / degradation potential can species stand.

NEED DATA………………………………

SIAM

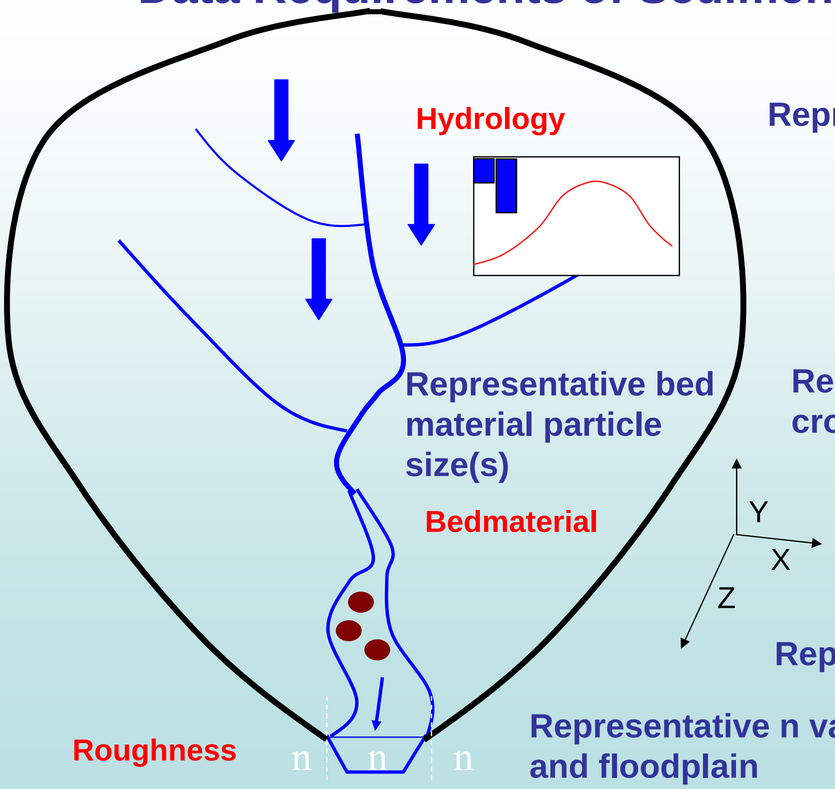
Could be used in a similar manner to REAS – habitat related to sediment load differentials. Difficult to calibrate a sediment load model.

ISIS

Slightly different in that the output is time variant – can be used to show how habitat in a dynamic system may change spatially and temporally with locations of aggradation and degradation:

BUT – we do not know when these changes will occurs

Data Requirements of Sediment Models



Hydrology

Representative flow(s)

Representative bed material particle size(s)

Bedmaterial

Representative channel cross-section

Geometry

Representative bed slope

Roughness

Representative n values for the channel and floodplain

Common Variables

Variables used in Habitat Models	*Available from Sed. Models?*
Velocity (usually only mean)	✓
Depth (usually only mean)	✓
Substrate	✓ (not from SPST)
Wetted perimeter	✓
Slope (bed/energy)	✓
O^2	✗
Temperature	✗ (v can be surrogate)
PH	✗
Chemical water quality	✗

Can Channel Stability Models be used to aid monitoring?

We must remember that rivers are dynamic in terms of sediment transport and therefore morphology both:

SPATIALLY & TEMPORILY

Therefore habitat status for difference plants / animals varies with Time and Space in any dynamic system.

It makes sense therefore to use a sediment modelling tool which predicts locations of change to highlight reaches that should be selected for special attention on post-project monitoring

It does not make sense for monitoring to be spatially static

The HDMAR workshop

Association of Rivers Trusts
where there's water there's life

Alistair Maltby, Director (North)
Association of Rivers Trusts

Some history…

Late 2000

- 2000 Westcountry Rivers Trust completing the Tamar2000 project. Catchment wide programme of farm environment improvements. Economic outputs strong, what about environmental?
- Eden Rivers Trust starting ‘Restoring Eden’ project. Lack of targeting information from statutory sources (EN & EA).

2001/02

- Early version of RHS used on some of the Eden catchment.
- Proposal to start catchment-wide electrofishing survey in addition to statutory monitoring.
- Proposal to fund catchment-wide aerial habitat survey and develop a diffuse pollution risk model.

2001/02

- Establish a technical working group for the River Trusts to develop a ‘matrix’ or ‘toolbox’ of techniques appropriate for targeting and monitoring River Trust activity.
- Not prescriptive, but well described…
- Team includes key Trust scientists and representatives from the EA and originally EN.

HDMAR

The HDMAR workshop…

- Habitat description, measurement and assessment in rivers.
- Process really moved on thanks to the EA, FRS and Westcountry Rivers Trust. Funding, facilities and time. EU Interreg funding.
- 2 day workshop 8th & 9th March 2006 at the FRS laboratories Pitlochry
- To be published as an AST Blue Book and an updateable website (IFM?)

Delegates

- SFCC
- FRS
- SNH
- ART
- Tweed Foundation
- EA
- Hull University
- CCW
- APEM
- FCB, NI
- Durham University
- McCaulay Institute
- Conon, DSFB
- EHS, NI
- CEH
- CEFAS
- Galloway RT
- Aberdeen University
- Cardiff University
- AST
- Eden Rivers Trust
- Marine Institute

Introduction to workshop

- ‘A common view amongst workers in the river fish habitat field is that there are inconsistencies in good practice, gaps in knowledge and lost opportunities that could be resolved, given better communication and co-ordination amongst the various bodies engaged in this work. ‘
- ‘The intention is to set the workshop firmly in the context of the Ecosystems Approach and integrated catchment management to ensure that future developments in this area are fully compatible with contemporary European and national regulatory framework. This requires that analysis and assessment must extend, as appropriate, from site to whole catchments and take on understanding of the fluvial and geomorphological processes that govern habitats and their connectivity across all scales.’

Outcomes

- better awareness of the issues surrounding the description, assessment and application of habitat surveys;
- collation and dissemination of good practice that will bring more consistency to the activity, enabling easier sharing of results and a common language across workers in the field. Various media options, to be discussed at the workshop;
- a framework for future development – through for example a standing group on habitat assessment, e-discussion group or repeat workshops; and
- a prioritised programme of key future research needs and benefits to put to potential funding bodies

Aims

- **AIM 1 to identify principle applications and their scales**
- **AIM 2. To identify and describe current methods.**
- **AIM 3. To propose a toolbox of techniques and good practice**
- **AIM 4 Data storage, access and management**
- **AIM 5 To summarise current research and recommend future work**

‘The Matrix’

- RIVPACS, SERCON, EFI / FAME, FCS, HABSCORE, PHABSIM, aerial survey, walkover survey, RFHI, RHS, fluvial audit compared in matrix
- Scale divided into catchment, reach, site or micro.
- Other attributes included the objective, the methods, and the key variables.
- References

Intense discussion!

- How to compare such a range of techniques developed for such a range of purposes!
- Some are techniques for collecting data, others more specific tools….
- Major concern from some of the fish biologists on the errors in HABSCORE and similar tools that predict ‘ecology’ from habitat when compared to electrofishing data – implications for WFD?

…more discussion!

- Concern from proponents of ‘linear’ habitat data collection techniques (walkover, aerial survey) about point based survey techniques – depends on the objective perhaps?
- A lot of discussion on the relative merits of RHS against fluvial audit tools.

Conclusions….for now.

- Most of the disagreement seems to stem from applying tools beyond their design scope.
- HDMAR will attempt to fully describe the techniques and their applications in the Blue Book – give up on the matrix for now!
- River / fishery scientists are able to pick the most appropriate tool for their application and follow references back to origins.
- Of course, linear data collection techniques for raw data are robust (walkover – habitat/fluvial, aerial – habitat/fluvial), but is it fair to compare with more ‘analytical’ tools?

Association of Rivers Trusts

where there’s water there’s life

Association of Rivers Trusts

Check out our website on:

www.associationofriverstrusts.org.uk

Monitoring & appraisal of river restoration schemes

Judy England
Environment Agency

Kevin Skinner
JE JACOBS

Matt Carter
Environment Agency

Contents:

- Why appraise?
- Best practice
- Draft appraisal selection model
- Thoughts of the group
- Points for discussion

PPA allows us to:

- assess project aims
- assess techniques
- understand planned & unforeseen consequences
- adaptive management
- test scientific hypotheses
- prioritise future investments

Best Practice:

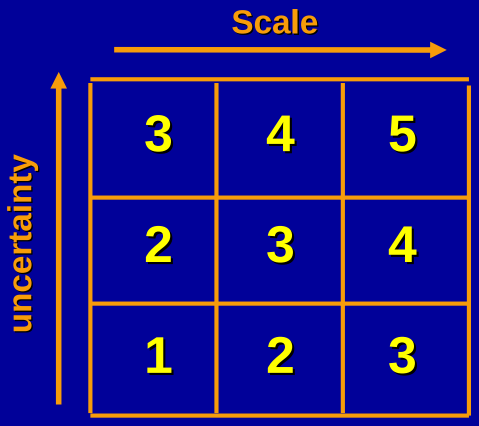
- objectives
- Specific, Measurable, Attainable, Realistic, Timely
- baseline data
- understand present state, help set objectives
- control/reference sites
- attribute changes to scheme/target to attain
- timescales
- balance between recovery & needing information
- reporting results
- effective communication
- importance of science
- BACI, replicated sample design, etc.

> ***“Almost as bad as no evaluation are poorly planned efforts that waste limited resources while providing meaningless or even misleading information.”***

Anderson & Dugger, 1998

Which schemes to monitor ?

- prioritise based on risk
- risk = balance x uncertainty



3	4	5
2	3	4
1	2	3

Risk 1-5

Monitoring effort 1-5

From: Skinner (2002)

Ecological Method Selection Model

Scale

New/Novel

Restoration Technique

Established

	0m Small	100m Medium	500m Large
C	Photos Plant mapping Habitat mapping Quantitative macro-invertebrate survey Quantitative fisheries survey	Photos Plant mapping Habitat mapping Quantitative macro-invertebrate survey Quantitative fisheries survey	Photos RCS/Plant mapping RHS/Habitat mapping Quantitative & qualitative macro-invertebrate survey Quantitative & qualitative fisheries survey
B	Photos Plant mapping Habitat mapping	Photos RCS Qualitative macro-invertebrate surveys Qualitative fisheries survey	Photos RCS RHS Qualitative macro-invertebrate survey Qualitative fisheries survey
A	Photos	Photos RCS	Photos RCS RHS Qualitative macro-invertebrate survey Qualitative fisheries survey

From: England, Skinner & Carter (in press)

What you thought: Fisheries

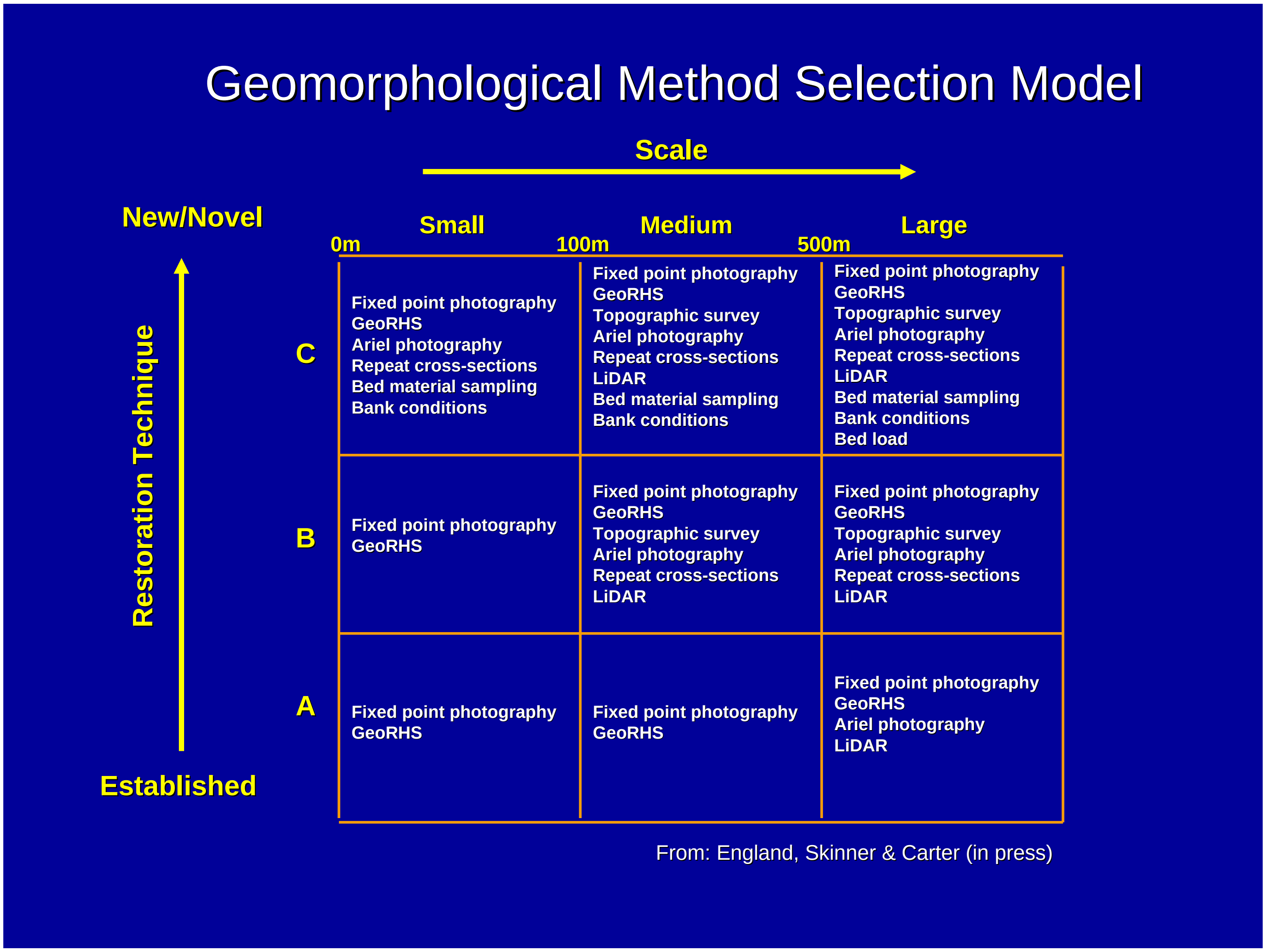
Scale

New/Novel

Restoration Technique

Established

	0m Small	100m Medium	500m Large
C			Hydro acoustic survey – 3D Tracking/Tagging
B	Radio tracking Species specific trapping	Radio tracking Species specific trapping	Radio tracking Species specific trapping Hydro acoustic survey - 2D
A	Electrofishing Fish counts / pass Spawning habitat assessment (visual or quantitative) Seine & stop netting Tagging Scale analysis (age & growth) HABSCORE	Electrofishing Fish counts / pass Spawning habitat assessment (visual or quantitative) Seine & stop netting Tagging Scale analysis (age & growth) HABSCORE	Electrofishing Fish counts / pass Spawning habitat assessment (visual or quantitative) Seine & stop netting Tagging Scale analysis (age & growth) HABSCORE



Geomorphological Method Selection Model

Scale

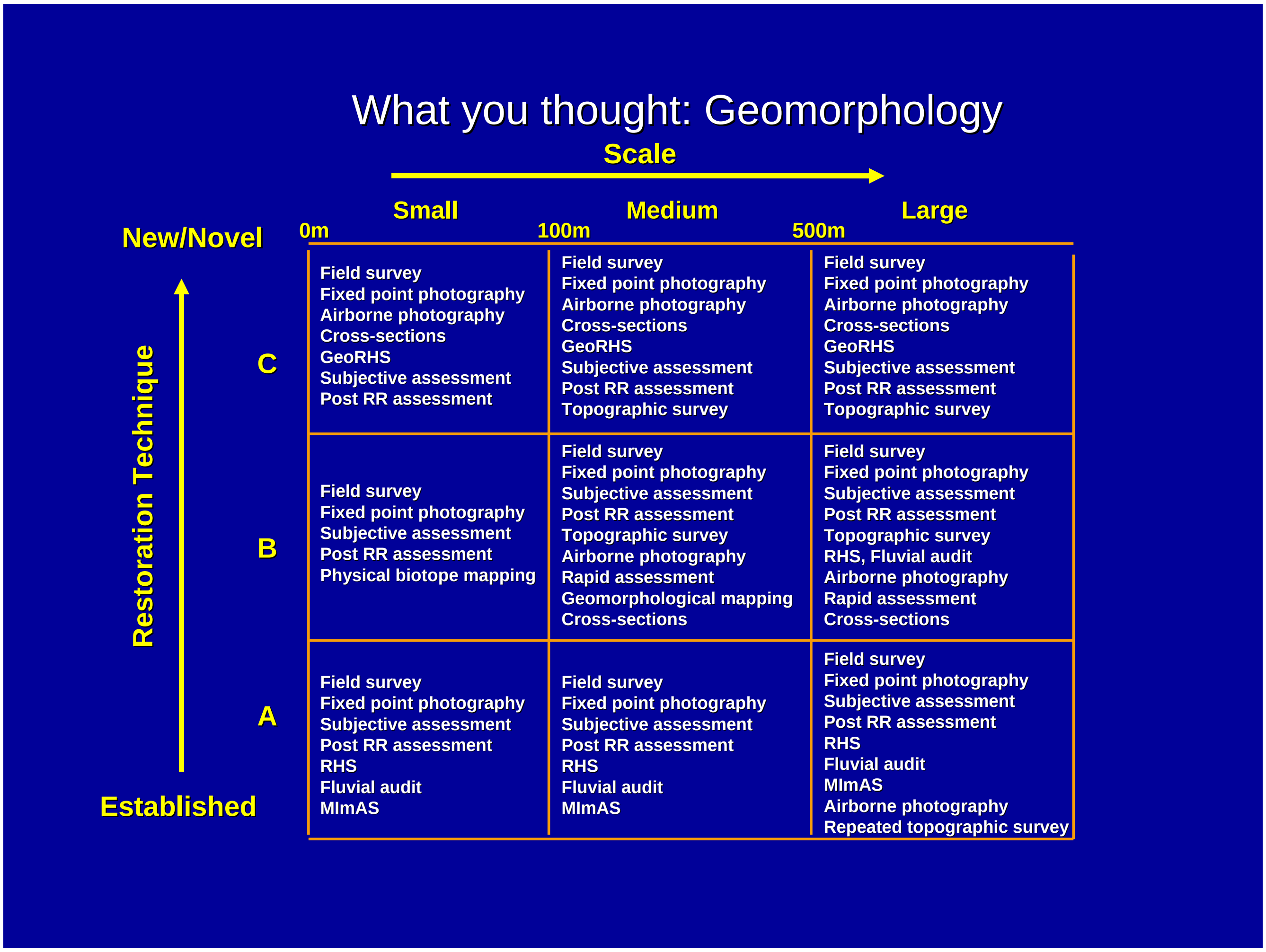
New/Novel

Restoration Technique

Established

	Small	Medium	Large
	0m	100m	500m
C	Fixed point photography GeoRHS Ariel photography Repeat cross-sections Bed material sampling Bank conditions	Fixed point photography GeoRHS Topographic survey Ariel photography Repeat cross-sections LiDAR Bed material sampling Bank conditions	Fixed point photography GeoRHS Topographic survey Ariel photography Repeat cross-sections LiDAR Bed material sampling Bank conditions Bed load
B	Fixed point photography GeoRHS	Fixed point photography GeoRHS Topographic survey Ariel photography Repeat cross-sections LiDAR	Fixed point photography GeoRHS Topographic survey Ariel photography Repeat cross-sections LiDAR
A	Fixed point photography GeoRHS	Fixed point photography GeoRHS	Fixed point photography GeoRHS Ariel photography LiDAR

From: England, Skinner & Carter (in press)



What you thought: Geomorphology

Scale

New/Novel

Restoration Technique

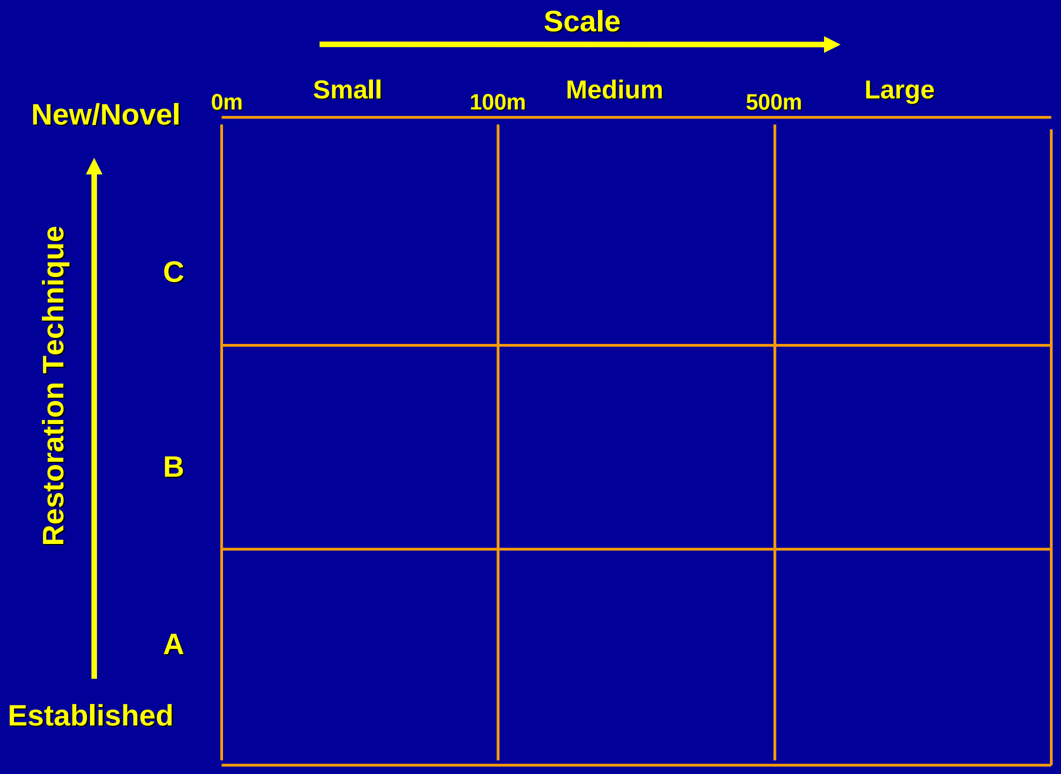
Established

	Small	Medium	Large
	0m	100m	500m
C	Field survey Fixed point photography Airborne photography Cross-sections GeoRHS Subjective assessment Post RR assessment	Field survey Fixed point photography Airborne photography Cross-sections GeoRHS Subjective assessment Post RR assessment Topographic survey	Field survey Fixed point photography Airborne photography Cross-sections GeoRHS Subjective assessment Post RR assessment Topographic survey
B	Field survey Fixed point photography Subjective assessment Post RR assessment Physical biotope mapping	Field survey Fixed point photography Subjective assessment Post RR assessment Topographic survey Airborne photography Rapid assessment Geomorphological mapping Cross-sections	Field survey Fixed point photography Subjective assessment Post RR assessment Topographic survey RHS, Fluvial audit Airborne photography Rapid assessment Cross-sections
A	Field survey Fixed point photography Subjective assessment Post RR assessment RHS Fluvial audit MImAS	Field survey Fixed point photography Subjective assessment Post RR assessment RHS Fluvial audit MImAS	Field survey Fixed point photography Subjective assessment Post RR assessment RHS Fluvial audit MImAS Airborne photography Repeated topographic survey

Points for discussion :

- **framework**
- do you agree with the philosophy?
- what should be on each axis?
- scale
- define small (<100m), medium (100-500m) & large (>500m)
- **uncertainty**
- establish what is known - catalogue schemes appraised & techniques used
- novelty of RR technique or monitoring technique?

What do you think?



Scale

0m **Small** 100m **Medium** 500m **Large**

New/Novel

Restoration Technique

C

B

A

Established

Kevin Skinner JACOBS

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Judy England Environment Agency

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Why monitor river “restoration” projects?

Mark Diamond

River Basin Characterisation

About half of river waterbodies in England and Wales are at risk of failing good ecological status because of morphological pressures

1996
2006

Environment
Agency

WFD: some key points

- No deterioration
- Aim for good ecological status
- Protected areas

- Heavily modified / artificial waterbodies

- Cost-effectiveness

1996
2006

Environment
Agency

Objective setting

- Clear stating point
- Clear objective
- Clear required effect

- Competing measures selected on basis of cost-effectiveness

- Caveats

Key deadlines

2006 Inception (River Basin Liaison Panels established)

2009 Final River Basin Management Plans

2012 Implementation of Programmes of Measures

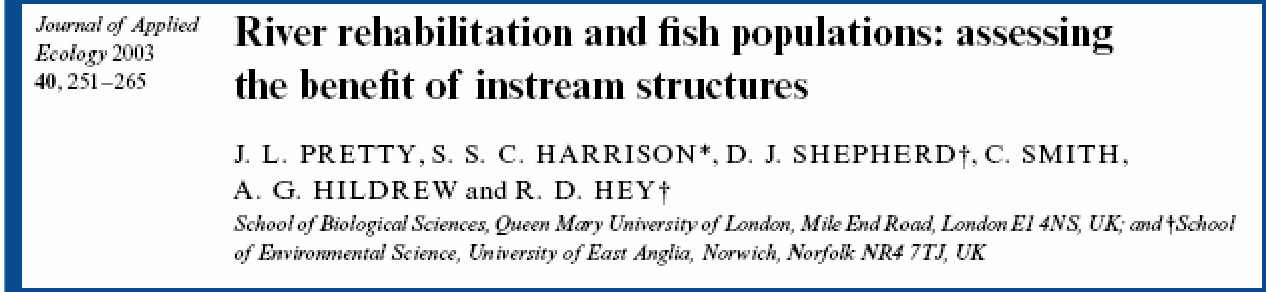
2015 Ongoing implementation and review; start of second River Basin Planning cycle

2021 End of 2nd cycle

2027 End of 3rd cycle

Good practice manuals

“Based on techniques that have been tried and tested in the USA over last 50 years”



Journal of Applied Ecology 2003
40, 251–265

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

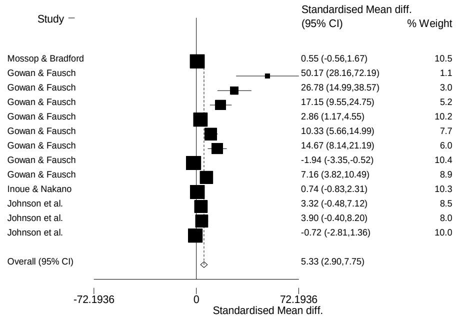
J. L. PRETTY, S. S. C. HARRISON*, D. J. SHEPHERD†, C. SMITH,
A. G. HILDREW and R. D. HEY†
School of Biological Sciences, Queen Mary University of London, Mile End Road, London E1 4NS, UK; and †School of Environmental Science, University of East Anglia, Norwich, Norfolk NR4 7TJ, UK

"From this substantial sample of lowland rivers, there is little evidence of any general benefit to fish of small-scale instream structures in river rehabilitation."

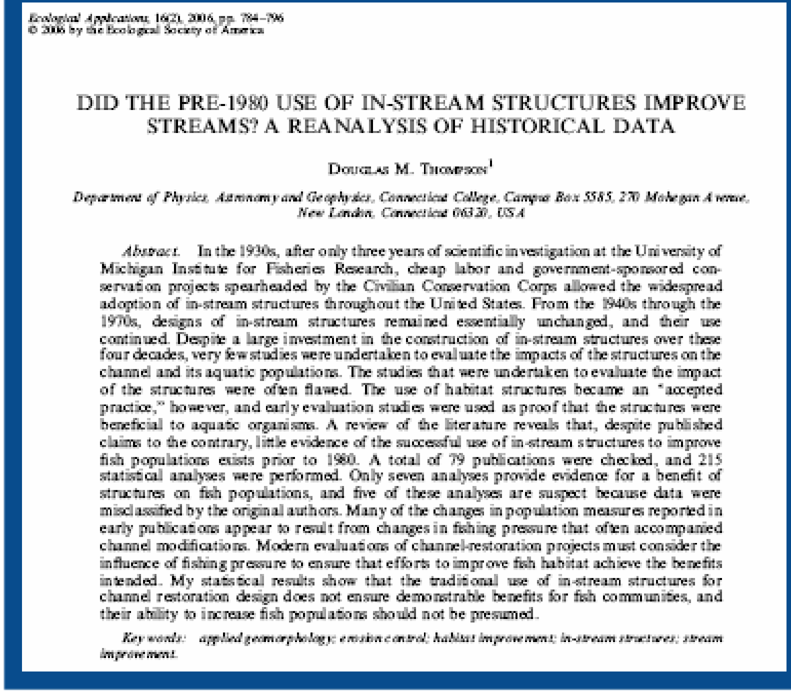
Do instream devices increase salmonid abundance?

- Systematic review of existing data
- Adding woody debris significantly increases salmonid abundance
- Large effect size
- Traditional in-stream devices significant but negligible effect size

Stewart et al @ www.cebc.bham.ac.uk



Review of pre-1980 data



Ecological Applications, 16(2), 2006, pp. 784–796

DID THE PRE-1980 USE OF IN-STREAM STRUCTURES IMPROVE STREAMS? A REANALYSIS OF HISTORICAL DATA

Douglas M. Thompson[1]

Department of Physics, Astronomy and Geophysics, Connecticut College, Campus Box 5585, 270 Mohegan Avenue, New London, Connecticut 06320, USA

Abstract. In the 1930s, after only three years of scientific investigation at the University of Michigan Institute for Fisheries Research, cheap labor and government-sponsored conservation projects spearheaded by the Civilian Conservation Corps allowed the widespread adoption of in-stream structures throughout the United States. From the 1940s through the 1970s, designs of in-stream structures remained essentially unchanged, and their use continued. Despite a large investment in the construction of in-stream structures over these four decades, very few studies were undertaken to evaluate the impacts of the structures on the channel and its aquatic populations. The studies that were undertaken to evaluate the impact of the structures were often flawed. The use of habitat structures became an "accepted practice," however, and early evaluation studies were used as proof that the structures were beneficial to aquatic organisms. A review of the literature reveals that, despite published claims to the contrary, little evidence of the successful use of in-stream structures to improve fish populations exists prior to 1980. A total of 79 publications were checked, and 215 statistical analyses were performed. Only seven analyses provide evidence for a benefit of structures on fish populations, and five of these analyses are suspect because data were misclassified by the original authors. Many of the changes in population measures reported in early publications appear to result from changes in fishing pressure that often accompanied channel modifications. Modern evaluations of channel-restoration projects must consider the influence of fishing pressure to ensure that efforts to improve fish habitat achieve the benefits intended. My statistical results show that the traditional use of in-stream structures for channel restoration design does not ensure demonstrable benefits for fish communities, and their ability to increase fish populations should not be presumed.

Key words: *applied geomorphology; erosion control; habitat improvement; in-stream structures; stream improvement.*

"...the traditional use of in-stream structures for channel restoration design does not ensure demonstrable benefits for fish communities…"

Riparian fencing

- Sustainable fisheries project: Wales
- Sustainable rivers project North West
- Tweed Foundation
- Wild rivers Scotland
- Compelling evidence for recovery ?

“Hydromorphology and river biota: linking river physical structure to ecology.”

> “…links between assemblage composition, biological indicators, biological models, physical structure and physical processes are insufficiently quantified at any scale in European rivers to support key policies and legislation.”

S. J. Ormerod, I. P. Vaughan and I Durance

Some priority questions

- Do the most frequently used reach scale measures work ? (£££’s, HMWB)
- What are their unintended consequences ?
- How extensively should they be applied ?
- How should we take account of the catchment context ?
- How should we analyse river systems to decide where interventions will be most efficient and effective?

In conclusion

- We are are unlikely to use physical restoration as a major measure in the 1st cycle
- Exception: making barriers passable and cheap techniques
- Need experiments

Towards an Integrated Approach to Monitoring River Restoration Projects.

David Sear
University of Southampton

Why do we need Monitoring?

- Evaluate “success”
- Create knowledge.
- Codify experience.
- Promote learning.
- Transfer knowledge.
- Essential component in adaptive management.

Why, what and how you monitor a restoration project depends on the values of your management system.

“Making a difference” *vs.* “learning opportunity”

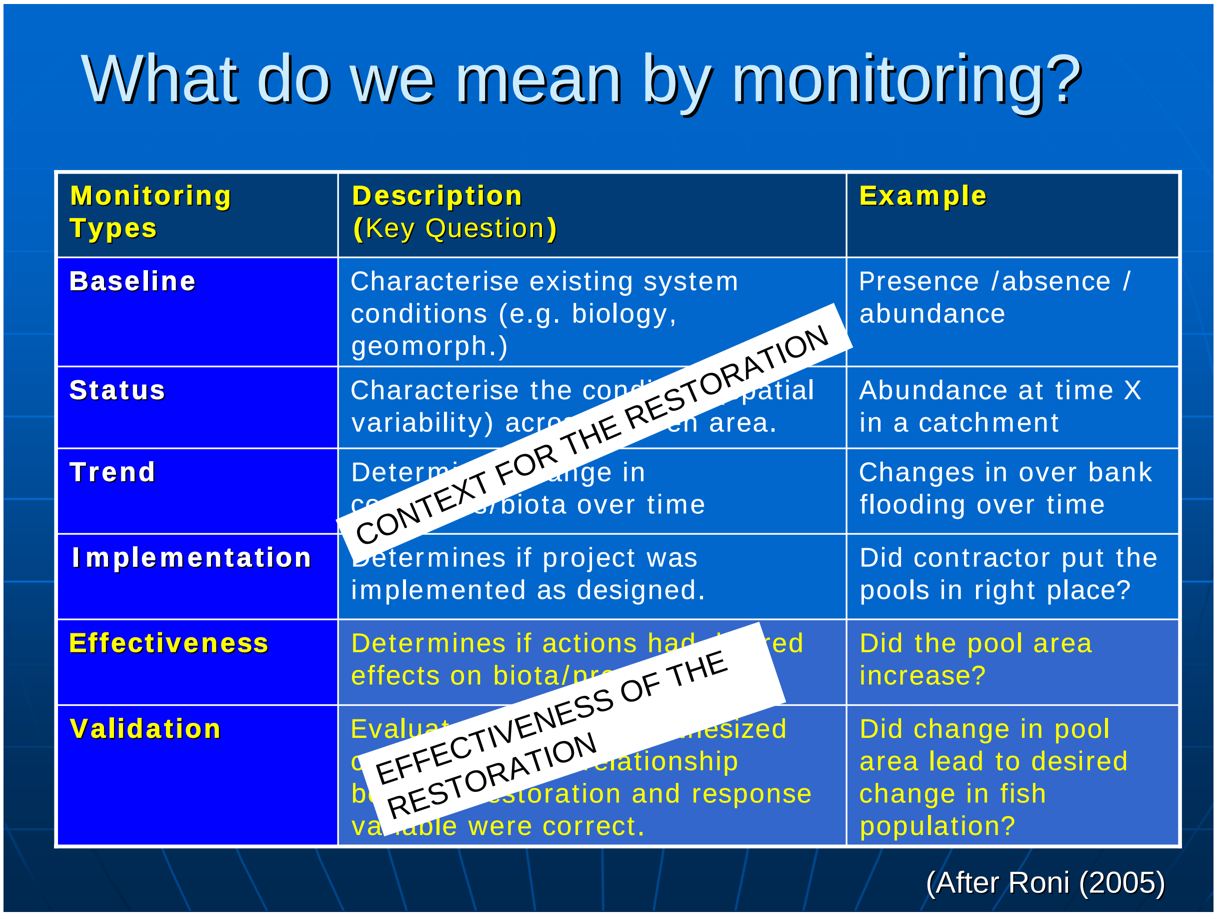
Towards an integrated approach to monitoring: Problem Definition.

- Monitoring = What do we mean by it? How should we do it?
- Uncertainty = a measure of information quality – too high and we learn nothing and it limits what we can say about attaining targets.
- Integration =Multi-disciplinarity (understanding each others science & values). Across different scales (how many, how often?).

What do we mean by monitoring?

Monitoring Types	**Description (Key Question)**	**Example**
Baseline	Characterise existing system conditions (e.g. biology, geomorph.)	Presence /absence / abundance
Status	Characterise the condition (spatial variability) across a given area.	Abundance at time X in a catchment
Trend	Determines change in conditions/biota over time	Changes in over bank flooding over time
Implementation	Determines if project was implemented as designed.	Did contractor put the pools in right place?
Effectiveness	Determines if actions had desired effects on biota/processes etc.	Did the pool area increase?
Validation	Evaluates whether hypothesized cause and effect relationship between restoration and response variable were correct.	Did change in pool area lead to desired change in fish population?

(After Roni (2005)



What do we mean by monitoring?

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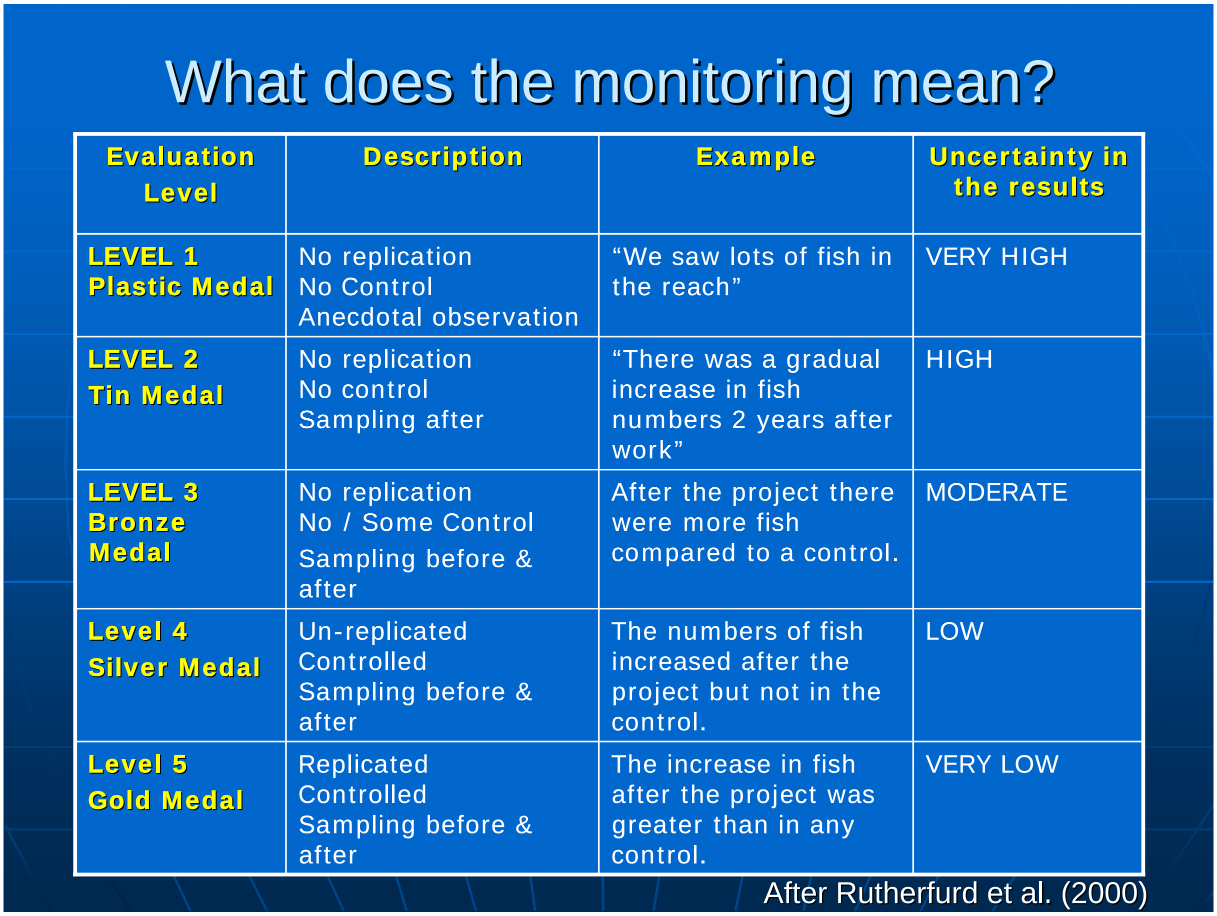
Effectiveness	Determines if actions had [illegible]red effects on biota/pr[illegible]	Did the pool area increase?
Validation	Evaluat[illegible] c[illegible]esized [illegible]relationship b[illegible]storation and response va[illegible]able were correct.	Did change in pool area lead to desired change in fish population?

CONTEXT FOR THE RESTORATION

EFFECTIVENESS OF THE RESTORATION

(After Roni (2005)

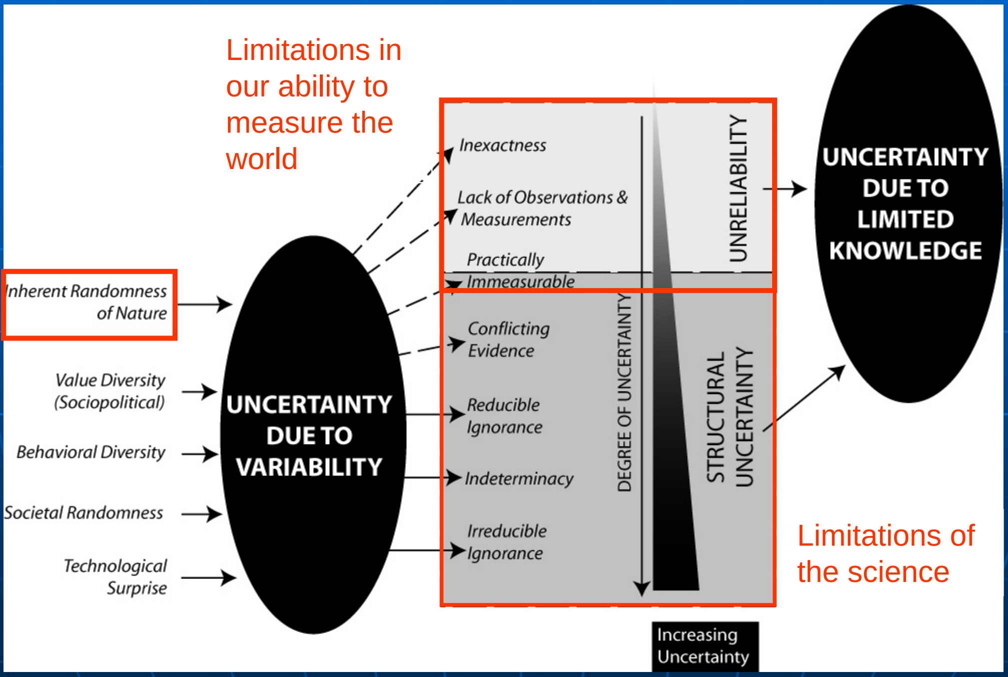


What does the monitoring mean?

Evaluation Level	Description	Example	Uncertainty in the results
LEVEL 1 **Plastic Medal**	No replication No Control Anecdotal observation	“We saw lots of fish in the reach”	VERY HIGH
LEVEL 2 **Tin Medal**	No replication No control Sampling after	“There was a gradual increase in fish numbers 2 years after work”	HIGH
LEVEL 3 **Bronze Medal**	No replication No / Some Control Sampling before & after	After the project there were more fish compared to a control.	MODERATE
Level 4 **Silver Medal**	Un-replicated Controlled Sampling before & after	The numbers of fish increased after the project but not in the control.	LOW
Level 5 **Gold Medal**	Replicated Controlled Sampling before & after	The increase in fish after the project was greater than in any control.	VERY LOW

After Rutherfurd et al. (2000)

What do we mean by uncertainty?



Limitations in our ability to measure the world

Inherent Randomness of Nature

Value Diversity (Sociopolitical)

Behavioral Diversity

Societal Randomness

Technological Surprise

UNCERTAINTY DUE TO VARIABILITY

Inexactness

Lack of Observations & Measurements

Practically Immeasurable

Conflicting Evidence

Reducible Ignorance

Indeterminacy

Irreducible Ignorance

UNRELIABILITY

STRUCTURAL UNCERTAINTY

DEGREE OF UNCERTAINTY

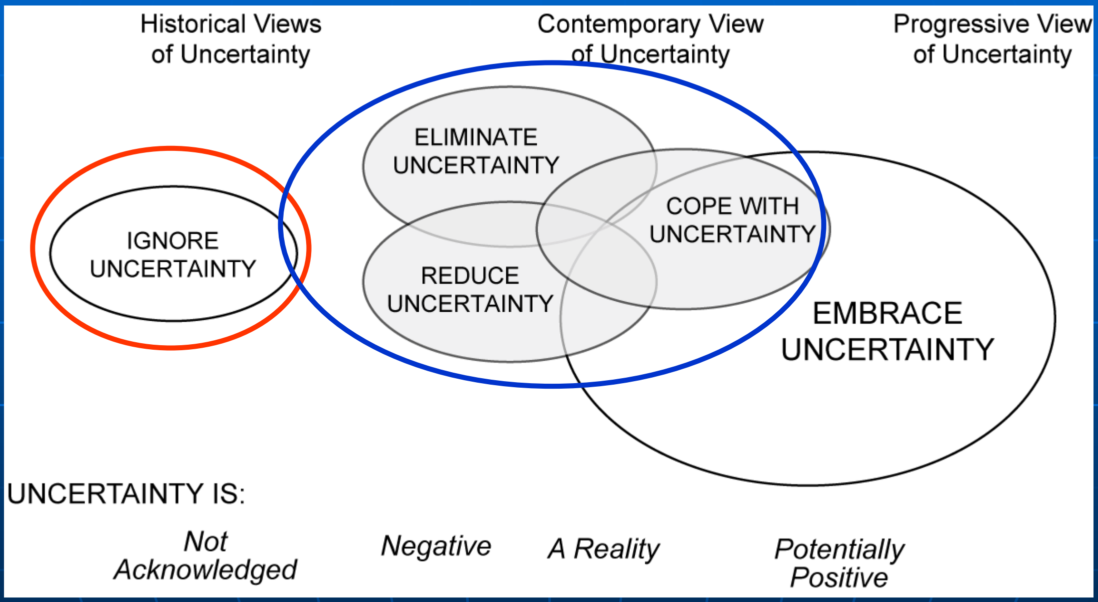
Increasing Uncertainty

UNCERTAINTY DUE TO LIMITED KNOWLEDGE

Limitations of the science

After Van Asselt (2000)

Approaches to uncertainty



Historical Views of Uncertainty

Contemporary View of Uncertainty

Progressive View of Uncertainty

IGNORE UNCERTAINTY

ELIMINATE UNCERTAINTY

REDUCE UNCERTAINTY

COPE WITH UNCERTAINTY

EMBRACE UNCERTAINTY

UNCERTAINTY IS:

Not Acknowledged

Negative

A Reality

Potentially Positive

Conclusion: Uncertainty in River Restoration Projects is ubiquitous and pervasive. We currently do a very poor job of communicating it. Monitoring will reveal its effects!

Key challenge to improved monitoring is to change our management approach.

A management approach that recognises:

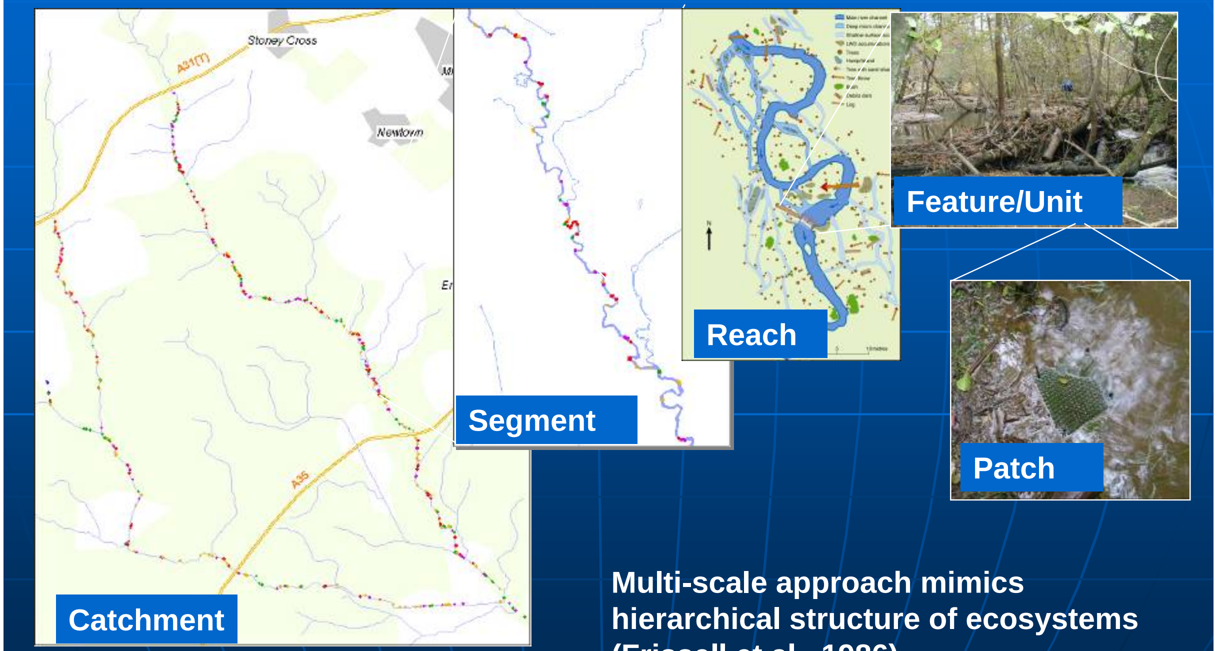
- Variability and complexity is an essential part of the system.
- Uncertainty is recognised and embraced.
- Management targets are flexible rather than restrictive.
- Education and participation are an essential method of management.

Adaptive Management

Summary so far….

- Monitoring is perhaps the most valuable part of a restoration in this stage of the practice/science – it is an essential part of adaptive management.
- Need to determine WHY we are monitoring a restoration project before we attempt WHAT & HOW we should monitor.
- Need to recognise the uncertainty and limitations of different monitoring methods FIRST before rushing off to deploy them.

Integration: across scales



Multi-scale approach mimics hierarchical structure of ecosystems (Frissell et al., 1986).

Scale Matters!

- Catchment scale – restoration affect lost in natural variability.
- Segment scale – Reduction in pool and riffle habitat frequency rel. to a SN Reference site.
- Reach Scale – Less riffle habitat and more pool habitat compared to SN Reference.
- Patch Scale – Process rates same as SN Reference site.

Integrated Monitoring & Multi-disciplinarity

- River restoration aims are essentially ecological but their implementation is typically physical!
- Essential to link the two more robustly!

1) Monitor at spatial & temporal scales meaningful across disciplinary boundaries.
2) Develop conceptual models for restoration together not in isolation.
3) Develop monitoring plans together.

Integrated Monitoring: Some ways forward.

- Improved and increased dialogue between disciplines (KTNetworks, R&D Projects).
- Establishing knowledge gaps and filling them (R&D Projects – EU/RC/DEFRA?).
- New use of existing datasets (RHS/Bio, Fluvial Audit & Bio) where relevant (Data Mining).
- Demonstration monitoring network? (trialling monitoring methods & techniques).
- Defining monitoring schemes for specific management requirements (not just WFD!).
- Disseminating the knowledge – Monitoring Handbook??

My view (as an aquatic ecologist):

'River restoration should bring together the many natural and human related components that characterise the river as it is now, into a whole system integrated approach to conserving, enhancing and promoting the riverine and associated ecosystem processes & functions'

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Natural components that characterise a river

- Physical properties of water & channel
  - eg. flow, density, solubility, temperature, profiles, mesohabitats
- Chemical properties of water
  - eg. rain, catchment characteristics (geology/weathering; run-off; soil vegetation relations)
- Biology
  - eg. species presence/absence; species occurrence and abundance; detritus, particulate organic matter
- Temporal & spatial aspects
  - eg. seasonality, altitude & location
- Ecology
  - eg. trophic interactions, longitudinal connections, lateral connections, in-stream processes, predation & competition

Scope out the project

- What do we need to know?

  What do we already know?

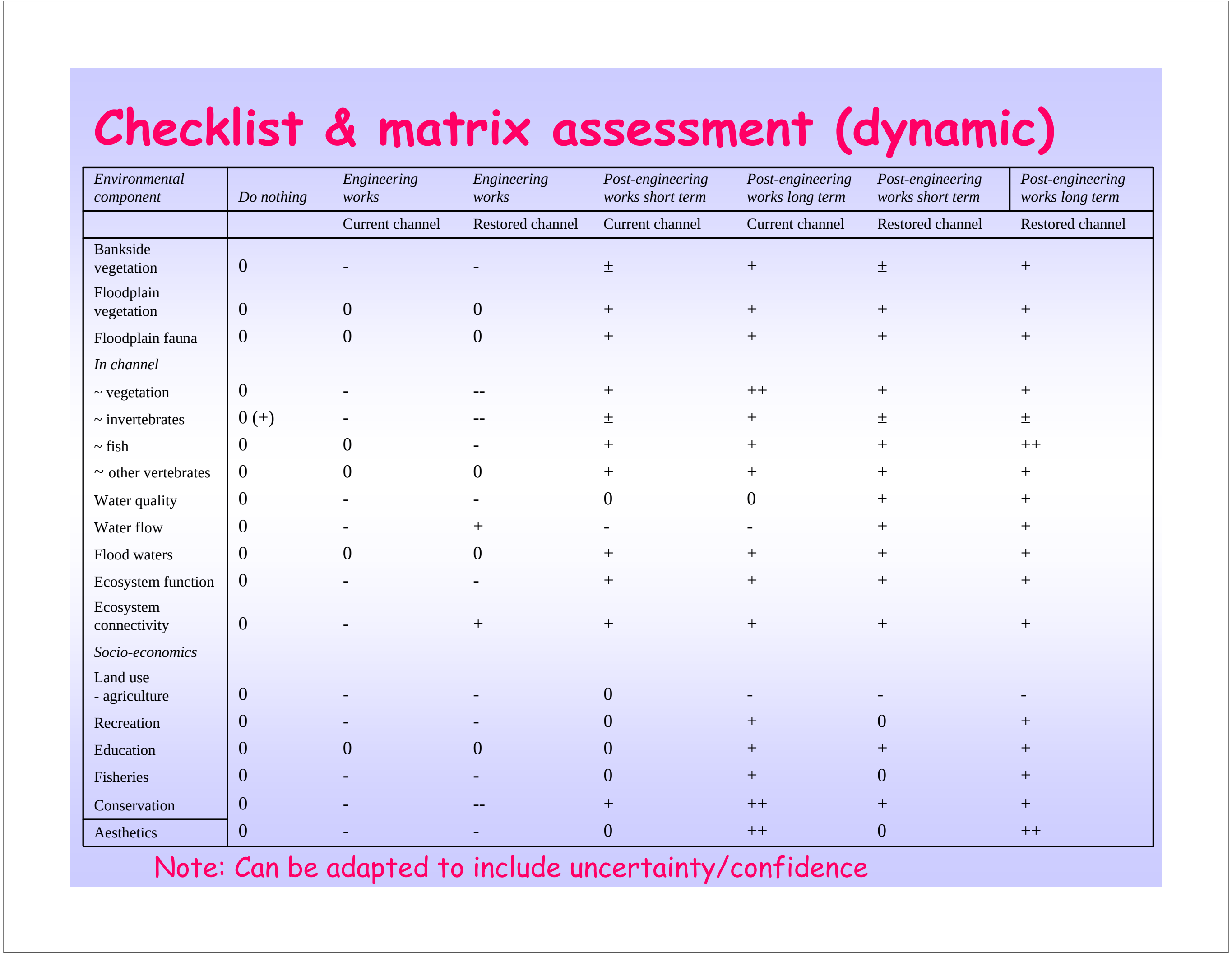
  eg. Objective = improving conservation value & biodiversity through physical reconnection

- River restoration engineering
- Stakeholders (incl. the experts)
- Biodiversity
  - site vegetation community
  - site invertebrate community
  - site vertebrate community
  - floodplain
  - adjacent biotic sources
  - available data and further requirements
  - conservation designations
- Land & water course use (incl. history)
- Hydrology
  - water course
  - wetland
- Flooding
  - upstream
  - downstream
- Recreation and amenity
- Other site associated environment plans (existing or future eg. LEAP)

Assumed ecological consequences of undertaking engineering specifications - following scoping and characterising

- Increased habitat heterogeneity
- Increase invertebrate diversity & abundance
- Improved local in-stream conditions for macrophytes
- Increased hydro-morphological diversity
- Improved access to functional habitat (eg. refuge, nursery)
- Better potential for upstream and downstream movement (longitudinal connectivity)
- Reconnection laterally (ie. floodplain function)
- Slower rate of nutrient spiralling
- No significant implications for species of conservation or ecological importance (eg. Annex II *Luronium natans*) if conservation measures are put in place (eg. translocation)

Can form the basis of hypotheses



Checklist & matrix assessment (dynamic)

Environmental component	*Do nothing*	*Engineering works*	*Engineering works*	*Post-engineering works short term*	*Post-engineering works long term*	*Post-engineering works short term*	*Post-engineering works long term*
		Current channel	Restored channel	Current channel	Current channel	Restored channel	Restored channel
Bankside vegetation	0	-	-	±	+	±	+
Floodplain vegetation	0	0	0	+	+	+	+
Floodplain fauna	0	0	0	+	+	+	+
In channel							
~ vegetation	0	-	--	+	++	+	+
~ invertebrates	0 (+)	-	--	±	+	±	±
~ fish	0	0	-	+	+	+	++
~ other vertebrates	0	0	0	+	+	+	+
Water quality	0	-	-	0	0	±	+
Water flow	0	-	+	-	-	+	+
Flood waters	0	0	0	+	+	+	+
Ecosystem function	0	-	-	+	+	+	+
Ecosystem connectivity	0	-	+	+	+	+	+
Socio-economics							
Land use - agriculture	0	-	-	0	-	-	-
Recreation	0	-	-	0	+	0	+
Education	0	0	0	0	+	+	+
Fisheries	0	-	-	0	+	0	+
Conservation	0	-	--	+	++	+	+
Aesthetics	0	-	-	0	++	0	++

Note: Can be adapted to include uncertainty/confidence