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River restoration: a comprehensive framework

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Abstract:

River rehabilitation is an important step towards healthier ecosystems leading to social, economic and ecological gains. Social gains may include the feeling of contribution to our society or knowledge that there is a minimisation of impacts to rivers, allowing more uses of the river eg. tourism, and a greater sharing of the resource. Economic gains may include more sustainable and cost-effective management. Ecological gains may include an increased resilience to disturbance by re-introducing habitat choices for aquatic species.

Most of our river systems have been heavily modified, resulting in aquatic ecosystem degradation. Degradation can come from many causes including habitat alteration, such as desnagging and commitments to irrigation and flood protection. Attempts at river restoration to date have been conducted largely in an uncoordinated way, often concentrating on only one component of a river system eg. flows. As river systems are complex, variable, interacting environments with a diversity of habitats river restoration must consider all components.

In order to undertake restoration in a most cost effective manner, priorities must be set in addressing which components and methods should be rehabilitated first. These should be examined in a way that allows linkages within an ecosystem to be addressed. Multiple benefits may then be derived from a particular solution. Some components remain as ‘flexible’ variables eg. snags whilst others may remain fixed eg. the amount of available water. These factors must be considered in a comprehensive framework which allows priorities to be set.

THE MAIN POINTS OF THIS PAPER

- There is a need to assess the condition of the river in a comprehensive way and to prioritise issues so that river rehabilitation can be undertaken in the most cost-effective way.
- Assessment must take into account the biological and physical attributes. This may best be done using a multi-disciplinary expert panel approach.
- Monitoring of rehabilitation works needs to be undertaken with a clear understanding of the objectives. Documentation should enable us, as the community, to build on past successes and reduce failures.
- Participation in river rehabilitation will lead to - healthier ecosystems, greater skills and more efficient river management, and will help to ensure that the community as a whole will increase its knowledge and attain best management practices.

1. INTRODUCTION

River restoration presents us with the opportunity to ensure that actions which are detrimental to our river systems are halted and damage which has occurred repaired. Decision-making for restoration planning and the resultant works require a strong ecological foundation and a comprehensive catchment management framework to ensure river health and environmental integrity. The prototype of an evaluation tool has been developed which can be used to assist authorities involved in river restoration and rehabilitation practices. The evaluation tool helps decision-making through appraisal of the ecological condition of a river system. Works can then be undertaken from a more comprehensive and scientific basis by the inclusion of current knowledge of physical and biological components, taking into account social, political and institutional settings. The priorities which arise through this evaluation process can then be placed in a more comprehensive framework. Such expert assessment helps further prioritisation by managers and community by providing an ecological basis to increase the effectiveness of the social, economic and political objectives and criteria that are taken into account when making decisions. Effectiveness is also increased by ensuring that the best available knowledge is used at the time of the decision and will hopefully lead to a reduction in inappropriate works and greater understanding of a river system.

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2. THE APPROACH

Restoration of river systems involves widening the scope of our thinking about river management to include known issues that are currently impacting upon rivers. The concept for the evaluation tool was developed by examining how to achieve environmental benefits using an integrated approach to river restoration through flow and habitat management actions.

The approach taken to formulate the evaluation tool was the establishment and use of a multidisciplinary expert panel. This allowed for multiple perspectives to be taken into account to minimise incremental and ad hoc planning and development decisions. The multidisciplinary nature of the panel ensured that development was undertaken within a broader ecological framework. Increased interaction between experts introduced concepts and ideas and different ways of viewing restoration and allowed the pooled knowledge of all the disciplines to provide a solution to the problem.

Key steps in the development of the tool were the:

- collation of existing biological and physical information
- identification of knowledge gaps and sources
- formulation of key questions and priorities in target areas and at a catchment scale
- and development of a systematic approach to integrating both knowledge and methods.

Further workshops are intended to be held to fine tune this decision tool.

A review of knowledge relevant to the instream environment occurred for: fish ecology, invertebrate ecology, water quality, river flows, instream habitats, floodplain ecology, hydrology and geomorphology, introduced species, barriers, riparian vegetation, waterway and ecological management and management options.

We have used a long-term perspective for river restoration. This is to try not to close down solutions before they arise and to aim towards the highest level of restoration that can be obtained. We believe it is important to recognise that there are gaps in our knowledge which will prevent the attainment of the most effective management of our rivers, but by the continued learning of techniques and processes we can move towards best management practice. We recognise that regulation and modifications to our river systems have limited the flexibility for change to some elements, but not all. We also recognise the aims and visions for rivers and catchments will vary with community desires and practicalities. That said, for development of this tool, we view river restoration as aiming to rehabilitate the physical and biotic processes of a river in a way that is conducive to the progression of ecosystems toward their natural state.

In heavily modified rivers this definition can be translated into: choosing restoration planning and rehabilitation works which do not cause further damage to the river system and enable such functions such as habitat availability and fish migration to recommence if they have been affected. It also recognises that there may be situations where there is currently no flexibility to alter some components.

3. CONSIDERATIONS FOR AN EVALUATION TOOL IN THE MURRAY-DARLING BASIN

3.1 Characteristics of the natural system

Australian river systems can be characterised by complexity and variability. Complexity is expressed in the view that very stable Australian river systems can be broken by periods of rapid change, rather than continuously fluctuating around a particular average value ie. river systems are not in dynamic equilibrium (Koehn et al. 1997). Our native aquatic flora and fauna evolved in response to these characteristics.

Different mechanisms account for different types of complexity. Connectivity along the river, spatial scales and the timing of river processes all influence complexity. These were three important concepts for river management arising from the workshop and are summarized below.

- Connectivity along the river is important as alterations at one point can have effects upstream and downstream of that point, for example water impounds behind a weir wall decreasing the river gradient but increasing erosion downstream leading to changes and losses of habitats.
- Processes have boundaries which contain all the actions for that process. The boundary indicates the scale at which a process is operating. A smaller scale process may influence larger scale processes. Reach scale processes such as those affected by the sequence of riffles and pools may be a key cause of the longitudinal organization of stream ecosystems (Clifford and Richards, 1992), for example, channelisation may alter the river gradient and cause upstream bed erosion which can degrade aquatic habitat.
- A threshold change is one in which there is an abrupt change from one state to another. This may occur when a critical value for a particular process is exceeded. A movement across a threshold may be intrinsic to a landform or may be induced by progressive change of an external variable. For example, flow causes the lower section of a bank to erode; the upper section is left overhanging, eventually this upper section will collapse. A large load of sediment may reach the stream at one point of time rather then smaller amounts gradually over time. Overhanging banks can provide protection for some aquatic species during high flows. They are a natural

feature. Vegetation on banks may help slow this process back to natural rates of change.

Flow regimes in Australia are variable by world standards and are characterised by large fluctuations in annual flow and peak discharges (Finlayson et al. 1986), which create a diverse range of habitats. These are able to support a range of native flora and fauna during their life cycles with many native species being opportunistic (Finlayson and McMahon, 1991). Such species have developed life strategies to deal with the complicated interactions and sudden changes between such physical factors which influence the distribution and abundance of species and aquatic communities.

3.2 Regulation and rehabilitation

Regulation of river systems for such activities as agriculture and water supply, have affected the natural ecological processes. Regulation has led to a decrease in the complexity and variability of flows and hence the functional properties of a river system eg. provision of habitat. A variety of native flora and fauna are dependent on ecological processes, such as droughts and floods, that enlivened the river systems. For example, the recruitment of Murray Cod is thought to be associated with flooding. Hence, maintaining flooding may be an important factor in the conservation of this species.

Problems arise in the reinstatement of processes when commitments to other uses leave little flexibility to adjust key components, (eg. flow), and there is a lack of knowledge and understanding of the effects of management practices on other components of a river system. Using the flow example, three critical concerns exemplify this:

- do we know enough about the ecological requirements of flow to specify appropriate levels?
- are we aware of other factors that also provide for the long-term sustainability of aquatic species and communities?
- are there other factors which may be equally or more critical to provide for species and their life cycle requirements?

3.3 Biodiversity

Biodiversity concerns the sum of all our native species of flora and fauna, the genetic variation within them, their habitats, and the ecosystems of which they are an integral part (Natural Resources and Environment 1997). Biodiversity is an important ecological component and needs to be taken into account in river restoration.

4. THE FRAMEWORK

Restoration and rehabilitation practices need to be undertaken by providing a broader framework that will ensure that all factors are considered. This is unlikely to occur when focussing only on one particular issue.

A framework for river restoration is shown in Figure 1. This broad decision-making framework splits the steps involved in undertaking river restoration into discrete units which may be considered separately whilst still acknowledging the various linkages of the different steps. This integrated approach will allow management options to be evaluated to prioritise strategies which can maximise environmental benefit in a cost-effective manner. The restoration process places river management within environmental, managerial, political, social and economic spheres.

4.1 Reality Triangle

Multiple uses of rivers include water for irrigation agriculture, water supply, commercial and recreational fisheries and water for the environment. River management works such as rock beaching, desnagging and flood protection are also actions performed on rivers. In order to maximise the cost effectiveness of rehabilitation works there is a need for community and institutional aspirations to be considered. Cooperative approaches must be engendered between stakeholders and a process of community empowerment undertaken so that maximum support and ownership can help drive the restoration activities.

There is a need to continue to recognise the complex interactions between the various processes affecting the instream environment and how they effect the structure and functions at different stream reaches. More cost-effective solutions will result as proposed solutions will be able to addressed synergies between different problems. to strive to incorporate better knowledge as it becomes available.

4.2 Decision making

A typical decision making process is to:

- identify that there is a problem
- assess what the problem is impacting upon
- determine the cause of the problem
- propose solutions
- assess methods of measuring that clearly detect degree of success
- document the management decision process and results.

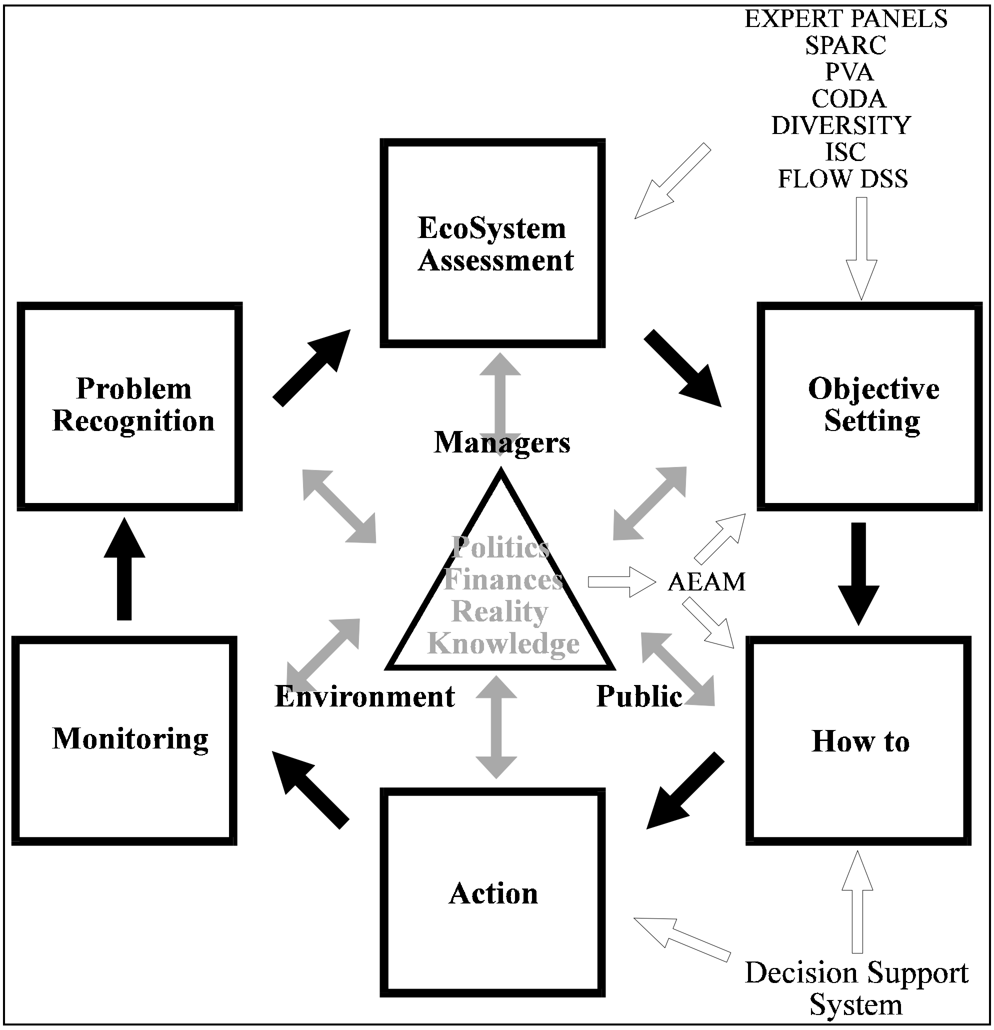

Figure 1: Process and direction by which river restoration through integrated management must flow. River restoration has been thought of as a series of steps in which biophysical information can enhance the decision making process. Dark arrows represent the direction in which the biophysical steps of river restoration must be evaluated. Grey arrows represent the interaction between the expectations, costs and benefits of the public, managers and environment with each step of the process. Clear arrows represent where and what type of decision making tools may be useful to assist each step. The required steps for the process are:

- Problem recognition - to identify what restoration needs to take place;
- Ecosystem assessment - assessing the key processes operating to enable the underlying causes of the restoration issues to be addressed.
- Objective Setting - concerns the proper allocation of goals that can be clearly measured
- How to - methods available to pursue rehabilitation works
- Action - the doing of the work
- Monitoring - is required to ensure the effectiveness of actions.

5. EVALUATION TOOL

The evaluation tool will allow for the user to take an informed approach to river restoration in order to isolate probable causes and direct interest to those areas. A systematic approach to objective setting and ecosystem assessment will enhance the decision-making process by allowing clarification of the steps and issues involved in determining appropriate solutions to restoration issues.

The tool will allow key priorities, as determined by the relevant authority, to be examined in comparison with other priorities and restoration activities at a catchment scale to maximise benefits by addressing synergies eg. An action for addressing water temperature may also be beneficial for other aspects (eg. overall productivity).Multiple benefits/constraints of priorities and/or activities can therefore by drawn out, increasing cost-effectiveness. A matrix format can be used to give options, benefits and constraints for priorities. Specific guidance questions could include:

Where are you in the catchment? (examines sources of information such as river classification)

What are the issues?

What do you expect to achieve?

What are the degradation issues of concern?

Finer detail is required as you evaluate site requirements:

1. Set goals for each module. Do this by a site assessment for each module/discipline undertaking a question/answer process and list the threats.

2. Prioritise these threats and:

- predict results
- construct if/then scenarios
- aim for greatest nett benefit

Considerations when clarifying the steps must include:

- In order to ensure proper objective setting the type and purpose of restoration, available tools, community expectations and the measurement of the objectives must be decided. Addressing uncertainty by hypothesis testing may be a key consideration due to the heterogeneity of sites and the difficulties of comparisons between different components.
- Before determining priorities, relevant issues must be canvassed.

An example of three different issues considered for a reach of the Murray River downstream of Albury are:

1. Reduced summer temperatures
2. Habitat Loss
3. Changed flow regime

Prioritising of these issues were undertaken and placed in this order of importance for restoration. There is limited flexibility for altering any of these issues at present but they need to be addressed in future river management decisions.

- Inequalities in scale may be addressed by a hierarchical evaluation which can set boundaries for the scope of objectives and clear measurements. That is, some instream processes may only need to be examined at a reach level whilst others may necessitate evaluation over a larger reach (many kilometres) or landscape level. Processes identified at various scales are likely to differ depending on whether it is a landscape, threatened species or community which is being restored.
- It is also important to identify that the recovery of different components of a river system will also vary with time. Some biological recovery periods can be slow (decades) and time-treatment interactions must be taken into account when setting objectives which can be clearly measured. In some components very little is currently known about recovery rates whilst in others the system may not reach recovery before the next perturbation.
- Assessment provides an understanding of how the system is currently functioning and identification of those components which are constraints and those which can be manipulated. Assessment must consider the natural functioning of the ecosystem, the processes and the spatial scale at which they are operating within the ecosystem. Examining processes allows the underlying causes of degradation/restoration issues to be determined and therefore enables the source of the problem to be addressed.
- Examining knowledge gaps can help direct attention to those areas where further work is required. The expert panel approach identified that priority setting and restoration concepts were generally not hampered by knowledge gaps, however there were still gaps in restoration details such as the requirements and effects of works on a river system.
- There are tools and information available to assist with restoration decision-making. Figure 1 contains some current tools that can be used at the various steps in the restoration process. These encompass expert systems, knowledge bases and protocols for setting priorities.

Tools presented in the figure 1 are:

Expert panels - bring together experts in areas relevant to the chosen problem (multidisciplinary). They can provide an appraisal of environmental conditions and requirements using best available information.

SPARC - (Setting of Priorities and Assessment of Risk in Conservation) determines the risk of threats confronting any number of species and allows for prioritisation.
PVA- (Population Viability Analysis) allows a systematic attempt to understand the ecological processes that make a population vulnerable to decline or extinction.
CODA - (Conservation Options and Decision Analysis) enables goals and objectives to be set taking into account natural features, design criteria and competing uses
DIVERSITY - allows priorities to be set based on the maximising biological diversity.
ISC - (Index of Stream Condition) - allows planning to be undertaken on the basis of monitoring of key characteristics of a stream eg. physical form, macroinvertebrates,
Flows DSS - (Environmental Flow Decision Support System) a support system that will assist in the determination of environmental flows.
AEAM - (Adaptive Environmental Assessment and Management) can be used for development and exploratation of management options for complex systems by bringing key stakeholders together.

Further detail of the restoration process and the evaluation tool can be found in Koehn et al. 1997 and Koehn et al. (1998).

6. CONCLUSION

The river restoration process enables objective setting and ecosystem assessment to be placed within community and institutional requirements.

The evaluation tool has a broad basis to enable a range of issues relevant to restoration to be considered for river management.

This comprehensive framework will enable future objective setting and ecosystem assessment for restoration to continue with greater consideration of environmental benefits and in a more cost-effective manner.

8. REFERENCES

Clifford, N.J. and Richards, K.S. (1992). "The reversal hypothesis and the maintenance of riffle-pool sequences: a review and field appraisal." In Carling, P.A. and Petts, G.E. Lowland floodplain rivers: Geomorphological Perspectives John Wiley & Sons, Chichester, England: 43-70.

Finlayson, B.L. and McMahon, T.A. (1991). "Runoff variability in Australia: Causes and environmental consequences." International Hydrology and Water Resources Symposium Perth 2-4 Oct 1991. The Institution of Engineers, Australia National Conference Publication No 91/22: 504-511.

Finlayson, B.L., McMahon, T.A., Srikanthan, R. and Haines, A. (1986). "World hydrology: a new data base for comparative analyses." Hydrology and Water Resources Symposium 1986, Griffith University, Brisbane 25-27 November 1986. The Institute of Engineers, Australia, National Conference Publication No. 86/13: 288-291.

Koehn, J.D., Nicol, S.J. and Lucas, A.M. (1997). "River Restoration through Integrated Management." Draft report to the Murray-Darling Basin Commission. Department of Natural Resources and Environment, Melbourne.

Koehn, J.D., Lucas, A.M. and Nicol, S.J. (1998) "River Restoration through Integrated Management: A pilot study." In: Banens, R.J. and Lehane, R. (eds) 1997 Riverine Environment Research Forum. Proceedings of the Riverine Environment Research Forum of the MDBC Natural Resource Management Strategy funded projects, held in Canberra, November 1997. (Murray-Darling Basin Commission: Canberra). Proceedings of the Murray-Darling Basin Commission Riverine Environment forum.

Natural Resources and Environment (1997). "Victorias Biodiversity Strategy - Victoria's Biodiversity: Our Living Wealth, Sustaining Our Living Wealth and Directions In Management." Crown (State of Victoria).

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