Challenges for improving the science underpinning river restoration practices

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Abstract

Throughout the world there is a growing interest in river restoration and billions of dollars are being spent to address the problems that have arisen from our misuse of river ecosystems. The field of restoration science has much to contribute to the practice and assessment of river restoration projects. However, the development of this discipline is being impeded by several factors including: the lack of long term scientific experiments and testing of hypotheses that underpin river restoration practices; a lack of consensus as to what constitutes successful restoration; aversion to risk; entrenched practices; and limited integration among disciplines. Several recent developments that are providing direction for the future of restoration science are discussed. Some of the challenges in the field of restoration science are: to improve the planning of scientific studies; secure funding for long term trials; to adopt new approaches; improve communication between all stakeholders; improve integration among disciplines; and deliver innovative education and training programs. If these challenges are embraced we are more likely to achieve better restoration outcomes. In particular, if we undertake integrative river science incorporating biophysical, social and economic aspects we will advance the development of a 'whole of system' approach to river management.

Keywords

Restoration science, scientific process, evidence based practice, monitoring, interdisciplinary research

Introduction

Throughout the world there is a growing interest in river restoration and billions of dollars are being spent to address the problems that have arisen from our misuse of river and floodplain ecosystems (Palmer *et al*, 2005). Consequently, river restoration has become a major industry involving sponsors, funding bodies, scientists, practitioners, natural resource managers and the community (Giller, 2005).

There are a wide range of practices that are referred to as river restoration. Gillilan *et al.* (2005) describes a continuum of restoration types (Figure 1) that range from those with strong ecological goals to those that are essentially erosion control and do not implement the basic principles of ecologically based restoration, such as those outlined by the Society of Ecological Restoration (SER, 2002). Consequently, while some projects will have ecologically effective outcomes, many others that are referred to as restoration projects will result in little improvement in ecosystem function (Gillilan *et al.*, 2005). Increasingly river managers are shifting from hard engineering solutions to ecologically based restoration practices (Palmer *et al*., 2005).

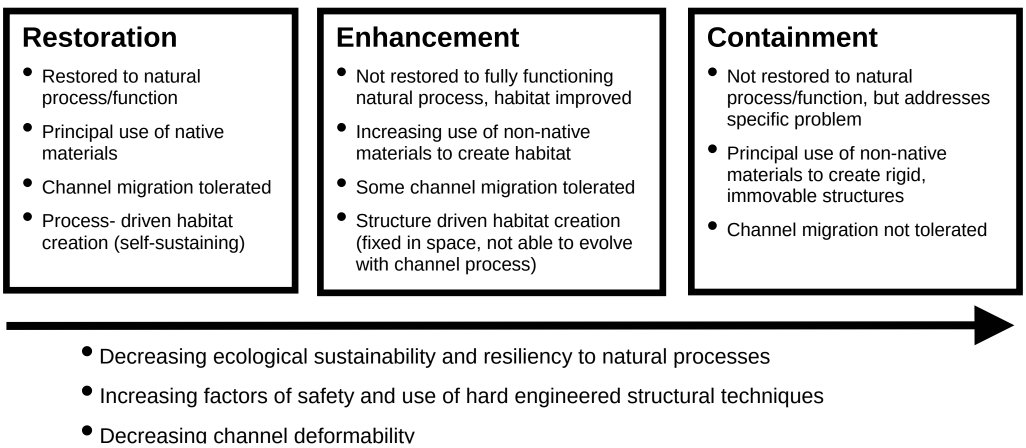

Figure 1. Continuum of restoration types (Modified from Gillilan *et al.*, 2005)

The question that we should ask of river restoration projects is 'Are they making a difference?' This question is not as simple as it may seem, because the success of a restoration project can be evaluated by different stakeholders in different ways, such as those outlined by Palmer *et al.* (2005):

- Was the project accomplished cost-effectively?
- Were the stakeholders satisfied with the outcome?
- Was the product aesthetically pleasing?
- Did the project protect important infrastructure near the river?
- Did the project result in increased recreational opportunities or community education about rivers?
- Was the restoration an ecological success?
- Did the project advance the state of restoration science?

Palmer *et al.* (2005) suggest that successful projects should, ideally, satisfy stakeholder needs, advance the science and practice of river restoration (learning success) and also be ecological successes (Figure 2).

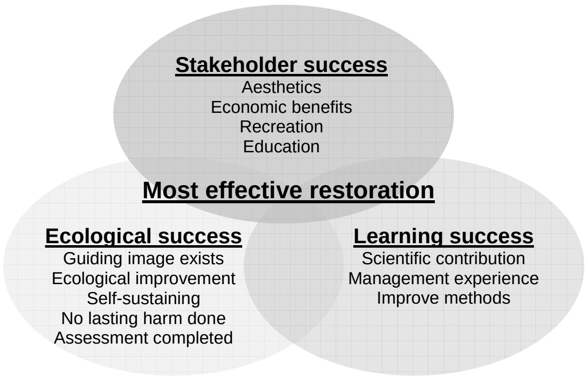

Figure 2. Model that describes how the most effective restoration projects lie at the intersection of stakeholder success, learning success and ecological success (Modified from: Palmer *et al.*,2005)

The field of restoration science has much to contribute to the practice and assessment of river restoration projects. In this paper I will discuss some of the current issues facing restoration science and introduce recent ideas that have been proposed to progress the practice of river restoration and restoration science. Finally I will discuss some of the challenges we face to improve the science underpinning river restoration.

Factors impeding the development of restoration science

Restoration science is still an emerging field. The development of this discipline is being impeded by several factors. Five factors I will discuss here include the lack of long term scientific experiments and testing of hypotheses that underpin river restoration practices, a lack of consensus as to what constitutes successful restoration, aversion to risk, entrenched practices and limited integration among disciplines. I will also discuss some interesting recent developments that provide direction for the future of restoration science.

Lack of long term scientific experiments and testing of hypotheses that underpin river restoration practices
The urgent need for on-ground works, the depth of community support for river restoration and the availability of funding through a variety of programs have, to some extent, resulted in the practice of river restoration running ahead of restoration science. As a result, some of the measures that are routinely employed by river restoration practitioners have not been tested by the scientific process, so advances have progressed on an *ad hoc*, site- and situation-specific basis (Hobbs and Norton, 1996). Consequently, we cannot be sure that the commonly used practices can be transferred from one situation to another or that they will be effective in the long term. It is imperative that the practice of river restoration be based on rigorous science and include hypothesis testing (Lake, 2001), otherwise we may be implementing measures that are quick fixes that will not produce the best outcomes in the longer term.

The main stages of the scientific process (Figure 3), as they relate to river restoration are:

1) Through observation and description we develop an understanding of how a river system works and develop a theory about how it has been impaired,
2) Using available knowledge we develop a hypothesis or a model that predicts the outcome of an intended restoration strategy,
3) Restoration projects are undertaken, accompanied by rigorous scientific trials to test hypotheses, and
4) Following several independent experiments a theory gains support and is accepted, or loses credibility and is rejected and possibly modified.

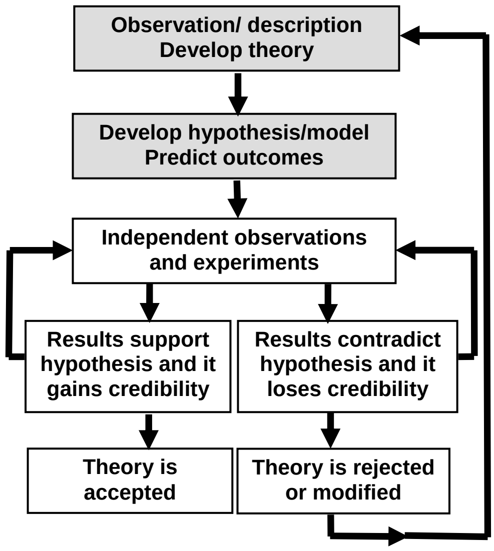

Figure 3. Stages of the scientific process. Shaded boxes indicate stages that have reasonably good coverage in restoration science.

There is a large body of research that describes how river systems function and have been degraded (stage 1). There have also been major advances in the development of tools for river restoration that are based on sound science (stage 2), many of which will be discussed during the 5th Australian Stream Management Conference. However, there is general agreement that there is a lack of long term experiments testing river restoration practices (stage 3 of the scientific process), and very few projects and practices have been adequately evaluated in terms of their ecological success (Lake, 2001; Jansson *et al.*, 2005; Palmer *et al.*, 2005). Furthermore, the results of the limited number of well funded assessments (e.g. the Living Murray Initiative of the Murray-Darling Basin Commission) are not yet available. Thus, we are still really in the process of testing many of the hypotheses and models relating to river restoration.

If we do not undertake rigorous scientific assessments of restoration practices there is a risk that some restoration practices may become entrenched even though they are based on untested models and there is not sufficient evidence to underpin the practice. Some practices that appear to be ‘common sense’ may tempt us into believing that no scientific test of the practice is needed.

There are strong parallels of this problem in the health industry. There is growing concern that there is limited evidence-based medicine being practiced and that a number of medical treatments being employed have never been scientifically tested (ABC, 2007). Treatments are often used because medical practitioners were taught to use them. Ian Harris (Director of Orthopaedic Surgery, Liverpool Hospital, Sydney) recently stated that “One of the problems with surgery is that it's an apprenticeship. I was trained to do what the people I worked with did, I wasn't taught evidence based medicine, I was just taught how to operate” (ABC, 2007). Consequently, many treatments are based on belief and convention rather than on solid evidence. Treatments become entrenched because, if on many occasions the treatment appears to work out according to the prediction but other times it doesn't, we tend to be swayed by observed positive outcomes. When randomised trials have been undertaken, some widely used medical treatments have been shown to have no benefit at all. For example, a randomised, placebo-controlled trial of arthroscopic surgery for osteoarthritis of the knee (of which there are hundreds of thousands of operations done in the US) found that after surgery the patients receiving the treatment were no better off than those receiving a placebo procedure (Moseley *et al.*, 2002). This is an example of a practice that has become entrenched but is not based on evidence. There are other examples of medical treatments that have also been shown to be useless or even harmful (ABC 2007).

In the field of river restoration science there is also the need for more evidence based practice. If we do not commit to this, we may not target resources for restoration as well as we could and in some cases may actually end up doing some harm. In the absence of rigorous assessment we may also be missing opportunities to improve our understanding of river ecosystems and learn lessons for future projects.

Lack of consensus as to what constitutes successful restoration

Many authors (eg Hobbs and Norton, 1996; Lake, 2001) have argued that evaluation of restoration projects is crucial to the future of ecological restoration. However, many of the evaluations undertaken have un-replicated and uncontrolled designs (see six levels of evaluation described by Rutherfurd *et al.* 2004) that might describe outputs or trends but do not conclusively evaluate restoration approaches. Furthermore, even if there was adequate funding to assess river restoration projects, there has been little consensus as to what constitutes successful restoration and there are no agreed criteria for judging the ecological success of projects (Palmer *et al.*, 2005). A major problem is that some practitioners planning and/or implementing restoration projects assume that physical restoration of habitats is likely to be of ecological benefit. This stems from the erroneous notion that ecology is simple and the idea that “if you build it they will come”. Consequently, some projects that are claimed to be successes may in fact not be ecologically successful.

To address this, Palmer *et al.* (2005) have recently proposed a set of five criteria for measuring ecological success of river restoration projects and Jansson *et al.* (2005) added a sixth criterion. The six criteria are:

1) the project design be based on a specified guiding image (model) of a more dynamic, healthy river
2) the river's ecological condition must be measurably improved,
3) the river must be more self-sustaining and resilient to external perturbations (minimal maintenance)
4) during the construction phase, no lasting harm should be inflicted on the ecoysystem,
5) both pre- and post-assessment must be completed and data be made publicly available, and
6) the guiding image should be supplemented by a description/prediction of the ecological mechanisms through which the intended restoration strategy will achieve its goals.

The practical application of some of these criteria (eg. criteria 6) may pose significant challenges and would require more involvement of scientists in restoration projects (Giller, 2005). However, this increased involvement of scientists would provide more opportunities for recommending and implementing appropriate strategies across river systems.

Aversion to risk

Risk management is now a well established process in most organisations. Gillilan *et al.* (2005) have suggested that by increasing factors of safety in restoration projects, many projects have been driven away from ecological restoration towards erosion control and containment (Figure 1). They suggest that an over-reaction to even moderate channel adjustments in a restored channel can often lead to overly enthusiatic 'site repair'. Gillilan *et al.* (2005) suggest this may be the result of projects adopting an unrealistic goal of ecosystem restoration that does not accept any adjustment or failure during a channel-changing flow event. If we consider this aversion to risk in the context of restoration science, it is possible that many opportunities to improve our understanding of river restoration practices may be lost by overly enthusiastic site repair following channel readjustment. The community should be prepared for, and be more accepting of, unexpected changes and use those events as opportunities to learn more about river restoration practices.

Entrenched practices

The selection of appropriate restoration practices and indicators to monitor the outcomes of restoration projects is an important part of restoration science. Scientists and practitioners involved in restoration projects often show personal bias when selecting restoration techniques or choosing indicators for monitoring (Boulton, 1999; Fairweather 1999). This is because people tend to choose specific approaches they are familiar with and those in which they have a vested or intellectual interest. There is a parallel example of this in the health industry. Ian Harris (Director of Orthopaedic Surgery, Liverpool Hospital) recently stated "Surgeons tend to operate - if you go to see a spine surgeon with back pain, odds are you'll come out of there with a spinal operation. If you go and see a chiropractor with back pain, you're not going to get out of there without a spinal manipulation. I think it's the same thing for radiation oncologists or rheumatologists. People just do what they do because they think that it's the best"(ABC, 2007).

In river restoration projects the most appropriate technique or indicator may not be applied in some cases because scientists and practitioners continue to promote what they are familiar with. We need to be aware of and avoid this type of bias or we may be limiting restoration outcomes and the advancement of the field of restoration science.

Limited integration among disciplines

One of the factors that may be limiting the development of river restoration science is the lack of integrated projects. It has been said that interdisciplinary collaboration is one of science's missing links (Jewitt and Gorgens, 2000). There are many examples of multidisciplinary projects where different disciplines (eg. ecology, geomorphology, hydrology, social science and economics) have contributed to projects. However, multidisciplinary projects are often broken into discipline-based components at an early stage of the project and the research outcomes of different disciplines brought together in a simplistic way only towards the end of the project. This approach does not adequately integrate the biophysical complexity of river ecosystems and the complicated and often conflicting social, economic and political context in which river are managed.

There is an increasing interest in using a more integrated approach to solve natural resource management issues, where contributions from different disciplines are interlinked throughout the project. One of the impediments to achieving this is that the process of integration is not easy and there are not many good examples to learn from where (a) the collaboration has been recorded (b) the process has been examined (c) the collaboration has been successful. We need to spend more time reflecting and thinking about how we do interdisciplinary projects and trying to overcome the very real sociological, academic, and structural barriers to integration. There appears to be some progress in this direction. For example, organisations such as the Institute for Land Water and Society at Charles Sturt University are encouraging the process of integration among discipline groups by establishing and providing research funds for integrated research programs. A new book entitled 'River Futures' edited by Gary Brierley and Kirstie Fryirs (currently in preparation) aims to highlight the importance of integrative river science by bringing together a series of papers that will discuss the cross-disciplinary approach to analysis of rivers.

Challenges for the future

There are many challenges that lay ahead for the field of restoration science but if these challenges are embraced we are more likely to achieve better river restoration outcomes.

Better science

There are many ways in which the science underpinning restoration projects can be improved. One of the greatest challenges is that we need to design and undertake projects that examine multiple disturbances and landscape scale issues. Projects also need to incorporate hypothesis testing, reference reaches and appropriate indicators to determine the ecological success of projects. In some cases this may involve establishing long-term projects to assess the effectiveness of restoration works, including sites with different levels of environmental degradation (Watts and Wilson, 2004). One contribution of scientists will also be to identify and test appropriate sets of indicators to evaluate ecologically successful restoration, which could range from re-establishment of single species or multi-species communities, to more complex foodwebs or enhanced ecological functions (Giller, 2005). Finally, we need to strive towards employing an interdisciplinary approach to projects so that the best outcomes for river systems can be achieved.

Funding for long term and extensive trials

A few high profile projects in Australia (e.g. the Living Murray Initiative) have funding for long term monitoring, however most projects continue to lack adequate funding for monitoring. While there are good reasons that we cannot evaluate all restoration projects (it would probably be a waste of money and time to do so) there is a need for more well designed, large scale projects (Lake, 2001). As the majority of river restoration works in Australia are now coordinated by catchment management organisations there may be more opportunities for this to happen. Governments, natural resource management agencies and funding bodies have the responsibility to ensure that there is adequate funding to assess a range of restoration projects that will help to further develop the field of restoration science.

Adaptability of scientists and practitioners

As mentioned earlier, scientists and practitioners tend to favour approaches they are familiar with and may show bias when advising on techniques or indicators for monitoring. As new information becomes available about the efficacy of restoration techniques or the appropriateness of ecological indicators, scientists and practitioners should be prepared to modify their approach. We need to be sure that techniques and indicators are not selected before the guiding image of a project has been developed (Gillilan *et al.*, 2005). In the health industry it has been suggested that practitioners who develop a reputation for doing particular procedures are often reticent to change as new evidence becomes available or do not keep up to date with new evidence (ABC, 2007). We need to ensure that does not happen in the field of river restoration.

Better communication

Good communication is a vital part of restoration projects. If we are to carry out large-scale restoration projects as hypothesis-testing experiments, it is essential that strong partnerships are formed between management agencies, stakeholders and scientists. In addition, restoration assessments need to be communicated widely (beyond project proponents and funding bodies to other stakeholders, practitioners, scientists and policy makers) to ensure the rapid uptake of new findings. This may require a communication approach that is different to that which some scientists are currently comfortable with. Developing effective communication among all stakeholders will consume time that may otherwise be spent undertaking other pursuits. However, it is essential that the outcomes of all projects, including the failures, are widely disseminated (Watts and Wilson, 2004). Well documented projects that do not achieve expected objectives may contribute more to restoration science than projects that are considered successes (Palmer *et al.*, 2005).

Innovative education and training programs

The field of river restoration requires more, well trained scientists and practitioners that are aware of new developments and are ready to embrace an interdisciplinary approach to solving river management issues. It is the role of all educators (eg TAFE, short courses, university) to encourage students to consider all evidence rather than promote particular techniques. We also need to inform students that some restoration techniques are still hypotheses in testing. Not all participants in courses will be satisfied with that approach. Some will be seeking definitive answers and want cookbook solutions they can apply in the field. However, if we are to achieve better restoration outcomes in the future we need to challenge students, continually improve our teaching approach and incorporate new knowledge as soon as it becomes available.

Conclusion

Restoration science has much to contribute to the practice and assessment of river restoration projects. Although there are some factors impeding the development of this discipline, several recent developments are providing direction for the future of this science. If the many challenges that lie ahead are embraced, we are more likely to achieve better river restoration outcomes. In particular, if we undertake integrative river science incorporating biophysical, social and economic aspects we will advance the development of a holistic approach to river management and will ultimately result in much better river restoration outcomes.

Acknowledgments

Thanks to Andrea Wilson and two referees for constructive comments on this paper

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