Challenges faced in the integration of science in river management in Australia

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Abstract

Best management practice in river rehabilitation requires an integrative team-based approach among researchers, managers and stakeholders. Management endeavours that aim to enhance the recovery of aquatic ecosystems should not be undertaken independent of best scientific understanding. This paper examines a major challenge in the era of river repair – that of integrating diverse, discipline-bound knowledge and practices within cross-disciplinary and trans-disciplinary approaches to analysis and management of rivers. In this paper we use the term *cross-disciplinary* to describe the integration of science used to explain and predict ecosystem integrity. A coherent, catchment-framed scientific platform must be provided with which to guide river rehabilitation practice. Such thinking must be framed within its social, economic and political context, emphasising a trans-disciplinary approach to river management. We use the term *trans-disciplinary* to describe the merging of science with social perspectives and the use of science in river management practice. Trans-disciplinarity provides the foundations for developing an integrative approach to river science AND management. To highlight how science has been used in river management, a review of literature in the stream management arena has been conducted to track how perceptions of science (in its broadest sense) have changed, what types of science have been used in management, the scale at which science has been used in management and the tools and techniques that have been used to incorporate science in management. This review is conducted for the period since the mid-1990's.

Keywords

Integrative river science, river management, cross-disciplinary, trans-disciplinary, use of science

Introduction: A brief history of river management in southeastern Australia

The history of post-European settlement disturbance to rivers in Australia is well documented (e.g. Brierley *et al.*, 2005; Rutherfurd, 2000). The clearing of vegetation from riparian zones and floodplains and removal of woody debris from rivers induced rapid river metamorphosis within the first generation after colonisation. In addition, post-European land use and associated water resources development resulted in widespread nutrient enrichment of Australian rivers and alteration of flow, sediment and solute regimes, and consequent changes in biological communities (Young *et al.*, 1996; Harris, 2001).

River management activities in Australia began with modifications by Aboriginal peoples, such as the arrangement of boulders to create fish traps and weirs (Bandler, 1995). In the early post-European era, the focus was mainly on dredging for navigation, the construction of weirs, and the removal of woody debris. The need for reliable water supplies for urban centres and irrigation industries, led to an extensive program of dam construction and other structural works, which culminated in large-scale engineering programs (e.g. the Snowy Mountains Scheme). In the 1950s and 1960s, large scale channelisation schemes (e.g. in the Hunter River catchment, NSW) and 'stabilisation' of channels occurred through installation of engineered control structures. Flood mitigation was also a prime concern, resulting in extensive removal of large woody debris from channels and the construction of levees. Vegetation removal from riparian zones and the planting of willows and other exotic plants was still occurring in places until the early 1980s. Gravel extraction also occurred on a relatively large scale.

From the 1970s onward, the conservation and rehabilitation of riverine ecosystems became common additional goals of river management, reflecting an increasing scientific understanding of river ecosystem dynamics, greater community awareness of environmental issues, and corresponding developments in public policy (Allan & Lovett, 1997; Erskine & Webb, 2003). This 'paradigm shift' (Connick & Innes, 2003) was associated with changing institutional and social arrangements that, at least in theory, are better placed to deal with more complex and potentially conflicting objectives. These new arrangements include increasing effort to involve groups of landholders and other volunteers in collective management of natural resources, multi-institutional partnerships, and the emergence of regional bodies (catchment management authorities or the equivalent) that are progressively assuming responsibilities formerly held by State government departments or single-purpose local bodies (e.g. river improvement trusts). The Federal Government has also assumed a greater role through direct funding to regional bodies and by fostering inter-governmental agreements and national guidelines and principles for the management of natural resources.

Catchment Management Authorities (CMA) or their equivalents have been formed in almost every state and territory of Australia in the last decade. The intended aim of these regional bodies is to deliver integrated, coordinated and collaborative planning and management close to the multitude of stakeholders involved (Farrelly, 2005). The CMAs aim to provide a link between government planning and operational activities undertaken by local community groups. This is the nexus between bottom-up and top-down processes that has strengthened the middle ground in environmental management (Carr, 2002; Hillman & Brierley, 2005). There is also an increasing interest in the adoption of adaptive management by the inclusion of monitoring and evaluation, and a shift away from individual project-based approaches towards regional investment and longer time scales. It is argued that through adoption of these policies, CMAs will improve management efficiency and on-the-ground implementation (Jennings & Moore, 2000).

This paper examines whether these 'advances' in practice can be detected through an examination of the river management literature since 1996. Although only very recent literature is used, it provides us with a basis to then discuss how well river science is integrated and how science is being used in river management practice in Australia. We use the term ***cross-disciplinary*** to describe the integration of science to explain and predict ecosystem integrity. ***Trans-disciplinary*** describes the merging of science with social perspectives and the use of science in river management practice. This paper asks whether we are really doing cross-disciplinary and trans-disciplinary science and management in Australia?

Methods

One way of tracking the development of science and how it is used in river management in Australia is through examination of the six volumes of refereed papers that have been produced from the four national stream management conferences held since 1996 (Rutherfurd & Walker, 1996; Rutherfurd & Bartley, 1999; Rutherfurd *et al.*, 2001; Rutherfurd *et al.*, 2005). These conferences represent the largest gathering of personnel involved in river management in the country. The success of these conferences attests to the increased integration and transfer of knowledge within the river management community. We have chosen to confine our analysis to these volumes as they provide a snapshot of knowledge at the time. We recognise that there is a wider body of academic and 'grey' literature that could be added to a more thorough analysis.

We initially classified the papers according to their dominant theme (whether that is science, social, management, economic, education) and then noted those that have cross-disciplinary and trans-disciplinary components. For each paper we then analysed the types of scientific methods used, the scale of analysis, and the degree to which monitoring has been examined. By analysing the content of all the papers, some important trends have been detected. While these results may well be a function of who attended the conference and the core theme of the conference, they can still be used to reflect a broader change in practice that is poorly documented in Australia.

Results

The key themes of the conferences have evolved from single issues such as erosion, sedimentation and human impact, towards a more holistic examination of rivers in their landscape context (Table 1). The conferences have also seen the emergence of community and education themes in river management that are absent from earlier conferences. Nevertheless, by far the majority of papers presented at the conferences have been scientific (Figure 1). Papers addressing social dimensions, and institutional and governance themes accounted for only 15-20 % of papers at each conference, while economic and education papers were rare. Only in 1999 did the number of scientific papers decline and the number of social and institutional papers increase.

Table 1. Themes of the four national stream management conferences held since 1996.

1996 – 1st stream management conference	1999 – 2nd stream management conference	2001 – 3rd stream management conference	2004 – 4th stream management conference
Conference title			
n/a	The challenge of rehabilitating Australia's streams	The value of healthy rivers	Linking rivers to their landscapes
Conference themes			
Sediment sources and sinks	Challenges of rehabilitation	Ecosystem services provided by streams	Landscape processes that influence rivers
Stream processes and human impacts	Integration of issues between science and community	Biophysical interactions in streams	Identifying/managing values associated with river landscapes
Organising management	Cross-disciplinary science	Hydrological connectivity	Education and change
Vegetation and streams	Evaluation of rehabilitation projects	Tools/techniques for management	River management at the grass roots level

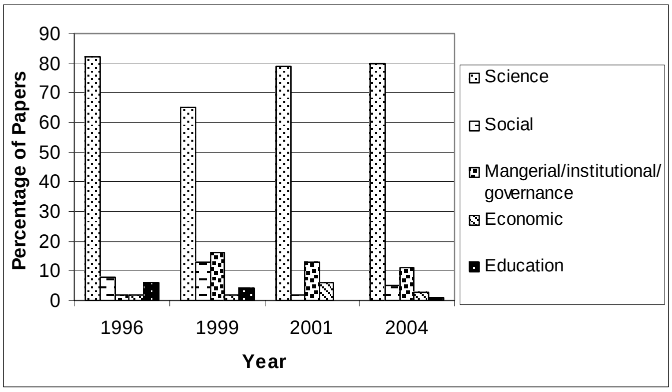

Figure 1. Types of papers written for each stream management conference.

If one examines the scientific papers, it is clear that river management practice still uses a significant proportion of discipline-bound research (Figure 2). However, an encouraging trend is the increased use of cross-disciplinary research (i.e. integrative river science) since 1996. Use of trans-disciplinary research (i.e. integration across science and social dimensions) remains poor. The scientific methods used in management have also evolved over time (Figure 3). In general the science has become more applied and less qualitative. Surprisingly, the number of modelling papers has dramatically decreased over time. This likely parallels the trend away from experimental and site-specific applications of science towards larger scales of analysis and integration (Figure 4). The catchment was the favoured scale of application of research and projects across all conferences, and reach-scale applications have increased slightly since 1996. National and regional scale applications remain consistently low over time. Possibly a more disturbing trend is the lack of monitoring or auditing papers that address success or failure in river management. Even though there have been calls for greater evaluation and appraisal of rehabilitation projects in Australia, and supposed adoption of adaptive management frameworks, the number of papers that document rehabilitation success is very low. Documentation of rehabilitation failure, and hence the ability to 'learn by doing' which is a mandate of adaptive management approaches, is almost nonexistent (Figure 5).

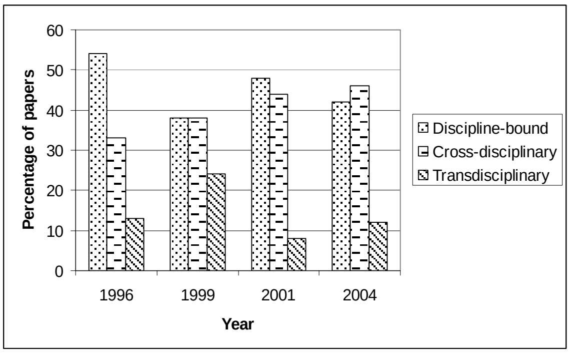

Figure 2. Types of science presented at each conference.

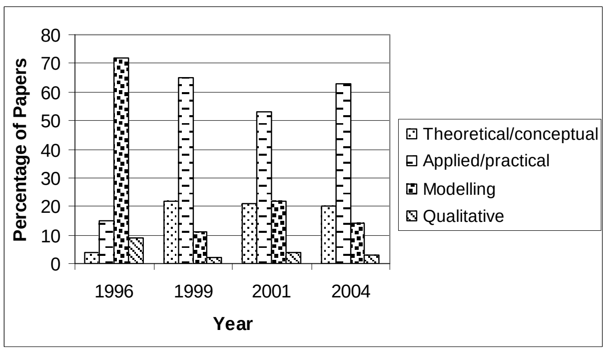

Figure 3. Types of scientific methods presented at each conference.

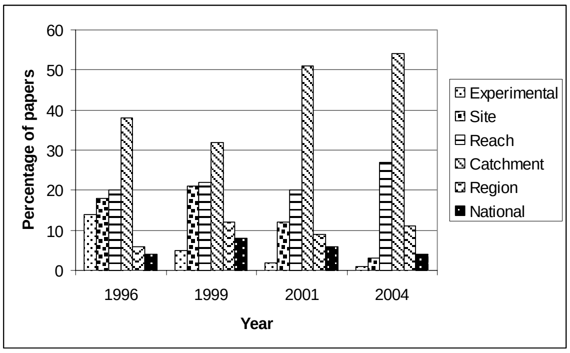

Figure 4. Scale of science and river management application.

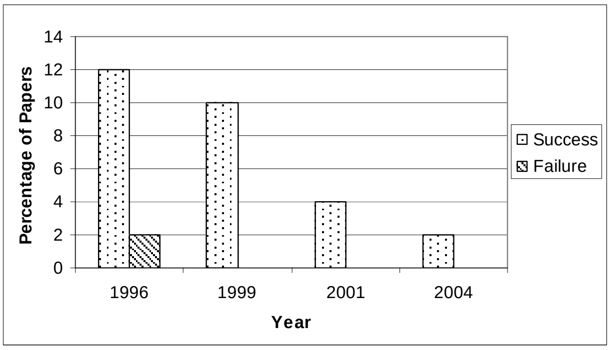

Figure 5. Papers that present monitoring or evaluation findings in river rehabilitation.

Discussion: Integrative river science and use of science in management

Integrative river science – cross-disciplinarity
Although significant scientific advances have been made, we still know little about many of our river systems and their unique qualities (Rutherfurd & Gippel, 2001; Brierley & Fryirs, 2005). Rutherfurd and Bartley (1999) asked the question: do we know enough about Australian river systems to manage them effectively? While we have a solid understanding of how rivers operate and have changed since European settlement in south-eastern Australia, significant gaps remain in the coverage of baseline information. Across much of the country we have little appreciation of how our rivers and their associated ecosystems are likely to adjust in the future, particularly with climate change. These limitations are largely a function of the small pool of scientists and the size of the continent. To some degree, the patchy understanding of ecosystem dynamics is a function of the lack of integrative river science occurring in the country.

Until the 1970s, river science (and management) in Australia was heavily dominated by civil engineering, because of the focus was on navigation, flood mitigation, water supply and the generation of hydro-electricity. Although generally effective in meeting these objectives, this single-discipline approach ignored other ecological values of rivers. As side effects on such values became more evident, significant sections of the public grew increasingly critical of river development schemes. This development in public attitudes coincided with the growth of freshwater ecology (or limnology) as a discipline in Australian Universities, and an increase in the number of ecologists within public sector agencies. Following the massive cyanobacterial bloom in the Darling River in 1991, and release of the National Water Quality Management Strategy in 1992, the concept of "river condition" or "river health" was increasingly promoted, and became the basis of various scientific programs, such as the National River Health Program. The "river health" field has been dominated by aquatic ecologists and biologists, who generally equate "health" with the preservation of natural values, in direct contradiction to the older engineering approach. The gap between engineers and biologists has often been bridged by the geographical sciences, and particularly by geomorphologists. From about the 1970s, geomorphologists increasingly questioned the basis of hard engineering solutions to perceived problems of riparian flooding, and described the unintended physical consequences of poorly designed works. Geomorphologists both worked with progressive engineers to design more sensitive and effective works, and also explored the ecological implications of geomorphology through collaborations with aquatic biologists.

With the shift in emphasis away from engineering towards ecosystem sciences, integration between the sciences has improved. Recent years have seen the emergence of integrative science projects (e.g. the Upper Hunter River Rehabilitation Initiative; the SE Queensland and Morton Bay projects etc.) that are supported by industry, state agencies and research agencies. These projects aim to improve understanding of Australian river systems, ecosystem dynamics and river condition through examination of geomorphology, ecology, hydrology and chemistry. This science is underpinning the development of management programs and the design of rehabilitation techniques for Australian conditions. While considerable progress has been made in linkages among the biophysical sciences and civil engineering, a major challenge remains in the integration of resource economics with the natural and social sciences (the "triple-bottom line") within a trans-disciplinary approach.

Use of science in river management – trans-disciplinarity

Recent decades have seen an almost exponential increase in the use of science in river management. Prior to this, science and techniques were imported from overseas (largely from North America and Europe) where conditions and the history of human disturbance are quite different (Rutherfurd & Gippel, 2001; Brierley *et al.*, 2005). As a result, misapplication of scientific principles occurred (and still occurs). However, with the increase in place-based knowledge about Australian river systems a shift in management practice is occurring (Brierley *et al.*, 2006). Given the relatively small scientific community working on fluvial issues in Australia, many of our leading river scientists are actively communicating and applying their research in river management practice. This has helped to stem the importation and misapplication of river rehabilitation techniques and processes from overseas (Rutherfurd & Gippel, 2001) and aided the development of techniques that are suited to Australian conditions (e.g. Rutherfurd *et al.*, 2000).

With increasing use of science in management, Australia has seen a progressive evolution and shift in community and manager attitudes towards river management and the process of implementation in the community. For example, the 1980s saw the shift away from the engineering paradigm of river management where stability and control were priorities and a blanket approach to river rehabilitation was adopted. An ecosystem-based approach to river rehabilitation emerged that embraces such dictums as ‘work with nature’, ‘respect diversity’, ‘work with change’ and ‘recovery enhancement’ (Brierley & Fryirs, 2005). Many Australian agencies now generate geomorphic templates to assess a range of biophysical attributes. This information is then used to set targets and prioritise river rehabilitation and conservation programs. Having said this however, in many places, baseline information does not exist or is poorly organised and archived. Understanding of problems, prioritising of activities and determination of best management practices often require detailed analyses and ongoing research and development for which few longer-term investments have been made. The use of science in many plans is therefore inadequate. As a result, there is reliance on community preferences without adequate assessment of their scientific or economic realism (Pannell, 2006).

While catchment management institutions across Australia have largely embraced the implicit biophysical and social message of sustainability, translating this ideal into rehabilitation policy and practice is on ongoing challenge (Bellamy & Johnson, 2000). A central issue in new approaches to river management in Australia, exemplified in the Living Murray Initiative, is the importance of integrating biophysical and social information in decision-making on where rehabilitation efforts should be focused. Whilst there are apparent parallels between biophysical and social criteria in the setting of priorities, this can be misleading and it is quite possible for these two sets of priorities to clash. For instance, it may be scientifically more rational to focus on sections of rivers in relatively good condition, whereas a community’s desire to remedy ‘basket cases’ pushes priorities in the opposite direction. The need for such cross-dimensional understanding is reinforced by the wide range of motivations (conservation, social, educational, etc.) for volunteer involvement in rehabilitation. For rehabilitation practice, such involvement is crucial, and the most inclusive and engaging agenda will be one that openly recognises and balances this range of priorities and motivations. The development of holistic rehabilitation programmes to achieve social as well as biophysical gains will depend on measures of ecosystem health, modelling of the economic value of rehabilitation investment, and indicators of social capital and community capacity in an integrated assessment process.

There is also increasing recognition in Australian river management practice of uncertainty and the need to adopt adaptive approaches. With moves towards adaptive management, a shift towards more effective prioritisation of activities and the emergence of a range of frameworks that advocate a conservation first approach has occurred (see Rutherfurd *et al.*, 1999; Brierley & Fryirs, 2005). A similar recognition of the need to work within a catchment-context and a recovery enhancement approach has seen the approaches for examining river condition and recovery potential developed (see Brierley & Fryirs, 2005). Approaches to visioning and application of adaptive management principles have also evolved. The monitoring and evaluation of river rehabilitation projects have started to receive long-term funding via regional authorities and scientific support groups such as state government departments, universities and the CSIRO. Monitoring and evaluation have the power to integrate river science and management in Australia, by bringing together geomorphologists, ecologists, hydrologists, geochemists, social scientists, economists etc. to track river health and rehabilitation success and feed that into adaptive management structures.

Conclusion

Significant progress has been made in the use of river science in management in Australia. Although our understanding of rivers in a cross-disciplinary manner is still developing we have the foundations upon which to capitalise on our place-based knowledge through strategic research programs that tackle cross-disciplinary issues. The challenge lies in undertaking trans-disciplinary research so that the best possible use of science in river management can occur.

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References

Allan, J., & Lovett, S. (1997). Managing water for the environment: impediments and challenges. *Australian Journal of Environmental Management*, *4*, 200-210.

Bandler, H. (1995). Water resources exploitation in Australian prehistory. *Environmentalist, I* 97-107.

Bellamy, J.A., & Johnson, A.K.L. (2000). Integrated resource management: moving from rhetoric to practice in Australian agriculture. *Environmental Management, 25 (3),* 265-280.

Brierley, G.J., & Fryirs, K.A. (2005). *Geomorphology and River Management: Applications of the River Styles Framework*. Oxford, UK: Blackwell Publications.

Brierley, G.J., Hillman, M.,& Fryirs, K. (2006). Knowing your place: an Australasian perspective on catchment-framed approaches to river repair. *Australian Geographer*, *37(2),* 131-145.

Brierley, G.J., Brooks, A.P., Fryirs, K. ,& Taylor, M.P. (2005). Did humid-temperate rivers in the Old and New Worlds respond differently to clearance of riparian vegetation and removal of woody debris. *Progress in Physical Geography, 29(1),* 27-49.

Carr, A. (2002). *Grass Roots and Green Tape. Principles and Practices of Environmental Stewardship*. Leichardt, NSW: The Federation Press.

Connick, S., & J. E. Innes (2003). Outcomes of collaborative water policy making: applying complexity thinking to evaluation. *Journal of Environmental Planning and Management 46(2)*, 177-197.

Erskine, W.D., & Webb, A.A. (2003). Desnagging to resnagging: new directions in river rehabilitation in southeastern Australia. *River Research and Applications, 19,* 233-249.

Farrelly, M. (2005). Regionalisation of environmental management: A case study of the Natural Heritage trust, South Australia. *Geographical Research, 43(4),* 393-405.

Harris, G.P. (2001). Biogeochemistry of nitrogen and phosphorus in Australian catchments, rivers and estuaries: effects of land use and flow regulation and comparisons with global patterns. *Marine & Freshwater Research,52,* 139-149.

Hillman, M., & Brierley, G. J. (2005). A critical review of catchment-scale stream rehabilitation programmes. *Progress in Physical Geography,* 29(1), 50-70.

Jennings, S. F., & Moore, S. A. (2000). The Rhetoric behind Regionalization in Australian Natural Resource Management: Myth, Reality and Moving Forward. *Journal Environmental Policy & Planning, 2,* 177-191.

Pannell, D.J. (2006). Seeking more effective NRM policies. *Pannell Discussions, 82(3),* 1-3. Available at http//cyllene.uwa.edu.au/~dpannell/pd/pd0082.htm Accessed 9/8/06.

Rutherfurd, I.D. (2000). Some human impacts on Australian stream channel morphology. In: Brizga, S. & Finlayson, B. (Eds.) *River management.* John Wiley & Sons, Chichester, 11-49.

Rutherfurd, I., & Bartley, R. (Eds.). (1999). *Proceedings of the 2nd Stream Management Conference, Adelaide*, Volumes 1 and 2. Melbourne: Cooperative Research Centre for Catchment Hydrology.

Rutherfurd, I.D., & Gippel, C. (2001). Australia versus the World: Do we face special opportunities and challenges in restoring Australian streams? *Water Science and Technology, 43(9),* 165-174.

Rutherfurd, I., & Walker, M. (Eds.). (1996). *Proceedings of the First National Conference on Stream Management in Australia, Stream Management '96, Merrijig*. Melbourne: CRC for Catchment Hydrology.

Rutherfurd, I.D., Jerie, K., & Marsh, N. (2000). *A Rehabilitation Manual for Australian Streams, Volumes 1 and 2*. Canberra: CRC for Catchment Hydrology and LWRRDC.

Rutherfurd, I., Sheldon, F., Brierley, G., & Kenyon, C. (Eds.) 2001. *Third Australian Stream Management Conference Proceedings: the value of Healthy Rivers.* Melbourne: CRC for Catchment Hydrology.

Rutherfurd, I, D. Wiszniewski, I., Askey-Doran, M.J., & Glazik, R. (Eds.) (2005). *Proceedings of the 4th Australian Stream Management Conference: Linking Rivers to Landscapes*. Hobart, Tasmania: Department of Primary Industries, Water and Environment.

Young, W.J., Marston, F.M., & Davis, J.R. (1996). Nutrient export and land use in Australian catchments. *Journal of Environmental Management, 47,* 165-183.