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Integrating research results into decision making about natural resource management at a catchment scale

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Abstract

The operational reality behind the rhetoric of integrated natural resource management poses significant challenges for resource managers, resource use planners and researchers. A variety of frameworks for integrated resource planning and use have been espoused. These tend to reflect the bias of the discipline or stakeholder group fostering the approach and may therefore be unpalatable to, and ignored by, other groups. In this paper, we are concerned with improving the integration of research outcomes into decision making. Rather than propose a framework, we take a pragmatic view of the roles of managers, planners and scientists. In doing so, we draw principally on practical experience derived from an initiative in a rural catchment in tropical Australia. On this basis, we propose a particular and emerging role in designing approaches to adaptive decision support that provide opportunities for integrating research outcomes into decision making. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Decision support systems; Participatory approaches; Decision-making tools; Stakeholders; Multiple scales; Planning

1. Introduction

While the global imperative to achieve ecologically sustainable development has become something of a truism, the particular problems associated with operationalising this imperative are far from resolved. The need to undertake management at multiple spatial and temporal scales is one such challenge. Off-site impacts, cumulative impacts and other externalities have precipitated interest in seeking more

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effective natural resource use, management and planning at diverse geographic and temporal scales or within panarchies (Gunderson et al., 1995, pp. 522–3) such that the impacts of actions at any one level of operation in the hierarchy of spatial and temporal scales can be managed at other levels. Such initiatives pose substantial methodological and operational challenges, and provide a significant opportunity for research and development (R & D) initiatives.

The requirement for integration across multiple scales generates a 'convergence zone' for a range of different resource management paradigms. Thus, catchment or regional-scale management is strongly influenced by experience in, and approaches to, management at an enterprise scale, as in Farming Systems Research and Extension (FSR/E), and approaches to resource use planning at a catchment or landscape scale (as in regional resource use planning); while an increasing emphasis on management of resource use impacts has led to growing interest in ecologically based methods such as adaptive management. While valuable, these approaches modify theory and practice from disciplines with different objectives operating at different spatial scales. In effect, they attempt to fill a disciplinary void in approaches to integrated resource use and management through adaptation of precepts developed in quite different contexts.

All three activities (management, FSR/E, planning) have been strongly impacted in recent decades by the growing influence of participatory approaches. At the enterprise level, the shift from a linear 'science-push' technology transfer model for agricultural R & D to the FSR/E paradigm has been enormously influential (Chambers, 1992). Participative democracy has concomitantly emerged as an increasingly influential paradigm in the evolution of approaches to resource use planning in the post-war period. Traditionally, most decision making in planning has been vested with regulatory authorities. However, in recent years policy makers in many countries have increasingly sought community involvement in the decision-making process, on the premise that more robust and workable solutions will eventuate (Hyman and Stiflel, 1988). Similarly, adaptive management has progressed from an expert-based process relying primarily on extensive quantitative modelling to a more inclusive and participatory paradigm (Dovers and Mobbs, 1997). Assumptions about what is required to achieve sustainable resource use, particularly the role of technocrats, resource users and the broader community in resource use decision making have been challenged accordingly.

1.1. Roles in integrated resource management

The convergence of practice and a range of theoretical perspectives in integrated approaches to regional natural resource management provides opportunities for synergies, although in practice competition for 'territory' is often more evident. In particular, disciplinary diversity allows 'triangulation' of theory and methods to make effective use of complementarity between different disciplines — particularly in ameliorating the flaws of any one perspective or methodological approach (Yin, 1994). Nevertheless, the lack of a common and agreed theoretical basis suggests that integrated natural resource management is a domain more of praxis, integrating

interpretation, empirical research, dialectic analysis and practical action (Lather, 1986), rather than a disciplinary domain with a potential unitary theoretical basis. We argue, therefore, that the adaptive core of integrated resource management should remain as a shared objective and ethos (or paradigm in the strict sense) but should not be formalised. We propose that from a pragmatic and theoretical perspective, approaches to integrated resource use and management might best be considered from the perspective of activities with specific characteristics. For the sake of discussion, we distinguish four broad categories of activity, which equate broadly (but imperfectly) to four categories of 'actor' commonly recognised as being involved in integrated resource management at a catchment scale. On the basis of consideration of a case study, we will then present the case for a fifth actor and, therefore, activity, involving design of decision support to integrate research results into the management process. Our four categories are:

1. Resource use. The activities of industry and community in interfacing with the resource base.
2. Resource management. The operational control of resource use activities as undertaken by managers within government departments and resource managers within the private and community sector (including primary producers). Resource managers are, therefore, the clients for the integrated R & D products discussed here.
3. Natural Resource Planning. The establishment of goals, policies and procedures for resource use and management. The planning function has traditionally been the domain of professional planners. However, the evolution of planning theory and practice has substantially broadened and redefined this role, such that activities undertaken by individuals with no formal planning background, who may not even recognise their activities as planning, are being increasingly recognised and fostered in policy.
4. Research. Incrementing understanding of the systems being managed. As the domain of the professional researcher (including socioeconomic as well as biophysical scientists), advancing understanding of the systems being managed is frequently the activity most removed from decision making. However, participatory research methods and a growing recognition of the role of local knowledge mean that an increasingly inclusive view of opportunities for incrementing knowledge is becoming recognised.

With the exception of the resource user, these categories may be viewed either as activities in integrated resource management or disciplines and professions that play a role in the process. Resource users independent from management are, for the sake of this paper, not considered within the remit of professional activities, and management and use are hereafter considered as a single activity. This duality reflects the value and role of strong professional disciplines and the reality that professional monopolies on research, planning and resource management are potentially inefficient and anti-democratic. Scientists, planners and resource managers are recognised occupations with professional and institutional structures that foster efficacy and rigour. While valuable, these structures provide challenges for integrated approaches

analogous to the conflict between participatory research and academic success (Cancian, 1993). Furthermore, it is axiomatic that increasingly participatory approaches to resource use planning require community representatives to assume some research, planning and management roles.

Thus, a move towards community-driven natural resource management at a range of scales that integrates impacts at the enterprise level up to the regional has implications for roles and relationships of professionals working across these scales from a range of disciplinary perspectives. In this paper, we explore these roles and responsibilities through consideration of a case study of the integration of increments to understanding gained through research initiatives into the decision-making process. We identify a role for natural resource professionals in designing tools, methods and structures for integration and ask whether resource managers, planners or scientists are well placed to undertake this role.

1.2. Case study: integrating R & D into decision making in the Herbert River catchment

1.2.1. Context

The Herbert River catchment drains an area of approximately 10 000 km^2 in Australia's sub-humid to humid tropical north east and has a population of approximately 21 000. Large areas of the catchment remain under natural vegetation (much managed for cattle grazing), with approximately 40% of the coastal lowland cleared for crop production, mainly sugar, or improved pasture. The catchment is bounded by two World Heritage areas, the Wet Tropics and the Great Barrier Reef. The area is one of strong economic growth through agriculture and tourism. The sugar industry dominates with 70 000 ha supporting two mills producing sugar worth US$152.75 million (Aus$235 million) in 1996/1997.

Like much of Australia's coastal zone, there is strong competition between alternative resource uses in the Herbert — agriculture, forestry, conservation, tourist and recreational uses, urban expansion, public utilities and hobby farms. Competition has intensified through increasing community expectations for preservation of the natural environment, involvement in decision making and conflict resolution. A plethora of government and statutory industry agencies claim, or are assigned, responsibility for aspects of catchment management. A number of agencies also contribute to management through research and development.

Sugar production has the potential for significant negative environmental impacts (Johnson et al., 1998). Soil erosion; removal of riparian vegetation in cane growing areas; clearing of riverine forests, coastal wetlands, swamps, billabongs and waterholes; and the potential for diffuse source pollution of ground and surface water are all issues. These impact wildlife habitat areas, the hydrological regime and water quality, and are perceived to be of particular concern given the close proximity of the Great Barrier Reef. These concerns are balanced by the regional and national importance of an economically vibrant sugar industry.

In order to achieve ecological and economic sustainability, reconciliation of industry imperatives need to be balanced with the requirements of other users. In

response, Governments have sought to implement integrated resource management approaches to avoid the environmental and social damage sustained by land use conflicts (e.g. Integrated Catchment Management, Anon, 1991). The effectiveness of these initiatives is frequently constrained by a paucity of data at spatial and temporal scales relevant to decision making, poor co-ordination or communication between participating stakeholders, limits to the data processing and analytical capabilities of participants, and a poor understanding of key issues.

1.2.2. The research intervention

In 1992, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) initiated research to assess the implications of land use change and land management strategies in the catchment with a particular emphasis on water quality. This initiative involved significant biophysical research (e.g. Mitchell et al., 1996) but also incorporated the development of a decision support system (DSS) to integrate the outputs of this research into decision making.

The research started from the premise that a technical decision support approach was warranted. However, it has been demonstrated that only a small proportion of such systems achieve operational uptake. The research group were therefore concerned with balancing scientific and operational applicability. The initial project cycle therefore comprised 'needs analysis' and research innovation to design tools, methods or structures that were adapted to the decision-making context. These activities are captured in the top section of Fig. 1. However, the needs analysis process (Walker and Johnson, 1996a) demonstrated that to achieve operational uptake the research team had to become significantly involved in capacity building, which inescapably involved consideration of improving the planning process (the middle section of Fig. 1). These activities represented a significant time investment and demanded the development of means of evaluating the impact of the process and product on decision making (the bottom section in Fig. 1).

1.2.3. Designing appropriate interventions

The design of tools, methods or structures adapted to the decision context demands the integration of needs analysis with technical and research innovation. For project groups with a research bias, needs analysis represents a significant departure from standard practice.

In contrast, investigation of context as a basis for the design of R & D-based interventions is a well developed and widely applied process (e.g. Chambers, 1992). There was, however, a particular challenge to be faced in the Herbert catchment — there was no tradition of management at the scales (spatial and temporal) necessitated by ecologically sustainable development. Therefore, the research group was investigating a decision context in which existing structures and processes were acknowledged as inadequate and a substantial objective of the research process was their improvement.

This experience is by no means unique, and may be a general feature of interventions for integrated resource management at a catchment scale. For example Zhu and Dale (2000) had to apply a soft systems methodology (Checkland and Scholes,

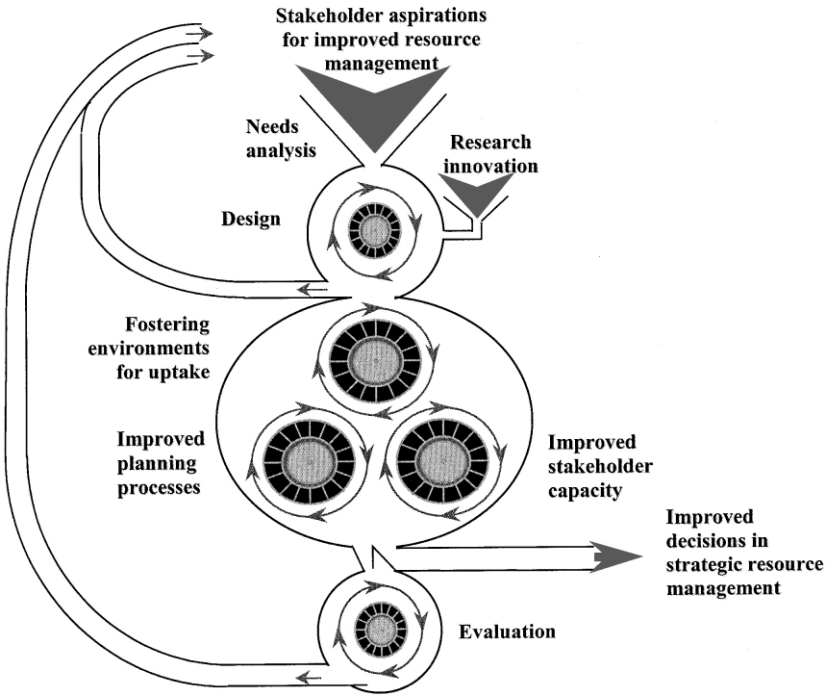

Fig. 1. A schematic presentation of the project lifecycle.

1990) to identify the opportunity for developing and delivering decision support systems in support of regional resource planning. They did so to consider conceptual models of current practice, thereby providing a basis for designing changes that might be precipitated by the development and delivery of appropriate decision support systems (Zhu and Dale, 2000).

Once the present context, the desired context and thereby potential R & D interventions have been identified, it may be possible to test the appropriateness and viability of proposed interventions through a formal hypothesis-based analysis. The primary technical intervention developed for resource use planning in the Herbert catchment was called NRMtools. NRMtools (http://www.nrmtools.tag.csiro.au) is a distributed (Internet-based) decision support system for natural resource management in which natural resource professionals can specify, implement and use decision support tools that integrate, as appropriate, a range of technologies including geographic information systems, simulation models and knowledge-based systems (Walker and Johnson, 1996b).

The broad design specifications of NRMtools were formally tested before detailed design and prototyping was undertaken using interviews with potential users, characterising current tasks, contexts, constraints and the viability of initiating DSS-based solutions (Walker and Johnson, 1996a). This process substantially altered the course of the work in the Herbert. Early scoping revealed that decision making was

characterised by occasional or one-off tasks rather than routine, frequent and standardised processes. Planning and action used intuitive and flexible combinations of data, understanding, and techniques for synthesis and interpretation to meet a broad range of objectives. A decision support system focused solely on one issue (e.g. water quality) was likely to be of limited relevance. As a consequence, while a potential role for decision support was evident, it was not clear that a single system would meet a useful proportion of requirements. A decision was therefore made to develop a flexible, toolkit-based approach. This conceptual design (i.e. the research innovation) was formally tested through a further interview-based process (Walker and Johnson, 1996a).

1.2.4. Capacity building

The decision support tool under development potentially fulfilled a significant role in resource use planning in the catchment. However, it was apparent that given the existing capacity in terms of data, information technology infrastructure, technical skills and decision-making structures in the catchment, it was unlikely to be adopted. As well as developing the analytical tools, a concomitant investment in capacity building in the catchment was therefore required. It was proposed to use the development of a community-based collaborative Geographic Information System (GIS) to undertake this. GIS have demonstrated capability to improve decision making in resource management and underpin many of the decision support technologies for catchment scale management. Johnson and Walker (1997) describe the approach used to facilitate the development and implementation of the GIS — the Herbert Resource Information Centre (HRIC).

Development and implementation of the HRIC involved significant investment of time and resources on the part of stakeholders over a two year period. The agreement secured financial and non-financial (in-kind) support and bound stakeholders to support a non-profit, community-based collaborative GIS facility to support ecologically sustainable development. The HRIC provides expertise and skills to facilitate the collection, storage, maintenance and analysis of natural resource data. As such, the HRIC offers a bureau service to its stakeholders, provides free GIS consultancy and project management skills and acts as a conduit for the transfer of relevant R & D products.

This initiative was a significant undertaking for a rural community. The research team played a critical role in instigating and facilitating the initiative, including provision of technical inputs such as needs and cost benefit analyses (Johnson and Walker, 1997). This role took the research team outside the normal activities of a scientific research group but was a critical contribution that could not have easily been made by the resource managers or planners working in the catchment.

1.2.5. Evaluation of process and product

The objectives of the HRIC can be summarised as:

1. improved data quality for the Herbert catchment;
2. improved data access;

3. better informed decisions in planning and implementing data collection and use projects;
4. better informed natural resource management decisions; and
5. improved collaboration.

Evaluating progress against these objectives fell beyond the remit and expertise of the HRIC collaborators. Consequently, the research team undertook a formal evaluation which addressed the above objectives, while providing for the evaluation of less tangible outcomes — changed perceptions, attitudes, understanding and behaviour — as a consequence of involvement in the HRIC. The evaluation was conducted using qualitative research techniques and is reported in full in Walker et al. (1998).

1.3. Lessons learnt

The preceding narrative describes our experience as a research team established to contribute to the resolution of catchment scale issues in integrated resource use through traditional science-based R & D. Over a 5-year period we have come to play a different role.

Our needs analysis in the Herbert context clearly illustrated the general observation that approaches to integrated resource use and management in an attempt to achieve ecologically sustainable development significantly complicate the activities of the resource user or manager and may increase conflict between stakeholder groups. Management for sustainability, both on-site and off-site, is inherently more complex than managing solely for maximum productivity or conservation.

Our consideration of the decision-making environment in the Herbert case study suggested that in order to make defendable and effective decisions, resource managers and planners require:

1. effective access to information pertinent to resource use and its impacts;
2. the 'tools' to make effective use of that information;
3. the capacity to make appropriate use of the information and tools in decision making, negotiation and conflict resolution between stakeholders;
4. an appropriate decision-making environment (including legislative and institutional structures); and
5. effective means of evaluating the outcomes of decisions made and planning activities and processes used.

The adoption of participatory approaches to resource management, the increasing complexity of the domain of resources being managed, and the need to reconcile increasing competition for resources to meet the multiple objectives of different stakeholder groups, extend the range of pertinent information, the range of tools required and the skills needed to use them. Much of this increase in complexity can be attributed to the expectation that resources can be managed effectively at multiple spatial and temporal scales. This places demands on managers, planners and

researchers to take an integrated and comprehensive view and to meet the needs of multiple stakeholder groups equitably and efficiently. Our experience in the Herbert illustrates some approaches to meeting this challenge that have taken us beyond the traditional roles of researchers and have contributed an improved stakeholder capacity to negotiate natural resource use options and futures. Thus, the evaluation of the HRIC undertaken by the research team demonstrated that negotiation underpinned by shared and, therefore, trusted natural resource data for the catchment, analysed with shared and understood analytical tools, facilitated the resolution of resource use conflicts. This does not mean that the need to resolve disputes or to negotiate outcomes from disparate perspectives was removed, but rather that some of the sources of uncertainty and mistrust were removed, meaning that fundamental differences could be addressed on a more informed and constructive basis.

These participatory approaches to natural resource use planning and management have significant implications for managers, planners and researchers. In this section we explore these challenges and consider implications for project development and implementation.

1.3.1. Role and requirements: the natural resource manager

As decision making becomes a more complex process addressing more complex issues such that a broader domain of information needs to be considered, managers are increasingly likely to lack the necessary expertise, and, therefore, capacity to make use of this expanded range of information and the tools to process it. Thus, in assessing options for expanding the area of cane production in the Herbert, the sugar industry, which has traditionally assessed land use suitability and economic viability on the basis of experience and local knowledge, is expected to investigate a much broader range of issues, including potential off-site impacts and cumulative degradation to the resource base at spatial and temporal scales beyond traditional expertise. This has necessitated the development of new skills to consider new information and apply new ways of thinking to consideration of that information. These changes, which will often occur in a highly politicised environment, can be a significant source of stress for both individuals and communities.

This has implications for the integration of R & D into decision making for catchment or regional scale natural resource management. Our experience in the Herbert demonstrates that an external agency may be required to facilitate transition. This role may include:

1. development of means of providing effective access to the broad range of technical data, local knowledge and process information that might be germane to decision making;
2. the development of operationally applicable tools for analysing (or 'ways of thinking about') the potential impacts of resource use in contexts in which testable predictions may be practically (or even theoretically) impossible; and
3. a role in building the capacity to bring these into existing and evolving decision-making processes.

1.3.2. Role and contributions: the planner

The traditional view is that 'planners' belong to a discrete profession, and are most frequently employed within government agencies. Further, it is widely assumed that planning, despite recognition of inequities in planning processes, is largely centrally driven in response to regional need. However, understanding of the planner and the planner's role is looking increasingly beyond state agencies to include both community and capital (after Alexander, 1994) such that, "*...planning is a general approach to decision making and is not tied to the activities of any profession or department of government*" (Faludi, 1973, p. 3).

It is useful to track the evolution of the planner's role, at least in the body of theory, and of the planners themselves over the last half century. As with any of the 'professions', planning has undergone a substantial intellectual revision, removing the modernist assumption of the technocratic planner maintaining critical distance, preparing blueprints for society to follow. Although this perspective remains, a necessary response to the challenges wrought by recognition of structural (power) and rational (knowledge) inequities in planning processes has been the redefinition of the planner away from agency, programmatic characterisations toward multiple actor and role definitions. The planner is now inter alia technician, administrator, mobiliser, mediator, entrepreneur, advocate, adviser, interpreter and communicator, with each role emerging in response to the planning context. Each of these roles carries with it specific skills, with the planner in a regional context frequently expected to fulfil many or all of them. Far from remaining a specific disciplinary field, planning is therefore increasingly having to internalise inter-disciplinary perspectives and functions and has thereby sought to address many of the issues canvassed in this paper. Nevertheless, access to appropriate tools to facilitate the planning process, and the integration of planning perspectives arising at multiple stakeholder scales remain key issues. From the perspective of integrating R & D into decision making, the planner must play a key role in informing the research agendas and in linking the outputs into the broader set of activities that comprise the planning process. However, the range of roles already faced by the planner means that they are unlikely to have the capacity to integrate 'raw' research outputs into forms appropriate for inclusion in the planning process.

1.3.3. Role and contributions: the researcher

We argue that the researcher (someone incrementing understanding of the functioning of a system, whether biophysical, economic or social) is also not best placed to undertake this role of integration. Research addressing natural resource management issues is often based on an unwarranted confidence that it will lead to "objective and rational management of natural resources". This implies that there are demonstrably correct discrete solutions to natural resource management problems; that is that we can achieve management outcomes based on irrefutable logic.

This reflects the pre-eminence of a belief system that asserts that there can be rational and objective management of natural resources (Funtowicz and Ravetz, 1990; Lang, 1990 for a more general discussion). This view persists more usefully in science than in planning or management in so far as it provides a clarity of objective.

Indeed, Boehmer-Christiansen (1994) asserts that "*The very success of physical and natural sciences ... lies in the self-seeking belief which scientists (but few others) tend to share that there is a very direct link between more knowledge and appropriate action*." Nevertheless, the view of the role of science that Boehmer-Christiansen identifies is naive, in that while lack of knowledge can sometimes constrain effective natural resource management, an ineffective political process is far more significant.

Quite apart from the political nature of natural resource management, the scientific consensus achieved in ecology and resource management is generally more speculative than in physical sciences. Predicting processes at an ecosystem scale may simply be an intractable task, since issues may be so complex and indeterminate that predictive understanding may be practically, or even theoretically, unattainable (Oreskes et al., 1994). Certainly, a strong case can be made that process-based understanding of ecosystem behaviour in response to stresses can often only be weakly predictive (Peters, 1991). Catchment scale resource management deals with complex ecological, social and economic interactions in a dynamic situation with long time-frames and often considerable separation between cause and effect and the potential for irreversible outcomes (e.g. Norton et al., 1995). So, the traditional assumption that science can provide unambiguous answers becomes hard to defend when applied to natural resource management. As a result, uncertainty and ignorance need to be managed and communicated so that they become recognised inputs to the decision-making process (Funtowicz and Ravetz, 1990; Costanza et al., 1992; Dovers, 1995).

Nevertheless, the challenge to the rational scientific approach resulting from the apparent irrelevance of much research to decision making (in as far as it often has minimal impact on practical resource management) may have dangerous consequences. Undermining the scientific process by demanding that the researcher become participatory, political or post-modern may seriously undermine the ability of the scientific establishment to make valuable contributions to resource management issues. So, while scientists may usefully seek to understand the context of decision making and its implications for R & D (e.g. Barnes et al., 1997) they are not necessarily productively placed as integrators and facilitators.

1.3.4. An emerging role: the development of adaptive mechanisms for decision support

The key thesis in this paper is that the process of integration of R & D outputs and the development of adaptive mechanisms for decision support is an increasingly important activity in seeking inclusive, equitable and defendable decisions in natural resource management. In the previous section we have argued, on the basis of our experience in the Herbert, that this activity is distinctly different to those of manager, planner or researcher and not one that sits appropriately within any of these categories but one that could evolve from any of these starting points. The objective is to design methods, tools and structures for the synthesis of information (including data and knowledge about systems function) into integrated resource management activities. We propose that this activity involves the development of integrative tools or methods to support decision making and also involves capacity building in the use of

such tools or methods and the provision of evaluative processes for tracking their role and impact. Our experience in the Herbert illustrates each of these functions.

2. Conclusions

Science is often more comfortable in providing advice on what ought to be done and why, rather than practical advice on how it might be achieved (Boehmer-Christiansen, 1994). Our work in the Herbert has led us to focus particularly on this latter challenge. The design of adaptive decision support mechanisms through initiatives such as the NRMtools and HRIC is intended to provide practitioners with access to scientific resources which they can then apply to identifying potential solutions to resource use issues. The challenge for integration is to develop approaches by which data, knowledge and scientific judgements of that data and knowledge can all be made available for integration into a negotiation process that attempts to deal with inherent uncertainty through communication of the principles, values and assumptions underlying analyses.

A variety of frameworks, paradigms and methods for integrated resource planning and use have been espoused to tackle this challenge, including adaptive management (Gunderson et al., 1995), communicative planning (Healy, 1997) and community-based approaches such as Integrated Catchment Management (Anon, 1991). These frameworks tend to reflect the bias of the group fostering the approach and as a consequence, may be unpalatable to, and therefore ignored by, other groups. Nevertheless, they are potentially compatible with a role-based view of the process of improved natural resource use planning and management.

We argue that the functional design (as opposed to the implementation) of decision support tools, the design and facilitation of capacity building exercises such as the HRIC, and the design and implementation of evaluative strategies for assessing the impact of the process of such initiatives and their products, represent an increasingly important activity in natural resource management. Furthermore, while often and successfully performed in an ad hoc manner by scientists or planners, we believe that this is not a research or planning role.

We propose that the development of decision support mechanisms such as those outlined in this paper is an increasingly widespread activity. Recognition of these activities and the role of the professionals involved in them will allow the comparative evaluation of methods and the establishment of best practice. It may also help to counteract the pressures on managers, planners and scientists to seek practical and theoretical approaches to comprehensiveness in all their activities and to thereby become equally and competitively involved in sloppy science, poorly executed planning processes and unprofessional resource management.

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