Integrated catchment management research: lessons for interdisciplinary science from the Motueka Catchment, New Zealand

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Abstract: Integrative research projects are becoming more common and inherently face challenges that single-discipline or multidisciplinary projects seldom do. It is difficult to learn what makes a successful integrative research project as many of these challenges and solutions often go unreported. Using the New Zealand Integrated Catchment Management (ICM) for the Motueka River research program, we reflect on the demands confronting research programs attempting to operate in an integrative interdisciplinary manner. We highlight seven key lessons that may help others learn of the benefits and difficulties that confront scientists and stakeholders involved in undertaking similar research. These are(1)clarify the goal and work with key people; manage expectations; (2) agree on integrative concepts and face the challenge of epistemology; (3) leadership; (4) communication in an atmosphere of mutual trust and respect; (5) acknowledge that different modes of learning mean that a wide range of knowledge products are needed, and (6) measure and celebrate success. The recognition that many environmental problems can only be solved through the creation of new knowledge and through social processes that engage the research and management domains has been a major benefit of the research program.

Additional keywords: evaluation, lessons, success, multi-disciplinary, ICM, integration.

Introduction

Over recent decades, the challenges facing landowners, resource managers and scientists have multiplied. Where once our rural environments were viewed simply as productive landscapes dominated by single sectors (such as dairy, horticulture, forestry), many new players have emerged to voice their views on issues such as landscape, recreation, conservation and tourism (Parliamentary Commissioner for the Environment 2004; Allen and Kilvington 2005). This is particularly true for large-scale landscape and ecosystem management issues where the decision-making environment is increasingly characterised by multiple stakeholders and many perspectives of resource management, and where science and other information is subject to diverse and contested interpretations (e.g. Blackstock and Carter 2007; Giller et al. 2008; Macleod et al. 2008). Indeed, the concept of 'resource management' itself can be criticised for its extractive connotation of the environment as a 'resource' to be 'managed'. To advance sustainable land and water management, practitioners now seek approaches like integrated catchment management (ICM) that accommodate multiple perspectives and draw on multiple sources of information (Cullen 1990; Allen and Kilvington 2005).

Funding agencies, at both national and international levels, are increasingly prioritising projects that accommodate shared environmental interests, such as the health of a catchment and its community (Parkes and Panelli 2001) and those that link science and policy (Stevens et al. 2007; Cronin 2008). This encourages the development of projects that seek to work towards integrating disparate disciplinary knowledge and that involve non-academic stakeholders in the research process (Bammer et al. 2005a, 2005b; Dwyer and Ross 2006). The number of research projects, research teams and individuals dealing with integrative research on environmental and landscape issues is therefore rising (e.g. Bruce et al. 2004; Tress et al. 2005a; Brierley and Fryirs 2008).

Despite the recent prevalence of terms such as 'interdisciplinary', 'integration', 'stakeholder participation' and even 'collaboration' in the environmental science funding arena, efforts to carry out interdisciplinary multi-agency collaborations with a high degree of stakeholder participation still present challenges that are difficult to categorise and quantify (Parkes and Panelli 2001; Lélé and Norgaard 2005; Kilvington and Allen 2007). Further, although the benefits of integrative landscape research projects are, or appear to be, greater than discipline-focussed projects, there are barriers to effective integration of research disciplines and knowledge communities (Rogers 2006; Roux et al. 2006; Morse et al. 2007). Factors such as insufficient time, lack of common terminology, and different organisational or cultural approaches have been previously identified as barriers (Allen et al. 2001; Tress et al. 2007; Morse et al. 2007; Uiterkamp and Vlek 2007). Other factors include clarifying concepts around disciplinarity (Pickett et al. 1999; Jakobsen and McLaughlin 2004), problem definition (Westley et al. 2003; cited in Dewulf et al. 2007), cross-disciplinary publication (Tress et al. 2006); time (Pickett et al. 1999); and career advancement (Kates 2005). The result is that many projects fail, research teams become disenchanted, and projects can be costly in terms of time, personal grief, and money (Benda et al. 2002; Boulton et al. 2008). Further, because failures are often not analysed and written up as project lessons, it is often difficult to learn what makes a successful integrative research project and what things to avoid (Tress et al. 2005c).

Integrative research can often seem more demanding than traditional research projects for several reasons (e.g. Naiman 1999). One major issue is that the research question being addressed is often developed independently from those parties who have a stake in the outcome of the research (e.g. Blackstock et al. 2007; Ison et al. 2007). In contrast, research programs developed in collaboration with a range of stakeholders using multi-stakeholder processes (e.g. Prell et al. 2007) often do not have clear research directions at the outset; rather, these coalesce as relationships and trust between the players develop over time (Daily and Ehrlich 1999). Accordingly, the refinement of high-level questions into tractable projects in an integrated research approach often takes place in a collaborative way between scientists and/or scientists and stakeholders.

This collaboration brings a further set of problems. It often seems as though great pressure and expectations are placed on the outcome of interdisciplinary and trans-disciplinary projects because they include a greater variety of participants, and therefore the results are measured in many different ways – not all of which are conducive to traditional research metrics. Because there are many different actors involved in the process, each with their own different view on the issue, more time and money are required to facilitate the actual integration process. Because traditional disciplinary-based initiatives do not provide for the active involvement of other stakeholders in the research process, researchers in integrative projects feel more pressure from the expectations of stakeholders (Tress et al. 2007). There are also dangers for integrative research projects if science teams, or mixed science–policy teams, ignore the knowledge structure of individual disciplines (Miller et al. 2008).

In this paper, we reflect on the challenges confronting research programs attempting to operate in an integrative and collaborative manner, using the New Zealand-based Integrated Catchment Management (ICM) for the Motueka River research program as a case study. We begin by describing the case study context. We then define the different kinds of science involved, taking care to articulate the differences between disciplinary, multi-disciplinary and more integrative approaches (interdisciplinary and trans-disciplinary). Based on experiences distilled from nearly a decade of involvement in this integrated research program, we then present seven key lessons so that others can learn of the benefits and difficulties that confront scientists and stakeholders involved in similar inter- and trans-disciplinary research.

Research context – the ICM Motueka case study

The Integrated Catchment Management (ICM) for the Motueka River research program (http://icm.landcareresearch.co.nz/) began in July 2000 after extensive consultation with end-users, stakeholders and input from two international experts (Bowden et al. 2004). The program will end in September 2010 when funding ceases, although we expect the legacy of knowledge and learning to develop over years to come. The seeds of the program were sown during a stakeholders' workshop in 1998. This workshop identified the holistic and sustainable management of land, river and coastal resources – a 'ridge tops to the sea' perspective summarised as 'Blue Water, Green Land' – as a top research priority (Bowden and Wilkinson 2000).

The primary program partners include a consortium of crown research institutions (led by Landcare Research and the Cawthron Institute but including NIWA (National institute of Water and Atmospheric Research), GNS (Geological and Nuclear Sciences), and SCION (formerly Forest Research Institute), the local environmental management authority TDC (Tasman District Council) and community stakeholders from the Motueka catchment, including representatives from local Māori groups. Primary funding was from the New Zealand Government via the Foundation for Research, Science and Technology (FRST).

The 2170-km2 Motueka River catchment at the northern end of the South Island of New Zealand (Fig. 1) was chosen from other candidate catchments because of its broad range of environmental issues of importance to end-users locally and nationally, it was of sufficient size to provide variation in environmental gradients (rainfall, geology, productive v. conservation land use, etc.), and because it contributes 62% of the freshwater entering Tasman Bay – a productive, economically and culturally important bay (Basher 2003).

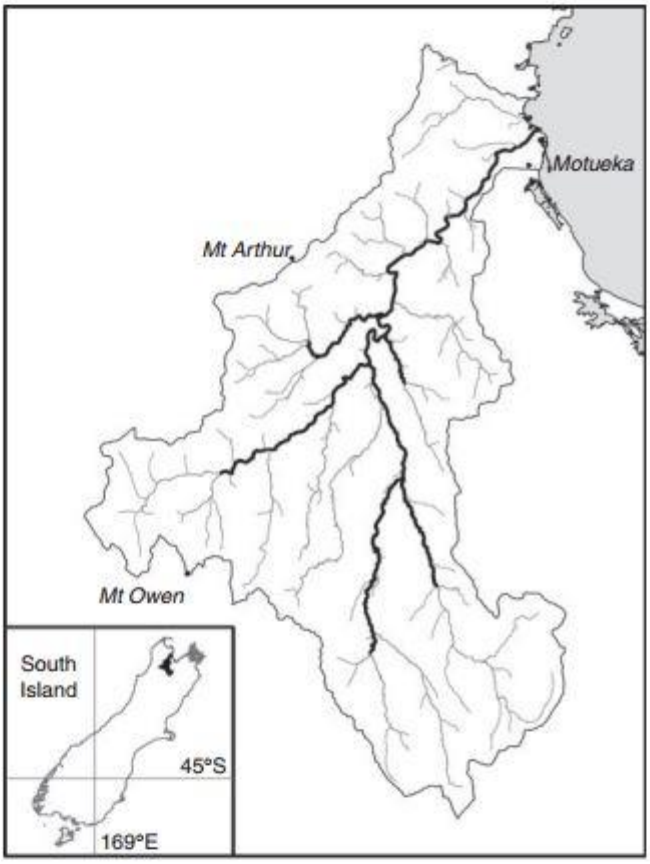

Figure 1: Motueka catchment, South Island, New Zealand.

The catchment is environmentally complex with, for example, annual rainfall ranging from ~950 mm to more than 3500 mm; elevation ranging from sea level to 1850 m; a dominance of mountains and hilly terrain with limited (but agriculturally-important) areas of flat terraces and floodplains; a wide range of rock types; a complex soil pattern; and vegetation dominated by native (35%) and exotic forest (25%). Productive land uses include production forestry, sheep and beef farming, some dairying, and horticulture (Basher 2003). Tasman Bay supports a commercial fishery for shellfish (cockles, oysters, and scallops), and finfish (snapper), and a large area is currently being developed for aquaculture (mostly Greenshell mussels). The Motueka River is regarded as a nationally important brown trout fishery. The catchment, with Kahurangi and Nelson Lakes National Parks, and Tasman Bay are also widely used for recreational activities.

The key resource management and environmental research issues in the catchment centre around water quantity (competing demands), sediment (gravel extraction and sediment impacts on ecology), water quality (nutrients and faecal microbes and potential impacts for aquaculture), aquatic ecology (decline in trout numbers), riparian management (where to focus and what would the benefits be), and the interaction of the Motueka catchment with Tasman Bay in terms of marine productivity and land-based threats to an expanding aquaculture industry. The Motueka catchment became a UNESCO-HELP demonstration catchment in 2001 (Bonnel and Askew 2000) and is one of several catchment-focussed research programs in New Zealand (e.g. Taieri: Parkes and Panelli 2001; Panelli and Robertson 2006; Quinn et al. 2009).

The objective of the Motueka River Integrated Catchment Management (ICM) Program is to improve the understanding of – and social learning about – land, freshwater and near-coastal environments in catchments with multiple, interacting and potentially conflicting land uses (Bowden et al. 2004). With a focus on catchment-scale resource management issues, it also includes catchment impacts on the adjacent coast in which the river plume extends more than 50 km2, effectively extending the catchment area (Forrest et al. 2007). The program was developed to improve the interconnectedness between science providers and community stakeholders and sectoral stakeholders as a way to maximise the uptake and use of new knowledge and tools developed from scientific research. It set out to do this by combining historical land management research, biophysical experimentation, and simulation modelling (Fenemor et al. 2008) together with collaborative learning (Allen and Kilvington 2005; Pennington 2008), to explore the potential to improve interactions

Early in the program, a primary goal was working with both stakeholders and researchers to develop a research program that supported the concept of integration from the mountains to the sea. Many meetings were held to 'get to know each other', share what we knew, and begin to develop work strands. The Motueka ICM framework (Fig. 2) was the product of a 2-year, multi-step design process (details in Bowden et al. 2004). In terms of program organisation, the key environmental management issues were matched with what appeared to be the most pressing issues and the questions that we thought – as scientists – could be addressed. In some cases, we decided not to pursue research that the science team thought was important, because its immediate value would be more theoretical than practical. In other cases, we decided not to address a particular issue because it was concluded that the issues actually required more input from stakeholders rather than 'more study'. The result was a program of research tailored to stakeholder needs and that explicitly included stakeholder input (Bowden et al. 2004).

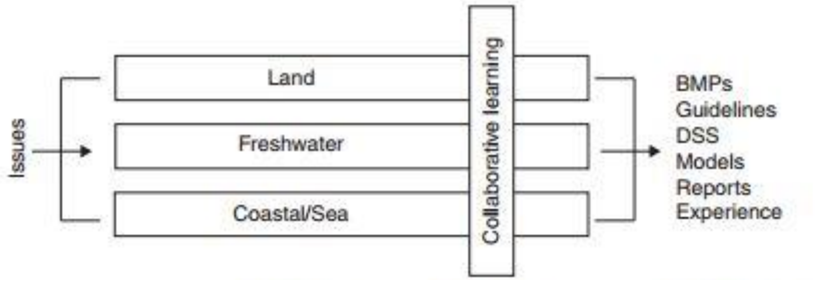

Figure 2: Basic integration framework for the Motueka River and Tasman Bay Integrated Catchment Management research program (Bowden et al. 2004). BMP- Best Management Practice; DSS – Decision Support System

In the 10 years since the program's conception, the trust and relationships developed between researchers, between researchers and stakeholder communities, and between different stakeholder communities of the Motueka River catchment are a reflection of the journey we all have made. We share our distilled wisdom so that others can benefit from what we have learned (Morse et al. 2007). In a similar vein to Ferreyra (2006), these reflections and opinions are those of the authors and original designers of the research program.

Different types of science

One way of looking at science is to view it on a continuum (e.g. Pickett et al. 1999), moving from disciplinary to trans-disciplinary (Jakobsen et al. 2004; Morse et al. 2007). Disciplinary science is characterised by the development of a deep understanding of a single problem, or aspect of a problem, within a well-defined specialisation. Multi-disciplinary science is an additive approach that combines the efforts of more than one discipline within a program (Tress et al. 2005a), and may require co-operation among the different contributors. However beyond that, researchers will largely work and publish in their traditional disciplines.

Although there are many interpretations and definitions of what interdisciplinary research (IDR) is (e.g. Brewer 1999; Pickett et al. 1999; Porter et al. 2006), we define it as projects that involve several unrelated academic disciplines in a way that forces them to cross subject boundaries to create new knowledge and theory and solve a common research goal. By unrelated, we mean that they have different research paradigms. IDR may synthesise results from qualitative and quantitative research methods, or between analytical and interpretative approaches that bring together disciplines from the humanities and the natural sciences. Beyond IDR, Tress et al. (2005c) define trans-disciplinary studies as projects that integrate academic researchers from different unrelated disciplines and non-academic participants, such as land managers and the public, to research a common goal and create new knowledge and theory. In this sense then, trans-disciplinarity can be seen to combine interdisciplinarity with a participatory approach.

However, integration does not come automatically by bringing different disciplines, stakeholders and organisational cultures together (Cottingham 2002; Jeffrey 2003). Even if an explicit objective, the actual definition or recognition of integration when it has been attained is an important goal because the outcomes from integrated studies will be more grounded and enduring. Achieving integration should be seen as an integral part of the project that needs organising. As Tress et al. (2005c) point out, if this is not done, there is a high risk of the research effort just ending up as a collection of individual disciplinary efforts.

Lessons or reflections

We identify seven key lessons for those developing an integrated environmental research project (Table 1).

Table 1. Lessons we have identified and references to previous recognition

Lesson	Recognised by others as lessons or strategies to overcome problems of integrated research
1. Clarify the goal and work with key people	Pickett et al. (1999); Allen et al. (2001); Allen and Kilvington (2005); Tress et al. 2005c
2. Manage expectations	Tress et al. (2007); Strang (2009)
3. Agree on what is being integrated and understand the epistemology	Tress et al. (2005c); Miller et al. (2008)
4. Leadership	COSEPUP (2004); Pennington (2008); Atkinson et al. (2009)
5. Communication in an atmosphere of mutual trust and respect	Naiman (1999); Tress et al. (2005c); Allen and Jacobson (2009); Atkinson et al. (2009)
6. Acknowledge that different modes of learning mean that a wide range of knowledge products are needed	Tress et al. (2005c); Allen and Jacobson (2009)
7. Measure and celebrate success	COSEPUP (2004); Tress et al. (2005c); Allen and Jacobson (2009)

In addition, factors such as institutional support and good facilitation are also relevant. These lessons are not unique and are also supported by others as ingredients for successful integrative research projects (e.g. Tress et al. 2005c; Strang 2009).

1. Clarify the goal and work with key people

One of the issues facing a potential trans-disciplinary research team is not just what they should focus on, but how those researchable issues fit within the 'big picture'. Formulation of a project goal with the identification of clear research questions is a critical early step for successful integrative projects (Allen et al. 2001; Tress et al. 2005c). Although the common goal should be formulated in a way that represents aspects of each participating discipline and is meaningful and of interest to the individual researchers, it also needs to represent the embodied views and aspirations of the stakeholders or end-users of the research. In this way, care is taken to link across science, local and indigenous knowledge systems.

As indicated earlier, the Motueka ICM research program was founded after extensive consultation with end-users and stakeholders over two years and input from two internationally- recognised US experts, Drs Gene Likens and Thomas Dunne (Bowden et al. 2004). In keeping with a collaborative learning approach, the goal and scope of the program was largely formulated 'outside' of the wider research team in conjunction with different stakeholders. This is one of the key differences of research undertaken in an integrative manner. It needs to be broadened from the conventional view of research, i.e. proceeding along a straight line, commencing with a hypothesis, seeking out facts that prove or disprove the hypothesis, and finally pulling out conclusions, which may then be displayed in a model or published in a paper (Wadsworth 1998). This broadened view of science (Fig. 3) will include several questions, common to collaborative learning inquiries in other areas (Allen and Kilvington 2005). These relate to the development of the hypotheses themselves, and the subsequent implementation of the resulting 'new ideas' – to ensure that science is better placed to make a difference on the ground. This is common across the range of community-based research approaches.

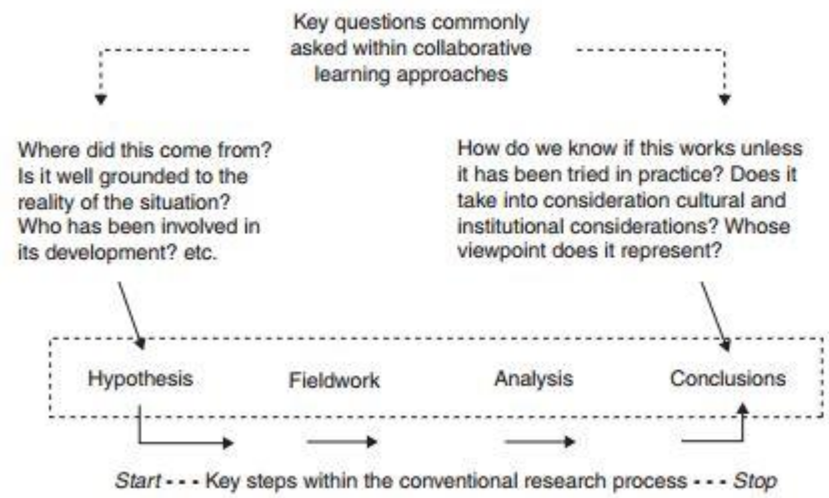

Figure 3: Steps within the wider research process showing relationship between collaborative-learning-based and conventional research (adapted from Wadsworth 1998; Allen and Kilvington 2005)

Identifying the roles and responsibilities of participants in and associated with the program from, for example, unpaid project partners, was an important initial step. In some cases, we entered into formalised arrangements including partnership documents, subcontracts, fee-for-service, and the creation of formal advisory structures such as our Community Reference Group, a touchstone group of catchment residents. Care was taken to ensure that local Māori (indigenous) groups were engaged through a capacity-building process and relationship building recognising Māori tikanga (cultural values) (Harmsworth 2005). In addition, the '7 lessons' that we address in this paper, were sometimes learned the hard way, i.e. we didn't necessarily anticipate and address each lesson up front, but had to learn through criticism and feedback.

It took time for people to get to know each other and what their backgrounds and roles within the program were; taking this time was important to capitalise on peoples' strengths and networks. This was particularly important where research strands relied on consulting community members on an issue or the gathering of anecdotal knowledge. In any long-term research program, researchers will move on, and new team members will bring different research skills. These changes are an opportunity to both evaluate progress in that research area and to refocus. However, they can also leave a large skill gap or delay completion. In our experience, this was often disruptive. This resulted in a level of re-adjustment by the team to redefine and accommodate the new players, as well as the participants learning the roles of the wider team and the goals and expectations of the program. Fortunately in this research program, there has been stability among the research team and stakeholder partners.

Working alongside stakeholders in an open, collaborative way also allowed the ongoing refinement of research questions, and the development of new lines of enquiry or the application of new tools. For example, research with our Māori partners comparing cultural indicators of river health with western scientific indicators such as water quality (Young et al. 2008) led to their involvement in quantifying cultural indicators in an agent-based model of the impacts of land use change in the catchment. Research collaboration also built capacity and knowledge of all within the research network in its widest sense.

Interestingly, many of the new research questions that emerged bridged what might have been viewed as different 'traditional' research disciplines, and were therefore evidence of the evolution of an interdisciplinary approach. This created challenges and opportunities for some individuals to develop a deeper discipline-based understanding alongside a broader, more integrative view of where the 'bits' fitted within the wider picture (e.g. Fenemor et al. 2008; Olsen and Young 2009). The benefit has been that the research is more user-driven and the results more readily applied, for example in developing Tasman District Council policy.

2. Manage expectations

Any research project, but particularly large broad multi- or interdisciplinary projects, sets up expectations around likely outcomes for researchers, stakeholders, and funders alike (e.g. Tress et al. 2005b; Turpin and Deville 2007). These include, for example, delivering the research and associated outputs on time and within budget, achieving contracted high-level outcomes, creating new knowledge, solving 'the problem' or some of its contributory elements, creating new avenues of enquiry, and building capacity. Of these, we briefly highlight two issues: researchers' time commitment, and meeting stakeholder and end-user needs. By their very nature, integrative research projects need time to allow for disciplines to come together and reach agreement on the goals of the work, and how it is going to be tackled. Generally, there is no method or theory available, so this needs to be developed (Miller et al. 2008), and how close interactions and dependencies are dealt with needs to be determined on a practical basis (e.g. waiting on field data before modelling can proceed, or building stakeholder relationships before social science can begin). These additional time demands, particularly in the early days of a project when research managers demand to see progress in the project, are not easily accounted for in project budgets and objective plans, and often accumulate to create pressures on participants (Tress et al. 2005c; Strang 2009).

In the formative years of the ICM program, significant time was involved in meetings. It was clear from meeting feedback and from informal conversations that some research members would rather have been ‘doing’ their science instead of talking about what ICM was or the benefits of integration. Research scientists, generally speaking, are driven by several factors such as curiosity or the desire to solve a problem and are, once the question and methods are set, keen to ‘get on with the science’. Many of these researchers may resent spending too much of their allocated time attending meetings to discuss things that do not appear to be immediately relevant to them. In the authors’ view, it took about two years for researchers from biophysical disciplines to capitalise upon linkages across their projects aligning to program goals, and longer to reach the same level of integration between biophysical and social scientists. The latter probably reflects the differences in how biophysical and social researchers see the world, their language, and the quantitative v. qualitative methodologies each uses.

The second element relates to managing the expectations of the non-academic partners, participants and stakeholders. Non-science stakeholders frequently lacked an understanding of either the scientific process, the New Zealand science funding system that research has to contend with (e.g. funding cycles, bidding arrangements, funding and contracting jargon, etc.), or the less-applied elements of the research (e.g. those with research ‘stretch’ such as exporing new methodological approaches, or new integrative modelling efforts). It took longer than expected to get to the point where end-users received the information or knowledge that they wanted and time had to be spent managing the expectations of this group in terms of what the researchers were producing and when they were delivering it.

Typically, stakeholders have an issue that is ‘immediate’ and expect information on relatively short time lines to make a management or policy decision, usually within a year. Their needs tend to be tactical. In contrast to consultancy, the science process by its nature is more exploratory, and strategic. Often considerable time elapses from the recognition of the issue, development of the research questions, seeking and obtaining funding, and then actually doing the work to resolve the problem or find a solution. Planning frameworks are also often clearly set, so there can be limited ability to incorporate new scientific knowledge in existing plans until they are due for an update. This can result in a mismatch between the time frames of the two groups. For example, one of the Motueka issues when the program was being developed was to understand the flows needed to maintain an abundant trout fishery for the purpose of setting water allocation limits in the Motueka Water Conservation Order (WCO). The WCO decision-making was made before the fishery research was complete. However, that research has begun to explain the variability in trout populations over the past twenty years for application in setting allocation and water quality standards at a finer scale across the catchment. As end-users and researchers together began developing research questions, this lag time reduced and the expectations of both groups started to converge. A benefit of this was an increasing acknowledgement and recognition by both research team and other stakeholders of what the non-academic participants brought to the wider research project. That this became evident largely arose as a result of deliberate facilitation by the social researchers in the team. This was done by forming learning groups (Cornwall et al. 2004) to engage the wide range of stakeholder participants into the working research environment. One example was the ‘sediment learning group’ – a group of researchers from several disciplines and representatives of resource management agencies and industry sectors who saw the benefits of sharing their views about sediment movement across the catchment; this in turn informed the integration of sediment process and freshwater ecology research, rather than the researchers moving directly into solving a given problem. Although the group centred on the topic of sediment impacts, its focus was on active and experiential learning about others' perspectives on the issue, and this dialogue process led to shared understanding of the topic from different perspectives (Allen 2006).

3. Agree on what is being integrated and understand the epistemology of the contributing disciplines and worldviews

Integrative research does not just happen. One of the key steps required is to find some agreement on a framework for the integrative research (Allen et al. 2001). However, as stated earlier in this paper, challenges arise when attempts are made to bridge the gap between disciplines of natural sciences, social sciences, and humanities and arts (e.g. Tress et al. 2005a, c; Bruce et al. 2004; Jakobsen and McLaughlin 2004; Strang 2009). In integrative research, there is no way to escape the epistemological challenge – the framing of the integration – as different disciplines have different underlying assumptions and different inquiry approaches. There is often an attempt to try to create an overarching epistemology; one that provides for legitimate knowledge for all involved disciplines and knowledge systems. This aim is further complicated by the challenges of communicating across the wider epistemological gulf between the biophysical and social sciences (Bracken and Oughton 2006; MacMynowski 2007).

In the early days of the ICM program, this particular step was not explicitly acknowledged or addressed by all participants and it was only after a few years that dialogue on what integration is, was, or might be, actually began to occur. A lot of time was spent both internally within the science team and between the science team and stakeholders, trying to get to grips with the 'integration' idea and the building blocks necessary to achieve the program goal.

In hindsight, our initial inability to identify a common research framework can be seen to account for the tension between achieving less integrative but more immediate sub-project goals compared with defining new integrative science perspectives for catchment management relevant to all of New Zealand. Facing the 'epistemological challenge' in the program and learning to appreciate the different worldviews and inquiry approaches used by different disciplines and stakeholders proved a fascinating journey for many participants. Recognition of others' approaches, jargon, and understanding related to the specific problem(s) at hand emerged as time progressed.

In retrospect, opening up this debate and assisting stakeholders to understand how they contributed to the wide range of views is a prerequisite for undertaking integrated catchment management. However, many participants. particularly in the early years, professed to understand what ICM meant, but did not fully appreciate the concept in its widest sense. Two threads that showed the benefits of this wider concept were in how the research program's knowledge and information was managed, synthesised and delivered (Phillips et al. 2004), and in the creation of IDEAS (Integrated Dynamic Environmental Assessment System, Fig. 4) – a strategic planning tool for testing 'futures scenarios' involving a triple-bottom-line approach, a collaborative learning development process, and assessment of cumulative effects in land and water management (Dymond et al. 2006; Fenemor et al. 2008; Dymond et al. unpub. data).

As the program now draws to a close, a set of concepts or understanding of ICM is emerging that constitutes a new legitimate knowledge for the research team. We now think of ICM as a process to achieve both ecosystem resilience and community resilience (Fenemor et al. 2008). This process requires not only biophysical knowledge developed by hydrologists and other environmental scientists, but an active partnership with catchment communities and stakeholders. It is this partnership and the processes we use to support engagement and shared understanding that serve to break the 'paradigm lock' described by the UNESCO-HELP program between science and users (Bonnel and Askew 2000).

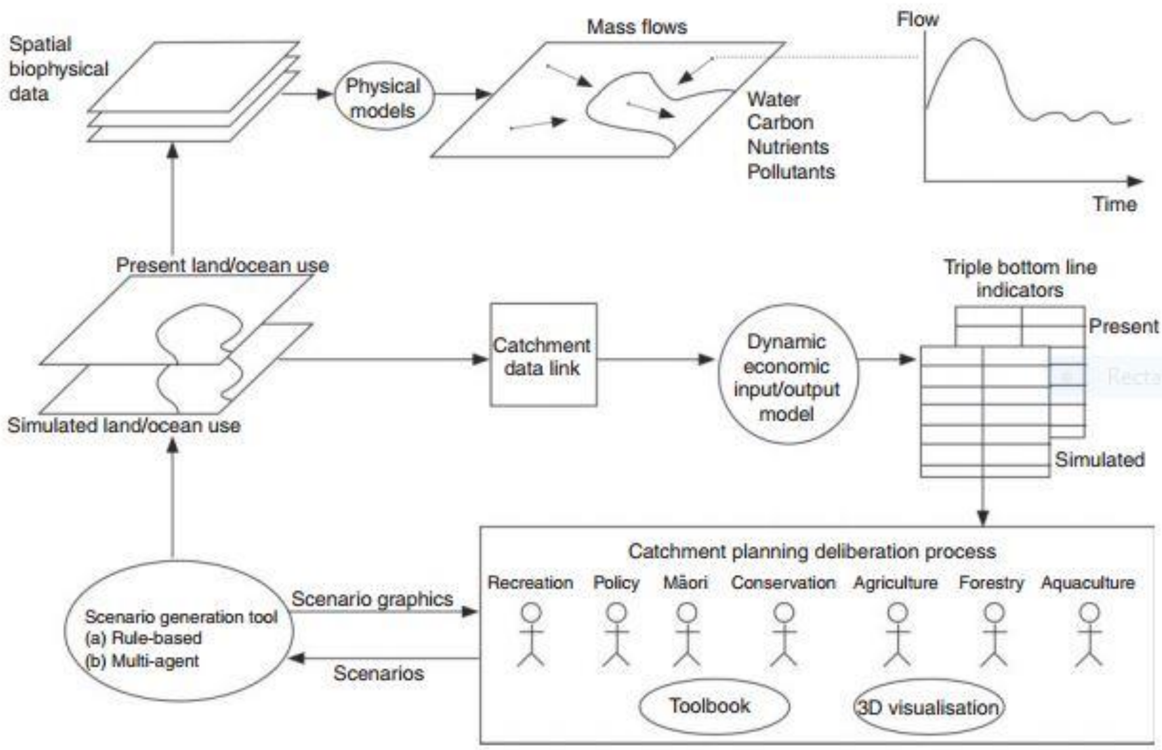

Figure 4: Representation of the IDEAS framework (Dymond et al. 2006, 2010).

For some program members, personal anecdotes and reflections during both formal and informal meetings during the program suggested an 'awakening' or recognition that they had got 'it' – the idea of integration or integrated catchment management. For some, it was expressed as being almost like a 'religious experience'. Those who had acknowledged that their world view had changed also reported that it was a challenge to describe this epiphany and to effectively communicate to others the transformation they had experienced. However, these experiences were not shared by all, and we are careful to acknowledge that working integratively and across disciplines is just one of many kinds of research. Discipline-focussed and interdisciplinary-focussed efforts are both necessary to transform science and society, a sentiment that is shared by many research scientists (MacMynowski 2007).

4. Leadership

Integrative research projects call for leaders with highly-developed interpersonal skills, research credibility, and the ability to maintain the motivation of the team, even when things go wrong. Further, leaders need to be greatly involved in the actual project and should have a significant amount of their time allocated for leadership (Tress et al. 2005c). There have been two science leaders in the ICM program since it began. Each has brought a different set of technical as well as management skills to the project. Both were involved in doing some research in their areas of discipline or interest as well as providing leadership and management roles. Their significant roles were as integrators; initially forging relationships in a geographically and multidisciplinary research team, and later integrating in more depth with stakeholder groups.

As several reviewers acknowledge, there are several ways in which leaders can support integrative research and integrative researchers (e.g. Spencer et al. 2006; Pennington 2008). One key attribute is the ability to bridge across different viewpoints and help people develop and articulate a shared vision. Understanding different inquiry epistemologies – from positivism to constructivism (Pennington 2008) – and helping both social and biophysical scientists find ways of working together from their different epistemologies is also important (MacMynowski 2007).

It is up to institutions to recognise innovative, flexible leaders, and to encourage them to take risks in discerning and supporting fresh ideas (COSEPUP 2004). Traditionally, research leaders are rewarded for strengthening their own programs (or departments) and not on building links to others. In this regard, integrative research often calls for leaders to put the bigger vision before the immediate needs of their program or organisation. One highly successful example of leaders taking risks was the design and development of an art–science collaboration labelled 'Travelling River' (Atkinson et al. 2004). This collaboration among 60 artists, scientists and residents of the Motueka catchment resulted in a public exhibition weaving together ICM science and residents' perspectives within the Motueka catchment, which was seen by some 3000 people.

5. Communication in an atmosphere of mutual trust and respect

Frequent formal and informal contact is crucial for integrative teams, as is a good project atmosphere where the meeting of minds can occur. Mutual trust, understanding and respect are preconditions for integrative and collaborative work (Hollaender et al. 2002; Allen and Kilvington 2005; Allen and Jacobson 2009; Atkinson et al. 2009). Communication becomes more important in integrative projects and the ICM program has made a point of periodically reconstructing, implementing, and revising the way it communicates and delivers its messages. The program communication efforts are thus responsive to the ongoing learning and changing ways that the different stakeholders view the ICM landscape. Moreover, we have found it important to use several different modes and forums for communication. These also change over time as stakeholder relationships evolve.

In the initial stage of the ICM program there were many formal meetings, largely to determine work programs and implementation plans. There were also many informal meetings but generally only of subsets of participants (researchers with or without stakeholders). The nine ICM annual general meetings (AGMs) provided additional opportunities to bring people together for a period of three days each year to share results and ideas both within the project team and with stakeholders. An interesting reflection on the formal meeting process, and one that perhaps provides an indicator to the creation of a successful integrative research team, was that meetings shifted from being fairly heated and lively discussions in the formative parts of the project (often with some dissension or a few key protagonists holding the floor and others sitting out), to ones where significant amounts of 'active listening' and full participation occurred. A high degree of facilitation in those early meetings, largely by the social scientists, helped create this type of working environment. The success of the ICM research program is, to some large extent, a result of the inclusion of those social scientists, who provided opportunities to both challenge and educate traditional biophysical scientists. This awakening and recognition that many environmental problems can only be solved through the shared creation of new knowledge and through social processes that engage the research and management domains has been a key outcome of the research program.

The distributed nature of project participants (geographically and across different agencies) created a need to enable more 'engaged' communication approaches beyond traditional email and one-to-one dialogue or face-to-face meetings. Information technology became a key element for communication within and from the program team, as well as providing a way to manage the program and deliver the knowledge base being created within the project (Phillips et al. 2004). Although relatively uncommon for research programs in New Zealand in 2000, a program decision was made to develop, as part of the communication and marketing strategy, both an external website (http://icm.landcareresearch.co.nz/) and an internal 'intranet' for managing administrative functions. This not only provided a new way of working for many, but also allowed for the wider team (researchers, partners, and key end-users) to see what others were working on. From the outset, a joint program decision was also made to enable timely direct access to research results. All knowledge products, such as papers, reports, work-in-progress statements, and presentations, were intentionally made available on the internet. This emphasis on ensuring such a wide selection of outputs was readily available is still a relatively novel practice for research programs, and has received favourable reactions from a wide range of stakeholders. In addition, an online dialogue space called 'Confluens' was created to enable interaction and conversations to occur within the project team and with a limited range of stakeholders. Although trialled early in the project, it was initially abandoned and then re-introduced a few years later when trust and relationships between the team had developed to a point where participants felt comfortable about sharing their knowledge and asking 'dumb questions' of their colleagues. It also created a virtual space from which emerged several new cross-discipline projects and ideas that perhaps would not have occurred if that 'space' had not been created for this interaction to happen. Efficiencies in terms of project management and reporting were also improved with the use of this suite of information management tools. Further, strong social elements have emerged from the interactions of participants in the program and friendships have formed as a result of involvement in the project. The AGMs all aimed to have a balance of social activities – be it a field trip, a boat trip, and shared meals – as well as time for the more serious business of discussing, presenting or planning research activities. This emphasis on relationship building has turned out to be one of the strengths of the program.

6. Acknowledge that different modes of learning mean that a wide range of knowledge products are needed

One of the differences between single-discipline and interdisciplinary/trans-disciplinary or integrative projects is that the range of products or outputs from the latter is usually broader in scope. This occurs in response to the involvement of a wider group of stakeholders, each with their own needs and views on program outcomes. Increasingly, these type of projects use not only scientific peer-reviewed papers to communicate their results, but also develop project reports or updates, fact sheets, websites, video clips, virtual tours, and multi-media tools. This range of knowledge products reflects the range of learning styles across the stakeholder community. Because of the wider range of stakeholders involved in such integrated research, outputs include science, local and traditional knowledge products (Allen and Jacobson 2009).

Balancing between more fundamental and applied research and knowledge synthesis and delivery became a key focus for the team. This required periodic reflection to avoid the trap of becoming too focussed on delivering more applied or consulting aspects. Particularly in the first few years, these issues were agenda items at the program's annual general meeting. Meetings or workshops were facilitated either by the program's social scientists or by a professional facilitator. The aim of these discussions was to involve the wider research team in developing (or revisiting) the communication and marketing strategy, and identifying creative ideas and opportunities to present our research to end-users. In terms of meeting the goal of the program, we not only had to help the resource management agency solve some of its practical resource management problems, but we also had to produce outputs that gained academic merit and acknowledgement to meet the needs of the funder (FRST). Accordingly, obtaining a balance between science merit v. practical problem-solving and the production of knowledge products was also a consideration that was revisited several times during the program, and remains an issue for integrative research programs like ours.

The nature of teamwork in integrative programs can also bring challenges in terms of science outputs. The outputs of integrative projects are often multi-authored. Some discipline-based science teams and departments often give more recognition for single-authored papers, to lead authors only, and those that are in 'leading journals' or those that have high 'impact', such as a high citation index (e.g. 'h index': Tijssen et al. 2002; van Raan 2004; Hirsch 2005). Accordingly, it is important to provide recognition for integrated team members that are prepared to contribute to multi-authored papers. In many cases, our experience in this programme was that researchers enjoyed developing papers through a process of collective authoring that spanned disciplines.. Further, there is as much if not many times more written in comments and emails between authors than is actually contained in the narrative of a multi-authored, integrated paper. This discussion is the heart of research dialogue, knowledge development, and the evolution of shared solutions, and might well be described as 'scholarship'.

In many integrative projects, particularly those that are more applied, influential knowledge products are increasingly written in practical (e.g. stakeholder reports) rather than academic formats (science papers). In an applied project with concrete outcomes, a tension often exists for researchers to deliver knowledge products for non-scientific project participants and stakeholders, and at the same time deliver high-quality scientific outputs to meet the needs of the funder (Tress et al. 2005a). This tension needs to be recognised and understood by project leaders and research managers.

Within the Motueka ICM program, we moved from single-authored publications in the early days to more multi-authored, cross-discipline products. At the same time however, there are specific outputs still being generated that are more discipline-based. Although many researchers feel that a bias exists against publications of interdisciplinary research, independent studies have found no such systematic bias (Rinia et al. 2001). However, we agree with Tress et al. (2006) that issues remain around both the writing and reviewing of interdisciplinary studies because the cultural and stylistic norms of established disciplines tend to discriminate against interdisciplinary studies in the reviewing process. At the same time, we see that solving this problem will happen over time as more researchers learn to work and write from the basis of understanding both discipline and integration.

Producing a high count of outputs is not necessarily an indication of 'success'. There is also recognition that outputs can be 'intangible' as well as 'tangible', i.e. those usually associated with traditional research. The measure of true integrative project outcomes is whether the whole outcome is more than the sum of the parts (Tress et al. 2005c). In other words, true integrative outcomes could not have been produced by any one of the involved disciplines alone, but have emerged from the integrative effort. A unique example of such an integrative outcome emerged from the collaboration mentioned earlier, between artists and scientists. This project not only delivered new understanding to the participants in the ICM project but it also engaged with the community of the catchment who provided much of the material that was used in the 'Travelling River' exhibition (Atkinson et al. 2004; Peacock 2005; Kilvington and Horn 2006).

7. Measure and celebrate success

Clearly, many of the standard means for evaluating disciplinary research can also be applied to integrated research initiatives. These include using metrics such as number of publications, citations of publications, successful research proposals and benchmarking with other programs (when comparable programs exist), and recognition of researchers (e.g. Mansilla and Gardner 2003). However, some additional measures of success are required to capture the broader goals of integrated programmes that bring together a range of disciplines and stakeholders. Other success factors include the strength of the relationships that evolve across disciplines and between the immediate research team and the wider stakeholder community. Attention also needs to be paid to the increased capacity of researchers and stakeholders to work in other integrated and collaborative ventures either within or external to their institutes.

One of the biggest challenges for the new wave of integrated management–research projects around the world is to ensure that they are evaluated against the range of outcomes required by their diverse stakeholder partners. This means they have to go beyond traditional science evaluations of research programs that look at things such as key research papers, the specific disciplinary journals that are favoured, and international and other links (e.g. Patton 1990; Shadish et al. 1992). Certainly, there is a need to focus on environmental and social state changes. However, although end users tend to concentrate on the environmental outcomes sought, it is easy to forget that much of the challenge of implementing integrated management lies in promoting change in the behaviour of the different user-groups, departments and even wider communities (Allen and Jacobson 2009). Beyond that, we can also look to the capacity-building that can be expected to occur in researchers, institutions and end-user groups as they learn to collaborate and work together to create innovative solutions to the interlinked challenges facing catchments throughout the world today.

In our own experience, it is important for integrated research teams to keep their eye on all of these measures simultaneously. This is because we recognise that all of our audiences are important. For example, in our own case we are particularly mindful of the need to produce quality research publications. What we have noticed is that when these are produced, we gain increased recognition from peers and research funding agencies. Equally, many local stakeholders look to a strong personal relationship as an important intermediate indicator that things are moving along the right track. The implication of these findings in practice is that researchers working in integrated programs need to meet a wider range of success outcomes than their counterparts in more traditional disciplinary science initiatives.

It is also important that integrative research projects, particularly the larger and longer-term projects, have the ongoing support of agencies that are supplying key research capacity (research institutes and universities) that are often structured along traditional disciplines. Further, there is also a need that these types of projects are different from more discipline-based projects and hence need to be recognised as such and may thus require different levels or types of support (Strang 2009). For example, they may not deliver results as fast as more traditional single-issue-focussed projects, may require additional stakeholder contact time, and they are likely to be required to deliver a wider range of knowledge products other than just scientific papers. Researchers involved in such integrative projects also need to feel that their involvement in such studies is appreciated and that the special challenges and problems associated with their research is acknowledged by the organisations they work for.

Concluding thoughts

Our experiences are consistent with many findings in the literature (e.g. Naiman 1999; Tress et al. 2005c; Strang 2009). We concur with Tress et al. (2005c) that it is crucial to get things right at the start of the project. Research design, selection of participants, agreement on a research question, appointment of a skilled project leader, and creation of trust and respect are, to a large degree, setting the course for success.

Understanding of the biophysical processes (state and response, Fig. 2) within the Motueka River catchment and its coastal environments has been advanced significantly during the ICM program. Advances include, for example 'knowing what we know' (i.e. the state of knowledge about the catchment, coast, and its people) (Basher 2003); the condition and health of freshwater ecosystems (Young et al. 2005; Young and Collier 2009; Young et al. 2010) and marine ecosystems and productivity (MacKenzie 2004; MacKenzie and Adamson 2004; Tuckey et al. 2006; Jiang and Gibbs 2005); the use and interactions of surface and groundwater (Stewart et al. 2004; Davie and Fahey 2005; Hong et al. 2009; Olsen and Young 2009); trout movement (Young et al. 2010); catchment and river management including gravel extraction, sediment and faecal microbial sources (Davies-Colley et al. 2004; Forrest et al. 2007; McKergow and Davies-Colley 2010); and riparian management and plant soil-holding abilities (Marden et al. 2005).

We have worked to break down institutional barriers, principally among research institutions but also with resource managers. An example was where scientists and agency staff carried out joint investigations with the support of local landowners in the cow-crossing experiment (Davies-Colley et al. 2004). These types of investigations have contributed to changes in both policy and behaviour on the ground.

Further, our understanding has resulted in several integrated outputs (Dodd et al. 2009) such as the development of models that predict the effects of land use change on flows and water quality (Cao et al. 2006; Cao et al. 2009; Fahey et al. 2010), and the development of integrated scenario-modelling frameworks such as IDEAS that take into account biophysical, economic, and socio-cultural factors (Dymond et al. 2006; Andrew and Dymond 2007; Dymond et al. unpub. data). Integrated linkages have also enabled catchment residents and researchers to look at the system in a new light. Examples include the river plume ecosystem arising from a 'mountains to the sea' approach (Tuckey et al. 2006), arts–science interface (Kilvington and Horn 2006), linking groundwater to fish behaviour (Olsen and Young 2009), linking spatial and non-spatial modelling tools (Dymond et al. 2006), evaluating water governance, exploring how groups use and develop shared understanding though dialogue processes (Atkinson et al. 2009), and how institutions use science and knowledge in decision making.

In addition to traditional catchment-based research activities outlined above, new and innovative projects emerged, such as capacity-building across different communities (Jollands and Harmsworth 2007) and cultural approaches to environmental monitoring (Young et al. 2008). We refined a framework to encourage the use of clear steps and communication for dialogue and action that support participation and self-help in natural resource management (Allen and Kilvington 2002, 2005). The resulting ISKM (Integrated Systems for Knowledge Management) framework has been taken out of the catchment context to learn, for example, about issues related to oil and gas in British Columbia, Canada (Booth et al. 2004). Evaluation approaches that closely link institutional and social processes with biophysical and socioeconomic state changes have also been explored. This involved introducing the 'orders of outcomes approach' (Olsen 2003; UNEP/GPA 2006) to New Zealand to develop indicators and assess progress in developing integrated catchment management plans in Auckland city (Hellberg et al. 2009).

Perhaps one of the most significant areas of development though, has been in our understanding of 'integration'. Although it seems simple and is central to what we are doing, it has been one of the hardest things to define because it means different things to different people. For the research team, another key recognition has been the need to listen and value people's own 'ethics of care', and to identify how science can build on, and inform those ethics (Jollands and Harmsworth 2007). We have also recognised that involving local stakeholders provides the key for contextualising generic science findings so that solutions work at the local level. (Blackstock and Carter 2007). This raises the question of how science can harness and strengthen that sense of place. The project 'Travelling River' (Atkinson et al. 2004), as well as its successor 'Watershed Talk' (Atkinson et al. 2009), demonstrated both the sense of place and the connection between those who lived by or who had an affinity for the Motueka River and its catchment and the scientists who worked on it (Atkinson et al. 2009).

On reflection, we cannot only think about integration as it relates to linking science with those who manage, live in or use the catchment, but as research that involves multiple agencies and draws on multiple academic disciplines, research and management that crosses different geographical scales, and people working alongside each other. Often these boundaries are hard to see. Collaborations operate at multiple levels: between researchers, between institutions, across disciplines and, critically, between the potential end-users of science and the science providers. It is unquestionably challenging, and offers a critical learning opportunity for participants and would-be followers. These levels of collaboration are analogous to what Price (2003) describes as the multiple social spaces within which the process of generating, debating and utilising science knowledge in the program takes place; these social spaces ‘comprise their own unique boundaries, their own narratives, and their own contestations and negotiations’.

A particular challenge to achieving integration also comes from the different scales of interest or influence of those involved. For example, the whole-district management focus of the Tasman District Council contrasts greatly with the focus of landholders on individual properties. Scaling up knowledge of catchment hydrological processes from small catchment studies to a large catchment scale is challenging. In the ICM program, there are several examples of research that have been carried out at different scales. Scale is also one of three key components that Cottingham (2002) considered essential for successfully resolving biocomplexity problems – the other two being people and tools, a finding mirrored by our program (Fenemor et al. 2008).

As indicated in lessons 1 and 2, a critical element of integrative research projects involves ensuring there is enough time for engagement with others. Collaboration requires time so that all achieve at least a basic understanding of the theory, methods, data and analysis used by others (Strang 2009). Trust, mutual respect for others’ views and the ability to work alongside each other arise from creating the space for dialogue. Without continual and ongoing attention to relationships, the probability of either non-completion or project derailment becomes greater (Benda et al. 2002). Further, without attention to the development of a ‘common language’, communication between individuals can often be at cross-purposes, leading to unexpected outcomes and interpretations.

By informally evaluating the ICM Motueka case study, we have aimed to share our experiences so that others can learn from them. The integrative dimensions of the ICM approach have provided a workable framework for addressing the issues we and our stakeholders aimed to address. Although it is difficult to prove success in such approaches, it is clear that as the ICM effort proceeds to find and implement improvements in resource management, new pressures on resources and communities mount. Thus the target is always moving. It might be more appropriate to think in terms of how much worse things might have been had these efforts not taken place. Further, when stakeholders begin to take responsibility for success then it might be fair to say that this reflects to a degree the involvement of such integrative research projects.

The success of the ICM research program is also, to some large extent, a result of the inclusion and role of the social scientists who provided opportunities to both challenge and educate traditional biophysical scientists, who outnumbered them. The awakening and recognition that many environmental problems can only be solved through the shared creation of new knowledge and social processes that engage the research and management domains has been a key outcome of the program. It is clear that the role of the researcher is changing as is the range of activities defined as ‘research’. It is also clear that there needs to be greater dialogue between research and society or as Tress et al. (2005a) put it, ‘this will help interdisciplinarity to find its way between being seen as the anchor for solving landscape problems (rather than) as an academic experiment’.

To effectively respond to the challenge of managing complex social–ecological systems we concur with Roux et al. (2006) that 'scientists cannot afford to remain detached experts who deliver knowledge to managers, but must assume the roles of collaborative learners and knowledge generators in a science–management partnership'. We think this sentiment would fit neatly with the thinking of the late Peter Cullen.

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