# Bridging disciplines, knowledge systems and cultures in pest management

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**Abstract** The success of research in integrated environmental and natural resource management relies on the participation and involvement of different disciplines and stakeholders. This can be difficult to achieve in practice because many initiatives fail to address the underlying social processes required for successful engagement and social learning. We used an action research approach to support a research-based group with a range of disciplinary and stakeholder expertise to critically reflect on their engagement practice and identify lessons around how to collaborate more effectively. This approach is provided here as a guide that can be used to support reflective research practice for engagement in other integration-based initiatives. This paper is set in the context of an integrated wildlife management research case study in New Zealand. We illustrate how multi-, inter- and trans-disciplinary approaches can provide a framework for considering the different conversations that need to occur in an integrated research program. We then outline rubrics that list the criteria required in inter- and trans-disciplinary collaborations, along with examples of effective engagement processes that directly support integration through such efforts. Finally, we discuss the implications of these experiences for other researchers and managers seeking to improve engagement and collaboration in integrated science, management and policy initiatives. Our experiences reaffirm the need for those involved in integrative initiatives to attend to the processes of engagement in both formal and informal settings, to provide opportunities for critical reflective practice, and to look for measures of success that acknowledge the importance of effective social process.

**Keywords** Interdisciplinary – Transdisciplinary - Multistakeholder engagement - Environmental management – Integration - Action research - Rubrics

## Introduction

The success of environmental and natural resource management initiatives often depend on the coordinated actions of decision makers from the site level (e.g. farms and protected natural areas) to regional levels, and beyond. Gaining effective participation, and subsequent coordination, in these initiatives is not always easy, especially in relation to pest management issues, which are characterized by conflicting social perspectives and worldviews (Allen et al. 2001). Accordingly, managing the constructive involvement of diverse disciplines and stakeholders is a skill that requires as much emphasis as does developing our abilities in technical problem solving. A major challenge is to promote a more integrated approach which shares knowledge and experience freely between the different groups involved (Margles et al. 2010). The need for this integration is well illustrated in New Zealand vertebrate pest management, where a recent national-level biosecurity review called for people to work together in a more coordinated and collaborative way (Hellstrom et al. 2008).

An increasing number of science programs in natural resource management are being developed using collaborative or social learning approaches (Tress et al. 2005, Allen et al. 2011, Robinson et al. 2012). To be successful, the science in these programs needs to be broadened from the conventional approach, which typically involves the science team taking responsibility for developing and managing the research process largely independently from stakeholder input. In many cases such research-led inquiry management processes are defined by one discipline, to the subsequent detriment of other disciplinary epistemologies (Miller et al. 2008). Conventional program-based research typically begins with the science team developing a hypothesis, then seeking out of facts that prove or disprove this, and finally developing conclusions – which may then be displayed in a model or published in a paper (Wadsworth 1998). This science product is then given to stakeholders who are expected to incorporate it into their decision making process. A broadened view of science involves disciplines and stakeholders more overtly in developing hypotheses, and in thinking through the subsequent implementation of the results. These collective efforts help ensure that science is more aligned with stakeholder requirements, and therefore better placed to make a difference on-the-ground. Additionally, this level of involvement helps ensure that stakeholders understand the biases, assumptions and limitations of the science.

There are many examples of research leaders, scientists, and their stakeholder partners adopting this wider view of research. Scientists and practitioners in these research programs are sharing theories and methods that demystify science, and emphasize collaborative adaptive management (learning-by-doing). These programs follow collaborative problem solving and dispute-resolution principles that highlight the importance of working with a range of stakeholders to develop shared definitions and frameworks, cultural sensitivity and connection, and a sense of inclusion and empowerment (Allen and Kilvington 2005, Plummer and Armitage 2007, Jacobson et al. 2009). Given that these collaborative and social components often remain largely hidden in conventional research proposals and published conclusions, their application in design and practice can often be less rigorously reviewed and enacted compared to the design and practice of conventional research. If the science community wishes to ensure the relevance and rigor of collaborative and learning-based initiatives, then it needs also to be explicit about using robust methodological practice that ensures that these elements receive appropriate peer review, as well as subsequent considered and skilled implementation (Allen and Kilvington 2005, Reed 2010).

The challenge then, for nurturing this more inclusive approach to research and management, is to facilitate processes in which a wider range of disciplines and stakeholders can engage on equal terms and with common respect. This applies both to the theory and design of integrated program initiatives, and the relationship and trust building needed for successful engagement. Moreover, because these initiatives are increasingly designed to support both collaboration and adaptive management (Plummer and Armitage 2007; Allen and Jacobson 2009) there is a need to see these engagement processes as ongoing.

Increasingly, researchers are beginning to highlight how they are addressing the social challenges required by these more inclusive, adaptive and learning-based approaches. For example, Lisa Campbell (2005) outlines some practical obstacles to interdisciplinary research in general, and then offers suggestions for overcoming them. In 2010 a special issue of this journal challenged authors to think about how they contributed to interdisciplinary approaches (Margles et al. 2010). More recent papers reaffirm the need to learn from actual experiences that bring together decision makers and scholars from different disciplines (Podesta et al. 2012; Robinson et al. 2012). To paraphrase Margles et al. (2010) all of these authors, and journals, are moving beyond rehashing the myriad of barriers in conservation science and practice, and are seeking to contribute ideas, tools and experiences to the on-going efforts of those seeking to support collaborative approaches to conservation issues. A challenge beyond considering how we work together as researchers in interdisciplinary collaborations is to consider how best to include other knowledge systems (e.g. local and traditional) through the inclusion of practitioners, community and Indigenous groups as partners in the research process. This brings in the concept of transdisciplinary collaborations (Apgar et al. 2009, Jahn et al. 2012).

Recent literature in this area points to the importance of encouraging reflection among all those involved to identify and encourage approaches that foster a more collaborative and integrated production of knowledge (Plummer & Armitage 2007; Podesta et al. 2012). However, current research practice fails to provide guides as to how to develop such critical reflection. We used an action research approach to support a research-based group with a range of disciplinary and stakeholder expertise to think about their engagement practice and identify lessons around how to engage effectively in integrated environmental management. We begin by introducing the context provided by the Centre for Wildlife Management and Conservation (CWMC), whose work focuses on integrated pest management in New Zealand. We introduce the action research approach that was undertaken. We then look at the discussion that was generated among the team in looking at inter- and trans-disciplinary initiatives, and provide examples of rubrics we developed to help this discussion. Examples of the different engagement approaches used to support both trans- and inter-disciplinary initiatives are provided from our own programs. Finally we identify lessons from the case study experiences for other researchers and managers seeking to improve engagement and collaboration in integrated science, management and policy initiatives.

## Program context and engagement framing

New Zealand has a unique set of animal pest problems impacting on both biodiversity and primary production. Native predators and grazers (all birds) are now largely extinct (Wilson 2004), resulting in ecological niches occupied by introduced animals, many of which have since become widespread pests (Cowan and Tyndale-Biscoe 1997). Thirty-one species of exotic mammals have wild populations in New Zealand, and 25 of these are actively managed as pests (Parkes and Murphy 2003).

The problems caused by these pests are significant. For example, the possum (*Trichosurus vulpecula*) has detrimental impacts on both the environment and the agricultural economy. Possums are the major cause of decline of numerous native tree species, and destroy the nests of many native birds (PCE 2011). They are also the main vector for bovine tuberculosis (TB), which poses a serious threat to New Zealand's beef and dairy exports (Coleman and Caley 2000). Possums are estimated to cause production losses to the agricultural, horticulture and forestry industries of approximately NZ$52 million annually (Ministry of Agriculture and Forestry 2009). New Zealand's native birds are also at risk from other introduced predators. For example, it is estimated that half of the 95% of juvenile brown kiwi (*Apteryx mantelli*) that die in the wild each year can be attributed to stoat (*mustela erminea*) and feral cat (*Felis catus*) predation (McLennan et al. 1996).

Feral animal pests are found across the range of New Zealand landscapes, including a mosaic of production and conservation lands. Key stakeholder groupings involved in management include individuals and corporate organisations owning production lands and lands under conservation covenant, public lands under conservation covenant, local government managed lands, and Māori[1]-owned land. As a result, the delivery of effective and efficient pest management depends on the adoption and uptake of good practice by a diverse range of stakeholders, ideally working in a coordinated fashion across broadly linked landscapes.

This political/social landscape has contributed to research initiatives geared towards close engagement of stakeholders in research. One example is the Centre for Wildlife Management and Conservation at Lincoln University, which has been established with the vision of helping increased recovery of native biodiversity over extended areas of New Zealand. Two programs in particular contribute towards the lessons for bridging disciplines, knowledge systems and cultures outlined in this paper. These are the New Zealand government funded pest management research programs, "Pest Control for the 21st Century" (PC21) and "Completing the Arsenal for Possum and TB Control" (CAPTB). Key research themes include the development of new toxicants and baits with improved safety and field efficacy, low residue risk, welfare and cultural considerations as primary points of focus, and the development of new resetting control technologies to support long-term suppression of pest populations. An underpinning social theme aims to identify integrative processes that help stakeholders with pest management decision-making.

These research programs involve both science and community expertise. Scientific expertise includes animal ecology, wildlife management, pharmacology, toxicology, food manufacturing and design engineering. Social science expertise covers multi-stakeholder engagement, outcomes planning and indigenous knowledge. Two key advisory and advocacy groups provide insights into stakeholder aims and needs regarding biosecurity, biodiversity and agricultural production. An Industry Advisory Group includes representatives of major New Zealand end user bodies and agencies (e.g. Regional Councils, Department of Conservation, TBfree New Zealand). The second is a national Māori advisory and advocacy group known as Ngā Matapopore ("The Watchful Ones."). Both groups provide a mechanism for end-user oversight of new tools and techniques under development. Ngā Matapopore plays a particular role recognising that a key component of the Centre's research strategy

[1] Indigenous people of New Zealand

involves more closely linking pest management science with Mātauranga Māori (Māori knowledge), to ensure that pest management solutions are appropriately integrated with Māori cultural aspirations.

**An action research approach**

As part of the social research theme at the Centre, we aim to identify processes that help stakeholders to integrate ecology, culture and local knowledge within the wider thinking and decision-making processes that support effective pest management. This research objective is also tasked to ensure that these processes build on general behaviour guidelines for daily life and interaction in Māori culture ('Tikanga'). Tikanga is commonly based on the experience and learning that is associated with a Māori worldview and has been developed and handed down over generations (Kōrero Māori website n.d.).

We have used an action research approach to underpin the social research theme. Action research involves an approach to reflecting on processes that can result in change in practice (Kemmis 2009), and can support social learning in complex interpersonal and organizational situations (Ison 2008; Flood 2010). Its purpose is not just to understand the social arrangements in place, but also to effect desired change as a path to generating new knowledge about collaboration, and empowering the participants in the study (Huang 2010). As a methodology, action research is consistent with the call to improve engagement in research. We need to support researchers in critically reflecting on factors that foster or impede cooperative production of knowledge, and in changing their practice accordingly (Plummer & Armitage 2007, Podesta et al. 2012). Critical reflection requires us to challenge assumptions and beliefs that may be socially restrictive, and to think about how we could enable transformative social action and change (Finlay 2008).

Action research involves practitioners (researchers and their partners) managing systematic enquiries in order to help them improve their practices and better realize their desired outcomes, which can in turn help them contribute more effectively towards the longer term outcomes desired by their wider end-user communities. Through their observations and communications with their wider stakeholder groups, research team members are continually making informal evaluations and judgements about the best way to engage. The difference between this and carrying out these activities as part of an action research inquiry is that during the action research process the research team will need to develop and use a range of skills to achieve more critical reflection and evaluation.

Our project took the core spectrum of disciplinary, multi-, inter- and trans-disciplinary research as a starting point for thinking about how we engaged with the wider research stakeholder community. This builds directly on earlier work by some researchers in this team reflecting on a ten-year integrated catchment management research program (Allen et al. 2011). It was felt that introducing discussions around this model at an earlier stage than had occurred in other integrated programs would help build a research team culture of evaluative thinking and awareness around engagement issues earlier.

The research team is distributed across New Zealand, and members participated in this process in a number of ways. Individual discussions and focused workshops around the development of simple rubrics provided an entry point for thinking about how engagement across the disciplinary spectrum supported integration.

A rubric is an easily applicable form of assessment. They are most commonly used in education, and offer a process for defining and describing the important components of work being assessed (Oakden 2013). Although the format of a rubric can vary, they all have two key components:

- A list of criteria – or what counts in an activity or task
- Graduations of quality – to provide an evaluative range or scale.

The development and use of the rubrics was designed to support critical reflective practice and formative assessment around the range of collaborative initiatives undertaken by the research team. The primary sources for developing the evaluative criteria include expert contribution from those members of the research team with technical expertise in managing participation and engagement, a literature review and the workshop insights generated by other team members. This source material provides the basis for generating a useful discussion among team members around inter- and trans-disciplinary collaborations. In this setting we had to actively think about and discuss the characteristics of good integrated engagement practice, providing depths of insight and understanding that would be unlikely to be achieved from using an externally developed rubric. A range of case studies were provided by different researcher groups to illustrate these collaborations in practice.

These discussions were facilitated by the lead author, with the Australian-based researcher playing the role of a critical friend. All authors actively participated in the paper development, in the main, contributing comments on three successive drafts through personal conversations, phone or email. This mixed method approach to generate critical reflection, and encourage active involvement in the rubric and paper writing was chosen as an economical way to best meet the time and budget constraints facing a multidisciplinary research team in practice.

## Modes of engagement in practically-oriented research

### *Integrated science*

Taking a collaborative and learning-based approach to integrated resource management research requires researchers and other stakeholders to find better ways to understand, and work in a way that respects, multiple social perspectives. Approaches are needed that help different disciplines engage more closely with each other, and research teams as a whole to engage more closely with a diverse range of stakeholders. We suggest that in any one applied research program, conversations are likely to need to be held across the core spectrum of disciplinary, multi-, inter- and trans-disciplinary research (Fig. 1).

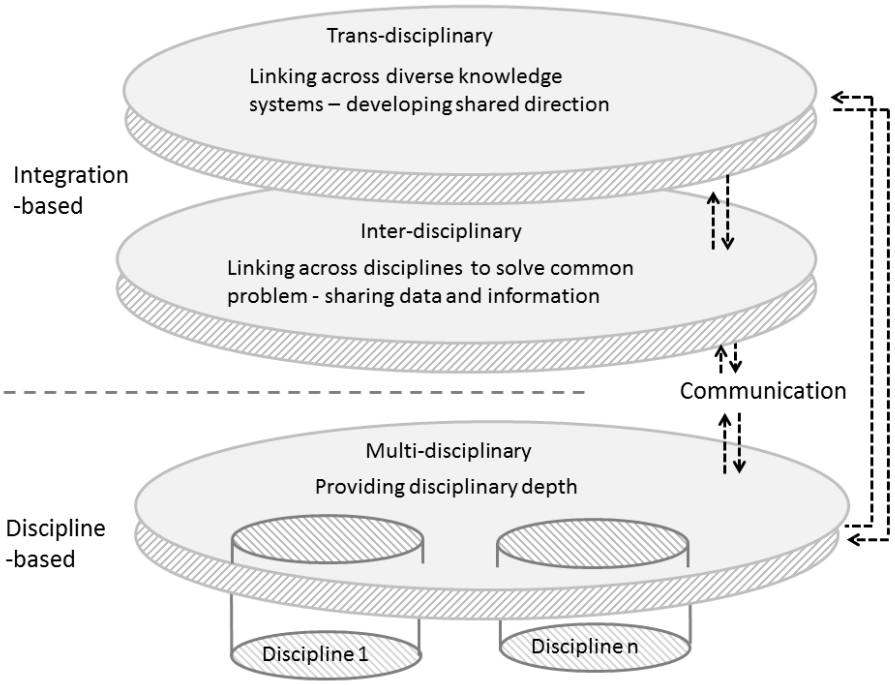


**Fig. 1** Different types of science-driven initiatives and engagement likely to be required within an applied research program

As Fig. 1 illustrates, inter- and trans-disciplinary collaborations are primarily integration-based, and characterized by the need for active dialog and learning among different social and disciplinary perspectives. Transdisciplinary discussions provide a forum for reflection on societal and research perspectives, and for deciding on research approaches and directions that best meet the needs of society. Given this level of direction research teams will often need to link across disciplines to develop a solution to a problem. With the problem set, key research discussions will revolve around how to work in an interdisciplinary manner. These discussions may look at how best to link across disciplines, or how to share data and information between disciplines.

At the same time science disciplines increasingly provide more depth and understanding in their fields, and so ongoing disciplinary discussions and work will always be contributing to each individual discipline. This is important because science depth is built on the efforts of disciplinary activities. Similarly, multidisciplinary science is an additive approach that combines the efforts of more than one discipline. This is a common program configuration, and one that many researchers in the environmental management arena will be familiar with. Multidisciplinary research may require cooperation among the different contributors, however, beyond that researchers will largely work and publish in their traditional disciplines. In this paper we focus on integration-based approaches, given the difficulty of managing them in practice.

### *Transdisciplinarity*

A common definition of transdisciplinarity is far from agreed (Jahn et al. 2012). It does, however, seem generally accepted that transdisciplinary collaborations involve discussions that integrate the experience and worldviews of researchers and other stakeholder groups (e.g. land managers, policymakers, local communities, indigenous communities). Such

collaborations commonly seek to establish priorities and then foster research that helps different parties move towards commonly sought outcomes, while creating new knowledge and understanding (Allen et al. 2011). These discussions are likely to involve epistemological and ontological perspectives that are unique to the situation, and that may be foreign to the science disciplines involved (Eigenbrode et al. 2007; Miller et al. 2008). Conversations do not focus on the detail of methodologies or technologies, but rather place an emphasis on the areas and interests to inquire into, and people's values. Discussions at this level are also likely to address issues of ethics and power such as who has the right to benefit from, decide on, or manage new technologies (Allen et al. 2011).

With the benefit of these broad characterizations the research group identified a number of criteria that demonstrate the practical application of transdisciplinary collaborations. These emphasize the importance of relationships, the development of a shared language and understanding of the range of stakeholder visions. Clarity of research direction and communication were additional key criteria. An initial rubric was developed around these concepts, and then was iteratively fine-tuned by authors. This is shown in Table 1. A simple framing was used to outline elements that one could expect to see in well-developed transdisciplinary collaboration, an emerging initiative, and an under-developed example that highlighted a lack of intent and skills.

**Table 1:** Rubric for evaluating research team's transdisciplinary collaborations

| Rating | Evaluative criteria |
|---|---|
| Well-developed | Good example of best practice in this area<br>• Clear evidence of long-term relationships with stakeholders that goes beyond individual research projects<br>• Shared definitions (both technical and non-technical)<br>• A clear and shared understanding of the wider long term vision(s) that stakeholders have<br>• Research leaders can demonstrate how their research contributes to the wider long-term visions that stakeholders have<br>• Discussions lead to the development of research directions that are understood by key stakeholders<br>• Good communication back to research team |
| Developing | Some good examples of best practice, and other emerging areas<br>• Clear evidence that relationships are being developed with stakeholders that goes beyond individual research projects<br>• Shared definitions are being developed among the range of key actors<br>• Stakeholders are encouraged to outline their long term vision(s)<br>• Research leaders can explain how their research contributes to the wider vision<br>• Discussions contribute to the development of research directions<br>• Good communication among some of the research team |
| Under-developed | Lack of best practice in most areas<br>• Little or no evidence that relationships are being developed with stakeholders that goes beyond individual research projects<br>• Few efforts made to develop shared definitions among key representatives<br>• Few discussions that explore longer term visions that stakeholders are working towards |

| | |
|---|---|
| | • A focus on research outputs rather than research outcomes<br>• Poor communication back to research team |

***Interdisciplinarity***

Integrated research approaches support a process of coordinated and collaborative inquiry into a common problem. Interdisciplinary collaborations typically involve unified problem formulation (having regard to the results of previous transdisciplinary collaborations), sharing of methods and data, and perhaps the development of new questions. Ideally, collaborators accept, understand, and sometimes apply one another's disciplinary methods and approaches (Eigenbrode et al. 2007). We see local and traditional knowledge systems as contributing in a similar manner as disciplinary-based knowledge systems. These interdisciplinary processes involve the sharing, creation and synthesis of knowledge among disciplines, and other knowledge systems (Morse et al. 2007).

Again, with the benefit of these broad characterizations the research team identified a number of criteria that needed to be demonstrated in practice to realize effective interdisciplinary collaborations (Table 2). These focused on problem definition and research direction, an understanding of the strengths and weaknesses of individual disciplines and knowledge systems, and a quality team environment. Team communication is a criterion common to integrated initiatives.

**Table 2:** Rubric for evaluating research team's interdisciplinary collaborations

| Rating | Evaluative criteria |
|---|---|
| Well developed | Good example of best practice in this area<br>• Clear recognition of the research task, and where it fits back into the wider management environment<br>• A good knowledge of where different disciplines can contribute<br>• A good team environment, that encourages sharing of data and information<br>• High trust and respect between disciplines, without epistemological sovereignty<br>• A focus on outcomes for researchers and end users<br>• Good opportunities for multidisciplinary authored publications<br>• Good communication back to research team |
| Developing | Some good examples of best practice, and other emerging areas<br>• Developing recognition of the research task, and where it fits back into the wider management environment<br>• Evidence of trying to find good knowledge of where different disciplines can contribute<br>• Evidence of efforts to create a good team environment, that encourages sharing of data and information<br>• Processes in place to build trust and respect between disciplines, without epistemological sovereignty<br>• Some awareness and focus on outcomes for researchers and end users<br>• Some opportunities for multidisciplinary authored publications<br>• Good communication among some of research team |
| Under | Lack of best practice in most areas |

| | |
|---|---|
| developed | • Little clear recognition of the research task, and where it fits back into the wider management environment<br>• Little knowledge of where different disciplines can contribute<br>• Little evidence of efforts to create a good team environment, that encourages sharing of data and information<br>• Few processes in place to build trust and respect between disciplines, without epistemological sovereignty<br>• Little awareness and focus on outcomes for researchers and end users<br>• Few opportunities for multidisciplinary authored publications<br>• Poor communication back to research team |

**Using multiple approaches to support program engagement**

In both of the CWMC programs, we recognize a range of engagement approaches as part of collaboration and integration. The following examples provide a sense of the different engagement approaches we used to support trans- and inter-disciplinary initiatives. It is important to appreciate that integrated programs need to engage people at a range of decision-making levels or hierarchies, each providing context to the other.

***Transdisciplinary collaborations***

Transdisciplinary collaborations reflect the principle of empowering and harnessing the creativity that comes from different stakeholder groups thinking together. These collaborations facilitate a better understanding of other groups' needs and worldviews to ensure responsiveness from the project. We provide two examples illustrating different ways in which the research team links with members of the Ngā Matapopore advisory and advocacy group.

*Ngā Matapopore hui (formal meetings)*

A key component of the research strategy involves more closely linking pest management science with mātauranga Māori (indigenous knowledge), and ensuring that the Centre's pest management solutions are appropriately integrated with Māori cultural aspirations. One of the main conduits is the Ngā Matapopore, advisory group. The group was established in 2010 and is ongoing.

The Ngā Matapopore team has come together with program researchers in five hui (meetings), each being held in a different part of the country. This geographic spread of hui has allowed for hau kainga (the home people) from different areas to listen in and participate with the discussions as they see fit. At the same time, these hui offer researchers the opportunity to link with local Māori, and the Ngā Matapopore team, both in conversation, and through experiencing Iwi[2] culture on local marae[3]. Each hui has been deliberately based around traditional Māori meeting protocol, and designed around a two night stay on the Marae to allow for both informal and formal cultural processes.

[2] Māori tribe
[3] A traditional Māori tribal meeting place

Following traditional Māori meeting protocol has resulted in more time being spent at the beginning of each meeting in getting to know where each person has come from, and linking the conversation back to the connection between people and the local environment where the meeting is being held. The usual 20 minute data-rich PowerPoint slide presentation that researchers begin with was condensed in favour of a more personal introduction around underlying ethical approaches, aims, outcomes, and 2 to 3 key 'take-home' messages for the work being undertaken. This served to move the emphasis of the research discussions away from the technical issues (how to do it) toward the aims (what to do, and why), and the broader implications that these discussions raise for both researchers and end users.

Involvement in these hui brings a number of benefits. They have already begun to provide Ngā Matapopore members with on-going insights around a range of research initiatives. By supporting better opportunities to link researchers with iwi and hapu[4] representatives this will not only help guide individual research initiatives, it is also expected to build the capacity of the scientists on the research team to understand both tikanga and mātauranga Māori, and to help ensure proposed solutions are appropriately integrated with Māori cultural aspirations.

*Fieldwork*

The program does not just rely on formal forums to support engagement and create a shared understanding across knowledge cultures. In a recent major field trial of a new resetting toxicant delivery system for stoats, the research team was joined by members from both Ngā Matapopore and the Industry Advisory Group. The trial site was difficult to access, in difficult terrain, and in a high rainfall area. There were some days when the field team members all emerged from the trial site at 8:00 p.m. after working all day in heavy rain. By working together in this way, a sense of teamwork among all involved was developed. It also helped the non-research members of the field team to gain insights into the work involved, and provided for informal conversations over the course of the working day in which research members gain the benefit of different end user perspectives.

The Iwi representative helped support this sense of teamwork by acknowledging the efforts of the team, and was able to report back to Ngā Matapopore about the effort being put in by so many people. She took the opportunity to arrange a meal for the research team that included traditional Māori foods such as tītī *(*the seabird, *Puffinus griseus)* and paua (the abalone, *Haliotis iris)* which were new to many of the team. The meal also provided the opportunity for her to talk about the importance of the research for future generations and which helped reinforce the feeling of solidarity. As one of the researchers said, the result of all this was that, "in the field, in the presence of native forest and singing mohua[5], it seemed there was an enormous sense of solidarity between people that supported an integrated perspective – that we were here for a greater good".

***Interdisciplinary collaborations***

Interdisciplinary collaborations differ from transdisciplinary in that they more commonly focus their dialogue around issues of methodology, data sharing and scale. We provide two examples. The first looks at communication approaches between biophysical and technical

[4] Māori sub-tribe
[5] Endemic New Zealand passerine bird, *Mohoua ochrocephala*

disciplines, while the second looks at our efforts to bridge the links between biophysical and social disciplines.

*Technical disciplinary engagement*

In our programs, work at the intersection of ecology-based disciplines, toxicant and bait development, and design engineering support the development of a range of interdisciplinary outputs (e.g. Eason et al. 2010, Blackie et al. 2011, 2013, Dilks et al. 2011). The development of a technology linking the use of safe toxicant deployment within a multi-resetting pest animal control device illustrates the approaches to engagement across discipline areas. Toxicants applied broadly across the landscape face issues of target specificity as well as social concerns. The drawback of single-set traps is that they cannot usually be serviced frequently owing to issues of distance and scale. Once a trap is activated, killing an animal, it is unable to kill further animals until it is serviced.

An alternative to single-set traps is to use a species-specific device that dispenses a toxicant, and then resets itself to allow for another interaction. After exiting the device, the animal removes the toxicant through natural self-grooming behavior. Along with the ecological interest and challenge of monitoring and demonstrating device efficiency in the field, there is also toxicological interest and challenges in developing a toxicant of sufficient dosage within a paste of a certain consistency, and of appropriate palatability, to do the job. Then there is the engineering aspect of developing a device that can do what the ecologist wants, by delivering the toxicant that the toxicologist has identified as appropriate, in a machine that can work efficiently and in a sustained manner for long periods in natural environments. As such, the development of these new tools involves close involvement and collaboration between toxicologists, engineers, design specialists and animal ecologists.

The basic method for communication between the disciplines in this project has been through meetings and iterative feedback. During the meetings, the ecologists table what they want and the toxicologists and engineers put forward their ideas of how to reach the goal. However, early iterations of the device highlighted that engineers did not fully appreciate the physical rigors that the device would be subjected to in the field, and the ecologists didn't fully appreciate the complexities of the engineering requirements. With the iterative feedback process, designs were assessed and the three disciplines (toxicology, ecology and engineering) worked together to discuss what went wrong and what went right. Further ideas were then developed that support incremental improvement. These iterations continue until the device is effective enough to deliver a conservation result (such as enhanced kiwi populations) in the field.

While such iterations are not new, and "we usually get there in the end", our concern in this social research strand was to see how we could adapt our practice to improve the efficiency and efficacy of these interdisciplinary interactions. To help people better understand the perspectives and potential technical contribution of each discipline, efforts are now made to hold meetings in engineering labs, design studios and at field sites where the devices are being tested. This provides for members of each discipline to get a broader knowledge and understanding of the related disciplines involved. This also assists with product development feedback. For example, engineers are able to see their prototypes in action in the field, and are able to get a first-hand look at both the challenge which may arise, and the developments which contribute the most promising results.

*Integrating social and bio-physical sciences*

At the other end of the interdisciplinary spectrum lie challenges of collaboration between disciplines that do not directly appear to reinforce each other. This is most pronounced in collaborations where epistemologies differ widely, especially between constructivist-based and positivist-based researchers (e.g. Campbell 2005, Sievanen et al. 2011). Linking biophysical sciences (with their emphasis on looking for the right technical answer) and the more interpretive social and management sciences (looking to support different viewpoints and cultures) is not easy (Roughley and Salt 2005; MacMynowski 2007). A number of factors contribute to these challenges in integrating social science research and methodologies in natural resource management R&D programs (Sievanen et al. 2011, Robinson et al. 2012). These include differing perspectives about the role and drivers of humans in ecosystems, scale and data issues, and the practice of involving social and cultural researchers late in the process, and lack of clear frameworks for integrating natural and social sciences. Sievanen and colleagues (2011) also point to challenges that arise because of expectations by natural scientists about the role of social science research, and the tendency to see social scientists primarily as educators, people who can remove political and other obstacles to change, or outreach coordinators (as opposed to scholarly researchers).

In these programs we have set out to use the action research orientation in this research strand as a mechanism to bridge this social-biophysical gap. This has provided the opportunity for the socio-cultural scientists in the program to provide the engagement framings outlined in this paper and to use these to catalyze discussions and critical reflection around their use by other team members with other disciplines. Collectively, the authors of this paper acknowledge that these opportunities have provided some useful insights around the research process and research communication in general.

## Discussion

After three years of collaborative research we are not suggesting that we have found generally applicable rubrics that address the many barriers and challenges that face those involved in applied and integrative research. In any case, rubrics will always need to be tailored to the particular context and people involved. What we have been able to do is to collectively raise our awareness of these challenges to collaboration early in the program, and in so doing we have begun working on ways to provide for better communication across different stakeholder groups, and foster a more co-ordinated approach to collective action. The early indicators of progress in these endeavours are supported by the reflections of the multi-author writing team who collectively cover end-user representatives, as well as representatives from the technical, ecological and social sciences involved. In turn, stronger collaborations support the range of research disciplines and end users to engage more effectively in discussions around technical research areas of focus. By way of example, feedback from the Māori advisory and advocacy group, Ngā Matapopore, highlighted a preference for avoiding the use of aerially-applied toxicants for animal pest control. This led to more rigorous discussion between researchers and Māori around the use of toxicants within the resetting toxicant delivery systems as a more acceptable intermediate approach.

The use of the multi-, inter-, and trans-disciplinary framework has provided a useful guide to aid the research team in critically reflecting on a range of collaborative initiatives. Our examples highlight that collaboration requires more than a reliance on formal meeting

formats. Developing an understanding of different viewpoints and knowledge systems is not just a matter of bringing people together. If these collaborations are to be successful they require time to be invested in building a culture of trust and respect between disciplines and stakeholder representatives alike (Haapasaari et al. 2012). Time is needed both to wrestle with unfamiliar concepts and cultures, and also to develop the friendship and collegiality that Campbell (2005) reminds us is so important to integrative success. As Phillips and colleagues (2010) point out, these additional time demands are not always easily accounted for in project plans and budgets – particularly in the beginnings of a project when people are getting to know each other – and often accumulate to create pressures on research participants. In the examples we provide here it was clear that existing social relationships and some prior expertise in working across disciplines and cultures significantly shortened this phase of the engagement process. Moreover, as the use of on-going collaborative adaptive management initiatives become more established, the building and maintenance of these relationships will look to support collaborations that extend far beyond the life of any one initiative (Allen and Jacobson 2009).

It is important is that those who are responsible for initiating these trans- and inter-disciplinary discussions actively concentrate on looking to bridge communication gaps that are commonly problematic in integrative settings. Key gaps can often be found between science knowledge and management decisions, between agencies and communities, and between science disciplines. Recognizing the need for multiple engagement initiatives and approaches is an important plank in the success of integrated projects. The examples given here highlight the importance of using field experiences, frameworks, diagrams and stories as aids to help people find common ground, and to discuss desired outcomes. Good engagement will nearly always involve a mix of formal and informal communications. When these are done well, and with good intent by all those involved, they cater for the different dialog and learning needs of different participants and allow for creative and spontaneous developments to emerge.

The action research approach has also been useful in providing a guide and methodology to support a critical reflective inquiry process. This has proved particularly useful in developing links between social and biophysical researchers, particularly as it sets out a clear role for the researchers with engagement and social learning expertise in terms of developing frameworks for reflection and interaction. However, our experience – across these and other programs – is that some people are always more interested in participating than others, particularly as such critically reflective practice can often be seen as an additional activity in an already busy work schedule. This reminds us that despite best intentions, more will be learnt in an action research inquiry by a few genuinely committed co-researchers reflecting on their integrative practice within a smaller case study approach (as we have done here), than may be gained by engaging with a larger number of less willing participants (Allen and Jacobson 2009). It has provided a methodology to involve participants in a study of their engagement practices, and the effects of these practices, in a workplace context. We see this as the start of an ongoing exercise that will continue through the life of the program. As the program progresses topics are likely to become oriented more towards issues of extension.

Once we think more about how we work together, it becomes clear that successful integration cannot be judged on the basis of meeting disciplinary milestones, and its evaluation in practice poses a challenge to conventional program evaluation. Research program milestones are often set up at the beginning of projects, and are based on what different disciplines know is achievable. However, the strength of many collaborative research initiatives is that

solutions develop from the new ways of looking at the problem that emerge from inter- and trans-disciplinary engagement. In these integrated programs it becomes clear that we need to look for new measures of success. The use of rubrics in this paper contributes both to the type of content and the methods that may be used to identify appropriate measures. For example, intermediate indicators of success also need to look at the strength of relationships and the functionality of cross-disciplinary and cross stakeholder teams. In a research context, this requires us to look beyond individual productivity to how well teams are supporting a culture for collaborative innovation (e.g. sharing data, producing multi-authored papers that link disciplines and other knowledge systems). In a management context we need to look to evidence and metrics around things such as empowerment and effective partnerships. There are a number of activities and actions within such reflexive practice that greatly support both collaboration and, simultaneously efforts to build capacity for collaboration.

## Concluding comments

In the broadest sense, collaborative endeavours such as those described here are intended to improve efforts to achieve long-term societal outcomes. As we have worked together to build a more nuanced understanding of how to operate within inter– and trans-disciplinary approaches we have learned to look at how we can all communicate more effectively. This provides us with a more reflexive approach to communication and engagement, grounded in an understanding of how our own work contributes to other disciplines, knowledge systems and cultures. The lessons that emerge help us improve our own practice in this area. In turn, by documenting them through forums such as this we can contribute, as Margles (2010) suggests, to the on-going efforts of practitioners and researchers to bring disciplines and knowledge cultures more in tune with each other when addressing conservation and environmental challenges.

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