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Conducting integrated research:

A critical literature review of interdisciplinary and transdisciplinary research

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Summary

Integrated research is being seen by an increasing number of researchers as having failed to deliver on its considerable promise for scientific learning. Yet, the need for developing integrated research projects to tackle increasingly complex social-ecological issues has never been higher. Because the rapid expansion of integrated research programs is a relatively new phenomenon, understanding of how to conduct integrated research remains in its infancy. The report provides a critical perspective on the nature of integrated research, an assessment of its contemporary critiques, and an outline of key elements of 'best practice' in integrated studies. It builds on an extensive review of literature undertaken as part of a research programme funded by AgResearch 'Developing socio-ecological systems research capability' that was extended during a Norwegian exchange as a part of a strategic institute program 'Natural resources in forest and mountain communities – between marginalisation, commercialisation and conservation', funded by the Research Council of Norway.

Some conclusions: There are fundamental issues concerning the legitimacy of integrated research that are yet to be resolved - i.e. who are the 'gate-keepers' and who validates integrated research? Further, there is considerable confusion within the literature concerning what the terms inter-, trans- and multidisciplinarity mean – with various researchers establishing different definitions. The report develops suggestions for the construction of an integrated research program that addresses the key challenges and delivers 'effective integrated research'.

Keywords Interdisciplinarity, transdisciplinarity, integrated research, literature review

Forward

As science increasingly acknowledges the complexity of human and environmental interactions, the need for integrating disciplinarily developed expertise to reflect the 'real world' complexities is growing ever more apparent. This is of particular concern to rural research institutes. Devising policy-based solutions to issues such as greenhouse gas emissions from agriculture, biodiversity loss on farmland, and environmental externalities from agriculture requires an understanding of complex interactions between human and biophysical systems. For this, greater interaction is required between both scientists and institutions.

This report emerges from a 3 month exchange of staff between Centre for Rural Research (Bygdeforskning), Norway and AgResearch (New Zealand). It builds on an extensive review of literature undertaken as part of a research programme funded by AgResearch 'Developing socio-ecological systems research capability' that was extended during a Norwegian exchange as a part of the strategic research programme 'Natural resources in forest and mountain communities – between marginalisation, commercialisation and conservation', funded by the Research Council of Norway. As such, while the review is literature based, it is influenced by interactions (both formal and informal) with staff from both institutes and draws together expertise and experience from different sides of the world. It provides a critical perspective on the nature of integrated research, an assessment of its contemporary critiques, and an outline of key elements of 'best practice' in integrated studies. To avoid presenting simply a disciplinary perspective on integrated research it draws not from a single discipline, but from a variety of disciplines such as systems thinking, geography, economics, ecology, and landscape studies studies (i.e. studies that relate to rural, agricultural and/or environmental issues), from studies involving both positivist and interpretivist epistemologies, and from studies with levels of integration ranging from multi-disciplinarity to transdisciplinarity.

We hope that this collaboration is the beginning of an extended and increasingly integrated cooperation between our institutes and other institutes in both the Northern and Southern hemisphere.

Dr Rob Burton   Dr Katrina Rønningen   Dr Liz Wedderburn

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1. Introduction – the need for integrated research

“The new face of science will be more public spirited and be characterised by its problem solving capability. It will draw upon the disciplines and not compete with them. It will seek models in which there is no longer the separation of the human from the rest of the biosphere, and in which uncertainty, surprise and in-completeness are not taken as signs of failure, but rather as better approximations of the real world” (Rapport 1997: 289).

1.1 Introduction

Despite the fact that the rapid growth of integrated research is a relatively recent phenomena, the concept of problem solving through integrating academic disciplines has been in existence since at least the 1930s (Sills, 1986). Integrated research has thus had almost 80 years to develop and become firmly established within scientific traditions, form a standard part of our scientific education, and contribute in a major sense to our understanding of complex real world problems. Yet if one thing is clear about integrated research it is that, given the length of time it has been in existence, it has failed to deliver on its considerable promise for scientific learning. For example, Max-Neef (2005) observes of transdisciplinarity (the highest form of integrated research) that it remains an ‘unfinished project’. Tress et al. (2004) found in a review of landscape literature that, while there were an increasing number of papers referring to integrative approaches, many of these were guest editorials or aspirational pieces concerning the future direction of landscape ecology. In fact, they observe that the debate on integrative concepts had developed little over the two decades reviewed.

There are numerous examples of critical stances being taken towards integrated research in the literature. According to Balsiger (2004) the whole history of integrated research has been one where typically projects begin with high expectations but end with poor outcomes – or, as Petts et al. (2008: 595) suggest, “hope tends to triumph over experience.” Similarly, Stevens et al. (2007) argue that, while there has been much recognition of the need for linkages to be developed between the ecological, policy and social science communities it is easier to ‘talk the talk’ than ‘walk the walk’. In another example, Loibl (2006) suggests that many researchers are personally frustrated by integrated research and that it often delivers ‘poor outcomes’ coupled with a ‘rhetorical boom’. Some researchers even reject the whole notion of integrated research. For example, one renowned anthropologist (Clifford Gertz, 1980: 16 – cited in Giri, 2002) commented that “most of the discussion which arises around it (trans-disciplinarity) seems to be condemned to a certain sterility…” [5, p. 16].

1.2 The need for integrated research

Despite these concerns, the need for developing integrated research projects to tackle increasingly complex social-ecological issues has never been higher (MacMynowski, 2007). This is being driven by a paradigm shift in thinking that is occurring in contemporary society. It has been suggested that the dominant social paradigm is moving away from a technocratic view of society/environment relations (i.e. the notion that the environment is too robust to be affected by human activity and that any externalities that do occur can be addressed by technological solutions) towards a more environmental paradigm (i.e. human activity can negatively affect the globe and that technology does not provide the solution – rather it is an issue of encouraging adaptive human behaviour) (see Dunlap et al., 2000). Change in research practices as a result of this come from three different sources.

First, from the scientific community itself. Attwater et al. (2005) suggest that the need to engage in transdisciplinary research is increasingly recognised in a number of disciplines including, but not limited to: resilience to ecological and social systems, post-normal science and environmental research, landscape ecology, soil and water management, global change, systems and complexity theory, ecological economics, professional development and education, and health. This is associated with a shift in thinking away from a narrow reductionist approach (often criticised, e.g. Higgs, 2005 – see Naveh, 2005) to one that recognises “that the present and future paths of environmental dilemmas are inextricably linked to dynamics of coupled human and biophysical systems” (MacMynowski, 2007: 1 – also see Naveh, 2005). Jackson (2006: 650 & 653) contends that this recognition is in part associated with the realisation that the "world has grown more complex[1]" (650) and, consequently, "only multi-methodology and multi-method practice can cope with the increasing complexity, change and diversity managers encounter" (also see Hadorn et al., 2006; Nidumolu et al., 2006).

Part of this increased emphasis the coupling between human and biophysical systems is the recognition that a full and authentic understanding of any real world problem requires the participation of all people involved in taking action (McCown & Parton 2006). McCown & Patron (2006) report that the crisis in confidence of Farm Management Research that occurred in 1990 was as a result of a lack of progress in the field of biometric modelling after more than 2 decades of trying to use it to improve farm management. One reason for this, according to Dent (1990) was that the resources allocated to investigating determinants of the behaviour of farm families had been "trivial" and, he suggested, researchers needed to take a more holistic perspective in developing their models. In the same edited book, Doyle (1990) also complained that systems concepts and simulation models had failed to have any practical impact on farming – which he attributed to the failure of researchers to liaise with farm decision-makers and a preoccupation with the construction of models rather than considering their practical application.

Thus integrated research practices involve not only a paradigm shift in our conceptualisation of society/environment interaction, but also a recognition that to solve the problem one must engage with the communities at the centre of the issue. Hence, integrated research places a new emphasis on involving the communities affected as part of the research process – rather than regarding them merely as objects of investigation (e.g. Höchtl et al., 2006; Deconchat et al., 2006).

[1] This suggestion that the "world has grown more complex" is questionable. Technological, governmental and consumer changes may be occurring at a faster pace and thus the dynamism within the system may have increased – giving the appearance of increasing complexity without necessarily altering the actual complexity of the system. Further, as our understanding of the connections between various parts of systems increases a system may appear more complex, again, without any actual increase in system complexity. As a result, perhaps it is more appropriate to suggest that our knowledge and research systems need to adapt faster to keep up with systems changes and developments in systems knowledge than to suggest that the system itself is becoming more complex. Thus, one issue may be whether reductionist approaches that do not focus on how parts of a system interact are responsive enough to deal with a rapidly changing world.

This is also, in part, to resolve the issue raised by (Nidumolu et al., 2006) – that the failure to engage stakeholders within the project often leads to a low acceptance of any recommendations/tools developed at the end (also see Matthews et al., 2008, re the acceptance of decision support systems).

Second, Lowe & Phillipson (2006) suggest that integrated research may also be seen as part of the movement towards a more democratic version of science. They observe that this is particularly important in the areas of food and agriculture as there is increasing public distrust of the industrial top-down, technologically driven model of agricultural development and its environmental, health and ethical implications (see Lowe, 1992). Consequently, the authors note there are increasing calls for civil society to be involved in the research process and for the development of integrated research to ensure that scientific and technological developments are seen within appropriate environmental and social contexts.

The third (and arguably most important) source of change comes from governmental and intergovernmental bodies themselves increasingly seeking real-world solutions to real-world complex problems and operating the funding regimes accordingly (Wood & Lenné, 2005; Tress et al., 2004). This is partly in recognition of the fact that governments have too often been "sold simple solutions to complex problems" (Jackson, 2006: 647) as a result of the failure of disciplinarity to get to grips with complex issues (also see Meltvik, 2006). There are many examples of an increased emphasis on integrated research at the funding level. For example, Hoell & Nilson (1999) observe that the Danish government allocates budgets specifically to support integrated research programs. Similarly, in the UK the recent advent of the Rural Economy and Land Use programme has seen considerable quantities of government funding shifted from traditional disciplinary work to integrated studies with the intention of capacity building for the future (Lowe & Phillipson, 2006). This, the authors contend, is part of a shift towards more 'strategic' investment in research – away from the more traditional approach of classifying research as 'basic' or 'applied'.

There are many advantages to disciplinary research[2]. Petts et al. (2008) observe, for example, that disciplines provide scientists with frames of reference, methodological approaches, topics of study, theoretical canons, and technologies. In addition, they provide researchers with a shared language and concepts, accreditation to practitioners within their fields (i.e. recognition of competence by others within the shared institution) and, importantly, the epistemological and ontological security that is required to progress science without constantly having to question the nature of science itself. In effect, they provide the framework that enabled the rapid development of science in the 20th Century (Rapport, 1997; Giri, 2002; Bruce et al., 2004) .

Traditional disciplinary sciences (particularly natural sciences) were built on the positivist assumption that if we are to explain processes we must break down the system and study the components separately in order to explore the regularities that govern the relationships between observable events and phenomena (Cloke et al., 1991). However, in the process of development disciplines have become targeted at a specific part of the system and often lack the methodologies/ epistemologies (see Appendix I) required to understand the links between the system parts. This refers particularly to the relationship between the natural and social sciences where social sciences have developed interpretive approaches to deal with the human world – whereas natural science has continued the embrace of positivism. The need for integrated approaches is thus driven by the need to examine 'real-world' connections across disjoint bodies of knowledge that may require different methodological/epistemological positions to understand the connections between the components.

1.3 The social-natural science conflict – a key issue

Integrating research is necessary as different kinds of research (disciplinary, subject matter, and problem solving research) require different approaches and methods (Bitsch, 2005). One of the key conflicts in integrated projects results from the differences between the positivist and interpretivist positions in science. Interpretivism emerged in the 1960s as a result of the dissatisfaction of many

[2] One may see disciplines as historically developed forms of organizing knowledge that continuously is under change (Smeby, 2003).

social scientists across a variety of disciplines with the positivist approach which had previously dominated the social sciences. Sarantakos (1993) suggests the criticisms were widespread and fundamental, including positivisms' perception of reality, its methods, its lack of moral prescription, its gendered nature (from the feminist perspective), and its perception of the world as mathematically derived (and therefore able to be explored with mathematics). As a result the positivist position in the social sciences has gradually lost its hegemony and this trend – through the increasing application of qualitative interpretivist approaches in social sciences has continued today (e.g. in Geography the 'cultural turn' did not occur until the late-1980s- early-1990s – Valentine, 2001[3] – See section 3.1 for further details).

One issue of difference between the qualitative and quantitative approaches is in the way that the research is formulated. Whereas quantitative studies rely on hypothesis testing, as Bitsch (2005: 77) observes, a qualitative project typically does not begin with a theory from which hypotheses are deducted but with a field or study or a research question. The focusing of the broader research area is then something which happens as part of the research process – rather than being formulated as hypotheses to be tested. Further, as sampling procedures are not representative but based on 'theoretical sampling' decisions on who to sample are based on the theory and results emerging from the analysis – consequently the sampling process cannot be planned prior to embarking on the study. This is a difficult issue to deal with both in terms of planning coordinated projects with natural scientists (for whom a detailed and rigorous research plan is necessary prior to research commencing) and in terms of presenting a proposal to funding agencies.

Qualitative social science research is strong in four areas (a) the description and interpretation of new or not well-researched issues, (b) theory generation, theory development, theory qualification, and theory correction, (c) evaluation, policy advice, and action research, and, (d) research directed at future issues (Bitsch, 2005). All of these are highly important for developing resolutions to real-world

[3] Despite the growing use of interpretivist approaches in social sciences, the vast majority of science continues to be conducted under a positivist framework. In fact, according to Balsiger (2004), the natural sciences paradigm is so dominant that in the English language the word 'science' is generally taken to mean the positivistic approaches employed in natural sciences.

complex problems and for this reason, the interpretivist social science paradigms are widely used (in fact, they are an integral part of the 'transdisciplinary approach', the highest form of integrated research). It is the introduction of this entirely new approach to looking at knowledge that leads Naveh (2005: 229) to suggest that integrated research represents no less than a "scientific revolution" – and one that is rooted in the paradigms of science evolving "from reductionist and mechanistic approaches, to more holistic, organic and hierarchical ones, grounded in complex systems thinking." Within this, he maintains, linear and deterministic processes been replaced by new paradigms of nonlinear, cybernetic, and chaotic processes and, at the same time replacing the "almost irrational belief in the objectivity of science".

1.4 The need for integrated research in New Zealand and Norway

In the past, New Zealand (as with many countries throughout the world) has not fully embraced the need for research to take an interdisciplinary perspective. It may be argued that this has resulted from a research culture focused primarily on improving economic performance rather than considering environmental consequences of land management issues. For example, Massey et al (2006: 141) observe that the agricultural industry in New Zealand "has to date been characterised by the need to answer questions that are best answered by research based on 'scientific' (and therefore objective and positivistic) models." This has grown from a focus on improving productivity (such as investigating nutrition and pasture growth) which has, in turn, led to the development of a scientific worldview that underpins these approaches. The authors observe that this worldview, on the whole, has not been challenged and, as a result, funding for research into agriculture in New Zealand has been largely objective and positivist in its perspective.

However, this is changing. In the 2007 roadmap for environmental research the Ministry of Research, Science and Technology (MoRST, 2007:3) acknowledge in the executive summary that

> *"Environmental management decisions increasingly require an understanding of whole system processes and a multidimensional approach, including linking*

biophysical, socio-economic and health research. More integrated and systems-based approaches can offer environmental managers and decision-makers answers to many of the questions they are facing."

Thus they observe as Direction One of their five directions for policy that "The government wishes to see additional emphasis on integrated multidisciplinary research to support improved understanding of environmental systems". Similarly, Direction Four states "Over the next few years, the government will give priority to developing more integrated multidisciplinary approaches"(MORST, 2007: 7-8). The Ministry is upbeat about the possibilities of success. It should be noted that the roadmap observes that other countries have followed integrated research projects and that "once started, integration has proven its worth" (MORST, 2007: 15). In reality, there is very little evidence to support this and a considerable level of contradictory evidence. As noted above, international studies have suggested that integrated research has often delivered high expectations and poor outcomes and there are commonly misunderstandings about the potentials of integrated research (Balsiger, 2004). In terms of the papers reviewed here, considerably more print space appears to have been spent reviewing the difficulties of constructing integrated research projects than actually presenting quality results (see Chapter 4).

Although laudable in its intent, if one criticism could be levelled at the MORST environmental roadmap it is that it fails to grasp (in the way that other OECD countries such as the UK, Germany and Denmark have) the key role of placing people within the improved understanding of environmental systems. As noted above, environmental dilemmas are inextricably linked to the dynamics of coupled human and biophysical systems (MacMynowski, 2007; Naveh, 2005) and yet the concern for MORST roadmap focuses squarely on developing an integrated understanding of biophysical systems (largely through modelling). The coupling of the human and biophysical realms is an essential element for integrated research (as detailed in Chapter 2) and it is widely recognised that interdisciplinary collaboration between social scientists and environmental scientists is necessary to make environmental research policy relevant (Stevens et al., 2007). As observed by Lowe & Phillipson, (2006) above (and as is detailed in Chapter 2) a primary benefit of integrated research is its ability to bring the people and the problem together to frame the problem in a 'real world' context.

In Europe, the increasing acknowledgement that most conservation conflicts (particularly on agricultural land) are social conflicts has been important for the increased emphasis on including social science and humanities in research projects that would previously mainly consist of biologists and ecologists. This has been very evident in the Norwegian context, and probably some of the most significant recent works on understanding conservation conflicts have grown out of this. However, it also reflects that the Research Council of Norway, the major funder of natural science, social science and humanities projects in Norway, increasingly stresses transdisciplinarity as important criteria for successful funding, effectively throwing different disciplines into each others' arms.

A brief analysis of strategic documents and reviews of the Research Council shows this development. From in 2002 emphasising that "'there is no interdisciplinary method' and that interdisciplinarity is not an aim in itself (Norges Forskningsråd 2002:5) to stating in the major research program on land use, AREAL, that "Interdisciplinarity, quality and good and broad user participation are central keywords" (Forskningsrådet 2008a:1). The major environmental research programme MILJØ 2015 has interdisciplinarity as a core factor: "Through strengthened multidisciplinary and interdisciplinary research as well as broad contact with users the program shall contribute to that environmental research to an even stronger degree than previously will be making premises and developing the foundation for future policy formulation" (Forskningsrådet 2008b:5). There is some suggestion that 'soft' (or 'social') sciences are very much the minor partner in this research, with their methods, theoretical approach and results being compromised – while 'hard' sciences are benefiting in terms of broadening their perspectives and increasing their legitimacy. On the other hand, over time several scientific collaborations have developed in which trust and mutual understanding of each others competence have developed, making a good basis for future interdisciplinary or multidisciplinary research projects.

1.5 The study

1.5.1 Research rationale

There are a multitude of analyses of integrated research processes in existence (see Chapter 2) – thus it could be argued that there is no particular need to reanalyse the literature. However, there are a two key reasons why it is necessary to take this approach to understanding integrated research.

The first reason is the pace of change of integrated research. Because the explosion of integrated research is a relatively new phenomena (although, as observed, it has been around for considerably longer) understanding of how to conduct integrated research (in particular the synthesis of social and natural sciences) remains in its infancy and changes on an almost daily basis. For this reason, a review is necessary to provide the most up-to-date perspective.

Second, research on integrated research is almost invariably written up by disciplinary groups and consequently the breadth of understanding of integrated research often has, ironically, a very disciplinary basis (Giri, 2002; MacMynowski, 2007). Observations by MacMynowski (2007: 3) suggest that

> *"evaluations of interdisciplinary research in journals targeted at biophysical scientists include virtually no citations from the social science literature on disciplinarity and interdisciplinarity ... Likewise, in the social science literature, there are virtually no citations from the biophysical literature. The two discussions are running in parallel with stunningly little crossover."*

Examples to support MacMynowski's contention are easily found in the literature. For example, Cummings & Kiesler (2005) in a paper entitled "collaborative research across disciplinary and organisational boundaries" based their findings almost entirely on the organisational/management literature – citing only 2 sociology and 2 psychology publications (11% of total). Jackson (2006) forwards a holistic critical systems approach to complex problem situations, but cites only two papers (7% of total) from outside of the systems/management literature[4]. Many other systems papers are similarly weighted towards management-systems literature (e.g. Luckett et al., 2001; Gao et al., 2003; Pollack, 2006) Thus, while

[4] It is interesting that Jackson (2001: 234) proposes that within critical systems thinking "systems concepts encourage interdisciplinary, or, at least, multidisciplinary practice" – and yet most of Jackson's research (e.g. Jackson, 2001, 2005, 2006) is based on a single disciplinary perspective.

the rhetoric is often of holism and integration (particularly in Critical Systems Thinking), in practice the emerging discipline stands relatively isolated within wider academic circles. In an example from ecology, Redman et al. (2004) constructed proposals for integrating social science into long term ecological research networks. Of the 30 papers cited 24 clearly came from the natural sciences (mostly ecology) and 6 (20% of total) clearly came from the social sciences.

This suggests that many of the contemporary analyses of integrated research are, in fact, disciplinary in their outlook and emphasises the need to undertake an analysis based on a wider range of literature. In particular, the bulk of the literature pays little attention to the 'soft science' paradigms – in particular the use of interpretivist epistemologies and methodologies as undertaken through qualitative research of human behaviour. As noted above, the integration of social and natural sciences is one of the key features of recent emphasis on integrated research – yet this aspect, in particular, is often ignored (see Chapter 3).

1.5.2 Key objectives

The objective of this report is to review the literature on integrated research in order to ascertain how best to conduct inter- or trans-disciplinary research projects. This will focus on addressing three primary questions:

- What are the characteristics that define integrated research?
- What are the key challenges facing integrated research?
- How can we construct an integrated research program that addresses the key challenges and delivers effective integrated research?

1.5.3 Methods

In order to provide an up-to-date assessment of current thinking this review focuses largely on recent international peer reviewed journal articles. The review is targeted at recent peer reviewed journals for two main reasons. First, as noted above, the literature on integrated research has been moving very rapidly over recent years with integrated research programs begun in the early 2000s (which saw a considerable expansion of integrated studies) finally reaching the publication stage. Thus the review needed to cover as up-to-date literature as possible. Second, as outlined in section 4.2.1, there are fundamental issues concerning the legitimacy of integrated research that are yet to be resolved (i.e. who are the 'gate-keepers'? Who validates integrated research?). In this case, one study is not as good as the other. Restricting the review largely to peer reviewed studies thus enhances the likely validity of the review as far as is possible.

A process of scanning the literature was begun using the two largest databases of scientific (social and natural science) literature – namely, Scopus and the Thompson ISI database. The search was conducted using the terms 'integrated research', 'interdisciplinarity' and 'transdisciplinarity' which resulted in multiple papers from a wide range of disciplines. Medical journals (where the highest levels of integrated research are conducted) were discarded, with the review instead focusing on literature that examined the environmental, ecological and/or economic impacts of human land management practices, principally – land use and landscape changes, systems approaches to management, agricultural literature (although this is not common) and ecological/environmental studies. The bulk of the papers reviewed extend from 2001 to 2007. Interestingly, this was not a deliberate selection but, rather, it was clear from the search that integrated research into complex systems has increased considerably over the last half decade (see figure 1.1).

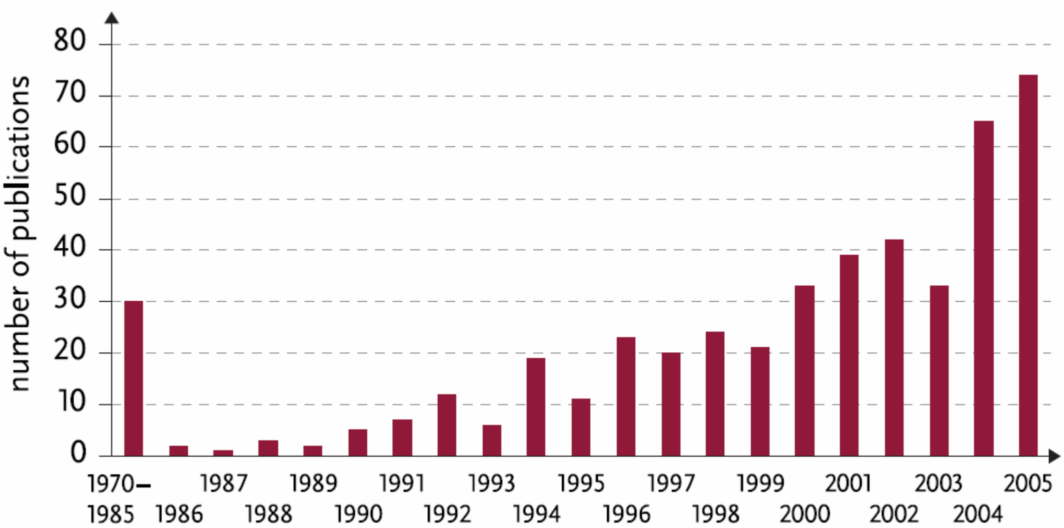

Figure 1.1: Number of publications per year that include the keyword "transdisciplinary" or "transdisciplinarity" in the title, keywords, or abstract (search performed through Web of Science on October 12, 2006). Between 1970 and

1985, only zero to five publications appeared per year, resulting in 30 in total (from Kueffer et al., 2007: 23).

The chapter titles for this review are:

- Chapter 1: Introduction
- Chapter 2: Defining integrated research
- Chapter 4: Integrating natural and social sciences
- Chapter 3: Problems with integrated research
- Chapter 5: Constructing an integrated research project – lessons from the literature
- Chapter 6: Conclusion

1.6 Conclusion

Scientists focusing on resolving complex real-world problems are increasingly turning to integrative research approaches. While these approaches are acknowledged as having enormous potential, there is also considerable concern in the literature that the outcomes of integrated research has often been poor – particularly relative to extremely high expectations. AgResearch will inevitably have to engage in integrated research in order to meet MORST's ambitions to improve the problem solving capacity of its science organisations (MORST, 2007). Thus, it is critical that we use this opportunity to discover – on the basis of existing literature – how to avoid the problems associated with integrated research and ensure the production of high quality problem targeted integrated science. The following chapter will begin by defining and investigating the three most common forms of integrated research – multidisciplinarity, interdisciplinarity, and transdisciplinarity.

2. Defining integrated research

2.1 Introduction

As is discussed in a later chapter (Chapter 4) the development of a common language between participants in the research process is one of the keys to the conducting of effective inter/transdisciplinary studies. This refers not only to the jargons and discipline specific meanings of the research teams but also – and arguably critically – to the terms used to describe the integrated research process itself. The reason for this is simple. If all researchers are to share in a common vision for the integration, then all must be aware of the way in which that vision is to be constructed.

2.2 A collective term for integrated problem solving research

In integrated research the different types of projects involving multiple disciplines are often confused and incorrectly labelled (Jakobsen et al., 2004). Robinson (2008: 70) goes so far as to suggest that integrated research has been "bedevilled for years by an ongoing and unresolved discussion about terminology". There are three possible factors that contribute to this confusion. First, the lack of disciplinary gatekeepers leaves no individual body in charge of defining terms for integrated research (see 4.2.1). Second, the lengthy and complex research procedures are often not reported in interdisciplinary papers (to meet journal publication requirements) and, as a result, the description of the integrated concepts is often so limited that it is difficult to determine what is actually meant by the terms or how they were operationalised (Tress et al., 2005). In addition, François (2006: 621) suggests "sloppy and inaccurate linguistics and semantics" in journalistic and scientific publications that is confusing the notions of inter-, multi- and trans-disciplinarity and suggests that this be harmful for an understanding of scientific discourse. Third, the issue may be institutionally driven as neither research councils, academia nor the government (in the UK and New Zealand at least – see Chapter 1) appear to clearly understand what is being sought in integrated research and why (Petts et al., 2008) – leading to an indiscriminant, almost random use of referential terminology.

Poorly defined terminology creates potentially serious problems for the research process as the lack of a common understanding of the nature of integrative research is one of the key barriers to integration (Tress et al., 2006). Tress et al. (2007) observed from a study of integrated research participants that while almost all researchers reported that they had discussed the issue of what integrated research is, fewer than half had actually been able to agree on a common understanding. The authors further observe that researchers were using a large variety of terms to refer to the integrative research process, i.e. integrated, integrative, cross-disciplinary, interdisciplinary, collaborative, multidisciplinary, participatory, and transdisciplinary.

Differences in the meaning of integrated research terms can easily be found in the literature. For example, MacMynowski (2007) and Deconchat (2007) both use the term 'interdisciplinary' as a collective term to refer to all types of research providing a framework for combining social and ecological knowledge. Janssen & Goldsworthy (1996) on the other hand consider that 'interdisciplinarity' is a different type of 'multidisciplinarity' (although they do not go on to explain how it is different). For the majority of researchers, however, interdisciplinarity refers to a particular type of integrated research that lies – in terms of levels of disciplinary integration – between multi-disciplinarity and transdisciplinarity. Similarly, the term 'crossdisciplinary' is generally used as a collective term to refer to all integrative projects where the extent of interaction and cooperation between the disciplines is unknown (e.g. Jakobsen et al., 2004; Cummings & Kiesler, 2005; Russell et al., 2007) – however, it has been used in the past to define a particular type of multidisciplinarity (Tress et al., 2004).

In this review the term 'integrated research' is suggested as the optimal collective term to refer to problem solving research involving multiple disciplinary involvement. The term cross-disciplinarity, also widely used, is rejected for two reasons. First, as noted above, 'crossdisciplinarity' has also been used in the past to define a particular type of multidisciplinarity – thus there is scope for confusion with a term it is purporting to represent collectively. Second, and most importantly, cross-disciplinary suggests that the research simply crosses disciplinary boundaries. While this does represent one defining feature of such studies, the underlying purpose behind employing multiple disciplines is the need to integrate the research process, not the need to cross research boundaries. While other alternatives have been forwarded (in particular, Balsiger, 2004, suggested the use of the term 'supradisciplinary') 'integrated research' is already in common usage in the literature (e.g. Janssen & Goldsworthy, 1996; Kooistra & Kooistra, 2003; James & Marcus, 2006; Stevens et al., 2007) and therefore is likely to be the most widely understood term within research teams.

'Integrated research' has its own problems. In particular, projects can be integrated within disciplinary frameworks (e.g. geographers deal with a multitude of research fields ranging from cultural studies to geomorphology) – thus the term does not necessarily indicate one of the key defining features of integrated projects. A more accurate term may be a combination of the two common collective terms (i.e. 'integrated cross-disciplinary research' or 'cross-disciplinary integrated research'). However, this is rather too unwieldy for regular usage. Another issue is that some researchers have suggested that some forms of 'integrated research' – specifically, 'multidisciplinarity' – are coordinated but not actually integrated (O'Riordan, 2000 – cited in Carey et al., 2003). While the term is thus problematic, the review contends that 'integrated research' is preferable as it indicates both to the researchers and the funders what the intent of the research actually is.

Under the umbrella of 'integrated research' many different terminologies are used to describe integrative projects – for example, collaborative, integral, integrated, complementary, combined, participatory, transepistemic, system oriented, transprofessional, comprehensive, problem oriented, cross-boundary, holistic, multidisciplinary, crossdisciplinary, interdisciplinary and transdisciplinary (Tress et al., 2004). While the basic principle of all these approaches is similar (i.e. focusing on integrated problem solving by crossing disciplinary boundaries) there are often subtle but significant differences between the terms which mean they cannot be used interchangeably. For this review there is no requirement to define all of the terms. However, it is necessary to outline the three most commonly applied forms of integrated research – namely; multidisciplinarity, interdisciplinarity and transdisciplinarity.

2.3 Defining the key concepts – multidisciplinarity, interdisciplinarity and transdisciplinarity

As noted above, in the literature there is a great deal of confusion concerning the different types of integrated research (Jakobsen et al., 2004). Thus the objective of this section is to review the range of literature dealing with these issues and clearly define the meanings and objectives of multidisciplinarity, interdisciplinarity and transdisciplinarity. While it is conceded that these definitions will not concur with all exiting research definitions (by virtue of the existence of different interpretations), by assessing the situation across a range of publications clear definitions that are meaningful in most cases can be established. These definitions can then be used by AgResearch in the preparation of integrated research projects in the future.

2.3.1 Multidisciplinarity

Multidisciplinarity is characterised within the literature as the least integrative form of integrated research – yet it is equally arguably the most attainable. The key features of multidisciplinarity are that it involves several academic disciplines in a thematically based investigation with multiple goals – essentially, studies "co-exist in a context" (Petts et al., 2008: 596). While researchers aim to share knowledge and compare results from the studies there is no attempt to cross boundaries or generate new integrative knowledge (Tress et al., 2005). Each member is able to contribute a professional perspective on the issue (Attwater et al., 2005). Thus the advantage of this approach is that, while the research approaches are disciplinary, the different perspectives on the issue can be gathered into one report for assessment (Max-Neef, 2005). There is some debate on the extent to which research is coordinated and integrated. While some suggest that multidisciplinary research is coordinated but not integrated (O'Riordan, 2000 – cited in Carey et al., 2003) others contend that there is no coordination but there is integration at a low level (Jakobsen et al., 2004). In general, it is hard to imagine that the research is not, in some way coordinated whilst maintaining even a slight degree of coherence, but it may indeed not be integrated.

Another area of difference in assessments of multidisciplinary research concerns the extent to which the approach is targeted at specific problem solving. While, in general, multidisciplinarity is seen as thematically organised rather than problem oriented (e.g. Tress et al., 2005; Wickson et al., 2006) some contend that the research would normally be focused on a common problem (Hammer & Söderqvist, 2001; Petts et al., 2008). The differences are partly attributable to semantics as it is difficult to imagine a theme that is in some way completely unrelated to a particular problem or series of problems. However, in general it could be surmised that – because of the lack of an iterative research process (i.e. formulating a question in one discipline and passing it to another for problem solving which may then generate new questions for another discipline, etc.) multidisciplinary research is not as problem focused as interdisciplinary or transdisciplinary research. The disadvantage of this kind of approach is clear. Whereas with interdisciplinary and transdisciplinary studies researchers are able to resolve discrepancies and explore synergies through an iterative research process between participants, multidisciplinarity simply ensures that the required expert opinions on the issue are provided. In a sense, multidisciplinarity thus provides the assessments required for others to do the problem solving themselves. This limits the extent to which the specific problem can be addressed during the research process and, therefore, the extent to which the process is capable of dealing with the complexity of real world systems.

2.3.2 Interdisciplinarity [5]

Interdisciplinarity may be regarded as a step up from multidisciplinarity. Interdisciplinary studies focus on addressing specific 'real world' system problems and, as a result, the research process forces participants (from a variety of unrelated disciplines) to cross boundaries to create new knowledge (Tress et al., 2005; 2007). Essentially the major difference from multidisciplinarity lies in the level of integration and cooperation as these projects seek to bridge disciplinary viewpoints (Attwater et al., 2005; Petts et al., 2008) and potentially enable the examination of existing accumulated knowledge from the perspective of a neighbouring discipline (Kutílek & Nielson, 2007). The necessity of bridging disciplinary viewpoints generally (as with transdisciplinarity) stems from the need to address complex "problems that involve an interface of human and natural systems" (Wickson et al., 2006: 1048) and, as such, the integration of natural and social scientists is standard practice for interdisciplinary research. This approach

[5] Nor. *Interdisiplinæritet* /interdisiplinært - *tverrfaglig(het)*/tverrvitenskapelig(het)

involves bringing people and ideas together from different disciplines to jointly frame a problem, agree on a methodological approach, and analyse data (Hammer & Söderqvist, 2001). Thus interdisciplinary research requires a much more collaborative approach to problem formulation and methodological development than multidisciplinary research.

One interesting feature of the use of the term interdisciplinary is that it is often applied to studies conducted in a multidisciplinary fashion. In Norway, Gundersen (2004) points out that, within landscape studies, the use of qualitative and quantitative methods to study people's landscape perceptions and preferences rather may be seen as supplementary/complementary approaches – not representing interdisciplinarity as it is often claimed, but rather multidisciplinarity. In other examples, Guyer et al. (2007) conducted "interdisciplinary" integrated research where they undertook 7 independent studies and then brought the research teams together at the end of the project to discuss the results and draw conclusions. Santelman et al. (2004: 358) describe their approach as *inter-disciplinarity*, however, the authors observe that "this interdisciplinary assessment of the alternative futures integrates the results from disciplinary teams that evaluated the social, economic, and environmental impacts" with the results simply summarised and compared. Hoffman et al. (2007: 562) conducted what they termed an interdisciplinary analysis by bringing together "unrelated research groups and projects" in a conference setting and then "synthesised" the key elements at the end of the project. Whether it is attributable to a lack of understanding of the requirements of interdisciplinarity or as a result of the interdisciplinary intent weakening during the course of the project is uncertain. However, this portrayal of multidisciplinarity as interdisciplinarity is relatively common and may simply reflect the difference between the attainable (multidisciplinarity) and the desirable (interdisciplinarity) with the two forms morphing into a compromise hybrid.

Some researchers have attempted to divide interdisciplinary studies into sub-categories based on what are seen as key distinguishing features of the approach. Two examples are particularly relevant. Jakobsen et al. (2004) observed that, in some disciplinary projects a single discipline may dominate and effectively control the integration of knowledge (e.g. adopting a modelling approach as a unifying framework). This the authors term as 'unidirectional interdisciplinarity'. On the other hand, in some cases the interaction and development of the project is guided by the nature of the issue (issue-centric) and this is termed ‘goal-oriented’ interdisciplinarity. As noted in Section 5.5.2, unidirectional approaches are problematic for both theoretical reasons (e.g. they limit the extent to which the research process can cross disciplinary boundaries by tying it to the methodological, epistemological and ontological position of a single discipline) and because the greater power provided to one discipline is likely to hinder the creation of trust within the research team (and thus transfer of information, extent of boundary crossing, etc.).

A more useful division is provided by Kutílek & Nielsen (2007). In this paper the authors differentiate between ‘big’ and ‘small’ interdisciplinarity, with big interdisciplinarity typified by links between distant disciplines (e.g. natural and human sciences) and small interdisciplinarity between isolated sub-disciplines (e.g. within natural sciences) where tools and knowledge are exchanged [Note that this has strong similarities with Max-Neef’s (2005) “weak” and “strong” transdisciplinarity]. The key to this concept is that it recognises that not all interdisciplinary research is integrated across disciplines to the same level. In terms of resolving real-world problems, the issue of whether to apply ‘big’ or ‘small’ interdisciplinarity should be a function of whether the problem is likely to require big interdisciplinarity or not. There are considerable costs in terms of developing projects that cross the major disciplinary divide (natural sciences and social sciences – see section 4.3.5) and thus, if small interdisciplinarity can be applied to solve the problem it is probably preferable from a managerial perspective. On the other hand, most (if not all) interdisciplinary and transdisciplinary research deals with environmental or resource issues where the interaction between the humans and ecosystems is the critical point of the investigation. Small interdisciplinarity is thus likely to be rarely employed.

2.3.3 Transdisciplinarity [6]

Transdisciplinarity is probably the most desirable and yet difficult to obtain form of integrated research[7]. Such studies seek a transcendence of disciplinary perspectives (in some cases "redrawing the disciplinary map" – Petts et al., 2008: 597) into a broader framework in "true systemic fashion" that involves practical engagement with "local and regional issues of concern" (Attwater et al., 2005: 186). In this sense transdisciplinarity is the highest form of integrated project, involving not only multiple disciplines, but also multiple non-academic participants (e.g. land managers, user groups, the general public) in a manner that combines interdisciplinarity with participatory approaches (Tress et al., 2006). Walter et al. (2007) suggests that transdisciplinary research is characterised by "a process of collaboration between scientists and non-scientists on a specific real world problem" and combines scientific research with the generation of decision-making capacity for the involved stakeholders. The multitude of disciplines included in many transdisciplinary frameworks is largely the result of the strong problem solving objectives of the research (Wickson et al., 2006: 1049; Walter et al., 2007) and the need for flexible methodologies in transdisciplinary research is driven by this problem solving approach as "methodologies employed in transdisciplinary research needs to correspond to and reflect the problem and context under investigation". To ensure that all relevant disciplines are represented within transdisciplinary projects, a pluralistic (rather than unitary) approach to methodology is standard (Attwater et al., 2005 – see Chapter 3).

This focus on the problem, rather than the disciplines excludes the possibility of unidirectional research as, as Hadorn et al. (2006) observes, within a transdisciplinary environment no single discipline has intellectual precedence. In fact, some researchers go so far as to equate transdisciplinarity with holism, arguing that "It solves disagreements and differences in knowledge and scientific approaches through dialectic thinking, not majority rule, tradition or compromise" (Jakobsen et al., 2004: 17) or that it is "a different manner of seeing the world, more systematic and more holistic" (Max-Neef, 2005: 15). As such, Rapport (1997: 289) suggests that "the essential element of transdisciplinarity is ...

[6] Nor. transdisplinæritet - transdisiplinært

[7] Pohl (2005: 1161) observes that the extent of the requirements for TR research suggest that it is to some extent "a 'megalomaniac' endeavour". In addition, Tress et al. (2001: 140) observe

'transcendence' – a creative process whereby a framework for characterising larger level processes transcends frameworks used to characterise the parts". Political ecology is an example of a transdisciplinary sub-discipline that has emerged from the transcendence of a number of disciplines – 'cultural ecology (ecosystems approaches to human behaviour); ecological anthropology (grounded in cybernetics and the adaptive qualities of living systems) and political economy (Johnston et al., 2000) – and has existed under the umbrella of a larger disciplinary body (Geography) since the 1970s (e.g. Muldavin, 2007)[8].

In promoting a holistic perspective, transdisciplinarity requires considerable effort on the part of engaged researchers to open up their research to alternative ways of thinking, or, as Giri (2002: 105) suggests to "overcome one's disciplinary chauvinism" and develop "an openness to perspectives of other disciplines". The adoption of a holistic perspective leads to another key feature of transdisciplinarity – that it has high aims of reconstituting and rearranging the nature of disciplinary knowledge thus creating, through fusion across arbitrary intellectual boundaries, new synthesised disciplines with which to address the real-world problems at hand (Naveh, 2005; Hadorn et al., 2006). The demands placed on researchers to collaborate and 'overcome chauvinism' means that transdisciplinarity, of all the integrated research forms, has a strong focus on the building of personal relationships and joint understandings (Naveh, 2005). Establishing trust and understanding between researchers within the projects is thus a key objective of building transdisciplinary capacity.

While transdisciplinary studies are invariably implemented with the intention of creating practical outcomes to facilitate change[9], one issue in the literature is whether the process of extension of the solutions should be incorporated into the research process as part of a process of evaluating possible solutions. In general, disciplines that have solution implementation as part of their standard practices (e.g. management and the various systems approaches that stem from it)

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that, despite the best intentions, "Transdisciplinary landscape research is an exception, even interdisciplinarity is seldom reached."

[8] Transcendence has also been associated by some with interdisciplinarity (Girard & Hubert, 1999).

[9] It should be noted that although the review of literature was quite extensive, it concerned mainly the journal *Futures* and, as such cannot be said to represent a wide cross-section of the

incorporate it into transdisciplinarity, and those disciplines where implementing solutions is not a standard part of the disciplinary work, do not. In general, as Höchtl et al. (2006: 327) observe that "The implementation of results is not essential for transdisciplinary projects" as such studies, while always problem oriented, can be either practice or theory based. However, it is not uncommon for studies choose to contain an implementation component (e.g. Höchtl et al., 2006; Jackson, 2006).

As with interdisciplinarity, researchers have proposed different categories of trans-disciplinarity. In particular, Max-Neef (2005) identifies two forms of trans-disciplinarity "*weak transdisciplinarity*" and "*strong transdisciplinarity*". Weak transdisciplinarity, he contends, is based on following traditional methods and logic. On the other hand, strong transdisciplinarity recognises simultaneous models of reasoning – rational and relational (non-linear). Lawrence & Després (2004: 399) observe that some transdisciplinary projects follow the model of weak transdisciplinarity in that they adopt positivist approaches as a framework for the investigation. However, the authors argue that we need to revise or dismantle such "epistemological positions that value rational, utilitarian approaches to interpret the layout, use and management of human and natural ecosystems" and adopt strong transdisciplinarity as the standard model of integrated research practice. Unlike Kutílek & Nielsens' (2007) notion of "big" and "small" interdisciplinarity, therefore, there is little utility in considering weak and strong forms of trans-disciplinarity as its more holistic nature renders 'weak' forms of integration non-transdisciplinary almost by definition.

2.4 Indentifying the differences in approach

The above sections have outlined and defined the nature of the three main integrated research approaches. Table 2.1 summarises and displays the major differences between the research approaches. Filled boxes represent a consensus that the form of integrated research includes this component, empty boxes suggests a consensus that it does not include this component, and half-full boxes that there is some degree of contention as to whether this component is necessary or not (in general, in this case, either is acceptable). This table may help

literature. Other disciplines engaging in transdisciplinarity (landscape studies for example) do not have such a strong focus on practice.

researchers to identify what kind of integrated research they are proposing to undertake.

	Synthesise new disciplines and theory	Problem solving focus	Iterative research process	Involve multiple disciplines	Involve stakeholders in research process	Knowledge sharing between disciplines	Thematically based	Research coordinated	Research integrated	Cross epistemological boundaries	Follows pluralist methodology	Involves implementation of results as part of process
Multidisciplinarity												
Interdisciplinarity												
Transdisciplinarity												

Table 2.1: Defining characteristics of integrated research approaches

The table suggests that the approaches share three common trends. They are all invariably thematically based, all involve multiple disciplines, and all share knowledge between disciplines on the theme. However, there are features that enable distinctions to be made between the three.

Multidisciplinarity: What divides multidisciplinarity from interdisciplinarity and transdisciplinarity is the lack of iterative research processes, a failure to cross disciplinary boundaries, the lack of integration in the research process and a failure to engage non-academic stakeholders as participants in the research. In addition, multidisciplinarity may sometimes focus on the theme under investigation – rather than being problem oriented, and may or may not involve a coordinated program of research.

Interdisciplinarity: Interdisciplinarity is similar to transdisciplinarity. In fact, the only key differences between the two are that transdisciplinary work aims to synthesise new disciplines and theory (whereas this is not an objective for interdisciplinarity) and that transdisciplinarity emphasises holism in its approach (this leads to increased participation from stakeholders and the more likely adoption of pluralist methodologies). The boundaries between interdisciplinary and transdisciplinary projects are thus diffuse and dependent more on a subjective judgement on the level of holism applied than on the presence of clear boundary markers.

Transdisciplinarity: As observed earlier, transdisciplinarity is the holy grail. It maintains a clear emphasis on developing an holistic approach to problem solving involving stakeholders and scientists in a joint project. While this is also often present in interdisciplinary work, with transdisciplinarity it becomes almost a philosophy – extending the research beyond simply problem solving towards synthesising new bodies of knowledge with which to address complex systems problems.

Despite the above definitions of the three main forms of integrated research, the exact construction of projects is likely to vary with every application. One reason for this is that as there are no formal rules for labelling or constructing projects under any of these frameworks and each is undertaken in response to a particular problem, there is no single prescribed approach to undertaking integrated research (Wickson et al., 2006). As a consequence, there can be no structured step-by-step or 'best practice' guide to conducting integrated research. In addition, for research employing a transdisciplinary or goal-oriented interdisciplinary approach the process of designing and conducting the research needs to be an iterative one and, consequently, setting too rigorous a guideline for the integrated project would remove some of the flexibility that is essential for its success. This is a key dilemma within integrated research – i.e. the less rigorous the outline of the research process the more difficult the research will be to conduct (and therefore the possibility of a lower quality result emerges) but, if the outline is too flexible, the research process will not be able to deal sufficiently with the complexity of the system and therefore, again, the research quality is likely to decline.

In reality, the boundaries between the three forms of integrated research are, if anything, even more fuzzy than indicated here. With "no clear consensus on what transdisciplinarity is or how it can be evaluated" and, further, no critically robust understanding of what good transdisciplinary research might look like (Wickson et al., 2006: 1046) researchers are pretty much able to define integrated research in their own terms. This creates problems for the development of integrated research theory (see Chapter 4). Many of the features that distinguish trans-disciplinarity from interdisciplinarity are highly subjective. For example, the key requirement for transdisciplinary research that it involves transcendence of disciplines (Rapport, 1997; Attwater et al., 2005) is made incredibly difficult to evaluate as disciplines themselves are in a state of flux – constantly adopting new ideas from other areas while abandoning others. Another key defining feature – that transdisciplinarity takes a holistic perspective (Max-Neef, 2005) is essentially also unevaluateable without knowing the boundaries of holism which are, axiomatically, non-existent. Similarly, with multidisciplinarity and interdisciplinarity the key defining feature – the level of integration and cooperation in the projects (Attwater et al., 2005) – also has no formal boundary with which to evaluate which approach the research is following.

In identifying the problem of defining the type of integrated research Max-Neef (2005) has suggested that transdisciplinary research actually involves two simultaneous research projects – first as a project to resolve the problem at hand and second as a project to develop transdisciplinarity itself. This could equally apply to interdisciplinary research as only multidisciplinary research is able to develop a rigid methodological framework for the research prior to its commencement.

While the integrated research projects are frequently associated with the crossing of boundaries between disciplines with conflicting research paradigms (namely the social and physical sciences) it should be remembered that integrated research can also occur within these paradigms. For example, researchers within the fields of Oceanography (Lafuente & Ruiz, 2007) and Hydropedology (Kutílek & Nielsen, 2007) have conducted interdisciplinary projects within their individual research paradigms. The feature defining the integration of natural and social sciences should again be problem based. If an issue is purely related to the human systems then there is no need to look outside that system for solutions – the answers may be obtainable by conducting integrated research within the paradigm. Similarly with natural sciences, there is no stipulation that integrated research requires the involvement of social sciences if the system under investigation does not involve human elements.

2.5 Conclusion

This chapter has explored the meanings of the main terms used in integrative research. The research in general points to there being a considerable degree of confusion concerning the differences between the main three integrated research approaches of multidisciplinarity, interdisciplinarity and transdisciplinarity. While this confusion persists, it is clear that of the three approaches, transdisciplinarity is the ultimate goal of integrated research and provides the most holistic means of understanding complex systems. Consequently, this will form the focus of the remainder of the study although reference will be made to other forms of integrated study where appropriate. However, in order to prevent confusion, the term 'integrated research' will be employed (e.g. Kooistra & Kooistra, 2003; Redman et al., 2004) to refer to all forms of 'x-disciplinarity'. The following chapter will extend the debate on integrated studies by addressing the key issue of the discrepancies between the natural and social science research paradigms and the need for them to work together to resolve complex 'real-world' problems.

3. Integrating natural and social sciences – developing a framework

3.1 Introduction

As noted in the first chapter, one of the key contentious issues within integrated research is how to combine social and natural science. The recognition that we need to look at coupled biosphere/human systems is a first important step towards developing a new way of looking at environmental change. Borch (2007) observes that for the conducting of an interdisciplinary 'foresight' analysis (in the context of developing sustainable agricultural systems) "The real challenge in this type of analysis is set by the combination of quantitative and qualitative methods". This chapter looks at the difficulties of integrating the two approaches – focusing on the core of the division – a discrepancy between the positivist epistemologies employed in the natural sciences and the interpretivist approaches of the social sciences. Reviewing these issues is key if we are to develop a research program that enables us to progress towards the higher forms of integrated research (see Chapter 2).

3.2 Positivism versus interpretivism – the core of the division

It is impossible to engage with the debate of how to integrate social and natural sciences (or 'hard' and 'soft' approaches) without considering the philosophical differences between the two sides. The level of tension between the social and natural sciences has been well noted in the literature. In fact, Gregory (1996: 616) went so far as to suggest that "… there are some paradigms, traditions, perspectives, value systems, or cultures that are so antagonistic to one another that there is no position from which they can be reconciled." The greatest conflict within integrated research is clearly between the perspectives of positivism in the natural sciences and interpretivism in the social sciences.

Positivism is frequently tied in with experimental approaches which are, themselves, predicated on the notion that the response of objects or beings when subject to some external force is predictable (within a margin of error). "The positivist approaches ... posit that if we are to explain processes we must discover the regularities that govern the relationships existing between observable events and phenomena.” (Cloke el al., 1991: 136). This leads to the development of experimental or stepwise methodologies where learning becomes essentially a question of trial and error potentially followed by a revision of the question and further trial and error. Thus, because of the need to ensure that the objects or beings are categorically representative, representativeness becomes a key issue. Likewise, the need to repeat steps and the supposed regularity of the response (in order to produce general laws or support or refute hypotheses) ensure that replicability is also a key issue within positivism.

The question that emerges is – as we know humans respond to drivers in their environment, why are the social scientists increasingly moving away from positivism and towards more interpretivist epistemologies? Borch (2007: 1063) suggests that one problem with positivism and the quantitative methodologies it employs is that it is simply not effective in situations where the environment is chaotic, uncertain, unstable and complex. For example, when calculating the relationship between grass-growth (response of the subject) and the environment (the drivers) it is a matter of experimenting by varying physical factors such as light, moisture, nutrients, or soils and exploring possible dynamic behaviour to establish the relationship. To do this, there is an implicit assumption that, given exactly the same environmental drivers, the relationship between growth and the environment will remain identical within a certain margin of error (the experiment must be replicated to account for the potential genetic variance in the gene pool and potential random factors). This enables the discovery of ‘regular relationships’ that form the basis of the positivist perspective and, once discovered, the scientist can move on with the knowledge that given no change in the measured variables this relationship will not alter.

However, what if the subject is able to choose its own response to the same set of drivers? While there would be restrictions on behaviour as a result of the simple physical and physiological limitations, the response to the same stimuli could vary enormously within these constraints – individual behaviour is not determined by the simple application of drivers. Now consider if the subject could adapt its behaviour both in response to internally driven changing goals and objectives, and in response to the perceived (subjectively analysed) success of previous behaviours at achieving goals. Changed behaviour may be entirely unrelated to the issue under study – for example, change may be prompted by a desire to pass resources to progeny, relationships to other individuals[10], spiritual objectives, moral and ethical considerations on resource use, and so on. To understand the relationship between one set of drivers and one set of behaviours it is thus critical to also consider other drivers and behaviours operating simultaneously. Further, consider that neither response nor the drivers of the response for the subject could be measured directly. Rather the researcher is required to ask subjects from the population to provide their own data. Consequently, measured reaction may not be actual reaction and measured drivers may not be actual drivers. In addition, the subject may believe that the researcher has the ability to influence their chance of achieving their goals and thus may provide 'data' they perceive will help achieve these goals rather than a 'true' response.

When potential social motivations for behaviour (i.e. the subject seeks to achieve group goals rather than individual goals) and the possibility that action is not measurable (i.e. subconscious or habitual) it becomes clear that the simple relationship outlined in the first case is not there. In this case, simple relationships do not exist between observable events and phenomena and, thus, the use of a stepwise experimental process is untenable – i.e. once the measurement has been made, there is no guarantee that the relationship will remain the same in the future nor is there any guarantee that it will apply to all members of the population. It is the recognition of these kinds of failings of positivism (this is not an exhaustive list) that lead major disciplines in the social sciences to abandon the positivist scientific method that dominated science until the 1960s and employ more flexible, context related approaches to understanding behaviour. The movement towards interpretivist approaches can be marked across all formally positivist social-science disciplines. For example, *human geography* began to move away from positivist approaches in the 1960s (Cloke et al., 1991)[11],

[10] Contemporary sociology asserts that basically persons live out their lives not in the context of large-scale society but rather in relatively small and discrete networks of social relationships." (Stryker, 1994: 17).

[11] whereas human and physical geographers used to share a common language in quantitative methods, now this rarely exists (Thrift, 2002).

qualitative 'soft systems' methodologies developed as part of systems thinking in the 1970s (Jackson, 2001)[12], the so-called 'cultural turn' emerged in *geography* in the late 1980s (Valentine, 2001) and *rural geography* in the 1990s (Burton, 2004), *organizational and vocational psychology* began to move towards qualitative work in the 1980s (Lee et al., 1999), *qualitative institutional economics* (dealing with adaptive problem-solving) has recently emerged from the economics discipline (Attwater, 2000), Dawson et al. (2006: 237) refer to the recent "decline of positivism" in *psychology,* and Gundelach (2000) refers to Kaare Svalastoga as 'the unceasing positivist' and describes how he became increasingly isolated from mainstream *sociology* during the 1970s.

The widespread demise of positivism in social sciences should not be seen as a 'dumming down' of science, rather it is a recognition that finally social sciences are developing methodologies that are able to cope with the complexity, flexibility und uncertainty in the social realm. The notion of developing an understanding of regularities that govern relationships is being eschewed with researchers moving away from the 'stimulus-response' understanding of behaviour to one where people are seen as determining their own courses of action (based on personal interpretations of the world) – rather being subject to biophysical type laws (Cloke et al., 1991). As a result, disciplines such as anthropology focus not on discovering 'laws' that govern behaviour but rather on understanding complexity and difference within the population[13]. As Guyer et al. (2007: 5) suggest, rather than looking for representativeness "heterogeneities are an anthropologist's conceptual stock in trade" and Giri (2002: 106) further observe that anthropology is characterised by "its emphasis on human voice and description of this voice". In their interdisciplinary study of temporal heterogeneity in land use Guyer et al. (2007: 5) thus observe that anthropological components are not attempting to supply variables to ecologists for calculating regressions or trends, but rather trying to "identify spatio-temporal patterns and their correspondence to processes on the ground and in the social life of modern Africa."

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[12] Jackson (2001) observes that traditional systems thinking was subject to criticism in the 1970s and 1980s as some believed it was unable to cope with ill structured and strategic problems. This lead to the development of more soft systems approaches such as organisational cybernetics (a result of the inability of traditional approaches to deal with extreme complexity), soft systems thinking (a response to an inability to deal with human and social aspects of problem situations) and critical systems heuristics (a reaction to its innate conservatism).

Many problems emerge from a lack of understanding between those using positivist and interpretivist epistemological positions and the incompatibility of the research methodologies. Pohl (2005: 1169) conducted a study of integrated research in Europe and found that the lack of compatibility (and understanding of the issues) can lead people to avoid integrated research. For example, he cites a sociologist involved in his assessment as saying "As a sociologist to collaborate intimately with a biologist. What should we write about? I don't know!" Ekasingh & Letcher (2005: 3) observe that social scientists are often "unwilling or unable to deal with very large scales and aggregation over large groups of individuals" and that consequently methodologies required to compromise between those scales are required. However, from the interpretivist perspective, aggregating up to these scales often simply makes no sense as the purpose of the research is to understand heterogeneity – not to produce generalisable results. This leads researchers such as Deconchat et al. (2007) to warn against the use of case studies (the stock approach of the social scientist) in integrated research, warning that "the ability to formalise, to generalise the results, and to apply them in other situations is of prime importance."

One other common area of misunderstanding is the need for philosophies within the social sciences. In his interviews of research scientists Pohl (2005) observes one issue that the natural scientists have is the belief that the 'philosophy' behind social sciences is unnecessary, expedient, and gets in the way of developing practical solutions to real problems. For social sciences, however, it is crucial that investigations of human behaviour are soundly theoretically grounded as without incorporating theory (and considering notions such as ontology and epistemology) social science studies would simply float in a sea of isolated observations – unlike the case in many positivist studies where theories are based on clear, incontestable relationships. Employing interpretivism means that there may be many philosophical perspectives to take on a particular issue, and it is important that these be clearly stated and not taken for granted. Problems integrating philosophical approaches in integrated research mean that social and biophysical disciplines sharing similar (positivist) philosophies form the basis of much contemporary research e.g., engineers, economists, climatologists, ecologists, and

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[13] Biophysical sciences are also moving towards this perspective (Abel et al., 2001; Janssen, 2001).

shared analytical structures, e.g., approaches to scale, systems thinking, etc. (MacMynowski, 2007)

3.3 Unitary theory or pluralism in integrated research?

This leads to another issue facing integrated studies. If positivist and interpretivist studies are based on fundamentally different principles and yet integrated research requires they work together, how should the different research disciplines (particularly across the natural and social science divide) be integrated? There are two main perspectives in the literature. One is that research needs to be methodologically and epistemologically coordinated such that a single unitary methodology (with a single epistemology) is developed and the other is that research should be conducted using a pluralistic approach where researchers retain their disciplinary perspectives.

3.3.1 Unitary theory

Essentially those who employ unitary theory believe that one of the objectives of integrated research is to try to reach a theoretical compromise (or synthesis) between the natural and social sciences such that all research can be conducted under a single conceptual paradigm. The term unitary theory (or research) is particularly used in systems research (e.g. Jackson, 2001, 2006; Pollack, 2006; François, 2006) and emerges within this discipline because original thinking within hard systems theory suggested that a general theory was possible with the discovery of "laws governing the behaviour of all systems, whatever their type." (Jackson, 2001: 234) and that all systems are simple enough to be mathematically modelled. Such an approach with modelling at the centre has advantages in that it limits the ability of disciplines to "branch off into disciplinary challenges that are irrelevant to the problem situation" (Janssen & Goldsworthy, 1996: 270). However, in Jackson's (2006: 652) opinion, while these methodologies were adequate at the time of their conception in the mid-20th Century, they "collapse in the face of the greater complexity, change and diversity of the modern era." This is not the only issue. As noted above, the social sciences are progressively moving towards a more interpretivist position while natural sciences – although more willing to accept the validity of the interpretivist approach – continue to be firmly rooted within positivism. Thus, if anything, the epistemic gap between the natural and social sciences is widening.

Unitary frameworks have another problem. As is observed in Chapter 2, one of the key advantages of truly integrated research is its flexibility – and approaching a research problem with a single fixed methodology to some extent negates this advantage. Further, the 'synergies' between disciplines that should occur as part of the transdisciplinary process (also see Chapter 2) are also likely to be hampered by the fixing of a single unitary theory or approach. As a number of researches have contended, transdisciplinarity is about extending boundaries (e.g. Giri, 2002; Hadorn et al., 2006) whereas a unitary approach is likely to require compromise and thus act to constrict the boundaries of the exploration. This may reduce the extent to which the research provides cutting edge science and solutions. Costanza (2003: 653) (a leading ecological economist) observes that the integration of the social and natural sciences should not be in the form of consilience (linking facts and fact-based theory across disciplines to create a common groundwork for explanation) as this is likely to result in a "total takeover by the natural sciences and the reductionist approach in general". He contends that a truly trans-disciplinary approach must be "sophisticated and multifaceted in its view of the complex world in which we live, the nature of 'truth' and the potential for human 'progress'".

Nevertheless, some integrated research studies (or research scientists) continue to explore the possibility of a unitary framework (generally based around modelling). For example, Naveh (2005: 230) describes the possibility of a general mathematical model of the universe (citing Laszlo, 2002) as being "at the cutting edge of the transdisciplinary scientific revolution." In another case, establishing similarities between economics, ecology and culture leads Costanza (2003) to the conclusion that it should be possible to develop a "coherent and consistent theory of genetic and cultural co-evolution" (662). In this he suggests that "The barriers between the traditional disciplines will dissolve and a true 'consilience' of all the sciences and humanities will occur" (651) based around a modelling framework. Pollock (2006), while similarly advocating a cross-over between natural and social sciences (which he believes are currently siloed) is less sure of the outcome, noting:

"It is possible that a single, practically applicable and widely accepted 'resolution' of the paradigm debate will not be found. The differences between the paradigms may simply have to be accepted and worked with at the level of practice."

It is interesting here that the push for the development of unitary theory emerges almost exclusively from the field of systems thinking. However, even within systems analysis there is doubt, with advocates of some research approaches (in particular Critical Systems Thinking) suggesting that methodological pluralism provides the only realistic way of integrating research programs without compromising the science or the objective of solving problems in the 'real world' (e.g. Gao et al., 2003; Luckett, 2004; Jackson, 2006). In general the current situation can be summed up by François', (2006: 621) statement that "A 'Unified Transdisciplinary Theory' still does not seem to exist".

3.3.2 Methodological pluralism

Methodological pluralism is by far the most common approach to integrated research. Unlike the case with unitary approaches, adopting pluralism as a framework does not require that the research project work towards epistemological and methodological integration. Rather, the main tenant of pluralism is that not all methods are equally valid in all situations. Instead "they make explicit use of theory to identify the strengths and weaknesses of different methods, and view them as complementary – addressing different kinds of question." (Midgely, 1996b: 25 – also see Jackson & Keys, 1984). Midgely and colleagues further contend that methodological pluralism represents a 'serious intellectual challenge' as it contains ideas about the nature of knowledge (epistemology) and the nature of reality (ontology) and, thus, requires the questioning of basic philosophical assumptions. Thus it is not the 'easy' option for integrated research as ontological/ epistemological differences (such as between positivism and interpretivism) are contentious and can be difficult to resolve. Yet questioning epistemologies and ontologies is, as Attwater et al. (2005: 191) suggest "crucial to our ability to develop genuinely pluralist and transdisciplinary approaches which maintain appropriate rigour and relevance."

Pluralism is also ideally suited for the problem solving objectives of integrated research as such projects need to "focus more directly on the problems, rather than the particular intellectual tools used to solve them" (Haddorn et al., 2006: 120) and "to correspond to and reflect the problem and context under investigation" (Wickson et al., 2006: 1049). Wickson et al. (2006: 1050) surmise from their review article that a transdisciplinary approach "calls for the development of methodology that involves interpenetration or integration of different methodologies and, ideally, epistemologies." This perspective is not held by all. As noted above reconciling methodologies at the epistemological level is likely to be very difficult – particularly the fundamental interpretivist/positivist divide. Thus researchers such as Madens & Adriansen (2004: 495) contend that "we do not believe in an integration of different epistemologies but in the possibility of combining methods that have been used within the same philosophy." This is probably a more realistic perspective.

In general, the pluralist perspective is more readily compatible with interpretivism than positivism (Pollock, 2006). Two possible reasons for this are, first that interpretivism (by its nature) is open to different multiple perspectives and therefore pluralism is entirely in keeping with its holistic epistemological viewpoint. Second (and related), pluralism makes more sense in the social realm as the heterogeneity and diversity in society is better represented by a multitude of perspectives than a single one (Taket & White, 1998; Sligo & Culligan, 2007).

The extent to which plurality is seen as the part of a research process varies not only between disciplines, but within disciplines as well. For example, Engel (2005: 21) points out that behavioural economists who follow 'rational choice' models are more likely to believe in a unitary theory, i.e. as (they believe) all decisions are made on a rational economic basis therefore laws governing social behaviour can be derived and incorporated within models. However, he further observes that they are generally more concerned about using the correct conceptual tools to understand behaviour rather than theoretical parsimony and that therefore most of these researchers are willing to accept plurality. On the other hand, ecological economists who, as a rule, do not share the 'rational choice' perspective take a pluralistic approach to methodological development in transdisciplinary studies (Forstater et al., 2004).

3.4 Can we integrate social and natural sciences?

3.4.1 The epistemological path

While the above section describes the two approaches of unitary theory/ methodological pluralism and social/natural sciences as opposing methodological positions, the distinction is not quite as clear cut. In particular, there are (as Pollack, 2006 observes) areas where social sciences continue to employ positivist research methods in integrated research (in particular, economics and landscape ecology/architecture) as not all schools of thought have moved towards an interpretivist framework. One easy way to resolve epistemological conflict, therefore, is for integrated research to predominantly involve social scientists who take epistemologically similar positions.

There are already examples of this in the literature. In particular, Chan et al. (2007) observe that transdisciplinary work in conservation has largely focused on economics because of the ability to generate integrated ecological-economic models. This is also indicated by the domination of ecologists and economists as recipients of current *Rural Economy and Land Use* funding (a major interdisciplinary initiative by the UK research councils) (RELU, 2007). By combining ecology with economics, coupled models are able to be developed which incorporate economic and ecological elements – thus, technically, bridging the social/natural sciences divide. Others have also noted the ease with which economists following a similar philosophical position can be integrated with natural sciences (e.g. MacMynowski, 2004, Santelman et al., 2004). Petts et al. (2008: 598) observe in their project on air quality that natural scientists showed a preference for disciplines that were either founded in economics or psychometrics as they were seen as providing "'real figures' to inform policy choices".

The argument then may be if economics (and other positivist disciplines) is easily integrated with natural sciences, should integrated research programs focus on economists to provide the social-science perspective? There are a number of problems with this idea. First, integrated research requires methodological approaches that are context dependent and flexible for effective deployment (Wickson et al., 2006) yet mainstream economics remains "stubbornly engaged with linear reason" (Max-Neef, 2005:15 – an economist). Thus, while economics aids the development of the modelling component of such studies, it is unable by itself to fulfil all the roles required for integrated research – for example, exploring contextual issues and encouraging the participation of stakeholders in problem formulation and solution. Ekasingh & Letcher (2005: 5) observe of an integrated watershed management project in Thailand that attempts to incorporate social scientists failed as "only agricultural economists continued to be involved throughout the life of the project". Further, the authors noted that researchers in the project formed distinct groups on the basis of ease of integration – for example, between hydrologists and agronomists – and that, as a result, non-economics social scientists were unable to "contribute in a meaningful and challenging way to the assessment".

Second, epistemologically and ontologically economics falls outside of mainstream social science. Nancarrow (2005) argues, for example, that economics has its own traditions of measurement and analysis and, as a result the epistemic divide between economists and non-economists can be as wide as that between natural and social scientists. This can lead to major discrepancies between economists and other social scientists – for example, in terms of the ability of economics to place an economic value on the environment (Cobb et al., 1999). One key difference between economists and other social scientists is the perspective in neo-classical economics that all decision makers (e.g. farmers) act in an economically rational manner to maximise income goals (e.g. Ekasingh & Letcher, 2005). The notion of economic rationality has not been widely accepted in the majority of social sciences for over 4 decades (Burton, 2004).

Third, engaging economists in integrated research, while clearly incorporating *one* social dimension into the study, fails to introduce the tension between positivist and interpretivist approaches that are widely considered a defining feature of transdisciplinarity (Tress et al., 2006). This is evident in Chan et al.'s (2007: 63) conclusion that while interactions between ecologists and economists have "yielded some important advances" collaborations between other social scientists such as cultural anthropologists, human geographers or social historians have been rare. As a consequence, the result of integrated research has been an improvement of the ecological models and a perceived opening up of dialogue with the social science 'discipline' but the difficult task of understanding social and cultural implications (not an issue for economists) has been neglected. The authors contend that this lack of integration is attributable largely to the epistemological challenges to objectivity within wider social science literature that may “alarm many natural scientists” (63).

3.4.2 The oblique approach

An alternative to integrating social and natural sciences through integrating disciplines with epistemic similarities is to employ one paradigm under the direction of the other in an ‘oblique’ usage, for example, by incorporating a positivist tool into an interpretivist study. Pollack (2006: 394) contends that, while researchers can only act under one paradigm at a time, they should be able to operate different paradigms sequentially over time as “the paradoxes between the different paradigms do not have to be fought, but can be accepted, understanding that both sides of the contradiction have merit”. However, he also observes that it is possible that a single, practically applicable and widely accepted ‘resolution’ of the paradigm debate will not be found and that others have criticised the oblique approach for its lack of intellectual coherence. A more practical issue here is to do with the amount of time taken to learn two epistemologically distinct research paradigms from two different bodies of work – should time be spent on improving interdisciplinary skills or on improving the depth of disciplinary knowledge? What about science disciplines where there is no logical cross-over with interpretivism – i.e. experimental disciplines such as chemistry where interpretivism is entirely inappropriate? Even if it were plausible and desirable to learn both paradigms the current disciplinary structure within the university system would be unable to cope with the development of this kind of epistemological duality without substantial revision (see Chapter 4).

3.4.3 The systems thinking path

The other possible means of integrating the social and natural sciences is through the development of integrated disciplinary perspectives, in particular systems thinking approaches. A general systems theory sets out to determine “laws governing the behaviour of all systems, whatever their type” (Jackson, 2001: 234). While systems analysis per se has a more general origin, the systems thinking approaches used in integrated research projects emanate from the management/ business schools where they are used primarily for the development of solutions to complex real-world problems. Systems thinking purports to provide a means of integrating many perspectives on a problem in order to devise effective solutions. For example, Janssen & Goldsworthy (1996: 270) contend "the development of a model based on systems theory is an excellent way of combining disciplines. The model ensures that in a later stage, research activities do not branch off into disciplinary challenges that are irrelevant to the problem situation."

Rather than viewing systems through the standard positivist/interpretivist dichotomy, systems thinking divides research methodologies into 'hard' methodologies that "enable us to question truth statements" and 'soft' methods which "primarily encourage us to investigate and make decisions on rightness issues" Midgely (1996b: 34). It is interesting that even within the systems thinking discipline (which enshrines a commitment to holism – Jackson, 2001) there are still disputes concerning the use of 'hard' or 'soft' systems methodologies. Jackson (2006: 652) suggests that hard systems methodologies (e.g. systems analysis and systems engineering) tend to make unitary and simple assumptions about problem situations and take it for granted that all systems are simple enough to be mathematically modelled. However, in his opinion, while these methodologies were adequate at the time of their conception in the mid-20th Century, they "collapse in the face of the greater complexity, change and diversity of the modern era" and, as a consequence, new systems methodologies are required.

There are a multitude of reasons for using soft-systems methodologies. Ekasingh & Letcher (2005) contend that soft systems methodologies are often needed for integrated research because 'hard' models are often too complicated for stake-holders to comprehend. Giving the example of the FAO's Integrated Mission for Sustainable Development program Nidumolu et al (2006) observe that the inte-gration of a soft systems approach is required because while the biophysical component of modelling has been adequately developed, the people's role component has been insufficiently developed, the socio-economics are not explicitly reflected in the outputs, and ('critically') the outputs of the model do not adequately integrated the biophysical and socio-economics aspects.

Combining hard and soft systems methodologies is, however, as difficult within the systems thinking discipline as it is between two disciplines following distinct epistemological positions (Pollack, 2006). In fact, Midgely (1996b) observes that in the 1980s there was a paradigmatic 'war' between authors using "soft" and “hard” methodologies in systems thinking. One of the outcomes of this war was the emergence of ‘critical systems thinking’ as an attempt to overcome the conflict. Of the approaches to systems thinking, critical systems theory (CST) is perhaps most in line with the thinking on integrated research from outside management studies as it recognises that all systems thinking approaches have strengths and weaknesses, and therefore it is sensible to use them in combination to address particular problem situations. Jackson (2001: 236) observes that one of the key tenants of critical systems thinking lies in recognising that diversity is a sign of strength in systems thinking and not an indication of weakness. He contends that soft systems thinking is situated within an interpretivist paradigm and that this constrains the ability of soft systems practitioners to intervene in many problem situations. Hard systems thinking has similar weaknesses associated with its paradigm in its inability to deal with human and social aspects of problem situations. Integrating the two provides an approach that is able to both provide practical solutions and deal with the human and social aspects of problem situations.

Although critical systems theory draws on the strengths of both soft and hard approaches should nevertheless not be accepted uncritically. What is probably most disconcerting is its isolation within the integrated research literature, as noted in Chapter 1, critical systems literature (and systems theory in general) draws very little from research outside of its management/business disciplinary origins (for example, see Jackson, 2001, 2006; Luckett et al., 2001; Gao et al., 2003; Pollack, 2006). Thus, while the rhetoric is often of holism and integration (particularly in Critical Systems Thinking), in practice the emerging discipline stands relatively isolated within wider academic circles. As a consequence, it is difficult to imagine systems approaches as providing an integrative framework for a multitude of disciplines – particularly with the need to ensure equal methodological inputs from across the disciplines if integrated research is to be successful (Chapter 5). One possible reason for this lack of integration is the reliance of systems methodologies on modelling. Janssen & Goldsworthy, 1996: 270) observe that the main problem with focusing on modelling is “that the model has to be developed at an early stage of the research process, when understanding of the problem is still limited” and thus “It is difficult to identify appropriate scientific methodologies during these early phases of multidisciplinary research planning”.

3.5 Conclusion

The issue of how to integrate the social and natural sciences is a difficult one. While some still believe in the creation of a unifying theory with which all systems can be understood the fundamental differences between positivist and interpretivist sciences make this extremely unlikely. Success in integrating social and natural sciences is most forthcoming when researchers use the best approaches available for addressing the question. Frequently this means using interpretivist approaches (and disciplines) for addressing social science issues and positivist approaches (and disciplines) when addressing natural science issues. Thus, it appears that integrated research is best facilitated through the use of epistemological pluralism – employing disciplines in a manner that takes advantage of their methodologies and epistemologies, and integrating the research through dialogue between scientists (see Chapter 5). However, the problem of integrating natural and social sciences is not the only one facing integrated research programs. The following chapter reviews other areas where integrated research is encountering problems in order to make these more apparent and, therefore, more readily addressable in AgResearch's research programs.

4. Difficulties in conducting integrated research

4.1 Introduction

Chapter 3 looks at the fundamental issue in integrated studies of how to reconcile the respective epistemological and ontological positions of the natural and social sciences. The chapter argues that reconciling these two conflicting perspectives on the validity of science and acceptable methodological approaches is key to developing successful integrated research. However, this is not the only problem integrated research faces. As may be expected from the regular reports of difficulties in integrated research (e.g. Balsiger, 2004; Stevens et al., 2007; Petts et al., 2008) a wide range of problems are encountered by interdisciplinary research teams on a routine basis – some of which are on a theoretical level, but many are mundane issues concerning the management, funding or organisation of integrated research. As Jakobsen et al. (2004: 28) suggest, "even when research projects are designed to be transdisciplinary, numerous barriers exist". This chapter deals with the problems that are widely encountered in integrated research and provides the basis for outlining possible solutions in Chapter 5.

4.2 Problems with developing integrated research out of a disciplinary research environment

At the root of the problem is that a unified methodological or theoretical framework for integrated research projects, as François (2006: 621) suggests "still does not seem to exist." Consequently, researchers undertaking an integrated research processes must start at the beginning with the time-consuming development of method and theory (Deconchat et al., 2007) – rather than beginning the research from established methodologically, epistemologically and ontologically secure positions as can be done within disciplinary studies. What theoretical development there is not (as might be expected in an area specialising in multi-discipline research) being formulated as a result of a collaborative project between the natural and social sciences. Rather, MacMynowski (2007) contends the two areas tend to largely ignore each other. She observes:

"... evaluations of interdisciplinary research in journals targeted at biophysical scientists include virtually no citations from the social science literature on disciplinarity and interdisciplinarity ... Likewise, in the social science literature, there are virtually no citations from the biophysical literature. The two discussions are running in parallel with stunningly little crossover." (MacMynowski, 2007: 3)[14]

In addition to each project having to go through a time-consuming methodological/theoretical development process, a second problem with having no theory of transdisciplinarity is that the lack of a standardised approach makes it exceptionally difficult to compare and evaluate studies for effective and ineffective integrated research practices. It could be argued that given time a single theory of transdisciplinarity will emerge but, given that integrated research has been around for almost 8 decades (Sills, 1986), it is clear that there are problems in establishing this theory. These issues are outlined in the following section.

4.2.1 Ownership of TD theory – who are the 'gatekeepers'?

A key problem in the development of a theoretical framework for integrated research is the issue of research validation. Wickson et al. (2004: 1054) contend that currently we do not have the experts capable of judging integrated research and therefore lack the "critically robust ways to discuss and evaluate the quality of transdisciplinary research". Within individual disciplines there are so-called 'gatekeepers' (such as established journals, established respected scientists or groups, etc.) who have the authority to determine what constitutes a valid contribution to science and what is invalid (and on what grounds).

This question is: Who are the keepers of interdisciplinary research? As Petts et al. (2008) suggest, disciplinary divisions are extremely advantageous in that they provide benefits such as methodological approaches, frames of reference, shared languages and accreditation (i.e. institutionalised symbols of competency/ recognition). In effect, disciplines provide researchers with the epistemological and ontological security that is a pre-requisite to further development of the science without having to constantly question the nature of science itself. In

[14] Tress et al. (2004) also observe that published papers fail to place much emphasis on discussing integrative research concepts.

contrast, integrated research has no 'college of peers' "who build and critique each other's work, in the process raising the quality and applicability of trans-disciplinary methodologies" (Kueffer et al., 2007: 26). As Madsen & Adriansen (2004: 487) contend, "without commitment to a particular philosophical stance, *it is not possible to decide whether one research method is more relevant than another method.*" A project designed by an anthropologist can be readily questioned on methodological, epistemological and ontological grounds by an economist – all claims to ownership are equally valid and, consequently, all are equally invalid. Winder (2003) warns strongly against integrated research projects adopting this perspective (epistemological relativism – the pretence that any know-ledge system is as good as another) as researchers need a strong theoretical under-standing of their own discipline in order to contribute knowledge to the overall project.

An analysis of interdisciplinary research in Sweden (Sandström et al, 2005) emphasised the scientific challenges linked to interdisciplinarity. Further, it concluded that interdisciplinary research has become so common that it needs no longer to be an aim of research policy. However, more 'radical' interdisciplinary research proposals have a lower grant success rate than 'mainstream' (inter-disciplinary) projects proposals. Further, they point out that too strong a focus on interdisciplinarity may in the long run undermine basic research.

Winder's warning above is not merely an academic issue. As Tress et al. (2003) point out, the lack of a recognised standard is a threat to future development of integrated research if funding bodies are unable to distinguish between 'good' and 'bad' proposals. Janssen & Goldsworthy (1996: 276) observe that "multi-disciplinary teams do not have very rigid scientific norms imposed on them. They must therefore develop their own standards of excellence". However, this too is problematic as the standards of excellence imposed on the research team are self-monitored (or at least self-established) and therefore open to self-interested bias. Evidence of the impact of a lack of 'gatekeepers' can be seen in the ongoing debate concerning what actually constitutes integrated research that has 'bedevil-led' integrated research (Robinson, 2008). The fact that we are now many decades into the development of integrated research and yet are still unable to define it suggests that there is a problem with legitimisation (i.e. the 'right' to define processes and methodologies within integrated research).

4.2.2 Problems with the complexity of integrated research

This issue is amplified by another problem – the extent to which integrated research needs to be tailored to complex real-world situations – complex situations that in one case may require specialist knowledge from sociologists, ecologists and landscape architects, while in another case require anthropologists, economists, chemists, soil scientists and hydrologists. In each case a different team of specialists is required (Hollaender, 2003; Balsiger, 2004). Each study is likely to encounter a different set of barriers and facilitators and, to make matters more complicated, barriers to some studies can act as facilitators to others (Jakobsen et al., 2004). In each case, likewise, a range of different – and sometimes conflicting – methodological, epistemological and ontological views must be incorporated into a unique agreed upon overall methodology (or at least 'research structure'). Wickson et al. (2006: 1049) argue that this is a fundamental cause of the lack of rapid emergence of anything resembling a transdisciplinary methodology, as "methodologies employed in transdisciplinary research need to correspond to and reflect the problem and context under investigation". Similarly, François (2006: 621) argues that a theory of transdisciplinarity has not emerged because the adaptability required for investigating complex situations and systems is not amenable to the sort of "top-down all-embracing abstract construction" provided by a single theory.

4.2.3 Problems with the need for integration of complexity

Constructing an 'all-embracing' theory to deal with almost infinite complexity is difficult enough, but this is made even more complex by another requirement of integrated research – that, ultimately, the complexity needs to be theoretically and practically integrated (e.g. Bournois & Chevalier, 1998 – cited in Massey et al., 2006). This problem is expressed by Höll, A.; Nilsson, K. (1999: 26):

> *"One specific problem emerging with interdisciplinary research is the task of synthesising results from sub-projects with different scientific methods and traditions. Interdisciplinary research obviously requires specific operational methodologies that integrate disciplines with different research tradition, different concepts of nature, and different expectations with regard to research results. To achieve optimal results, the methodologies have to be freshly developed for every project parallel to the ongoing investigations. This*

problem relates to insufficiently developed synthesising methodologies in general, and to insufficient knowledge of those methodologies in the research community."

In this sense, integrated research pulls in two dimensions: the more the research becomes diverse in order to examine the complexity, the more difficult it is likely to be to ultimately integrate the results. This can apply to both the research topics themselves and the diversity of the research team. Loibl (2006: 298) observes, for example, the need to "turn the identification of incompatibilities from a source of disintegration into a strategy of integration". There is therefore an inherent paradox in integrated research which may prevent the construction of 'synthesising methodologies' suggested by Hoell & Nilsson (1999).

Both diversity and integration are desirable for effective integrative research, however, as the study becomes more diverse (e.g. involves more disciplines, takes a more holistic perspective involving multiple research fields, involves more institutions, or uses different epistemologies, methodologies, ontology's) the problems in integrating the research increase[15]. Likewise, the production of a fully integrated study often requires the research program to minimise the level of diversity in the research program (e.g. focus on limited core research topics, employ unitarism rather than pluralism, or follow a single epistemological position) but, in doing so, the ability of the study to investigate all aspects of the system becomes limited. The obvious answer to this conundrum is either to limit the exploration of diversity or limit the extent of integration – neither of which are likely to be viewed as methodologically/theoretically desirable. It is apparent, however, from the observations of the failure of many studies to fully integrate (e.g. Tress et al., 2001; Pohl, 2005) that it is often integration that is neglected in the final analysis.

Examples of project diversity influencing integration are common across the literature. For example, Jakobsen et al. (2004) found that the size of the group involved in the project has an impact on the extent of integration as smaller groups are more able to maintain effective communications networks. Massey et al.

[15] Note that the level of diversity of the program will be related to the complexity of the problem (Balsiger, 2004) – thus, to some extent, the diversity of the program is fixed and non-negotiable.

(2006: 142) observe that their decision to use a plurality of worldviews, multiple data sources and mixed methods in their study of NZ dairy farmers "perhaps created more problems than it solved". Integrated research projects cited as successful are often those where the diversity is minimised in favour of integration. For example, while Stevens et al. (2007: 805) suggest that Santelman et al (2004) provides a "very successful example of ecologists and social scientists working together" this was achieved by embracing a single epistemological position (positivism) and employing a single methodological framework (modelling). While minimising complexity in the research process increases the likelihood of an agreed outcome of the research, it has its own problems. Primarily, such studies do not provide the methodological pluralism suggested by some as providing the only realistic way of integrating research programs without compromising the ability of the study to solve problems in the 'real world' (e.g. Gao et al., 2003; Luckett, 2004; Jackson, 2006).

4.2.4 Integrating different methodological, epistemological and ontological positions

A key problem with integrated research is getting researchers from different disciplines to work together despite differences in methodological, epistemological and ontological positions (see Chapter 3). Many issues that arise at very early stages of the research process emerge from simple, yet fundamental, differences in opinion of what constitutes valid research. Reconciling these can be the most difficult stage of the research process (Massey et al., 2006; Petts et al., 2008). Petts et al. (2008) observe there are two issues in particular where misunderstandings between natural and social scientists are common, namely, a distrust of key epistemological positions of the social sciences, and the (mistaken) perspective that social sciences are somehow epistemologically homogenous.

Distrust in epistemological positions

A key misunderstanding in terms of epistemological position arises from the role of subjectivity in research. MacMynowski (2007) contends that the valorisation of mathematics as an objective scientific ideal in the natural sciences leads many to perceive that subjective social sciences do not produce the same level of valid knowledge and consequently bring less power to the interdisciplinary meeting. Similarly, Petts et al. (2008: 598) found from their study that social scientists felt "their authority was undermined by an image of 'soft science' seen as arbitrary, replete with simple insights and open to competition from 'common sense' views of the world" (Petts et al., 2008: 598). If full plurality is to be introduced to integrated research, these issues need to be dealt with. In more than one case researchers have reported social scientists have walked away from integrated research programs as a result of dogmatic adherence to positivist paradigms in the formulation of the research question and approach (Ekasingh & Letcher, 2005).

Within the natural sciences, the complete dominance of positivism means that the attributes of alternatives to positivism are generally poorly understood. As a result, Massey et al. (2006) contend:

> *"the act of 'talking through' epistemological positions was at times difficult, as the individuals were not always able to articulate their particular positions and/or their favoured epistemologies. Nor could they all see the point of the exercise."*

Similarly, Petts et al. (2008: 598) observe that the issue of the validity of epistemological positions constituted "one of the most lively exchanges" of their research program. Thus developing an understanding of epistemologies constitutes an important (and challenging) part of any integrated research project (see 5.4.1). A particular problem is that the interpretivist perspective of many social science disciplines means that a multitude of different approaches can be employed, the breadth of which can lead to social sciences being portrayed as "disunified, in constant conflict, or poorly developed in their theoretical foundations" (MacMynowski, 2007: 5).

Epistemological homogeneity

Somewhat paradoxically, a second issue with integrated research is that integrated research projects often treat social sciences "as if they [are] 'epistemologically homogenous', with a tendency to sideline concepts and approaches that are incompatible with dominant, hard knowledges'" (Petts et al., 2008: 598). From within the social sciences distinctions between the various disciplines are (often) clear – but equally often, are methodological, epistemological or ontological rather than based on the subject area covered. For example, human induced changes in land use can be investigated by a broad range of disciplines (geography, economics, landscape ecology, sociology, etc) and these disciplines (particularly the newer disciplines) have a tendency to borrow methods and theoretical concepts from other disciplines (Musacchio et al., 2005). Consequently multiple social science disciplines can lay a claim to "expert knowledge" within a topic area (and even use the same theories/methodologies) – a situation which differs radically from that expected by natural scientists where, for example, a chemist is unlikely to claim to have the expertise of a hydrologist – even where both of them are working with soils.

In many situations natural scientists are unaware of these differences and, consequently, regard the 'social sciences' as a single disciplinary body (see Chapter 3). For example Deconchat et al. (2007) list their research team as landscape ecologists, forest ecologists, forestry scientists, entomologists, agro-ecologists and 'social scientists'. Pohl (2005: 1173) cites a natural scientist from a long-term transdisciplinary research program (6 years) commenting on his discovery of the diversity present within the social sciences. He/she observes:

> *"When I say 'social science' I think that's defined, but it's not! [Laughing]. There are so many disciplines within social science that work differently and look at the human being differently. Can you manipulate that human being or is it. Do we have a free will? Or do we have intentions or do we just react on what people tell us?"*

Further, he/she also observes an interaction with a 'social scientist' revealed problems that can emerge from making (incorrect) assumptions about any lack of disciplinary distinction within the social sciences. When asked to comment on an evaluation made earlier by a 'social scientist' a colleague 'social scientist' observed "the evaluation at that day was made by a sociologist – I'm not a sociologist. They have another theory ... I cannot use that" (Pohl, 2005: 1173).

A particular problem for integrated research occurs where disciplines selected for collaboration are done so on the basis of their comparability with the desired (positivist) direction of the research program (Petts et al, 2008). Within social science disciplines the methodological epistemological or ontological application of theory can be highly contested subjects, with the contestation itself often based around the positivist application of what are dominantly interpretivist concepts. A good example of this can be seen in the numerous quantitative measurements of ‘social capital’ (crudely, the trust that leads to communities working together to generate economic capital) derived by economists (e.g. Blanco & Campbell, 2007). Despite its frequent use in economics, interpretivist social sciences reject the notion that social capital can be quantitatively measured as, to measure it properly, one must consider the “volume of the capital (economic, cultural or symbolic) possessed in his own right by each of those to whom he (sic) is connected” (Bourdieu,1983: 191). In other words, a researcher would need to interview not only a primary respondent, but all of the social connections comprising their social capital network to establish their level of social capital – a clearly impossible task. As Holt (2008: 231) observes from the human geography perspective “... an understanding of social capital is *certainly not currently measurable* via the large-scale quantitative data sets favoured by many advocates of social capital”. Thus, while the selection of approaches embedded in psychometrics or economics may be “seen as providing ‘real figures’” (Petts et al., 2008: 598) by project coordinators – the absolutely critical issue of how theoretically valid these ‘real figures’ are is often either completely ignored or justified through publication records that are meaningful only to (in this case) economists.

4.2.5 Framing ‘real world problems’ in a research context

Petts et al. (2008) observe that there are two problems in framing real world problems in integrated research. The first is that the problem often needs to be framed in a manner that does not challenge the academic hierarchy. Some researchers have observed that research driven by application needs can be seen as undermining academic research and thus is “at best irrelevant ... at worst threatening” (Bruce et al., 2004: 460) (i.e. to disciplinary self-interests – Lowe & Phillipson, 2006). The second issue is that each participant in the research process may take a different perspective on framing the question. Petts et al. (2008) observed that some natural scientists saw the appropriate methodologies (for examining air pollution) as those of technical risk assessment, monitoring and modelling – and were deeply sceptical about the value of qualitative research. Social researchers, on the other hand, expressed considerable concern that environmental problems are often pre-framed as simplistic physical or technical problems, thus ignoring their social dimensions (e.g. seeing social political and cultural factors as “annoying constraints” that prevented the application of the appropriate methodologies rather than legitimate targets for research). On the whole these differences are not necessarily bad for the research as they represent exactly the sort of complex dimensions to a problem that need to be resolved. However, project leaders must purposively ensure that these perspectives are included in question framing – rather than being excluded or the 'troublesome' elements being allowed to drift away.

4.2.6 Publishing integrated research

Publishing results is a key area of concern for integrated research. There are a number of relatively minor issues in terms of the preparation of papers such as the impact of having a large number of authors (and negotiating the publication), and conflict over first authorship and 'ownership' of the data – all of which may have the impact of slowing the publishing process (Tress et al., 2006). Most problems, however, occur during publishing as interdisciplinary papers are reputed to be more difficult to publish than disciplinary papers (e.g. Heemskerk et al., 2003; Evans & Randalls, 2008; Lau & Pasquini, 2008). Höchtl et al. (2006: 328) observe that this is an issue because some researchers and publishers tend to "still think in tight categories, in terms of specific disciplines" (also see Hammer & Söderqvist, 2001). However, others dispute this. Janssen & Goldsworthy (1996: 272), for example suggest that, while lack of publishers of interdisciplinary work is perceived as a problem "many journals now print papers with a multidisciplinary [meaning interdisciplinary] focus". Similarly, in an assessment of journals accepting interdisciplinary papers (in rural landscape related journals) Tress et al. (2006) found no evidence to suggest that there was any kind of editorial bias against the submission and review of integrative research papers.

Although the willingness of many journals to review transdisciplinary research papers is not in question, the issue of which journals are more likely to accept such publications remains. Petts et al. (2008) suggest that the journals with highest impact factors (critical for career development of scientists – Tappeiner et al., 2007) tend to be those with the longest periods of development and these, in turn, tend to be disciplinary rather than interdisciplinary journals. Lau & Pasquini (2008) similarly contend from experience that even where inter- and multi-disciplinary research is explicitly encouraged in high-ranking journals, the areas where it is deemed permissible are limited to a few selected subjects. The problem here is that the more disciplinary the journal, the more difficult it is likely to be to convince reviewers that the transdisciplinary work is of relevance to the journal, and thus the more difficult it is for the authors to target their work

(Kueffer et al., 2007). In addition, taking in journal articles for review (as Tress et al. 2006 measured) is not the same as having journal articles published[16]. It seems that while the rhetoric is positive, the outcomes (in terms of acceptance of papers) are often poor.

The issue may not be so much that the reviewers and editors are unwilling to accept transdisciplinary research, but rather that reviewers may not feel comfortable judging research papers that incorporate more than one subject area. For example, Höchtl et al. (2006) reported that a reviewer of one of their submitted integrated papers believed the article should be subdivided into several parts, thus distorting the integrative character of the results. The problem is the difficulty in judging the integrative component of the research. Making judgements within the methodological, epistemological and ontological security of one's own discipline is relatively unproblematic. However, while a anthropologist may be able to review the quality of the anthropology component of a study and an ecologist the quality of the ecology they are unlikely to be in a position to judge the quality of the other's disciplinary work. The disciplinary components can be adequately reviewed but the others' disciplinary work cannot and neither can the synthesis – *the key component of integrated research*.

It is evident from the literature that this can act as a major barrier to new researchers engaging in interdisciplinarity. Evans & Randalls (2008: 589), for example, represent perhaps a new breed of researchers in the UK emerging from PhDs funded with the specific intent of producing researchers capable of transcending disciplinary boundaries (ESRC-NERC funded). Yet, in an extremely well written and theorised article that leaves no question as to their academic abilities, they observe that "We have both failed to get papers published that contain scientific and social elements getting criticised by referees for not elaborating enough on the complexities of concepts and debates within their own discipline, while failing to provide enough basics on those from others". A very similar story is presented by Lau & Pasquini (2008: 557) – again, two aspiring interdisciplinary

[16] While Kueffer et al. (2007) observe that over 70 papers mentioning 'transdisciplinarity' or 'transdisciplinary' were listed in the *Web of Science* database for 2005, this must be contextualised within the tend of thousands of papers in the database. Further, it may simply represent an increase in the total number of papers rather than a proportional increase in trans-disciplinary papers being published (see section 1.5.3 for graph). In fact, given the current heavy emphasis on funding integrated research it seems like a rather poor result.

researchers – as they observe "All too often, reviewers assess a paper's strength in relation to their own specialisms ... and its integrative strength is rarely taken on board".

The problem of how to develop researchers capable of judging disciplinary synthesis is a difficult one to resolve. Researchers such as Lau, Pasquini, Evans and Randalls represent possibly the best chance at developing the highly qualified integrated research experts desperately required to create a peer based review process for journal articles (Wickson et al., 2006) and research proposals (Lowe & Phillipson, 2006). Here, we have a paradox. To develop their careers in inter-disciplinary research young researchers need to be able to publish integrated research in good journals and in their chosen areas of expertise (rather than those determined by gatekeepers as suitable for integrated research publications). Yet, if the lack of interdisciplinary experts in the publishing system is preventing the development of new interdisciplinary experts (as suggested above), then these researchers are not going to be provided the opportunity to develop inter-disciplinary – other than through pre-determined disciplinarily controlled routes.

Training researchers with equal expertise in different subject areas is undesirable because it would lend itself to the production of researchers with no areas of deep expertise. We are limited in our ability to read, synthesise and store information and restricted in the time we can allocate to forming research related social networks, participating in exchange programs, attending conferences, and so on. Thus, to maintain the quality provided by in-depth disciplinary understandings, it is not feasible to produce 'experts' capable of understanding the vast array of disciplinary combinations within the social and natural sciences. Yet we require a high level of disciplinary specialism in order to "[guarantee] highly qualified feed-back and reviewing" (Tappeiner et al., 2007: 253). A better option therefore may be to change the review process so that papers are reviewed in panels and reviewers are able to question others in areas where they lack expertise. Currently the blind reviewing system means that it is not even possible to exchange any information with the other reviewers.

4.2.7 Career development

Associated with the publishing issue is the issue of career development of researchers – particularly younger scientists. As part of the EU "Changing Knowledge and Disciplinary Boundaries Through Integrative Research Methods in the Social Sciences and Humanities" project, a Norwegian study showed that too much interdisciplinary work was seen as presenting a risk to the researchers interviewed as it potentially reduced the researcher's chances for further employment (Meltvik, 2006). The extent and time-frames of integrated projects, issues of ownership of data and the difficulties of publishing results in high impact-factor journals can create problems for researchers in the early stages of their careers (Tappeiner et al., 2007; Petts et al., 2008) and, as Jones & Macdonald (2007) suggest, academia today (research organisations and funders in general can be added to this list) are fairly intolerant of failure. This may act as a disincentive for engaging in transdisciplinary projects. In one paper (Janssen & Goldsworthy, 1996: 272) it was suggested that a motivation for not engaging in integrated research is that researchers in transdisciplinary projects do not see "one's name in print as often as one would like to". However, this statement should be regarded with caution as it is not true that the number of publications is likely to be diminished (many integrated research papers list all researchers on the authorship list) nor is it fair to suggest (as career progression within the academic disciplines tends to be heavily reliant on publication record - Jakobsen et al., 2004) that the main motivation behind publishing is seeing one's name in print.

4.2.8 Problems evaluating the results

The evaluation of integrated research is an extremely important part of the research process (Balsiger, 2004) and judging integrated research programs in terms of publications only is not necessarily a good measure of success of projects. Cummings & Kiesler (2005) for example, from a study of 62 integrated projects found publication was only one of many outputs of such studies with other possibilities including: patents, grants, construction of websites, training of scientists, outreach and public understanding, and so on. While these are clearly all measures of the output of the project (and are one form of evaluation of the results), there is surprisingly little attention given to what should be considered the key output of the research process, i.e. the extent to which it resolves the real-world problem it is addressing in the first instance. The reason for this may be the lag times between the undertaking of the research, the implementation of structural solutions (or policy) and the societal, economic or environmental change resulting from the implementation of solutions. In addition, there are likely to be attribution difficulties across the chain, i.e. to what extent was it the research that influenced the solutions and to what extent were the implemented solutions responsible for the change?

It is understandable, given the cost and time-span of integrated research, that only one of the integrated research programs reviewed (Walter et al., 2007) sought to analyse the efficacy of the process. This study used stakeholders' involvement (i.e. degree of engagement) to measure the direct impact of transdisciplinary research on the stakeholders, the intermediate impacts through changes in knowledge, attitude or behaviour, and, finally, the long-term impacts through the increase in decision-making capacity of the stakeholders. Their assessment was made two years after the conclusion of the project – a time which the authors contend should be "long enough for important effects to surface" (329). The authors looked at seven outcomes of the transdisciplinary process to use as indicators, i.e. network building, trust in others, understanding of others, community identification, distribution of knowledge, system knowledge, goal knowledge, and transformation of knowledge. Of these they found significant mediation effects of the two impacts "network building" and "transformation of knowledge" and concluded that the transdisciplinary process was influencing the decision-making capacity of stakeholders.

While the quantitative measures (psychometric scales) employed by Walter and colleagues may provide some means of evaluating the success of integrated research, nevertheless a number of problems still need to be resolved. First, even though the assessment was able to conclude that 'network building' and 'transformation of knowledge' were improved by transdisciplinary research, this still does not necessarily equate to measuring problem resolution. Second, while the authors suggested 2 years was sufficient for 'important effects' to emerge, there is no plausible way of assessing whether this is actually the case as the length of time required for problem resolution is likely to be highly dependent on the nature of the problem being addressed and the means of resolution implemented. Third, the assessment looked only at change in participants – whereas in any real-world situation there will be, in addition, large numbers of stakeholders who are equally affected but not involved in the research process. Real world impacts are experienced in communities, not only in research participants.

4.2.9 Power structures within universities/organisations

Petts et al. (2008) suggest a further problem is that the history of science has been one of competition rather than collaboration – both between individuals competing for funding and between institutes. They point out that there is a discrepancy between government funding systems (such as those in New Zealand) aimed at encouraging competition, and the increasing concern of government that research should be interdisciplinary. One potential impact of this conflict could be a diminishment in the quality of research undertaken as scientists seek to collaborate with research teams within their own organisations – rather than collaborating with the research team perhaps more able to contribute to problem resolution. In any case, this type of funding does not provide an encouragement for organisations planning to engage with expensive integrated research programs. In addition, research bodies are increasingly looking towards knowledge intensive commercial activities and the commercialisation of intellectual property as a means of raising capital or recovering costs (Russell et al., 2007) – an activity which is not generally part of the more socially oriented inter/transdisciplinary research projects.

There have been recent attempts to address funding issues (for example, the development of the interdisciplinary RELU funding for rural research in the UK (Lowe & Phillipson, 2006), the UK's ESRC interdisciplinary early career fellowships (Jones & Macdonald, 2007), The US Environmental Protection Agency's new initiative to fund interdisciplinary research into links between human health and biodiversity (Pongsiri & Roman, 2007), and the NZ government's increase in emphasis on integrated research (e.g. in their environmental roadmap – MORST, 2007). Similarly, in Norway, the funding criteria of the Research Council stress cooperation and integration between research institutions and organisations. While this can create a positive output in terms of encouraging integration, it nevertheless also means that researchers can be forced to find partners outside their own organisation in spite of often being fully or even better capable of doing the job within the organisation, with less coordination and costs involved. The success of attempts to promote integration through funding requirements has yet to be established.

4.2.10 The need for better integrated research training

As observed above, there is a shortage of researchers skilled at integrated research. One often cited reason for this is the lack of training of integrated research methods within the university system. Getting universities to engage in integrated work has long been an objective of transdisciplinarity. Hadorn et al. (2006) observe that the origins of transdisciplinarity as a formal objective in Western or Northern societies extend back to a meeting of the OECD in 1970 where member states discussed how to overcome the continuing specialisation in research and higher education because, according to Jantsch (1972: 101) “the classical single-track and sequential problem solving approach itself becomes meaningless today.” What is of concern is that this observation was made 40 years ago, yet the lack of inter/transdisciplinarity is still a widely observed problem for educational institutions today (Redman et al., 2004; Max-Neef, 2005). Hadorn et al. (2006) contend that the reason for this failure has been a combination of (a) the unexpectedly high level of resistance by academics within universities (although there are good reasons for this – see Giri, 2002) and (b) the failure of the early proponents of transdisciplinarity to sufficiently recognise the role of stakeholders in the transdisciplinary process.

Regardless, the problem is (as Massey et al., 2006, observe in a New Zealand context) that insufficient people come out of university with any experience working with other disciplines. This creates a need for research organisations such as AgResearch to take on the training role themselves in the short term. In the long term, however, there is some evidence that disciplinary boundaries are being broken down. In the field of geography Thrift (2002: 295) observes that geographers must embrace broader interdisciplinary views of the world as the contemporary discipline is not able to consolidate its territory as there are “too many other disciplines interested in its domain and they cannot be kept out”. Whether this applies equally to other disciplines is questionable as geography has always acted as an integrative science (on a spatial basis) both in terms of strong and weak interdisciplinarity. However, it does suggests that interdisciplinary projects may be having an influence on where disciplinary boundaries sit.

4.3 Other problems with integrated research

As the above section illustrates, the act of moving away from a disciplinary to an integrated research culture creates many problems – and these issues need to be resolved if we are to develop an integrated research culture. However, there are a number of issues associated with practical structural considerations of integrated research that must also be considered.

4.3.1 Problems integrating local people into the research

Problems for integrated research also emerge from outside of the scientific community and, in particular, through the need to engage with local people. For example, Höchtl et al (2006) conducted a research project examining environmental change in Northern Italy as a result of land abandonment. In this, they observed a conflict between the demands of funders to deliver useable results within a short time-frame and the need – particularly at the early stages of the research – to establish intensive contacts. Problems occurred where the human factor played "a decisive role in the problems to be investigated" (328) as, in order to understand the human position and thus avoid precipitant action and superficiality, considerable time investment was required. Thus the problem is one of balancing the cost of time at the early stages of the research against the potential gains in the usability and quality of the outcome at the end of the research – and doing so against a backdrop of pressure from funders to deliver results as soon as possible.

Anthrop & Rogge (2006) also found the integration of stakeholder groups into their research to be problematic. Again, in this case, one concern was that the beginning of the research process required considerable investment – in particular to gather and analyse new data to represent the stakeholders position – meaning the deadlines stated at the beginning of the research became hopelessly unrealistic. A further issue was that stakeholders had a tendency to take a 'wait and see' attitude to the research. In other words, the initial stages required a period where the stakeholders were assessing the researchers – a stage which is probably equally as important as that the researchers initial study of the stakeholders.

Another problem identified with the engagement of stakeholders is that, for transdisciplinary research in particular, although assessments may be inclusive and comprehensive, “their research outcomes are often superficial” (Cundill et al., 2005: 8). The authors observed that while they were able to appreciate and record many factors that influenced the system, the time consumed in this process meant that they the ability to investigate and understand key processes declined. An in-depth understanding of the diversity of stakeholder findings was simply not possible in the time frame allocated for the research.

4.3.2 Building trust between scientists and stakeholders

Developing trust is a key issue in integrated research – both between the researchers involved in the project (Jakobsen et al., 2004; Stevens et al., 2007) and the researchers and the stakeholders at the centre of the investigation (Höchtl et al., 2006; Allen & Kilvington, 2005). Building trust is a complicated matter as it involves (a) long term interactions, combined with (b) a great deal of interaction – in order for all parties to ensure that the relationship is a trustful one (Lee et al., 1999; Choi & Hilton, 2005). While this is expensive and time consuming, building trust is extremely important as it reduces uncertainty, helps management of unforeseen contingencies and limits the amount of time spent trying to gauge whether the research partners are performing their role adequately or not.

There are a number of key issues associated with building trust between the scientists in the project. First, at the time of instigation of an integrated research program, bonds between the scientists are often very weak with researchers trained in different areas, publishing in different journals and attending different conferences having had little opportunity to establish social bonds (Cummings & Kiesler, 2005). In fact, there is often considerable distrust between disciplines (Stevens et al., 2007). Second, Jones & Macdonald (2007) observe that ‘essential’ to the development of trust is researchers having the opportunity to work together in the field, to make mistakes together, and to learn from them. This enables practical exploration of each others’ intellectual and epistemological frameworks. For example, experiencing the application of quantitative and qualitative research methodologies in the field may make the value of qualitative research methods clearer to natural scientists (Burton, 2004). Third, of key importance to the establishment of trust is simply for researchers to spend time together (Deconchat et al., 2004; Redmond et al., 2004) and, thus there is a need for integrated research projects to facilitate direct co-working when ever possible.

In addition to the issue of building trust between researchers, the problem solving nature of transdisciplinary work means that it is equally important to build up trust between the scientists and stakeholders and even among the stakeholders themselves. This is one reason why integrated research is time-consuming (Allen & Kilvington, 2005). Höchtl et al. (2006) suggest that 30% of the time in their project was dedicated just to building the trust between the scientists and the main stakeholder group (mountaineers) through informal discussions, workshops, presentations, information events, e-mails and public relations. Deconchat et al. (2007: 4) following the easier approach of unidirectional interdisciplinarity (see chapter 2) estimated that 10% of the project time "was devoted to coordination meetings where theoretical background, field sampling projects, and results were shared". However, this may not be possible in all cases. In particular where the research team is not located in the proximity of the study-site the lack of proximity reduces the frequency of the sort of regular face to face interactions that are required to build trust (Sligo and Culligan, 2007). Building trust among the stakeholders is also an important role of the integrated research – particularly where there is an element of extension integrated within the research proposal and, consequently, stakeholders require help working collaboratively on the problem at hand (Allen & Kilvington, 2005).

There is some evidence that the ability to build trust may be related to the size of the project as smaller projects generally enable more intimate relationships between scientists and between scientists and participants. For large projects, on the other hand trust building exercises such as workshops and field days are invariably more logistically expensive (and therefore such activities may be limited) and, when project-wide communication exercises are held, may be less personal. Trust building exercises – particularly in large complex projects – therefore require considerable thought and planning.

4.3.3 Shifting goals of funders

Antrop et al. (2006: 389) observed in their landscape study in Belgium that the "transdisciplinary integration suffered from shifting goals and expectations of funding bodies during the realisation of the project". This is an important issue to consider. During the normal term of an integrated research program it may be expected that the funding administration may change as may the objectives of the funding body. In addition, as new issues emerge over the time frame of the study funders may require the approach to be refocused on a new issue, or desire different outputs to those originally intended – creating problems, as Antrop and colleagues observe, for the integration of the research as changes in one area may have flow-on effects for others in the project.

4.3.4 Language issues

Another issue with transdisciplinary collaboration is the language of communication between disciplines (e.g. Hammer & Söderqvist, 2001; Uhrwing, 2003; Allen & Kilvington, 2005). The most obvious of these is the use of 'jargon' used by specific disciplines in research which a number of researchers cite as an issue that needs to be clarified (e.g. Spear, 2001; MacMynowski, 2007; Stevens et al., 2007). However, as Antrop et al. (2006) observe, the use of special terminology actually comprises a minor issue in integrated research – and one that is easily resolved through the use of a glossary of terms. Perhaps of greater concern is where a different meaning is ascribed to words common to two (or more) disciplines participating in the research. Müller et al (2005: 197) observe that communication among researchers in integrated projects is often complicated "because they use terms that have different meanings in different disciplines or institutions". An example of this is provided by Jones & Macdonald (2007) who observe problems created by the use of the word 'dynamic' as it refers to a completely different time-frame for hydrologists than for social scientists. Similar problems occurred in the recent EU BioScene project[17] where a considerable amount of time was required simply to develop a common understanding of the concepts of biodiversity, landscape and cultural landscape (Rønningen, pers. com.).

Hammer & Söderqvist (2001) suggest that the need for clarification goes beyond the different meanings of shared terms as disciplines also develop their own metaphors (termed by Attwater et al., 2005, as 'contestable concepts'). Metaphorical languages include for example, Luckett's (2004) 'language of duty', Zhu's (2006) 'language of pluralism' or Giri's (2002) 'language of marginal analysis and regression analysis'. Allen & Kilvington (2006), looking at an integrated research project between ecologists and Maori, observe that the building of a common language first involved building an understanding of the kind of rhetoric

[17] http://bf.publishpack.no/aktuelt/PDF-dok/bioscene.pdf

this language should employ (in their case a 'language of colonisation' – versus an 'environmentalist language'). James & Marcus (2006: 166) contend that there a major barrier to development of the cross-over discipline was that scholars in cultural studies "often use language that is alien to earth scientists, engage in protracted social critiques that are not perceived as germane to natural science concerns, and construct qualitative models that can be seemingly incompatible with quantitative models of natural systems." The authors observe that it is not just language that leads to problems but also styles of writing and data presentation that are accepted forms of communication in natural sciences may not be acceptable in social sciences. Even the 'language of science' can create problems as stakeholders in the research (or even funding bodies) may not understand the basic concepts used in scientific enquiry (Antrop et al., 2006).

It is widely observed that integrated studies should seek to clarify some of these issues at the very early stages of project development (Tress et al., 2007). This should not necessarily mean establishing a single meaning for shared usage (although some authors suggest that "a common terminology and a minimum of jargon is necessary" (Janssen & Goldsworthy, 1996: 271), but, rather, ensuring that other disciplines are aware of differing interpretations – at least of key-words in the study. The reason for this is that the appropriate use of language is needed within the disciplines to maintain the utility of the disciplinary perspectives (Attwater et al., 2005). In writing up the project report these differences need to be made transparent, however, when writing for publication the vocabulary used may have to reflect disciplinary perspectives to progress through the review process.

4.3.5 Costs

A final problem with integrated research that has bearing on all other aspects of the research is that research into complex real-world problems is generally an expensive exercise. When considering undertaking integrated research there is, as Cummings & Kiesler (2005) suggest, a tension between the benefits of working across the disciplinary boundaries and the costs involved in the coordination and development of collaborations. The need to write proposals for complex research programs (often between multiple organisations), to determine what the overall methodology should be (what integrated research actually is – Tress et al., 2004), to frame the problem in the context of the local community, to understand others' methodologies, epistemologies and ontologies, to negotiate and construct vocabularies amongst the scientists, to develop trust between scientists, to resolve language issues, to co-ordinate research between a number of potentially competing organisations, to organise and integrate sub-projects, to write papers as a process of iteration between numerous scientists, and to evaluate the success of the years after the completion of the scientific component means that integrated research often requires a large (if not massive) commitment of resources in order to be successful.

Throughout the research process, as Lawrence & Deprés (2004) suggest, the need for 'close and continuous collaboration during all phases of the research process' leaves activities requiring a level of coordination that is unlikely to be required for disciplinary work. Further, as elaborating the research to deal with new issues that may arise (for example, extending the research or bringing in new partners) increases the cost of the research (McCown & Parton, 2006) the temptation is often to define the extent of the integration not by the optimal level of explanation, but rather by the quantity of research funding that is available. The cost of integrated research is often the key limiting factor in determining the number of collaborators (Janssen & Goldsworthy, 1996).

An issue raised by Stevens et al. (2007) is that the cost of supporting more large-scale, long-term interdisciplinary activities (e.g. the 30% loss of time just to build trust between partners estimated by Höchtl et al., 2006) needs to be carefully considered against the potential return on investment should a similar amount of effort be spent on fewer, small-scale, short-term investigations. For organisations such as AgResearch where funding is entirely competitive this may be a key issue. The cost of building trust between researchers means that the loss of staff will present a greater economic loss to the organisation than were the staff engaged in short-term research. In particular, the costs of training replacement staff in the language, the methodological, epistemological and ontological positions of others, and establishing the new relationships with stakeholders will need to be borne by the organisation in addition to any normal cost of engaging new staff. An additional consideration here is that the turnover of staff engaged in integrated projects can be higher than normal research both because (a) changing timelines and the difficulties of working away from home place scientists under stress (Jakobsen et al., 2004) and, (b) failure to make the research process inclusive (e.g.

by adopting an unagreed unitary approach to the methodology) can lead to staff simply walking away from the project (e.g. Ekasingh & Letcher, 2005; Petts et al., 2007). This can place additional pressure on the remaining members of the research team, potentially slowing the research and further increasing costs (Jakobsen et al., 2004).

4.4 Conclusion

This chapter has reviewed many of the problems encountered by researchers in the process of conducting integrated research. The chapter is disappointingly long, but this could reflect the lack of integrated research projects being conducted (until recently) rather than any irresolvable issues with integrated research per se. In addition, within disciplinary areas many of these issues have already been resolved and accounted for through the development of accepted and standardised methodologies – making them appear less problematic. However, as discussed in this chapter, there is nevertheless an urgent need for the development of integrated research methodologies that are regulated for academic rigour, fit in with established research systems (e.g. allows career development, and is accepted by existing power/political structures), can deal with both the real-world complexity and the need for integration (without compromising the independence of participants), and are able to be evaluated – particularly in terms of the outcomes of the research rather than simple evaluations of the process (as is predominantly the case at the moment). These are the key preconditions for the development of an interdisciplinary science and yet, judging by the literature reviewed, they are also preconditions that are yet to be met.

Nevertheless, in understanding these problems there is hope that we may be able to develop effective means of dealing with them. The following chapter works towards this. By looking at examples where research programs have been undertaken and the method/results critically assessed we can hope to understand what makes integrated research effective and use these lessons to construct research projects within AgResearch.

5. Constructing an integrated research project

5.1 Introduction

The development of a 'best practice' guide for integrated research is problematic. As observed in previous chapters, the problem-based construction of integrated research projects means that the methodology must be developed based on the research problem at hand. There is no single 'best' way of going about conducting integrated research and, consequently, there is no way of producing a guide that is able to be applied in all situations. Nevertheless, clearly some practices are likely to be preferential to others. What is perhaps surprising is that, for all the papers investigating theoretical positions in integrated research, there is surprisingly little literature focused on how to actually conduct the research as published papers generally put little emphasis on discussing integrative research concepts (Tress et al., 2004).

Nevertheless, for the purposes of this review it is imperative that the 'best' means of conducting integrated research are assessed to produce, if not a "best practice guide", a summary of how researchers may like to approach the integrated research problem. Some of the recommendations are more definitive than others – for example, researchers' adherence to their own disciplinary expertise during an integrated research project is (perhaps surprisingly) strongly and widely advised (e.g. Tress et al., 2001; Giri, 2002; Mottet et al., 2007). Note that a number of the suggestions here are not 'unanimous' in the literature – there are simply not enough assessments available to make definitive solutions and researchers from different disciplines have different perspectives. Consequently, rather than using the chapter to provide a definitive checklist of 'things to do' it should be seen as an advisory guide relating the problems raised in previous chapters with possible solutions.

Note that many of the areas discussed here overlap. For example, the development of an environment of trust within the project is dependent on multiple factors such as the effectiveness with which the leader acts as a mediator, the openness of the research process, the structures set up to encourage communication, and so on. While it is simple for disciplinary studies to outline uncomplicated structures for managing projects, the use of multiple disciplines here, the need to deal with epistemological issues, and, above all, the importance of encouraging social factors such as friendship and trust make the defining of a process for integrated research far more complicated. The advisory points are listed and enumerated.

The remainder of this chapter is divided into 6 sections based on advice topics:

5.2 Qualities of leaders, staff and organisations
5.3 Defining the 'real world' problem
5.4 Establishing a collaborative research environment
5.5 Organising and developing research strategies
5.6 Evaluation of the research for funders

5.2 Qualities of leaders, staff and organisations

The quality of any integrated research will clearly be influenced by the quality of the staff involved in the process (both research and administration). The literature suggests many qualities a leader of integrated research should have – some generic to leadership – but others specific to the management of integrated research teams. Leadership is very important in integrated research (Hollaender, 2003). Similarly, the staff recruited for integrated research should have qualities that are conducive to the sort of interactions across disciplinary boundaries they are likely to encounter. Finally, there are qualities the organisation should have to create an environment where integrated research can take place. This section will deal with each of these in turn.

5.2.1 The roles and qualities of leadership

Practice shows that integrated research requires strong leadership to cope with the considerable demands on researchers (Petts et al., 2008). However, it is clear from the literature that 'strong' in this case does not mean powerful, dominating and controlling – but rather the opposite if anything. There are four key areas/ roles in which researcher leaders must have strengths.

1) Leaders must be able/willing to cross disciplinary boundaries

The ability to cross disciplinary boundaries is more than simply the desire/ willingness to cross disciplinary boundaries or even the organisational ability to cross boundaries. As numerous studies have suggested, the key to successful integrated research is in getting researchers to work together and, subsequently, the key quality of interdisciplinary leadership is the ability to facilitate collaboration – not necessarily the leader's standing as a research scientist. Jakobsen et al. (2004) contend from studying two integrated research projects that leadership was most successful where (a) the leader was respected by scientists across the disciplines, (b) the leader was able to integrate disciplines in his/her own mind, and (c) the leader had the ability to communicate effectively with scientists from multiple disciplines. This combination of skills, somewhat paradoxically, makes the role of a project leader in transdisciplinarity an extremely specialised one. Lack of experience in working with integrated research teams can create problems for the research process – for example, leading to the failure to adequately deal with the critical issue of epistemological/ontological differences within the team (Massey et al., 2006).

The question is, how can all these conditions be met? Gaining respect from all scientists, promoting communication and communicating effectively across multiple disciplines requires one skill in particular – namely the ability to comprehend, investigate and communicate to both the interpretivist and positivist perspectives of the social and natural sciences. Ensuring a balanced combination of social and natural sciences is an essential role of good leadership in integrated research (Ekasingh & Letcher, 2005). Janssen & Goldsworthy (1996) suggest that in disciplinary departments it is generally the pre-eminent researcher who has the natural authority (through their established academic credentials) to act as the research leader. However, they warn against following this principle for integrated research. In this case the scientific credentials of the leader are relevant to only one discipline and, as such, are not relevant to all the researchers involved. Instead, they suggest the leaders of an integrated research project must meet the requirements of (a) being well accepted by the other team members, and (b) derive their authority from their quality of leadership rather than individual disciplinary excellence.

2) Leaders must be good motivators

In addition to their ability to maintain power balances within the research team, leaders must also have the ability to both motivate the research team and, in case of disagreements, to mediate between disagreeing parties (Hollaender, 2003). Uhrwing (2003) suggests that the ability to motivate team members is likely to depend on the extent to which the leader has vision for the research and the ability to build links between different cultures. Through providing motivational encouragement the leader should help team members build on their own strengths and, simultaneously, build on the strength of the team as a whole (Janssen & Goldsworthy, 1996).

3) Leaders must maintain the balance of power within the team

Integrated research teams are likely to consist of people with a considerable variety of skills and qualifications – ranging from academically oriented professors to stakeholders on the ground with little formal education. It is critical, in this situation, that any power imbalance between researchers is minimised. Jakobsen et al. (2004) suggest that project leaders therefore need to be aware of the potential difference in educational levels and degree titles among participating scientists and, at the same time, ensure that hierarchies and power structures are minimised in order to facilitate constructive dialogue. Another area where the power balance needs to be maintained is (again) between the social and natural sciences – in order to prevent epistemological differences leading to some researchers withdrawing from the integration process (e.g. Jeffrey, 2003; Ekasingh & Letcher, 2005; Petts et al., 2008).

4) Leaders should try to retain key staff members

Massey et al. (2006) suggest that, while it is common that project team members change in the process of conducting a supradisciplinary project, it is important that at least some of the original project team are retained in order to preserve institutionalised 'project knowledge'. Yet, as noted in section 4.3.5 staff turnover in integrated research projects can be high as a result of the stress of changing timelines and working away from home (Jakobsen et al., 2004) and the failure to make the research process inclusive (e.g. Jeffrey, 2003; Ekasingh & Letcher, 2005; Petts et al., 2008). The research leader should therefore monitor the wellbeing of the staff as a priority as, as noted in section 5.4.2, the trust between researchers and the collaborative relationships are central to the success of integrated research. Losing key staff means the slow process of establishing these may have to begin anew (which may both be expensive and slow the research process).

5.2.2 The roles and qualities of integrated research scientists

As with leadership, integrated research also requires a different skill set of participating scientists than is required for disciplinary research. In terms of general skills, individuals engaged effectively in integrated research generally display a good attitude to the process, have good communication skills, are well educated, and have experience in research (Janssen & Goldsworthy, 1996).

5) Integrated research scientists must be 'team players'

Given the importance of working with other researchers, the requirement that interdsicplinary/transdiscipliany research scientists should be team players is fairly self-evident. Jakobsen et al. (2004) observe that the interpersonal skills of team members are important for the success of integrated research projects. However, not only must members have the interpersonal skills to work with other team members, they must also be committed to knowledge sharing and show a willingness to accept others' positions (Massey et al., 2006). As Janssen & Goldsworthy (1996: 270) suggest, "If a team is to address multiple objectives effectively, individual team members must be prepared to view their disciplinary ability as a contribution to a joint goal, and respect the contributions from other disciplines" and consequently "individuals must be prepared to accept constructive criticism and to overcome misunderstandings" (272). This also requires that researchers accept that the process of integrative research is time consuming (they should be made aware of this) and that, consequently, there will be costs in terms of the scientific productivity of the research process (Deconchat et al., 2007).

6) Integrated research scientists must be 'problem oriented'

The will to engage with researchers from different disciplines requires that the research scientists are oriented towards problem solving – rather than focusing on academic or theoretical questions, i.e. "team members have to be problem oriented" (Janssen & Goldsworthy, 1996: 270). In part this is a result of concerns that problem oriented research is sometimes seen as undermining the academic credentials of research (Bruce et al., 2004: Petts et al., 2008) and thus, where the researcher is not determined to address the problem, the temptation may exist to revert back to more disciplinary oriented questions. Discerning who is and who is not 'problem oriented' is another matter. Jakobsen et al. (2004) suggest that the inclusion of members in the team who are already experienced with transdisciplinary research may help with future research projects: however, even this is no guarantee that the researcher is problem oriented.

5.2.3 The roles and qualities of research organisations

In addition to leaders and individuals, research organisations also have an important role to play in ensuring the success of integrated research projects. In fact, while it is not given the same level of attention as analyses of leadership and individual qualities, the extended nature of integrated research and the high costs (in terms of both time and money) incurred mean that the attitude of research organisations towards integrated research is as important as that of the scientists involved in the research.

7) Maintain a strong team in-situ

Fundamental to this is the role of research organisations in maintaining research capacity. Pohl (2005) observes from experience with an integrated research project that researchers require "several years of collaboration to become acquainted with and develop respect for the other 'culture' before they will be able to develop joint concepts. This is the equivalent to the first funding period of a possible 6 year grant." This emphasises the importance of maintaining a strong team in situ in order to deal with integrated problems. Whereas in disciplinary sciences it may be relatively easy to replace one scientist with another with a similar skill set, the extent to which integrated research is based on personal relationships between individuals means that rebuilding an integrated research team for each project is likely to be an expensive business. For example, if every project has to begin with developing an understanding of key concepts, establishing trust, etc. it is likely to both add heavily to the costs of the project (e.g. the 30% loss of time just to build trust between partners estimated by Höchtl et al., 2006) and delay the start of the research process.

One way of maintaining continuity between contracts (suggested by Janssen & Goldsworthy, 1996) is to ensure that the leader of the research project has an additional role of ensuring continuity between contracts and thus, once an effective transdisciplinary team has been established, there is a long-term future that prevents the team from dispersing and losing its collective knowledge and social capital. The cost of building integrated research teams raises another important issue for research organisations such as AgResearch. Any strategic decision to engage with large-scale, long-term integrated research projects, needs to receive a long-term commitment and, as Stevens et al. (2007) suggest, careful consideration needs to be given concerning the potential return on investment should a similar amount of effort be spent on fewer, small-scale, short-term investigations.

5.3 Defining the 'real world' problem

5.3.1 Establishing and framing the problem

8) A clear research problem must be identified early on

The research problem provides the skeleton on which all research will hang throughout the duration of the project and is, therefore, an extremely important part of the research process. In order for the researchers involved to feel engaged with the research processes each must feel that they are addressing a question relevant to the solution and, consequently the problem should define the nature of the research and, indeed, the composition of the research team (Höchtl et al., 2006). As part of the problem definition the initial problem (as identified in the funding proposal) needs to be reformulated in a way that fits the scientific approach (Balsiger, 2004). Failure to define a clear research problem results in major problems for the integrated nature of the research. For example, Janssen & Goldsworthy (1996) observe that two ways in which integrated research is likely to fail are (a) when the problem environment is identified but the research attempts to address many different problems within it rather than establishing a clear common problem, and (b) when integrated research attempts to resolve all problems simultaneously rather than focusing on a single problem. Similarly, Antrop et al. (2006) report that one reason their project failed to attain true transdisciplinarity was the lack of a clearly defined research question to address. While the existence of a research problem may seem like a prerequisite to conducting integrated research, as the final question is not derived until after the researchers are recruited (i.e. somewhat after the funding has been obtained), identifying a clear research problem remains a key objective for all integrated research projects in the early development stages.

5.3.2 Identifying and defining the research problem

9) Engage stakeholders in problem definition

Given that integrated research is focused on 'real-world' problems, the best way to define a research problem will clearly involve the engagement of stakeholders at a very early stage of the research. This is common practice in integrated research. For example, Höchtl et al. (2006) made frequent visits to the research area (in northern Italy) in order to further define the human perspective of the research problem. This, they contend, enables researchers to see (and reflect on) the problem from different perspectives. This should be part of a process that continues throughout the research rather than being seen as a 'one-off' process of problem formulation. The research (and therefore the researchers) must, according to Wickson et al. (2006) become embedded within the local communities under investigation – although they observe that it is also important that the researcher retain some level of critical distance from the problem. Nidumolu et al. (2006) also suggest that it is also important in the early stages to gauge the expectations of stakeholders and that engaging stakeholders increases the likelihood of their acceptance of the outcomes of the research. Problems can occur when the expectations of the stakeholders are raised without stakeholders appreciating that the research process must remain flexible and, hence, does not guarantee a single desired outcome.

10) Defining the problem must be done as a team

It is important in the early stages of the research to engage not only stakeholders in the problem definition, but all members of the research team. Hollaender (2003) observes from a survey of researchers engaged in integrated research that 90% of respondents considered that formation of joint research goals is an important part of the research process (the highest reported response). The reason for this is clear. Different disciplines take different perspectives on research problem (e.g. seeing air pollution as a *technical* or a *human* problem, e.g. Petts et al., 2008) use metaphorical languages incompatible to other scientists (Hammer & Söderqvist, 2001), maintain different 'worldviews' (Massey et al., 2006), and so on. At the same time, for integrated research to work it requires high level of cooperation, communication and trust between scientists (see Chapter 4) – all of which are likely to be hindered should there be any attempt to force a single (unagreed) problem formulation on the research team. As Uhrwing (2003) observes, researchers need to share objectives and identify with the research team to which they belong.

11) Be prepared to redefine the problem (and research team) during the research

While defining the research problem in the beginning is a key step in the research, it is equally important that this not be regarded as a 'fixed' problem. Walter et al. (2007: 11) observe, for example, that the research process "must be designed to be as open and flexible as possible such that neither the exact goal nor the exact composition of the participants can be determined beforehand." Throughout the research the problem formulation will change as more information is collected about the study site or research area, new sources of knowledge are integrated into the process, and researchers come and go from research teams. This results from the need for praxis between the theoretical and practical forms of knowledge. Wickson et al (2006: 1053) suggests that theoretical and practical knowledge should be visited iteratively such that theory is remade through insights gained from practice and vice versa. This, the authors suggest, should eventually lead to a point where practice and theory are integrated or resonant – although they contend that the practical application of this process is "one of the integrative challenges for transdisciplinary researchers". Maintaining this iterative process between theoretical development, practice knowledge gathering and question formulation is a common responsibility for the research team (Hollaender, 2003). While it is not necessarily the easiest option for the research (it is more common in disciplinary research to identify and then stick with a common research question), failure to remain flexible could result in a one-dimensionality to the research outcome as rigid definitions limit the ability of the research to explore emerging knowledges (Hollaender, 2003; Uhrwing, 2003).

12) Use the problem to define the approach – not vice versa

A related issue raised by Höchtl et al. (2006) is that researchers should bear in mind that it is the problem that should define the research program, not vice versa. This ranges from the composition of the research team to the methodological and theoretical stances held within the project. Failure to do so may limit the ability of the team to redefine the research question in response to any new knowledge generated.

5.4 Establishing a collaborative research environment

As observed in Chapter 4, many of the problems with developing integrated research are associated with the ability of members of the research team to work together – rather than the problem itself. Consequently, an important aspect in the establishment and management of integrated research program is the need to establish and maintain the unity of the research team. This is a key role for any leader of an integrated research program (see 5.2 above).

5.4.1 Breaking down epistemological barriers

13) Outline personal epistemologies/ontologies early in the research

The importance of epistemological and ontological issues to the conducting of integrated research has been discussed at length in Chapter 3. Essentially, there are strong tensions between different disciplines engaged in integrated research programs (particularly the natural and social sciences – Gregory, 1996) that must be dealt with early in the project. Massey et al. (2006: 135) contend that the outlining of personal epistemologies facilitates the selection of a framework and methodology to address the research question. They further contend that there needs to be a process whereby those with expert knowledge in the field "enlighten other members of the team in terms of the vocabulary of the dairy industry [the subject of their study] and its seasonal peculiarities" – not with the intention of identifying a preferred epistemological or ontological position for the project, but rather to reach an understanding on how these differences were likely to effect the operation and outcomes. The authors observe:

> *In practice, the act of 'talking through' epistemological positions was at times difficult, as the individuals were not always able to articulate their particular positions and/or their favoured epistemologies. Nor could they all see the point of the exercise. (136)*

In the end they came to a joint decision that "different epistemological and/or ontological positions would be respected and valued – and that there would be no single dominant paradigm" (Massey et al., 2006: 136) thus the methodology/ epistemology was to be a pluralistic one. The objective of this process is thus not to agree on a single epistemological position for the research, but rather to enable researchers to understand others' positions and reach agreement on how these components should fit in together and thus promote methodological pluralism, i.e. to "identify the strengths and weaknesses of different methods, and view them as complementary – addressing different kinds of question" (Midgely, 1996: 25) – an important feature of transdisciplinary projects in particular (Attwater et al., 2005).

14) Encourage researchers to see alternate perspectives

Researchers working on different aspects of the same system within disciplinary bounds should be encouraged to look at the system from the perspective of others. For example, the ecologists in Allen & Kilvington's (2006) study needed to understand land use change from the perspective of the 'language of colonisation' to understand the Maori perspective on ecology. At the same time, the Maori group needed to understand that the issue could be looked at from an ecological perspective rather than just one of colonialisation. This issue reflects a particularly problematic division cited by Tress et al. (2001), i.e. that it is a common error for researchers to divide landscape into natural and cultural whereas the key to integrated research is for researchers to see it as a social-ecological system. It is as important for social scientists to accept the role of natural processes in environmental/ecological issues as it is for natural scientists to accept the role of cultural factors. As Lawrence & Després (2004) suggest, the maintenance of ontological frameworks that fail to embrace the complexity of the human/natural environment is one of the main barriers to integrated research.

5.4.2 Ways of encouraging collaborative research

15) Develop and maintain open dialogue/debate

Central to enabling researchers to see alternative positions is the development of open dialogues within the research team – an objective which may or may not occur organically as a matter of course. As Lawrence & Després (2004) contend, the lack of communication between scientists, politicians, the public and interest groups is one of the main barriers of integrated research that needs to be dismantled. The purpose of open dialogue is to encourage people to abandon the perspective that their point of view is the only point of view and to prepare researchers for the emergent synthesis of ideas (Tress et al., 2001; Giri, 2002). Deconchat et al. (2007) suggest that open dialogue means researchers essentially (a) listening to people discussing ideas not directly related to their own work and

(b) presenting their work to people not directly involved in it – and that this kind of dialogue plays a major factor in enabling the co-construction of the project and its results. This need to overcome personal barriers means that integrated research places a strong focus on the building of personal relationships and joint understandings (Naveh, 2005). Jakobsen et al. (2004) and Deconchat et al. (2007) advise this must be done through 'concrete activities' such as establishing question and debate stages (e.g. on the different meanings of concepts) and the establishment of paper writing teams that cross disciplinary boundaries. Keeping the dialogue open is particularly important given that it may take several years of collaboration before researchers begin to understand each others' research culture and develop joint concepts (Pohl, 2005).

17) Develop an understanding of others' language/ key concepts

Understanding others' language and key concepts is vital as failure to understand disciplinary languages is one of the key factors leading to a lack of trust within a research program (Stevens et al., 2007). However, as discussed extensively in Chapter 4, this refers to developing an understanding of others use of terminology and not, as some have suggested, to the development of a common terminology (e.g. Janssen & Goldsworthy, 1996; Massey et al., 2006). The shared understanding should be more in the form of a dictionary than a new language shared only within the project as developing 'project interpretations' for terms can make it difficult for the results to be disseminated beyond project members (see section 4.3.4 for further discussion).

18) Develop trust and friendship between scientists and others

Developing trust is "an intangible but crucial and constructive element of integrated research" (Redman et al., 2004: 168 – cited by Deconchat et al., 2007) – both between the researchers involved in the project (Jakobsen et al., 2004; Stevens et al., 2007) and the researchers and the stakeholders at the centre of the investigation (Höchtl et al., 2006; Allen & Killington, 2006). While this is expensive and time consuming, building trust is extremely important as it reduces uncertainty, helps management of unforeseen contingencies and limits the amount of time spent trying to gauge whether the research partners are performing their role adequately or not. Trust, however, is an elusive quality that cannot be quickly or artificially created but emerges as the result of numerous (often apparently insignificant) exchange interactions between members of a research team – i.e. through the process of collaboration or simply spending time together (Lee et al., 1999; Redmond et al., 2004; Choi & Hilton, 2005; Deconchat et al., 2007; Jones & Macdonald, 2007). Consequently, trust is likely to be created through the establishment of other components of integrated research that promote collaboration between scientists, for example, joint publications, shared fieldwork, open discussions on epistemology, joint problem framing, etc. Jones & Macdonald (2007) suggest from personal experience that the existence of trust prior to the undertaking of the research is not sufficient alone to guarantee its success as trust can also be lost in the process of conducting the research if the processes are not in place to ensure its creation. Thus, even where trust exists before the project (e.g. through an established research group - see 5.2.3) attention must be also given to trust building within the project.

19) Provide opportunities for informal interaction

A number of researchers have suggested that the provision of opportunities for informal interaction amongst the research team facilitates integrated research collaboration. Jakobsen et al. (2004) suggest this could be done by ensuring that formal activities are accompanied by opportunities for informal interaction such as dinners or lunches before, after or during meetings and using shared transport when undertaking fieldwork. These occasions facilitate collaboration by providing researchers with the opportunity to socially connect with others in an environment where (often well defended) epistemological or ontological positions are simply not an issue. As Winder (2003) observes, these informal events can allow the building of friendships between the research team and this can help build mutual respect. Heemskerk et al. (2003) suggest from interviews with scientists working on interdisciplinary projects that accompanying other researchers while they undertake their fieldwork is beneficial in this regard. However, they also warn that asking people to collect data with other disciplines as a matter of routine (rather than to see how it's done) is an ineffective use of resources.

20) Maintain team building efforts throughout the project

A frequently mentioned recommendation for ensuring collaboration and effective integrated research is the need for researchers to maintain frequent contact throughout the project – and not as a one-off action in the beginning (e.g. Höll & Nilsson,1999; Massey et al., 2006). The key reason for this is that, because of the time-span of integrated research projects, there is often a lot of staff movement in and out of the team (see section 4.3.5). Deconchat et al. (2007) suggests that the need to integrate new people who do not share the experience of others in the team comprises a 'serious difficulty' in integrated research and requires a "sustained and continuous effort" to be successful. Entering into an integrated project in the middle of a project rather than at its conception makes it difficult for new researchers to integrate properly with the research team – particularly if their epistemological positions conflict with those already selected. In this case, the same issues discussed at the beginning of the research (see 5.4.1) need to be revisited if the team is to remain a cohesive one. The need for regular meetings is also compatible with the iterative nature of the research program and regular reframing of the problem – e.g. Hollaender (2003) found from their questionnaire of researchers engaged in integrated research projects that 55% of respondents believed that continuous exchange throughout the project was important for the project to function.

21) Maintain mixed rather than disciplinary research teams

It has been suggested that encouraging integrative collaboration is best served through organising the research into mixed rather than disciplinary research teams. Using mixed teams is likely to encourage work and information sharing across disciplines and limit the development or maintenance of discipline-based power hierarchies among participants (Jakobsen et al., 2004). This is one way of encouraging the day-to-day interactions between scientists necessary for building trust within the group as discussed above. Loibl (2006) gives the example of a project where mixed teams were created as a result of needing to simplify project management – but these teams (after initial conflict) performed better than the planned teams that had started off harmoniously. Essentially, at some stage conflict inevitably arises and, Loibl contends, it may be better to establish an open culture of confrontation at the beginning of the research rather than later. On the other hand, Massey et al. (2006) observes that mixing teams can also be problematic as, unless researchers willingly engage with the integrated research process (see 5.2.2.) – and, in particular are willing to lay aside epistemological differences – mixed research teams can provide an arena for constant conflict rather than problem resolution. The example they provide is of a meeting to discuss the research protocol for qualitative farm interviews that was 'hampered' by the presence of quantitative researchers (psychologists) because of their lack of understanding of field practices related to qualitative data collection.

22) Consider publishing (where to publish) prior to undertaking the project.

The issue of publishing (or the nature of and credit for publications) can prove a particularly divisive one for integrated research programs (see section 4.2.6). Tress et al. (2006) observe that there is great potential for conflict over issues such as first authorship of publications the ownership of data and which journal to publish in. This is particularly a problem as the highest ranked journals (and therefore the most useful in terms of establishing an academic career) tend to be disciplinary (Petts et al., 2008) and career progression for researchers in disciplinary departments may be dependent on publishing in certain key disciplinary journals. To complicate the issue further, some researchers may prefer to aim publications at industry while others are more concerned with academic publications as observed by Massey et al. (2006). Developing a written strategy on publication and ownership issues at the very early stages of the project may help avoid conflict further down the research path (Pohl, in press) – however, equally, these issues may be resolved through building trust and collaboration as mentioned above. The potential scale of authorship when publishing from large integrated research problems suggests that the process may be made simpler by following Penker & Wytrzens's (2005) suggestion that the division of papers should be based on standalone modules within the research – and not negotiated amongst the entire research team. A further possibility to encourage the career development of staff members is to work towards publishing some papers in disciplinary journals.

5.5 Organising and developing the research strategies

5.5.1 Working together in the research process

23) Select appropriate disciplines for the research process

The selection of disciplines for engagement in the research process is key to the success of the research process as the team must have the right composition to deal with the particular complexities relevant to the research problem and, simultaneously, the extent of integration should be determined by the level of complexity of the problem (Balsiger, 2004).

24) Adjust the research team once the problem has been defined if required

It is important to note that the selection of disciplines for the project is likely to go through two key stages. Because the construction of the research team must reflect the research problem, the final construction of the team may not be known until the research problem is fully defined. For example, Flamant et al. (1999) observe that their integrated research project went through two stages. First, the 'diagnostic survey' phase focusing on problem identification and involving a high level of interaction with stakeholder communities. For this stage, the contribution of social science disciplines was important, namely; geography, agronomy and sociology. For the second stage – the 'modelling phase' – the authors note that specialists from animal production science (e.g. nutritionists and product technologists) were used more widely. While a stage based process will not apply to all studies it provides an important reminder that the research team must be able to respond to changes in problem definition – including (or even excluding) research components as required. The value of integrated research is limited if the research is fixed according to, for example, the disciplinary backgrounds of the original team who applied for the research funding.

25) Involve all the research team in designing the research method

As noted above, the involvement of the whole research team in early stages of the research process is useful for the development of trust and collaboration. However, it is also useful in terms of promoting integration of the research methods themselves – for example, Kooistra & Kooistra (2003: 616) observe "Careful integration of the first steps of research procedures enables correlation of individual results, justifies cross-links and references and leads to higher levels of integration, not possible otherwise" (also see Mottet et al., 2007). This should naturally follow on from the team based definition of the research problem (see 5.3.1) and should be accompanied by a consensus on the overarching goal or purpose of the research (Tress et al., 2001)

26) Allow all the research team access to the emerging results

Höll & Nilsson (1999) suggest that integrated work is promoted by making research files and data available to all project participants (comprising, in their case, GIS maps, floristic and faunal registration, and the results of extensive farmer interviews).

27) Provide regular reports to researchers of project progress

Janssen & Goldsworthy (1996) observe that regular progress reports are a necessity for integrated research program. They suggest that the high turnover of staff and time pressures means that there needs to be a means of rapidly familiarising new team members with the project. In addition, regular reports may facilitate a spirit of openness amongst the team (and therefore help build trust and collaboration) as well as assisting team members to understand the positions of other members of the team.

28) Integrate the knowledge of local stakeholders

The need to involve stakeholders in problem definition identified in section 5.3.1 also applies to the need to integrate their knowledge into the research stage of the project. As Deconchat et al. (2006) contend, indigenous knowledge based on direct experience with the local situation provides an important additional source of information to the scientific knowledge (in their case, concerning the management of natural resources). They further suggest that social sciences such as anthropology and sociology can provide necessary viewpoints for formulating and dealing with the type of questions likely to arise. Integrating the knowledge of stakeholders is particularly important as far as dealing with sustainability issues is concerned as there is generally a need to integrate the scientific knowledge with scientific knowledge to generate mutual learning between researchers and practitioners (Hadorn et al., 2006). Höchtl et al. (2006: 328) observe from their research that “The inclusion of indigenous knowledge, which is seldom recorded systematically in written form, was the key to an improved understanding of many sub issues. The systematic body of knowledge acquired from the locals through the accumulation of experiences, informal experiments, and intimate understanding of the environment sustained the development of perspectives for the future of the studied communities”. They further contend that the integration of the knowledge of local stakeholders helped to enhance the validity and transferability of the results.

29) Immerse researchers within the study area

As stakeholders form an integral part of an integrated research project (particularly a transdisciplinary project), it is important that they be fully engaged in the research program. The advantages of this approach fall mainly into areas 5.3 and 5.4 above – i.e. greater integration within the community aids in problem definition (through more open and rapid dialogue) and provides an opportunity for improving the collaborative research environment. Note, however, that immersing researchers within the research area can be an expensive exercise so the expected benefits of such an approach should be carefully considered. For some disciplines (e.g. sociology, anthropology, human geography) immersing the researcher in the research environment can be a standard practice of the research process (e.g. ethnography or participant observation – see Bryman, 1988; Crang, 2002).

5.5.2 Structuring the research approach

Developing an integrated research strategy to progress the research process is a key stage in addressing the research problem. As noted in the introduction, there is no single way of conducting integrated research. However, there are issues that are common to all research programs and will need to be dealt with by the research team to achieve positive results.

30) Do not adopt a single epistemological position to simplify the research

As discussed in Chapter 4 it is easier to make integrated research 'successful' (e.g. Stevens et al.'s, 2007 description of Santelman et al., 2004) by following a single epistemological position (i.e. engaging only social scientists who prescribe to positivist epistemologies). However, while some researchers (particularly from systems analysis or cybernetics) maintain that a unitary approach is both possible and desirable (Costanza, 2003), the notion is widely rejected – even in the systems literature (see section 3.3). For example, Barton et al. (2004: 30) suggest that many in the systems community "harbour the fundamental belief that the tendency in deductive scientific method to achieve rigor by disregarding important features of complex social gestalts must be resisted". In Jackson's (2001) outlining of Critical Systems Thinking he acknowledges "... that paradigms are based upon incompatible philosophical assumptions and that they cannot, therefore, be integrated without something being lost." The reason for this can be seen in Chan et al.'s (2007: 63) lamentation on the reportedly 'fruitful' collaborations between economists and conservation biologists on the basis of a shared interest in modelling. They suggest that, in doing so many social science disciplines (namely cultural anthropologists, human geographers, and social historians) have been neglected and that "This is a shame because these are the scholars who can best inform conservationists about the social and cultural implications of conservation work." Lund et al. (2006: 47) make a similar observation with respect to animal welfare work. They observe that, therefore "scoial science must not be looked upon only as a 'service sciecne' with the primary purpose of implementing the findings of the natural sciences."

Note that, as with all integrated research this will depend on the nature of the research problem. As noted in Chapter 2 integrated research comes in 'weak' and 'strong' (Max-Neef, 2005) or 'big' and 'small' forms (Kutílek & Nielsen, 2007) with 'weak-small' forms defined as those that do not cross the epistemological divide between the natural and social sciences. While few studies are likely to fall into this category there are examples in the literature where success has reportedly been achieved with the weak forms of integrated research. For example, de Jong et al. (2008) reported success in their "transdisciplinary analysis of water problems in the mountainous karst areas of Morocco" involving geologists, hydrologists and biologists[18]. In general, however, if a single epistemological position is to be adopted it should be considered very carefully and should be conducted only in agreement with all the participating scientists and local stakeholders.

31) Researchers should remain within their disciplinary backgrounds

It is perhaps slightly surprising, given the objectives of integrated research, that there is a strong emphasis in the literature (particularly those studies that assess real-world examples of integrated research) of the need to maintain disciplinarity within integrated research projects. Janssen & Goldsworthy (1996) observe that integrated researchers have a tendency to try to extend themselves into other fields of disciplinary interest but contend that 'this should be avoided' (also Gunderson, 2004). In their case the argument was largely an economic one – i.e. that specialists are more effectively used if they continue to focus on their

[18] Note, as discussed in Chapter 4, it is difficult to truely judge the level of success of such small-weak projects as, as with any integrated research, the extent to which the problem is solved is rarely assessed (and was not assessed in this example).

specialist area. However, other researchers contend (very strongly) that there are more fundamental reasons for remaining within one's discipline – principally that it is disciplinary expertise that provides structure and legitimacy to the integrated research process (Robinson, 2008). Statements within the literature are very strongly worded in this regard. For example, Tress et al. (2001: 140) from the field of landscape ecology/architecture observe in their recommendations for future transdisciplinary research that:

> *"Disciplinary backgrounds are a precondition for transdisciplinary research. Transdisciplinarity needs researchers who are well educated and firm in their own disciplines, but open-minded enough to transcend their disciplinary borders".*

Similarly, Mottet et al. (2007: 300) from a social-ecological perspective observe:

> *"The interdisciplinary questions must be answered without altering the coherence of the disciplinary approaches."*

Heemskerk et al. (2003: 8) conducted a workshop with scientists engaged in inter-disciplinary research and concluded that:

> *"the consensus was that high-quality interdisciplinary science requires skilled disciplinarians who are curious about theories and methods in other fields"*

And Giri (2002: 108) from a development studies background, contends:

> *"Transdisciplinarity calls for an art of authentic embeddedness in one's discipline and transcendence does not mean cutting off from the ground where one stands but widening one's horizons. In the practice of creative transdisciplinarity, transcending our disciplinary point of view provides us a new experience of immanence, of our immanent existence within our disciplinary homes" [emphasis added]*

A key aspect of this comment is the observation that crossing disciplinary borders is only possible when one has a firm understanding of where the border of one's own discipline lies. As Winder (2003) contends, the researcher needs an intuitive sense of where their own borders are in order to cross other intellectual borders. The author goes on to provide an explanation for why a 'melting-pot' approach in which every participant is completely embedded in all aspects of the research is "self-defeating" by suggesting that this would involve the development of a single over-arching world view and involve researchers repudiating their own knowledge bases. The impact would thus be to create a state of ontological insecurity within the research team rather than a conducive environment for progressing research.

There is also some doubt as to whether training researchers to work across disciplines necessarily makes integration easier. While evidence is limited, one study that looked at people trained in both social and natural sciences found that there was no difference between the epistemological barriers perceived by single disciplinary scientists and those with a background in both natural and social sciences (Tress et al., 2007: 382). The authors contend "a background spanning the natural and social sciences/humanities does not necessarily lead to a higher suitability for integrative research."

Extending researchers into other disciplines also raises the possibility that the research project may be overtaken by a belief in epistemological relativism (the contention that any knowledge system is as good as another – Winder, 2003). As noted in the earlier discussion this must not become the basis for integrated research programs as not all knowledge is equally valid. It is particularly problematic when disciplines begin borrowing theories from other disciplines as is relatively common in newer disciplines (Musacchio et al., 2005). While it may be possible for theories to cross disciplinary boundaries there is a danger that the understandings underlying the theory (and required for its successful or meaningful operation) will not (see the discussion on economists use of the concept of social capital in section 4.2.4.2). Alternatively, the theory may become diss-embedded from its theoretical origins over time such that theoretical developments in the parent discipline are not transferred to the 'borrowing' discipline (e.g. Burton, 2004 describes the incorrect use of the theory of reasoned action in agricultural geography following its dissembedding from theoretical developments in social psychology). In either case, the most effective way of guarding against these issues is remain immersed within one's own discipline. This enables the researcher to make a strong contribution to interdisciplinary debates when relevant issues emerge.

32) Do not employ a single 'core' or ' integrating' discipline or theory

Jakobsen et al. (2004) observed that in some disciplinary projects a single core discipline may dominate and effectively control the integration of knowledge (e.g. adopting a modelling approach as a unifying framework). Deconchat et al. (2006), for example, advocate the use of landscape ecology as a core discipline around which 'concentric components' rotate – to provide a central axis as a stabilising factor that "regulates the project development in its centrifugal dispersion tendency". Vos & Meekes (1999: 11) similarly promote landscape ecology as a core discipline for investigating social-ecological issues (although not as explicitly as Deconchat and colleagues) as, they suggest, it takes a multiple point of view (e.g. hydrology, zoology, geography), and looks at the historical, present and future role of humans – thus making it the 'interdisciplinary science par excellence' (also see Haber et al., 2004, Fu et al., 2008). Systems thinking has similarly been advocated as a core discipline. For example, Bosch et al. (2007: 217) report on a study where "Systems Thinking facilitated the sharing and integration of disparate sources and forms of knowledge".

By selecting a core discipline research programs can effectively deal with the problem of integrating methodological, epistemological and ontologically varying disciplines through basing the research around a discipline that purports to integrate both positions – thus enabling the investigation of complexity (through attaching numerous 'concentric components') while maintaining a clear integrating component. However, the approach is strongly criticised in the literature. Müller et al. (2005: 197), for example, warn that research design needs to be conducted in a balanced way to avoid developing a project that is "based on a hierarchy of one integrating discipline and several serving disciplines."

This is for two key reasons. First, for these disciplines to act as the focus for integrated research they must be demonstrably capable of integrating the various research disciplines and, critically, have dealt with the issue of how to settle epistemological differences between the natural and social sciences. This is definitively not the case. Landscape ecology is reported to be a 'discipline' in continual conflict between those from a biophysical and landscape architecture background (Bastian, 2001; Antrop, 2003) with the two sides not even sharing a common language (Antrop, 2003). A similar battle has been waging for many years within systems thinking between the interpretivists and positivists as 'hard' and 'soft' systems thinkers dispute the validity of their perspectives (Midgely, 1996; Jackson, 2001, 2006)[19] and between those who believe in unitary theory (e.g. François, 2006) and those who advocate methodological pluralism (e.g. Taket & White, 1998)[20]. The question must then be asked: If these disciplines are unable to resolve the most fundamental of the integrated research debates internally (and over decades) what hope is there that they can resolve the debates between scientists in philosophically opposed disciplines new to the notion of integrated research? The 'core' disciplines provide a source of integration only in that they have a history of dealing with integrated systems problems – whereas the fundamental problem in integrated research is how to get research scientists from a wide range of disciplines working together.

Second, by selecting a core discipline to provide the framework for the research the ability of the project to produce new syntheses of information is already limited to that permissible within the framework of the core discipline (i.e. pluralism is significantly reduced) – and that framework in the case of both core disciplines is overwhelmingly positivist (the same could be said of the common collaborations between economists and ecologists as noted earlier). Thus past reported success using 'core disciplines' (e.g. Vos & Meekes, 1999; Deconchat et al., 2006) is as likely to be as attributable to sharing a positivist focus with natural science disciplines as their focus on human/ecological interactions or experience in problem solving. The use of core disciplines thus deals with the problem of integrating complexity by sacrificing the ability of the integrated research problem to deal with diversity – i.e. the problematic integrate-diversify paradox inherent in integrated research remains unresolved (see section 4.2.3). It should also be observed that the key advocates of employing integrating disciplines are proponents of those disciplines themselves. For example, in Deconchat et al.

[19] Pollack (2006: 384) suggests that "At a philosophical level the different paradigms [soft and hard] can ... be thought of as mutually exclusive".

[20] Although some doubt the sincerity of this move. Zhu (2006: 769) concludes in his investigation of pluralism "It then posited that, particularly, the recent grand transformation from complementarism to pluralism is more presentation than spirit; more repackaging than substance."

(2006) and Vos & Meekes (1999) the lead authors are landscape ecologists and in Bosch et al. (2007), systems analysts (also see Fu et al. (2008) as an example of landscape ecologists claiming landscape ecology as a bridging discipline)[21].

Müller et al. (2005: 197) provide an example of where using a core discipline resulted in a failure of integrated research. In their experience 'The Ecological City' sustainability programme was marred by a majority belief that the problem could only be resolved through modelling, and that the other disciplines involved should simply provide the wider context of resource depletion, natural resource dependency on other regions, qualities of air, soil, and water systems, and the consequences for biodiversity. This, the authors term the "competition for the monopoly of integration" and warn that the result of this was a lack of clarity in the roles of the various researchers, no generally accepted framework, and a lack of valuing of researchers' own work (besides the modelling team) and the work of other team members (also coerced into the framework)[22]. As a result of their experience the authors contend that the challenge is to design a research approach that is not based on hierarchy or monopoly, but on equal contributions of researchers.

33) Consider whether a modular research strategy is required

As noted above, the development of a successful integrated research strategy is provided by a pluralistic epistemological approach, the maintenance of disciplinary expertise within the project, and equal authority provided to all disciplines involved (rather than a core discipline). One way to aid integration in the research may be to employ a modular systems as advocated by Deconchat et al. (2006). Modular systems are likely to allow greater flexibility in the methodological choices, allow different scales to be studied simultaneously, reduce the chance that one part of the project will be held back by another, enable research teams to focus on different parts of the problem (particularly valid in very large integrated programs), allow people to work in smaller groups (which helps the

[21] Disciplines have a self-interest in their problem diagnosis being accepted as the definitive one, and therefore cannot be trusted to be disinterested in asserting their claims to characterise a societal issue (Lowe & Phillipson, 2006).

[22] To this list could also be added that it promotes feelings of freedom and empowerment amongst the communities and individuals involved (Taket & White, 1998). Employing a single methodology when the public are integrated into the research process may make the research appear inflexible and driven from the scientists rather than the problem's perspective.

group become more socially cohesive), enable a clearer understanding of the objective (Winder, 2003), make publishing easier (Penker & Wytrzens, 2005). Deconchat et al. (2007) suggests that the modular approach may not be seen as reductive providing the modules are sufficiently integrated (and are designed to be so) and the research question continues to be holistically framed. Further, Jakobsen et al. (2004) suggest that larger projects tend to disperse into sub-projects naturally in any case – thus it may be better to purposively organise the division to

promote greater integration (i.e. limit overlaps or discrepancies between sub-projects).

5.6 Evaluation of the research for funders

34) Evaluate the problem solving ability of the research – not the research process

As discussed in Chapter 4 there have been numerous suggestions concerning how to evaluate integrated research, however there are as yet " ... no widely recognized quality standards that could be used to evaluate projects *ex ante*, intermediary and *ex post*" (Tress, 2003). When evaluation measures are proposed they are generally problematic in that they invariably evaluate the process of the integrated research and not its ultimate success in solving the problem (see section 4.2.8). Yet, as Hollaender (2003) observes, interdisciplinary practices must not be evaluated as if they are an end to themselves. The key problem is that solutions to complex integrated research problems are generally no less complex than the problems themselves and, as a consequence, it may be years or decades before their success becomes evident. In the literature researchers therefore focus on evaluating the 'success' of the project on the basis of, Janssen & Goldsworthy (1996: 275) suggest, "the progress that it made towards stated goals" – i.e. what is generally evaluated is the quality of the integrated research and not the quality of the outcome. For example, Wickson et al. (2006) suggest the evaluation of integrated (transdisciplinary) research should be based on a number of criteria:

1. Responsive goals – in transdisciplinary research, the scholar defines goals through ongoing consultation with the problem context and stakeholders.

Goals may therefore not be clear from the outset and may shift in response to developments over the course of the project.

2. Broad preparation – in transdisciplinary research, 'adequate preparation' would require accessing and integrating literature and theory across a broad range of disciplines, as well as engaging with the problem in its broader context.
3. Evolving methodology – an 'appropriate method' for transdisciplinary research is ideally epistemologically integrative and capable of evolving in response to a changing research context.
4. Significant outcome – the outcome of transdisciplinary research should contribute to the solution of a manifest problem in a way that is capable of satisfying multiple agendas, for example, be concurrently socially robust, environmentally sustainable and economically viable.
5. Effective communication – in support of collaborative processes, transdisciplinary research should initiate and maintain two way communication with stakeholders over the life of the project.
6. Communal reflection – in addition to personal reflection, transdisciplinary research should include a more communal reflective process – multiple disciplinary and stakeholder perspectives informing and transforming each other throughout the life of the project.

Of these, only the 'significant outcome' criteria relates directly to the problem solving ability of the research. Given that the expense of integrated research is probably only borne because of its problem solving ability, it is essential that at some stage the problem solving ability of integrated research is evaluated itself – rather than the research process. In particular a means of evaluating the social effects of integrated research programs is necessary in order to justify the results of integrated programs (Walter et al., 2007).

A further issue raised by Janssen & Goldsworthy (1996: 275) is the unsuitability of milestones as a measure of integrated research success. They observe "Since papers, reports, and other publications on the project do not necessarily report on any progress made towards resolving the problem, they may be unusable as indicators for evaluation purposes". Similarly problematically, Uhrwing (2003) suggest that disciplinary success does not necessarily indicate integrated research success and, as such, the quality of any predominantly disciplinary science emerging from the research does not reflect on the quality of the inter-disciplinarity. This suggests that we need to develop a different evaluation system for integrated research and perhaps – as with the evaluation of integrated research papers discussed in section 4.2.6 – this may require panel evaluations (with multiple disciplines represented) rather than standard report-review procedures. Janssen & Goldsworthy (1996) contend that, in terms of evaluating the contribution of individual researchers, the views of other team members on the extent to which others have contributed to resolving their problems could be useful. However, as such a measure could easily lead to a loss of trust within the research team, it seems an ill-advised suggestion.

There is, as yet, no silver bullet for integrated research evaluation. A possibility for future projects is that the research should be accompanied by an evaluation stage – potentially many years after the research has been completed and solutions implemented. However, as with may aspects of integrated research, this is not in compatible with current research procedures. Until we start evaluating the problem solving abilities of integrated research we are in danger of having funders loose faith in the process – as Tress et al. (2003) observe. In the meantime, it would seem critical (as discussed in Chapter 4) that we begin to evaluate integrated research in a team setting – i.e. through discussion by a panel of experts – rather than through the standard individual peer review process.

35) Be realistic about the difficulties of integrated research

Tress et al. (2006, 2007) observe that one problem with integrated research is that funding bodies generally have little concept of the difficulties involved and, therefore, need to be made aware of these at the early stages of the negotiation process. Deadlines set for integrated research must be realistic and must account for the additional difficulties of the research process. For example, there can often be problems with the engagement of stakeholders (who may take a 'wait and see' approach to the research before engaging – Antrop et al., 2006). Researchers thus need to be realistic about the amount of time needed to engage non-academic stakeholders and not set tight fixed deadlines to funders at the early stages of the research (Höchtl et al., 2006; Antrop et al., 2006). Chapter 4 outlines an array of issues that need to be resolved during the course of the integrated research – ranging from the need to debate epistemological positions to the need to retain staff – and all of these need to be considered when providing deadlines to funding bodies. There is no fixed time, for example, that it should take for trust to become established within the research team, yet the building of trust is one of the key requirements of the research process.

Where researchers are asked to provide deliverable results within a short period of time it is the intensive contacts with other researchers and stakeholders that is likely to be economised. However, if the human factor plays a decisive role in the problems to be investigated, a certain amount of time is required in order to avoid precipitant action and superficiality (Höchtl et al., 2006). If, on the other hand, the researcher tries to both build contacts and deliver to tight deadlines simultaneously the result can be stress amongst the researchers and, consequently, further problems meeting the deadlines (Jakobsen et al., 2004). If Höchtl et al.'s (2006) estimate that internal and external communication (e.g. for informal discussions, workshops, presentations, information events, e-mails and public relations) takes about 30% of the working hours and Deconchat et al.'s (2007) estimate of 10% just for coordination at a unidirectional level are applicable to other studies, then it suggests project leaders should add 10 to 30% to their estimated time requirements to account for the specific needs of building an integrated research team. If, however, a strong in-situ team is maintained within the organisation (section 5.2.3) this figure is likely to be lower (and increasingly lower as the experience of the team increases).

5.7 Conclusion

This chapter has reviewed advice from the literature concerning how integrated research ought to be conducted in terms of the qualities of staff, defining the problem, establishing a trusting and collaborative work environment, setting up joint research processes, organising and developing the research strategies, and evaluating the research results. Given the enormous range and variety of integrated studies in existence there are likely to be many more alternatives out there – many of which will be particular to particular types of research problems. While the advice presented here is good generic advice, it is advisable when constructing a new research project to consult the literature for specific advice on how to undertake the specific type of integrated research required. The final chapter concludes the review and suggests a framework for undertaking integrated research.

6. Conclusion

6.1 Introduction

The need for science communities to work together to resolve real-world problems is widely recognised – as is the potential for the development of integrated research methodologies and programs. There are three main reasons for this: the need to develop methodologies aimed at solving real world problems within complex social-ecological environments, the need for a more democratic version of science that considers the needs of the communities studied and not just interests of the scientific community, and (arguably most importantly) the recognition by governmental and intergovernmental bodies that, in the past, they have too often been "sold simple solutions to complex problems" (Jackson, 2006: 647). Yet despite this need many researchers contend that there is more rhetoric and hot air emerging from (and about) integrated research than there are practical solutions or real world impacts. The reality of integrated research is that despite high levels of funding the output from such research projects is low, the programs themselves are problematic (as is their evaluation), and it is often the lower forms of integrated research (multi-disciplinarity or unidirectional interdisciplinarity) that emerge rather than the holy grail of transdisciplinarity[23].

This literature review sought to address three primary questions, namely:

- What are the characteristics that define integrated research?
- What are the key challenges facing integrated research?
- How can we construct an integrated research program that addresses the key challenges and delivers effective integrated research?

This chapter will sum up the research by addressing these three questions in order.

[23] Höchtl et al (2006: 328), for example, observe that a transdisciplinary approach can have advantages but "it is in no way a panacea". They suggest that, while it is suited for some situations "it is obvious that transdisciplinary research is no 'better' or more fashionable than research within a single discipline" and that many problem situations can be resolved through the application of traditional disciplinary approaches.

6.2 What are the characteristics that define integrated research?

To answer the first question the three key forms of integrated research (multidisciplinarity, interdisciplinarity and transdisciplinarity) were outlined and discussed. From this it emerged that there is considerable confusion within the literature concerning exactly what these terms mean – with various researchers establishing different definitions (and key characteristics) for each of the three forms. To some extent these definitions were determined on a disciplinary basis (e.g. with those disciplines concerned about implementing solutions adding extension programs to their definitions), however, on the whole there was no discernable temporal development of the terms (the terms do not appear to be developing or being refined in any systematic manner). Rather, it seems as if every integrated research program is able to establish its own definition of what integrated research actually is. In Chapter 4 the issue of a lack of disciplinary gatekeepers is discussed as a possible reason for this. Without gatekeeping individuals, journals and organisations determining what is 'good' and 'bad' integrated research, the development of an integrated research science is problematic – as is any clear definition of integrated research itself.

It is important, however, that we are able to define these forms of integrated research if researchers are to understand what exactly they are engaging in and what the objectives of the research process should be. Definitions of the three types of integrated research (multidisciplinarity, interdisciplinarity, and transdisciplinarity) were developed in the research by critically assessing definitions from across a number of papers and disciplines (see Chapter 2). These are:

1. *Multidisciplinarity:* Multidisciplinarity is distinguished from interdisciplinarity and transdisciplinarity by the lack of iterative research processes, a failure to cross disciplinary boundaries, the lack of integration in the research process and a failure to engage non-academic stakeholders as participants in the research. In addition, multidisciplinarity may sometimes focus on the theme under investigation – rather than being problem oriented, and may or may not involve a coordinated program of research.
2. *Interdisciplinarity:* Interdisciplinarity is similar to transdisciplinarity. In fact, the only consistent differences between the two are (a) that transdisciplinary work aims to synthesise new disciplines and theory (whereas this is not an

objective for interdisciplinarity) and, (b) that transdisciplinarity emphasises holism in its approach (this leads to increased participation from stakeholders and the more likely adoption of pluralist methodologies). The boundaries between interdisciplinary and transdisciplinary projects are thus diffuse and dependent more on a subjective judgement on the level of holism applied than on the presence of clear boundary markers.

3. *Transdisciplinarity:* Transdisciplinarity maintains a clear emphasis on developing an holistic approach to problem solving involving stakeholders and scientists in a joint project. While this is also often present in interdisciplinary work, with transdisciplinarity it becomes almost a philosophy – extending the research beyond simply problem solving towards synthesising new bodies of knowledge with which to address complex systems problems.

The level of confusion within the literature means that it is difficult to use any of these terms with any degree of clarity. In response, the term 'integrated research' was adopted for the review as a collective term to refer to interdisciplinary and transdisciplinary studies (and multidisciplinary where the research crossed into the region of interdisciplinarity). While many studies refer to 'transdisciplinarity' as some researchers have observed, as yet transdisciplinarity appears to be more of an ambition than a reality.

6.3 What are the key challenges facing integrated research?

The literature review indicated that there are a considerable number of challenges facing integrated research. What is perhaps surprising (particularly given that the notion of integrated research has been around for several decades) is that many of these challenges are still fundamental ones, i.e. there does not appear to have been any significant progress towards a widely applicable approach to integrated research. Key problems are associated with issues as fundamental as what is seen as acceptable knowledge (epistemology) and the nature of reality (ontology). Disciplines with radically conflicting viewpoints are regularly in conflict in integrated research.

Resolving differences between disciplinary perspectives is an issue that regularly emerges in the literature. Two approaches are widely rejected. The first is the idea that researchers should be encouraged to somehow gain expertise in each others' disciplines (in particular natural and social scientists). While the review is not exhaustive, there seems to be a consensus that, if integrated research is to work, disciplinary expertise is required in order to contribute properly to the debates that arise. A solution is the use of integrating 'core' disciplines to act as a centre for the research project (around which other disciplines feed in information). However, this approach is also problematic in that it (a) does not allow all researchers/disciplines to contribute on an equal footing and (b) predetermines the methodology/epistemology of the project (e.g. modelling). In addition, the two most frequently cited 'core' disciplines are both strongly internally divided and, as such, there must be some question as to how effective they can act as integrating forces. The example of 'The Ecological City' project (Chapter 4) further suggests that integrating research programs in this manner is potentially as divisive to the research team as they are integrative to the research methodology as authors compete for "the monopoly of integration" (Müller et al., 2005: 197).

A further problem within integrated research is how to deal with the danger of epistemological relativism. This arises as a result of research programs developing whereby the research leaders are not sure of how to validate other disciplines' contributions (particularly across the natural – social science divide) and therefore, establish all knowledge as being equally valid. As a result, approaches that have been theoretically invalidated within some disciplines are accepted on face value by others. In Chapter 4 the example is given of the use of quantitative measures of 'social capital' by economists despite the widespread rejection of this approach on epistemological grounds within its founding disciplines. Were a choice available between an easily integratable quantitative measurement proposed by economists (i.e. the integration of compatible measurable data) or a qualitative study requiring in-depth analysis and resulting in anecdotal descriptive data it may be tempting to choose the economics position – despite the questionability of the theoretical approach. The danger with epistemological relativism is thus that all epistemologies and methodologies etc. are accepted on face value rather than being assessed within the broader scientific frameworks from which they emerged. In the worst case scenario the impact could be to invalidate the output of the research program (and thus its ability to resolve the problem) and, on a longer time-frame, hinder he development of science itself.

Related to this is the issue that the easiest way to ensure integration is through the engaging social science disciplines that employ similar positivist methodologies, epistemologies and ontologies as the natural sciences. As discussed in Chapter 3, social sciences have been moving towards interpretivist understandings of the world for decades now because of their greater ability to understand diversity and complexity within human populations. This makes their integration with natural sciences difficult – but potentially extremely beneficial for dealing with real-world issues. However, the option many choose is to integrate with those few disciplines that retain positivism as the main epistemological framework (e.g. economists, landscape architects, psychologists) to facilitate integration and cooperation. A preferential solution is that of methodological pluralism – whereby qualitative and quantitative (or 'soft' and 'hard') science work together under their own methodologies rather than adopting a single unitary position. Pluralistic approaches such as that advocated by Critical Systems Theory (see Jackson, 2001; 2006) offer arguably the best means of dealing with the differences between social and natural sciences while enabling each approach to maintain its integrity.

Integrated research is different from disciplinary research in that it does not emerge from an established epistemological or ontological security between members of the research team (e.g. common methodologies, theories, languages, etc). Therefore, a key challenge for integrated studies is getting the researchers (and other participants) to work together, to understand, respect and trust each other – something which may be taken for granted in disciplinary work. Thus issues such as choosing leaders on the basis of their people skills as well as scientific skills, building trust in the team through mixed research modules, involving all researchers in problem formulation and determining the methodology, etc., play a key role in integrated research. The success or failure (in terms of addressing the problem at hand) of an integrated project is likely to hinge on the extent to which people are problem focussed, open-minded and trusting and working towards a common goal.

One key challenge for integrated research in the future is likely to concern the evaluation of the results of integrated projects. Evaluating integrated research is highly problematic. Most studies that refer to evaluation focus on evaluating the research process (e.g. level of integration, etc) rather than evaluating the problem-solving outcomes themselves. Developing evaluations of the outcomes is critical for two main reasons. First, unless evidence is forthcoming that integrated research is delivering outputs (i.e. resolving real world problems) that justify its cost (and it is widely accepted that integrated research is more expensive than standard research) it seems unlikely that funders will remain enthusiastic about financing integrated projects. Second, evaluating the success of the various different applications of integrated research is key to establishing what constitutes 'successful' and 'unsuccessful' practice, and this in turn is critical for the theoretical development of integrated sciences (something that is badly needed in integrated research).

6.4 How can we construct an integrated research program that addresses the key challenges and delivers effective integrated research?

As noted in Chapter 5, the notion of 'best practice' in integrated research is somewhat different to that for any disciplinary research. As each case is likely to require a different formulation (based on the research problem and the research team) there is no one formula to integrated research. However, in summarising review of the literature we can make 17 key general recommendations integrated studies should follow.

1) Select a leader on the basis of their openness to alternative ideas and disciplines and not only their research record as the research record is only relevant to those in the same discipline. More important is that they can build a spirit of cooperation within the research team.
2) Select researchers who are both team players and problem oriented.
3) Once a strong integrated research team (or collaboration between organisations) has been established, it is important to maintain it. This saves the institution the cost of re-establishing a new team every time a new project is organised – a potentially expensive exercise.
4) Engage everybody involved in the research process (stakeholders, community and scientists) in the process of both formulating the research problem and designing the research methods.
5) Be prepared to reformulate the research problem, research method and even the research team during the research as new information emerges. Again, involve all participants in the revision process.

6) Develop and *maintain* open dialogue between the scientists. This involves having open discussions on (a) epistemological and ontological beliefs, (b) publishing and data ownership, and (c) the languages used within disciplines.

7) Regular forums for exchange (both formal and informal) are vital and help build trust within the group. Allow open access to results for all team members where possible.

8) Building trust is a key ingredient for integrated research as it facilitates the open movement of information between researchers and increases the likelihood that researchers will cross disciplinary boundaries. Set building trust as a goal of the research process.

9) When bidding for integrated research projects add between 10% (for simple integrated projects) and 30% (for complex projects) to time estimates simply to cover the need to develop collaboration and trust.

10) Organise researchers into disciplinarily mixed and relatively small research teams as this promotes mutual understanding and trust between scientists.

11) Do not adopt a single epistemological position (e.g. interpretivism or positivism) simply to make the research process easier – a diversity of perspectives (methodological pluralism) is not a hindrance, it is one of the strengths of integrated research.

12) Decisions should be made on the basis of disciplinary expertise, i.e. avoid the position of epistemological relativism (the idea that any knowledge system is as good as another).

13) Do not form the research around a single integrating 'core' or 'regulating' discipline (e.g. landscape ecology or systems analysis) as 'core' disciplines do not offer a resolution to the key epistemological debate, limit the extent to which the research is pluralist, and may lead to problems with establishing trust within the research team.

14) Social science should not be seen as a 'service science' for implementing findings as is the case in some projects.

15) Researchers should be encouraged not to extend their expertise into other fields but should contribute to the research from positions of disciplinary expertise. Integrated research requires people well versed in their own disciplines in order to contribute to the debates.

16) Establish criteria for publishing and authorship prior to the initiation of the project and provide opportunities for young researchers to build individual

disciplinary careers as well as engaging in multi-authored interdisciplinary publications.

17) Consider whether integrated research is really needed. Disciplinary research is cheaper, easier and, in many cases, equally as effective at problem resolution as integrated research.

6.5 Conclusion – the future for integrated research at AgResearch and Centre for Rural Research?

Integrated research (interdisciplinarity and transdisciplinarity) is a problematic and complex form of research that requires both a long term commitment and substantial research funding (additional to that that might be expected for disciplinary research). Further, despite some protestations to the contrary (particularly by those with an interest in its success e.g. Lowe & Phillipson, 2006), its worth remains relatively unproven. Given this, the question for us to address now is whether it is sensible to make the commitment required to integrated research – or whether it is best to continue addressing problems in a more disciplinary (or non-integrated multi-disciplinary fashion)?

Making a 'half-hearted' commitment is not really an option. In addition to its scientific results, good integrated research also generates a critical secondary product – a trusting environment that facilitates collaboration and knowledge transfer between the researchers. If trust and understanding has to be re-established at the beginning of each project, it can become an expensive exercise – adding 30% to the amount of time needed for the project by one estimate (Höchtl et al., 2006). As a result, a key to conducting integrated research on an institutional level is the recognition that it has to be a long term commitment – otherwise it is likely to be an expensive exercise. This requires a constant flow of integrated research projects, strong (and regular) collaboration between different parts of the organisation (and external organisations in some instances) as well as a focus on retaining staff within the teams. Every new researcher added to the team has to be 'educated' into the methodologies, languages, epistemologies, etc. of the team before they are fully effective – and this takes time.

The question is, whether the funding will be available for this kind of research in the future. The positive encouragement from funding bodies for integrated research in New Zealand and Norway suggests that research funding for interdisciplinary and transdisciplinary projects is likely to be forthcoming – however, how sustained this is likely to be is another question. As noted in the review, evaluating the success of the outcome of integrated research (as opposed to assessing the interdisciplinarity) is extremely difficult as attributing long-term problem-solving change to the research exercise is almost impossible within the framework of any given project. With the problem solving ability essentially unable to be evaluated and the publication record for integrated research lower than disciplinary research, the question is: how long will it be before politicians tire of funding this form of research and opt for simpler options? If integrated research is an example of hope triumphing over experience (Petts et al., 2008) or high expectations delivering poor outcomes (Balsiger, 2004), the future of integrated research may be very short. For this reason, careful consideration should be given not only to how to establish integrated research, but whether integration should be established as a key part of an organisations research strategy.

However, the current policy emphasis on inter- and trans-disciplinary research, means that not committing to integrated research would be a politically dangerous exercise. There is clearly a need for better integration of research disciplines if we are to answer complex real world problems and succeed in generating a successful and sustainable future for agriculture and its communities. It is simply a matter that, if we do this we need to do it properly. The review has analysed some of the debates around integrated research and highlighted the ways in which we may be able to address problems that have emerged in other studies. However, it does not provide a definitive guide to conducting projects as these will need to be discussed within research teams as they are established to address specific problems. Hopefully, it can nevertheless provide the basis for fruitful discussion and the establishment of effective integrated research within and between our organisations.

Appendix I: Definition of epistemology and ontology

Theories of knowledge begin with the notion of ontology. An ontology refers to "the theory of existence of or, more narrowly, of what really exists, as opposed to that which appears to exist but does not." (Cloke et al., 1991: 95) A primary ontological divide exists between relativism and objectivism (or realism) in that reality can either be seen as a tangible entity (and therefore governed by strict rules and measureable, modelable, etc.) or as socially constructed and intangible entity (fluctuating or context dependent, not based on definable rules and therefore not modelable or measurable). Relativism proposes that cognitive and cultural biases prevent us from observing anything objectively and, therefore, that all points of view are equally valid. An example of a relativist ontology can be found in the field of semiotics (the study of systems of signs and meanings). This observes that 'reality' is "a social construction, consisting of signs, in which language plays a primary role … From the semiotic perspective the whole of human experience, without exception, is an interpretive structure mediated and sustained by signs." (Echter, 1999: 49). This socially constructed view of reality is the more common perspective of the social sciences. Natural scientists, on the other hand, tend to follow an objectivist or realist ontology which holds that there is a mind-independent reality that can be sensed and that, therefore, the measurement of this reality is possible as are rules that predict its behaviour. A realist perspective holds that to understand a thing "then we must understand both their internal structure and the mechanisms and properties that enable them to produce or undergo particular changes when placed in contexts where they interact with other things." (Cloke et al., 1991: 136). The existence of measurable and definable characteristics means that from this perspective it is possible to understand or predict (model) the world.

Closely tied with the ontology is epistemology. Epistemology concerns the theory of knowledge, i.e. what is deemed to be warrantable and thus acceptable knowledge (Bryman, 1988; Phillip, 1998) and its principle varieties, sources and limits (Cloke et al., 1991). As with ontology there is a clear epistemological divide be-tween the natural and social sciences – this time into the positivist epistemology (natural sciences) and the interpretivist epistemology (social sciences). Positivist epistemology is based on the rejection of metaphysical speculation as acceptable knowledge, contending, rather, that only knowledge that can be verified through experience and data is acceptable within the scientific process. Its reliance on verifiable data means that positivism is heavily empirically based and it is therefore strongly associated with the 'scientific method' or reductionist step-wise experimental methodologies. Interpretivism, on the other hand, recognises the socially constructed nature of reality and, specifically, maintains that knowledge can not be independent and impartial as people's perceptions of the world is based on their own experience, culture, history, etc. (Weber, 2004). Thus realities are seen as multiple rather than singular (e.g. interpretivists may refer to knowledges rather than knowledge – e.g. Holloway, 2002) and that these realities vary across time and space. It further differs strongly from positivism in that it rejects the notion that 'reality' can be studied through a reductionist approach (i.e. by collecting information from parts of a phenomena) as this may miss important data concerning the working of the whole.

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