Foghorns to the future: Using knowledge and transdisciplinarity to navigate the uncharted waters of complex social-ecological systems

Cundill, G.[1], Fabricius, C.[1], Marti, N.[2]

[1] Environmental Science Department, Rhodes University, South Africa
[2] Ecological Economics and Integrated Assessment Research Group, Autonomous University of Barcelona, Spain

Abstract
Complex social-ecological systems are shaped by cross-scale interactions, non-linear feedbacks, and fast and slow changing variables. Transdisciplinary approaches that combine participatory and conventional methods, and which 'democratise' knowledge to enable inputs from local, informal experts are essential tools in understanding such systems. However, researchers and practitioners often need to make trade-offs when they enter the uncharted waters of transdisciplinarity, participatory research and democratised expertise. Furthermore, there is a shortage of information and consensus on the process, methodologies, and techniques that are appropriate to investigate such systems. This paper outlines some of the approaches to scale, complexity, and epistemology adopted by researchers and practitioners when investigating complex systems, and discusses some of the trade-offs involved. Through examples from South Africa and Peru, we highlight the 'navigational devices' or tools available to researchers who seek to 'bridge epistemologies' on the ground. We argue that a boat navigating between unknown shores may be a more appropriate metaphor than a bridge, where the start and end points are fixed and known.

Introduction

Communicating, translating and representing information between knowledge systems is just one of the challenges faced by researchers involved in community level assessments such as those conducted for the Millennium Ecosystem Assessment (MEA) (Alcamo *et al*, 2003). Understanding the relationship between people and the environment requires that researchers 'on the ground' navigate not only multiple worldviews (Gadgil *et al*, 2003), but also complex social-ecological systems (Scheffer *et al,* 2001; Berkes *et al*, 2003), characterised by cross-scale interactions, non-linear feedbacks, and uncertainty (Gunderson and Holling, 2002).

Transdisciplinarity, so often touted as the answer to these difficulties, proves useful only when researchers understand the theoretical underpinnings of the various disciplines they are required to 'bridge'. There is also a lack of guidance and experience in adopting integrated approaches involving different worldviews, and few academic curricula address these challenges. In this paper, we explore case studies from South Africa and Peru[1] to illustrate the multiple research outcomes, the challenges and the trade offs involved when researchers seek to heed calls to 'embrace the complexity' (Gunderson, 2003:74) through a systems approach, in the absence of clear practical guidelines.

[1] The generosity and assistance of Alejandro Argumedo, and all of the staff at Asociación Los Andes in Cusco, Peru is gratefully acknowledged. The views expressed in this paper are those of the authors, and do not necessarily represent the views of Alejandro Argumedo or Asociación Los Andes.

The variable theoretical landscape of complex systems

Theories about the relationship between people and the environment influence the ways in which natural resource management is understood and applied (Janssen, 2002). The earliest theories relied heavily on a dichotomy between people and the environment, emphasising the inherent ecological limits to population growth (Malthus, 1798; Meadows *et al,* 1972). Critiques of this heavy emphasis on linearity, carrying capacity and environmental determinism (see Tiffen *et al*, 1994), lead to inclusive approaches emphasising human adaptation to environmental and social processes (Boserup, 1965). More recently, this emphasis on adaptive capacity has paved the way for the systems approach, with principles and ideas that emphasise complex system dynamics (Kay *et al*, 1999), linked social-ecological systems (Berkes and Folke, 1998), non-linear feedback at multiple scales (Gunderson and Holling, 2002), and resilience in social and ecological systems (Holling, 1986; Scheffer *et al*, 2001). Researchers who take on the challenge of inclusivity with Quixotean zeal may, however, quickly become confused and frustrated by the many directions in which their analyses are being pulled. Three factors contribute to this confusion: scale, complexity and epistemology.

1) Scale

Scale refers to the spatial, temporal, quantitative, or analytical dimensions used by scientists to study objects and processes (O'Neil and King, 1998; Gibson *et al,* 2000). Ecological and social systems tend to organize into strongly interacting clusters of processes operating at similar spatial or temporal scales (Allen and Holling, 2002). Consequently, an understanding of how a selected scale of analysis may influence the patterns observed, and therefore inferences regarding causality, is essential in understanding interactions between human and natural systems (Gibson *et al*, 2000; Munda, 2000).

However, despite recent comprehensive reviews of scale (see for example Schulze, 2000) the disparate treatment that scale has received between the various disciplines (Table 1) makes 'scale' one of the most fundamental methodological challenges confronting researchers. A number of pitfalls exist when attempting to describe and interpret patterns and processes operating at different spatial and temporal scales; i) *Ostensible chaos*: patterns and processes that appear random at one level, may appear highly organised at another, and visa versa (Schulze, 2000). ii) *Misinterpreted trends*: if the duration of an observation is shorter than the characteristic temporal scale of the process, a declining trend in the process may be incorrectly inferred (Jewitt and Gorgens, 2000). ii) *Misread patterns*: if the resolution of the observation is greater than the characteristic scale of the process, spatial patterns may go undetected (Bloschl and Sivapalan, 1995; Leach and Fairhead, 2000).

[Insert Table 1]

Therefore, an acknowledgement of the importance of scale is essential for our understanding of human-environment interactions. But how should scale be approached? When researchers seek to become transdisciplinary, whose perspective counts? It is clear from Table 1 that a broad range of disciplines from both the natural and the social sciences are involved in scale and scaling issues. While systems ecologists would argue that scale is an explicit consideration when assessing any system (Levin, 1992), geographers place the emphasis on spatial scale (Wood and Lakshmi, 1993), historical ecologists on temporal scale (Balee, 1998), economists on emergent features (Martinez-Alier and Schlupmann, 1991), sociologists on interactions between scales (Coleman, 1990; Scheffer *et al*, 2002), and political scientists on institutional and conceptual spheres of scale (Ostrom and Hess, 2000). This makes for an inconsistent theoretical landscape for researchers who seek to become transdisciplinary in their endeavour to come to terms with scale in complex social-ecological systems.

2) Complexity

Complex systems have a number of unique attributes, including; non-linear processes, uncertainty, emergence, cross-scale interactions, self-organisation, novelty, slow and fast changing variables, and a nested hierarchical structure (Walker and Abel, 2002; Berkes *et al*, 2003; du Toit *et al*, 2004). Both natural and human systems are considered to exhibit characteristics of complex systems, and linked social and ecological systems are increasingly considered to be self-organising, with a loose hierarchical structure (Gunderson and Holling, 2002), various emergent processes (Kay *et al*, 1999), and to be subject to relatively sudden re-configurations from one state to another (Scheffer *et al*, 2001). Natural resource managers and systems researchers face enormous challenges when confronting this complexity in their work (Walker *et al.* 2002).

Many fields of research have contributed toward the recognition of complex system dynamics in human and natural systems. However, although the approach is fairly generally accepted, a myriad of perspectives and disparate emphases exist (Table 2).

[Insert Table 2]

While general systems theorists argue for an emphasis on connectedness, context and feedback (Von Bertalanffy, 1968), chaos and complexity theorists argue for the recognition of self-organising behaviours in social and ecological systems (Casti, 1994; Kay *et al*, 1999). Evolutionary theorists, on the other hand, argue for an emphasis on feedback to avoid simple dichotomies between human and natural systems (Wicken, 1987; Adger, 1999), while historical ecologists emphasise history (Balee, 1998). Post-normal scientists call for an emphasis on uncertainty and methods to ensure the validity of conclusions in inherently complex systems (Functowicz and Ravetz, 1990).

Researchers and practitioners who take a systems approach to local level assessments are therefore expected to confront uncertainty by incorporating the additional complexity of peer-review by local communities. They thus, often unknowingly, enter the equally varied theoretical landscape of epistemology while still grappling with scale and complexity.

3) *Epistemology*

Epistemology is the philosophy of knowledge, and more specifically, it is a field of research that seeks to come to terms with what we can know, and the status of knowledge about a particular reality (Jones, 2002). There are a myriad of perspectives on the topic, however, relevant to integrated natural resource management are a few key arguments, mostly from within the social constructivist school. Debates from within the field of epistemology have filtered into the natural resource management arena from various sources, and have had a cascade effect that has fundamentally changed the ways in which natural resource management is conceived (see for example Lele, 2000; Fabricius *et al,* 2001a; Campbell *et al,* 2001) through a move away from draconian conservation measures, and toward the acknowledgement of the potential role to be played by local people in conservation. This has therefore influenced the approaches adopted by researchers, and lead to a proliferation of participatory research techniques. However, multiple approaches, drawn from various ontological and management perspectives, exist for the integration of different knowledge systems.

A core debate in the field epistemology concerns the existence of an external reality, in other words, a reality that is not socially constructed by human beings. There is much disagreement about whether or not reality can be divorced from social experience, and therefore whether it can be objectively accessed by a particular knowledge system (Jones, 2002). For this reason, debates about knowledge are often centred on power (Healy, 2003), because logically the system of knowledge that is recognized as being able to tap into the 'objective reality' holds greater sway than other knowledge systems.

Debates about the value of science vis-à-vis other knowledge systems have been expounded for centuries; Bacon (1561-1626), followed by Hume (1739), and later Popper (1968), were some of the leaders in this debate. Social constructivism emerged from these early works and has, in the sense that it advocates that all reality is socially constructed (Demeritt, 1994), arguably lead the way for greater participation of local communities in natural resource management through encouraging the recognition of alternative, and equally valid, worldviews. The various approaches and rationales both for and against the integration of (western) scientific knowledge and local or traditional knowledge in natural resource management issues are summarised in Table 3.

[Insert Table 3]

If research is to become transdisciplinary then researchers and practitioners must come to terms with these variable perspectives. While some, such as the social constructivists, argue from ontological perspectives (Milton, 1996; Macnaghten and Urry, 1998; Jones, 2002), others argue from ethical and even management standpoints (Gadgil *et al*, 2000; Berkes *et al*, 2003). Still others reject the very idea of integration and argue that the communicating between knowledge systems leads to further marginalisation of the non-dominant knowledge systems concerned (Latour, 1987; Nadasdy, 1999).

Community level projects are already underway worldwide (Barrett *et al,* 2001*;* Chakraborty, 2001; Shackleton and Campbell, 2001), and therefore knowledge systems are coming to heads regardless of the arguments behind these varied perspectives. What is alarming therefore is the lack of debate amongst these groups concerning just how to integrate knowledge systems in a practicable way, and in a way that would avoid the concerns raised by the sceptics (Nadasdy, 1999, du Toit, 2004).

Comparative case studies are useful to assess the trade-offs and practicalities when complex systems of people and nature are assessed through the systems approach, especially if they share a common design and conceptual framework. In the process, however, many trade-offs have to made in bridging the divide between theory and practice.

Case studies from South Africa and Peru: multiple pathways

Different 'navigational tools' such as conceptual models, methods, and techniques, were used in local level assessments conducted in South Africa and Peru under the MEA framework[2]. In this section we highlight the trade-offs that had to be made when researchers endeavoured to study human-ecosystem interactions in the current theoretical landscape of complex systems. The case studies were similar in terms of the conceptual frameworks used, the involvement of local people and incorporation of local knowledge in information gathering. In all case studies there was a direct connection between local people and ecosystem services: all the communities needed ecosystem services in their everyday lives. They differed widely in terms of their ecological, tenurial and livelihoods profiles (Table 4).

[Insert Table 4]

[2] The Peruvian case study represents a training exercise conducted during 2001-2002. This exercise was intended to test and adjust tools and methodologies for the Vilcanota Millennium Ecosystem Assessment, which is still underway. The South African cases represent work conducted in 2003 as part of the South African Millennium Assessment (SAfMA).

Both case studies sought to answer the overarching question posed by the global level assessment; what are the current conditions and trends of ecosystems and the associated implications for human well-being? (Alcamo *et al*, 2003). In order to answer this, the South African and Peruvian studies branched off in different directions (table 5), paying testament to the multiple paths available in complex systems research.

[Insert Table 5]

Dealing simultaneously with scale and complexity

Both the South African and the Peruvian studies used the Millennium Ecosystem Assessment (MEA) framework as a conceptual guide (Alcamo, *et al,* 2003) (Table 5). The MEA framework assumes a dynamic relationship between people and ecosystems. Human and ecological systems are considered to be interconnected, with ecosystem change affecting human well-being and vice versa (Alcamo *et al,* 2003).

The MEA framework assumes that the relationship between ecosystems and human well-being cannot be understood without a consideration of multiple spatial and temporal scales, and also recognises cross-scale interactions. The mismatch between the scale of ecosystem processes and the scale of decision-making is considered to be a key reason for many environmental problems. The model also introduces the ethical problems encountered by researchers who conduct local level investigations into these kinds of linkages, and acknowledges that different knowledge systems may be more important when dealing with different scales of analysis. However, the MEA model alone does not do justice to the dynamism of human and natural system interactions at the local level.

To overcome this challenge, the South African local level assessments used the adaptive renewal model (Holling 1986; Berkes and Folke, 1998; Gunderson and Holling, 2002) as a conceptual guide to simultaneously deal with scale and complexity, and to address the short-comings of the MEA model for local level purposes. The Peruvian assessment took a very different approach, combining the MEA model with Complex Adaptive Hierarchial System (CAHS) theory (Giampietro, 1994) and, most significantly, the Indigenous Andean Cosmology Framework and Principles (TACFP) (Milla, 1983) in order to conceptualize multi-scale processes affecting local ecosystems and local cultures.

Gunderson and Holling's (2002) heuristic model of cross-scale interactions in linked social-ecological systems integrates the ideas of fast and slow moving emergent features of complex systems (borrowed from ecological economics), temporal scale (borrowed from geography and environmental history), vertical scale (borrowed from the political sciences) as well as the idea that micro level phenomena affect macro level processes to an equal extent as the macro affects the local (borrowed from sociology) (Table 1). Coleman's (1990) argument that the micro can affect and even shape the macro, comes across clearly in this model.

The model is premised on the idea that both natural and human systems undergo cycles of organisation, collapse and renewal. The adaptive renewal cycle emerged from earlier discussions around multiple stable states (Holling, 1973), and incorporates key processes underpinning resilience (Walker *et al,* 2002), institutional memory (Berkes and Folke, 2002), disturbance (Gunderson, 1999), adaptation, and novelty (Berkes *et al*, 2003). Thus, the model provides a useful navigational tool (Berkes *et al,* 2003) for conceptualising and assessing the self-organising characteristics of complex adaptive systems (Kay *et al*, 1999), historical processes (Balee, 1998), context and feedback (von Bertalanffy, 1968), as well as the evolutionary link between institutions, culture, resources and the physical environment (Adger, 1999). The model also acknowledges the adaptive capabilities of local communities and ecosystems, an aspect significantly lacking in the MEA framework.

In Peru, an entirely different set of 'navigational tools' was used. Complex Adaptive Hierarchial System (CAHS) theory (Allen and Starr, 1982; Lowrance et al, 1986; Giampietro, 1994) was used to show the feasibility of starting from the Traditional Andean Cosmology Framework and Principles (TACEP) to assess multi-scale processes. Hierarchy Theory is based on: i) *Hierarchy as a system of filters*. Society and its rules act as a system of constraints, that buffer the intensity and frequency of changes in ecosystems; ii) *Holons and the dual nature of hierarchical systems*. A holon is a component of the hierarchy, consisting of smaller parts which are lower in the hierarchy. The holon maintains its own integrity, while simultaneously supporting the other parts of the whole, on which it depends for its existence. iii) *Arbitrariness*. Investigators can arbitrarily select a particular window of observation to isolate, describe and simplify a part of a system as an independent entity. In assessing a social-ecological system and predicting its future, this model advocates that investigators need to select the windows of observation carefully and ethically, recognizing their limitations.

TACFP, the traditional Andean cosmology, has many similarities with CAHS. It identifies the existence of three main hierarchical systems containing the whole of ecological, social and cultural processes of life. These systems are Kaypacha, the real world, HananPacha, the world of sacred features and divinities, and UkuPacha, the world of dead people or ancestors (Milla, 1983). Each of these could be seen as holons of the whole system made of smaller components at lower hierarchical scales. Traditional Space Management Principles (TSMP), widely studied by anthropologists in the 70's (Mayer & De la Cadena, 1989; Murra, 1975), such as reciprocity, complementarity and diversification, take place and are implemented by each social unit (person, household, community, ethnic group, region) at each scale. These cultural conceptions of space, processes, and endogenous principles constituted the roots of the assessment strategy in Peru.

Divergent methods for dealing with epistemology

Both the South African and Peruvian assessments sought explicitly to include different knowledge systems and worldviews in the assessment process, however the reasons behind this were different in the two cases. While the South African local level assessments came predominantly from the ecosystem management school outlined previously, the Peruvian study emphasised the ontological and ethical aspects of systems assessments, highlighting the need to respect and empower local and traditional knowledge and rights (Table 3).

Conceptual models help researchers to navigate transdisciplinary research in complex systems, however local assessment practitioners require innovative methods and techniques if they hope to 'bridge' epistemologies on the ground. The problem does not only involve researchers communicating with and understanding local knowledge, it involves the additional difficulty of communicating the information thus received back to other scientists in a way that makes sense, and in a way that does not further marginalize the less powerful knowledge system (Nadasdy, 1999).

In the South African assessment, learning and memory was considered to occur and to be stored at the level of the group (a social constructivist approach, Table 3), and therefore the techniques and methods used to bridge epistemologies were consensus based. Realizing that the methods used during an investigation also have ethical implications (Munda, 1999), a combination of various participatory research techniques was used, incorporating a range of visual, verbal and interactive techniques (Motteux, 2001). These included forum theatre, focus group workshops and interviews (Borrini-Feyerabend *et al*, 1997), semi-structured interviews with key informants (Pretty *et al,* 1995), as well as a range of Participatory Rural Appraisal (PRA) techniques (Chambers, 1994; Von Kotze, 1998; Kapoor, 2002).

These techniques aided considerably in communicating between knowledge systems at the village level, but were less helpful in communicating findings back to decision makers. For this reason, and also to improve confidence in the data, qualitative findings were validated through household surveys, vegetation surveys, water quality testing, and histiography. Participatory mapping exercises were also conducted through the use of geo-referenced orthographic photographs rather than free hand mapping. The maps were then digitised and land-use maps developed based on local knowledge that could be presented in a scientifically acceptable way.

A final aspect of the South African local level assessments involved the dissemination of the combined local and scientific knowledge back to the communities involved. This was achieved through scenarios (van der Heijden 1996; Peterson *et al*, 2003), or storylines, representing a range of plausible futures. These scenarios were based on an interpretation of information already gathered at the local level, which was combined with national level data on political and economic changes. The scenarios were presented using forum theatre, and digitally enhanced posters summarising the key changes in the relationship between local communities and ecosystems. In this way advanced technology was used to represent local knowledge in a format that both scientists and local people could understand and relate to.

This use of scenarios in South Africa provides a useful example of how knowledge and information can be transferred across scales of analysis in local level assessments. Scenarios developed at broader regional levels were interpreted first by the researchers for the communities in question. These interpretations were based on the researchers' understanding of local level processes in each community. A development acting group, who spoke the same language as the communities, then turned these interpretations into simple storylines and later into dramas. These dramas were performed for the community, and then amended through feedback from participants, to demonstrate how broader level economic and political changes might play out at the village level. Through a video documentary and written reports, this information was then presented to other scientists. Scenarios therefore provide just one example of how information generated at broader scales can be translated to local level actors in a way that makes sense to them, and how local responses can be translated back to scientists working at coarser scales.

In Peru, on the other hand, the ethical component of complex systems research underlay the entire process, emphasising the need to respect and empower the local and traditional rights of communities involved. The inherent complexity of the system forced the assessment to select the most relevant services and processes to be assessed. The key question in this task was *"relevant services and processes for Whom?".* Therefore, local people identified the processes and services to be assessed through debates, where scientific and traditional information was cross-checked. An overview committee was established with local authorities to control the entire process. Once the services and resources were selected, methodologies and tools were designed and adapted with local technicians, who were identified and legitimated by Local Communal Assemblies, which constituted traditional governing institutions.

The Andean assessment dealt explicitly with a crucial question that arises from the issue of participation; who has the power to impose the research process? Within this question, are the questions of who decides on the key goals, the methodologies and tools to be applied, and who identifies the stakeholders and social groups to participate? In order to deal with these questions, the Peruvian assessment treated local experts not simply as stakeholders that were made to participate, but as leaders and specialized researchers with rights to raise relevant research issues, and to suggest appropriate methodologies and tools.

The main research strategies employed with local technicians included resource surveys, participatory mapping, local debates within learning groups, endogenous video reports, Arariwas (Traditional Citizen's Juries), Traditional Resources Registers for prioritised resources (potatoes and medicinal plants), household surveys, and in-depth interviews with people with specialised knowledge regarding key resources. Information thus generated was shared and validated with communities at two different two different levels: i) learning groups composed of volunteers from all age and sex groups, and ii) local communal assemblies with the entire community.

What are the trade-offs when embracing a complex systems approach?

The inadequacy of literature dealing with research processes (Campbell, 2002) in complex systems research means inevitably that researchers enter uncharted waters. Two key sets of trade-offs were identified for the South African and Peruvian case studies. The first set relates to the advantages and disadvantages of selecting a particular set of conceptual models and research approaches. This provides a useful organizing framework for researchers working in different contexts, but necessarily influences the questions asked, the selection of issues to be addressed, and the interpretation of results. The second set of trade-offs relate to the advantages and disadvantages of democratised expertise, the confrontation of uncertainty, and the resultant dynamic and unpredictable nature of the research process.

1) Selection of approaches and conceptual frameworks

The South African experience provides a useful example of the first set of trade-offs involved when particular approaches and conceptual frameworks are selected. The trade-offs in the South African case study related to: i) the convenience of pre-designed frameworks, vs. the loss of alternative perspectives on human-environment relationships; ii) the inclusiveness of transdisciplinarity, vs. superficial research outcomes; iii) the rigour of pre-designed questions placing constraints on reflexive learning processes.

Pre-designed frameworks, vs. the loss of alternative perspectives - The South African case study incorporated local knowledge predominantly from a natural resource management perspective, as opposed to the ethical and ontological approach adopted by the Peruvian study. This approach proved very useful in the identification of underlying causes of change, adaptive processes at the local level, as well as non-linear relationships between different spatial and temporal scales. The use of these frameworks also improved the legitimacy and validity of the local assessments in the eyes of scientists and most policy makers. However, these models and relationships represent particular worldviews, developed outside of the local context to identify processes deemed important by scientists. Therefore, the research team had to compromise between utilising local cosmologies to understand changing human-environment relationships, and the *a priori* identification of processes relevant to the scientific arena, in the form of pre-determined models and conceptual frameworks. The negative trade-off was that the process was less participatory than that advocated by the proponents of community-based natural resource management (Fabricius *et al*. 2004), and possibly less legitimate than a true 'bottom-up' assessment in the eyes of local people.

Inclusiveness vs. superficiality - Working across disciplines is indispensable when dealing with complex multi-scale systems. Local management systems and resource use patterns know no disciplinary boundaries, and the drivers of social-ecological systems are ecological, biophysical, geographical, climatological, historical, political and economic. A transdisciplinary, inclusive approach allowed us to appreciate and record the multitude of factors that influence such systems. The negative trade-off, however, is superficiality, i.e. sacrificing a more detailed understanding of key processes. In the South African case study, researchers were involved in participatory research, ethnography, biological surveys and historical analysis. While this allowed for a broad and inclusive analysis of key processes and linkages between them, it was impossible to attain an in-depth understanding of the respective processes. Some of these processes, such as the relationship between diversity and productivity in natural and anthropogenic landscapes (see for example Salmon, 2000), the social and institutional impacts of large-scale economic interventions, and the effect of globalisation, are critical to complex system assessments and remain poorly understood.

Rigour vs. reflexive learning - Time constraints introduced some urgency into the assessment to ensure prompt and rigorous delivery of results, but this affected our ability to facilitate reflexive learning in participatory processes. The pre-designed nature of the MEA helped us to get our assessments off the ground rapidly. While a great deal of freedom was given in how researchers approached the assessments as well as the techniques used, there was little time in the assessments for participatory learning. For example, when dealing with scenarios, the time constraints allowed only for community responses to the possible futures, in terms of how the community would cope with new challenges implicit in these futures. No time was available to explore how feasible or appropriate the community responses were, or to evaluate responses to allow for critical thought. While all of the methods were, to some degree, useful to both researchers and local participants, all failed to develop in-depth reflection as part of the assessment process.

2) *Democratised expertise*

The ability to plan and to predict, vs. participation - The Peruvian case study provides a useful example of trade-offs relating to the inability to plan and to predict the research process. In line with the ethical considerations throughout the Peruvian research process, a great deal of control over the research questions and methods was devolved to local level actors. The study therefore gained considerably by achieving desired levels of participation, and thereby integrating indigenous cosmologies into the research process.

However, the devolution of control over research goals and processes raised expectations held by all parties involved (see for example Fabricius *et al,* 2001b), and resulted in an inability on the part of the scientists to plan the research process. During the Peruvian research process three major expectations arose at the outset; i) from the research team, expectations related to the relevance, content and consistency of final results, ii) from the local communities, expectations related to immediate short term benefits, and iii) from politicians and institutions, expectations related to the legitimacy of their role, control and power in the assessment process.

Researchers decided on the goals and methodology at the outset of the process. This is normal in scientific assessments, and even a prerequisite when dealing with externally funded research. Therefore, researchers held expectations regarding the results and their validity. However, despite the shared understanding among researchers of the *sui-generis* nature of the work, uncompleted activities or information that was perceived to be 'less precise', provoked fuzzy uncertainty and even distrust on the part of some researchers. For example, it lead to questions regarding the influence of facilitators, the methodologies applied and even the usefulness of relying on local knowledge. In the end, the frequency of the situation just described forced researchers to redefine the process itself, to enable the validation of data in the scientific arena. The adaptive approach adopted aided considerably in allowing for this flexibility.

Expectations from the community level related predominantly to short-term benefits that would accrue to key individuals. Local participants expected to become more respected in their communities and to win socio-political power through their participation in the project because of the involvement of development orientated institutions. As the assessment progressed, doubts emerged regarding the true interests of local participants. Some tried to satisfy personal interests, leading to local conflicts at different levels; i) between local participants, ii) between local participants and the rest of the community, and iii) between the community and the research team.

A similar situation emerged with the politicians and governmental institutions involved. These participants entered the process with expectations about legitimising their competencies and control at the local level. This lead to some intervening in the assessment process, while others presented the process as their own. In both cases the aim was to maintain control over local processes.

This represented a major trade-off in the Peruvian study; expectations had to be confronted in order to achieve desired levels of participation. Each group embarked on the assessment process with existing expectations, and the final result was different in every case for every group. Therefore, the actual research process was only identifiable in hindsight, despite efforts by all parties to shape the process at the outset. The adaptive approach established at the beginning was essential to allow an intuitive process that allowed those involved to navigate the unchartered research process.

Confronting uncertainty, vs. simplification - Both assessments confronted uncertainty as an inherent property of both complex systems, and of knowledge systems that cannot be tested using traditional scientific techniques. Thus, a significant trade-off was made between simple data that lends itself to validation, and information that is more difficult to tease apart, but also provides a more realistic reflection of the relationships between drivers of change at broader spatial and temporal scales, and realities on the ground.

In order to deal with the uncertainty that this approach generated, the teams sought to validate information through a combination of community and scientific validation of both scientific and local knowledge. In the South African assessment, this uncertainty was dealt with by treating local knowledge as an equally powerful source of knowledge, and therefore subjecting it to scientific cross validation through quantitative surveys and relevant literature. In order to deal with uncertainty and 'fuzzy' data in Peru, the concepts of traditional space management were applied to methodologies and tools; special emphasis was placed on methods and tools that encouraged a diversity of responses, rather than on trying to identify methods that would eliminate uncertainty (O'Neill *et al*, 1996; O'Neill and King, 1998). Literature review and historical research was integrated with the interpretation of customary practices and norms, and traditional taxonomic systems were complemented with occidental taxonomic systems. Finally, oral traditional knowledge was registered through the use of video, and then analyzed by the communities concerned. In this way, uncertainty resulting from a systems approach and democratised expertise was confronted and dealt with.

Although scientific rigour is a significant trade-off in local level assessments, both studies sought various methods to deal with the uncertainty thus created (Table 5). This process of validation also has the positive effect of encouraging deliberative and reflexive learning as local participants are forced to debate responses and opinions. This does, to some extent, remedy the trade-offs discussed previously when dealing with rigour vs. reflexive learning.

Conclusions

The metaphor of 'bridging' different knowledge systems assumes that there are two known shores: science and 'local knowledge'. The paper has demonstrated that this is scarcely the case; multiple shores exist, both within the 'sciences' and within local knowledge. We argue that the metaphor of a boat, navigating between unknown shores is a more appropriate metaphor for local level assessments that adopt a systems approach in dealing with scale, complexity and epistemology.

If local level studies that embrace a systems approach are to add value to analyses taking place at coarser scales, and if these studies are to be meaningfully compared, then three advances need to be realised. Firstly, given the current theoretical landscape of complex systems, researchers who seek to become transdisciplinary must identify the various directions in which their analyses may be pulled; failure to do so may lead to frustration and confusion. Secondly, uncertainty can no longer be shied away from, and the role that local knowledge can play in confronting this uncertainty must be recognised.

Finally, a common framework for analysis is required that strikes a balance between complexity and simplicity. Both case studies discussed in this paper were forced to find tools that enabled them to meet the needs of their local contexts. These tools came from the proverbial 'toolbox' that exists for community level research, and exist because an agreed upon framework has not yet been developed. An effective common framework would need to be open enough that it is understandable and legitimate to different disciplines and worldviews; flexible enough to integrate and address different indigenous cosmologies, and therefore allow space for knowledge and information from various sources; broad enough to consider multiple spatial and temporal scales, while simultaneously acknowledging dynamism, adaptability, non-linearity, lumpiness, uncertainty and variability, and allowing for both rigorous and fuzzy data. This is a tall order by anyone's standards, and daunting enough to make most shy away from the complexity involved. Consequently, in the absence even of consensus on whether a single framework adds value or provides yet another means to extend scientific networks, this final challenge remains a seaman's fancy.

Bibliography

Adger,W.N. (1999) Evolution of economy and environment: an application to land use in lowland Vietnam. *Ecological economics* **31,** pp. 365-379

Alcamo,J., et al (2003) *Ecosystems and human well being: A framework for assessment/Millennium Ecosystem Assessment*. Island Press, Washington

Alcorn,J.B. (1989) Process as resource. *Advances in Economic Botany* **7,** pp. 63-77

Allen,C.R. & Holling, C. S. (2002) Cross-scale structure and scale breaks in ecosystems and other complex systems. *Ecosystems* **5,** pp. 315-318

Allen,T. & Starr, T. (1982) *Hierarchy: Perspectives for ecological complexity*. University of Chicago Press, Chicago

Balee,W. (1998) *Advances in historical ecology*. Columbia University Press, New York

Barrett,C., Brandon, K., Gibson, C., & Gjertsen, H. (2001) Conserving tropical biodiversity amid weak institutions. *Bioscience* **51** (6): 497 - 517. *Bioscience* **51,** pp. 497-517

Berkes,F. & Folke, C. (1994) Investigating in cultural capital for a sustainable use of natural capital. *Investigating natural capital* (ed Jansson,A.M., Hammer,M. Folke,C. and Constanza,R.), Island Press, Washington D.C.

Berkes,F. & Folke, C. (1998) *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press, Cambridge

Berkes,F., Colding, J., & Folke, C. (2000) Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications* **10,** pp. 1251-1262

Berkes,F. & Folke, C. (2002) Back to the Future: Ecosystem Dynamics and Local Knowledge. *Panarchy: Understanding transformations in human and natural systems* (eds Gunderson L. & Holling,C.S.), pp. 121-144. Island Press, Washington D.C.

Berkes,F., Colding, J., & Folke, C. (2003) *Navigating social-ecological systems: Building resilience for complexity and change. Cambridge University press, Cambridge.* Cambridge University press, Cambridge

Bloschl,G. & Sivapalan, M. (1995) Scale issues in hydrological modelling: A review. *Hydrological processes* **9,** pp. 251-290

Borrini-Feyerabend,G. (1997) *Beyond Fences: Seeking Social Sustainability in Conservation*. IUCN, Kasparek Verlag, Gland, Switzerland

Boserup,E. (1965) *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Aldine, Chicago

Callicot,J.B. (1994) *Earths Insights. A survey of ecological ethics from the Mediterranean basin to the Australian outback*. University of California Press, Berkeley

Campbell,B., Mandondo, A., Sithole, B., De Jong, W., Luckert, M., & Matose, F. (2001) Challenges to the proponents of common property resource systems: despairing voices from the social forests of Zimbabwe. *World Development* **29,** pp. 589-600

Campbell,B. (2002) A critical appraisal of participatory methods in development research. *Social Research Methodology* **5,** pp. 19-29

Casti,J.L. (1994) *Complexification: explaining a paradoxical world through the science of surprise*. Harper Collins, New York

Chakraborty,R. & N. (2001) Stability and outcomes of common property institutions in forestry: evidence from the Terai region of Nepal. *Ecological economics* **36,** pp. 341-353

Chambers,R. (1994) Participatory Rural Appraisal (PRA): Analysis and Experience. *World Development* **22,** pp. 1253-1268

Chase-Dunn,C. & Hall, T. D. (2004) *Rise and demise: comparing world-systems*. Westview Press, Boulder

Colding,J. (1998) Analysis of hunting options by the use of general food taboos. *Ecological modeling* **110,** pp. 5-17

Coleman,J.S. (1990) *The foundations of social theory*. Harvard University Press, Cambridge

Demeritt,D. (1994) Ecology, objectivity and critique in writings on nature and human society. *Journal of Historical Geography* **20,** pp. 22-37

Du Toit, J., Walker, B., & Campbell, B. (2004) Conserving tropical nature: current challenges for ecologists. *Trends in Ecology and Evolution.* **19**, pp. 12-17

Fabricius,C., Koch, E., & Magome, H. (2001a) *Community wildlife management in Southern Africa: Challenging the assumptions of Eden. Evaluating Eden Series*. IIED, London

Fabricius,C., Koch, E., & Magome, H. (2001b) Towards strengthening collaborative ecosystems management: lessons from environmental conflict and political change in South Africa. *Journal of the royal society of New Zealand* **31,** pp. 831-844

Fabricius,C., Koch, E., Magome, H., & Turner, S. D. (2004) *Rights, resources and rural development: community-based natural resource management in southern Africa*. Earthscan, London

Feyerabend,P. (1970) Against method: Outline of an anarchistic theory of knowledge. *Minnesota studies in the philosophy of science* (eds Feigl,H. & Maxwell,G.), pp. 17-130. University of Minnesota Press, Minneapolis

Forsyth,T. (1999) Science, myth and knowledge: Testing Himalayan environmental degradation in Thailand. *Geoforum* **27,** pp. 375-392

Funtowicz,S. & Ravets, J. R. (1990) *Uncertainty and Quality in Science for Policy*. Kluwer Academic, Dordrecht

Funtowicz,S. & Ravets, J. R. (1992) Post--Normal Science: A New Science for New Times. *Scientific European* pp. 95-97

Gadgil,M., Berkes, F., & Folke, C. (1993) Indigenous knowledge for biodiversity conservation. *Ambio* **22,** pp. 151-156

Gadgil,M., Seshagiri Rao, P., Utkarsh, G., Pramod, P., Chhatre, A., & and members of the People's Biodiversity Initiative (2000) New meanings for old knowledge: the people's biodiversity registers program. *Ecological applications* **10,** pp. 1307-1317

Gadgil,M., Olsson, P., Berkes, F., & Folke, C. (2003) Exploring the role of local ecological knowledge in ecosystem management: three case studies. *Navigating social-ecological systems: building resilience for complexity and change* (eds Berkes,F., Colding,J., & Folke,C.), Cambridge University Press, Cambridge

Giampietro,M. (1994) Using Hierarchy Theory to Explore the Concept of Sustainable Development. *Futures* **26,** pp. 616-625

Gibson,C., Ostrom, E., & Ahn, T. (2000) The concept of scale and the human dimensions of global change: a survey. *Ecological economics* **32,** pp. 217-239

Gunderson L.H. (1999) Resilient management: comments on ecological and social dynamics in simple models of ecosystem management by S.R. Carpenter, W.A. Brock, and P. Hanson. *Conservation Ecology* **3,** pp. 7

Gunderson L.H. & Holling, C. S. (2002) *Panarchy: Understanding transformations in human and natural systems.* Island Press, Washington

Gunderson L.H. (2003) Adaptive dancing: interaction between social resilience and ecological crises. *Navigating social-ecological systems: Building resilience for complexity and change* (eds Berkes,F., Colding,J., & Folke,C.), Cambridge university press, Cambridge

Hannigan,J.A. (1995) *Environmental sociology: a social constructivist perspective*. Routledge, New York

Healy,S. (2003) Epistemological pluralism and the 'politics of choice'. *Futures* **35,** pp. 689-701

Holling,C.S. (1973) Resilience and stability of ecological systems. *Annual review of ecology and systematics* **4,** pp. 1-24

Holling,C.S. (1986) The resilience of terrestrial ecosystems: local surprise and global change. *Sustainable development of biosphere* (eds Clarke,W.C. & Munn,R.E.), Cambridge university press, Cambridge

Holling,C.S., Gunderson L., & Peterson, D. (2002) Sustainability and Panarchies. *Panarchy: understanding transformations in human and natural systems* (eds Gunderson L. & Holling,C.S.), pp. 63-102. Island Press, Washington

Holling,C.S., Gunderson L., & Ludwig, D. (2002) In quest of a theory of adaptive change. *Panarchy: understanding transformations in human and natural systems* (eds Gunderson L. & Holling,C.S.), pp. 3-24. Island Press, Washington

Hume,D. (1739) *A Treatise of Human Nature: Being an Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects*. Published anonymously,

Janssen,M.A. (2002) A future of surprises. *Panarchy: understanding transformations in human and natural systems* (eds Gunderson L. & Holling,C.S.), pp. 241-260. Island Press, Washington

Jewitt, G. P. W. and Gorgens, A. H. M. Scale and model inferences in the context of integrated water resources management for the rivers of the Kruger National Park. 627/1/00. 2004. Pretoria, South Africa, Water Resources Commission.

Johannes,R.E. (1998) The case for data-less marine resource management: examples from tropical near shore fisheries. *Trends in ecology and evolution* **13,** pp. 243-246

Jones,S. (2002) Social constructionism and hte environment: through the quagmire. *Global environmental change* **12,** pp. 247-251

Kapoor,I. (2002) The devils in the theory: a critical assessment of Robert Chambers' work on participatory development. *Third World Quarterly* **23,** pp. 101-117

Kay,J., Regier, H., Boyle, M., & Francis, G. (1999) An ecosystem approach for sustainability: addressing the challenge of complexity. *Futures* **31,** pp. 721-742

Latour,B. (1987) *Science in action*. Harvard University Press, Cambridge

Latour,B. (1988) *The Pasteurisation of France*. Harvard University Press, Cambridge

Leach,M. & Fairhead, J. (2000) Fashioned forest pasts, occluded histories? International environmental analysis in West African Locales. *Development and change* **31,** pp. 35-59

Lele,S. (2000) *Godsend, Slight of Hand, or just Muddling Through: Joint Water Management in India*. ODI,

Levin,S.A. (1992) The problem of pattern and scale in ecology. *Ecology* **73,** pp. 1943-1967

Lovell,C., Mandondo, A., & Moriarty, P. (2002) The question of scale in integrated natural resource management. *Conservation Ecology* **5,**

Lowrance,R., Hendrix, P., & Odum, E. (1986) A hierarchical approach to sustainable agriculture. *American journal of alternative agriculture* **1,** pp. 169-173

Ludwig,D., Walker, B., & Holling, C. S. (1997) Sustainability, stability, and resilience. *Conservation Ecology* **1,** pp. 7

Macnaghten,P. & Urry, J. (1998) *Contested natures*. Sage, London

Malthus,T. (1798) *An essay on the principle of population as it affects the future improvement of society*. Johnson, London

Martello,M. (2001) A paradox of virtue?: "other" knowledges and environment-development politics. *Global environmental politics* **1,** pp. 114-141

Martinez-Alier,J. & Schlupmann, K. (1991) *Ecological economics: energy, environment, society*. Blackwell Publishers, United Kingdom

Mauro,F.a.H.P.D. (2000) Traditional knowledge of indigenous and local communities: International debate and policy initiatives. *Ecological applications* **10,** pp. 1263-1269

Mayer, E. and De la Cadena, M. Cooperación y conflicto en la comunidad andina: zonas de producción y organización social. Ed. 1989. Lima, Peru, Instituto de Estudios Peruanos.

Meadows,D., Meadows, D., Randers, J., & Behrens, W. (1972) *The Limits to Growth*. Universe Books, New York

Meentemeyer,V. (2004) Geographical perspectives of space, time, and scale. *Landscape Ecology* **3,** pp. 163-173

Milla, C. (1983) Génesis de la cultura Andina. Lima, Peru, Amautica.

Milton,K. (1996) *Environmentalism and cultural theory: exploring the role of Anthropology in environmental discourse*. Routledge, London

Motteux, N. The Development and Co-ordination of Catchment Fora Through the Empowerment of Rural Communities. 1014/1/01. 2001. Grahamstown, Water Research Commission.
Ref Type: Report

Munda,G. (2000) Conceptualising and responding to complexity. *Environmental valuation in Europe: Policy research brief, number 2.* (eds Spash,C. & Carter,C.), Cambridge Research for the Environment, United Kingdom

Murphree, M. W. Boundaries and borders: the question of scale in the theory and practice of common property management. 2000. Bloomington, Indiana, USA. Eighth Biennial Conference of the International Association for the Study of Common Property. 6-4-0000.
Ref Type: Conference Proceeding

Murra, J. V. Formaciones económicas y políticas del mundo Andino. Murra, J. V. 1975. Lima, Peru, Instituto de Estudios Peruanos. Lima, Perú.

Nadasdy,P. (1999) The politics of TEK: power and the 'integration' of knowledge. *Arctic Anthropology* **36,**

O'Neill, J., Martinez-Alier, J., and Munda, G. Incommensurability of values in ecological economics. Ecology, Society, Economy . 1996. Paris, International Society for Ecological Economics.
Ref Type: Conference Proceeding

O'Neill,R.W. & King, A. W. (1998) Homage to St. Michael: Or why are there so many books on scale? *Ecological scale: Theory and applications* (eds Peterson,D.L. & Parker,V.T.), Columbia University Press, New York

Ostrom,E. (1990) *Governing the commons: the evolution of institutions for collective action*. University Press, Cambridge

Ostrom,E. & Hess, C. (2000) *Private and Common Property Rights*. Center for the study of institutions, population, and environmental change, Indiana University, Indiana

Peterson,G.D., Beard, D., Beisner, E., Bennett, S., Carpenter, G., Cumming, L., & Dent, H. T. (2003) Assessing future ecosystem services: a case study of the northern highland lake district, Wisconsin. *Conservation Ecology* **7,** pp. 1

Popper,K.R. (1968) *The Logic of Scientific Discovery*. Harper and Row, New York

Pretty, J., Guijt, I., Scoones, I., and Thompson, J. A Trainer's Guide for Participatory Learning and Action. 55-87. 1995. London, Sustainable Agriculture Programme. IIED Participatory Methodology Series.

Scheffer,M., Carpenter, S., Foley, J. A., Folke, C., & Walker, B. (2001) Catastrophic shifts in ecosystems. *Nature* **413,** pp. 591-596

Scheffer,M., Westley, F., Brock, W., & Holmgren, M. (2002) Dynamic interaction of societies and ecosystems - linking theories from ecology, economy, and sociology.

Schulze,R. (2000) Transcending scales of space and time in impact studies of climate and climate change on agro-hydrological responses. *Agriculture, ecosystems and environment* **82,** pp. 185-212

Shackleton, S. and Campbell, B. Devolution in Natural Resources Management: Institutional Arrangements and Power Shifts. A synthesis of case studies from Southern Africa. 690-0251. 2001. Grahamstown, South Africa, CSIR.
Ref Type: Report

Symanski,R. (2004) Contested realities: feral horses in outback Australia. *Annals of the Association of American Geographers* **84,** pp. 251-269

Tiffen,M., Mortimore, M., & Gichuki, F. (1994) *More people less erosion: Environmental recovery in Kenya*. John Wiley and Sons, Chichester

Tilly,C. (1984) *Big Structures, large processes, huge comparisons*. Russell Sage Foundation, New York van der Heijden,K. (1996) *Scenarios: the art of strategic conversation*. John Wiley, New York

von Bertalanffy,L. (1968) *General systems theory*. George Brazilier, New York

von Kotze,A. (1998) Monologues or dialogues? Missed learning opportunities in participatory rural appraisal. *Convergence* **31,** pp. 47-46

Walker,B. & Abel, N. (2002) Resilient rangelands - adaptation in complex systems. *Panarchy: understanding transformations in human and natural systems* (eds Gunderson L. & Holling,C.S.), pp. 293-313. Island Press, Washington

Walker,B., Carpenter, J., Anderies, N., Adel, G., Cumming, M., Lebel, J., Norberg, G. D., Peterson, G. D., & Pritchard, R. (2002) Resilience management in social-ecological systems: a working hypothesis for a participatory approach. *Conservation Ecology* **6,** pp. 14

Wicken,J.S. (1987) *Evolution, thermodynamics, and information: extending the Darwinian program*. Oxford University Press, Oxford

Williams,T.O. (1998) Multiple uses of common pool resources in semi arid West Africa: a survey of existing practices and options for sustainable management. *Natural Resouces Perspectives ODI (Overseas Development Institute)* Number **38,**

Wood,E.F. & Lakshmi, V. (1993) Scaling water and energy fluxes in climate systems: three land-atmosphere modelling experiments. *Journal of Climate* **6,** pp. 839-857

Worster,D. (1988) *The ends of the earth: Perspectives on modern environmental history*. Cambridge University press, Cambridge

TABLES

Table 1: Approaches to scale that characterize different academic disciplines

Approach	**Emphasis**	**Source**
Ecology	Predictions are scale and level dependent	Levin, 1992; Gibson *et al*, 2000
Geography	Spatial scale. Understanding human behaviour requires joint spatial and temporal analysis	Meentemeyer, 1989; Wood and Lakshmi, 1993
Environmental history, historical ecology	Temporal scale. Identification of root causes of environmental problems through analysis of historical landscapes	Worster, 1988; Balee, 1998; Berkes *et al,* 2003
Economics (including ecological economics)	Fast and slow moving emergent features. Conceptually hierarchical sets of nested sub-systems. Temporal scale is vital.	Martínez-Alier and Schlupmann 1991; Gibson *et al*, 2000; Holling, Gunderson and Ludwig, 2002; Holling, Gunderson and Peterson, 2002
Sociology	Agency. Processes at smaller spatial and temporal scales react to macro level processes and may act to change them	Tilly, 1984; Coleman, 1990; Scheffer *et al,* 2002
Political science (including political ecologists)	Spatial and institutional scale. Actions and outcomes of aggregated units of governance at different spatial scales. Several actors, each with unique definition of knowledge, resources, and ecological relations.	Gibson *et al,* 2000; Williams, 1998; Murphree, 2000; Ostrom and Hess, 2000; Ostrom, 1990

Table 2: Approaches to complexity

Approach	Emphasis	Source
General systems theory	Connectedness, context and feedback. Challenge ideas of linearity and reductionist science.	Von Bertalanffy, 1968; Berkes *et al*, 2003
Chaos and complexity theory (in party with non-equilibrium thermodynamics and catastrophe theorists)	Natural and social systems as open systems exhibiting similar self-organising behaviour. Self Organising Holarchic Open (SOHO) systems. Multiple stable states – coherent behaviour only within limits, focus therefore on disturbance, unstable equilibrium or catastrophe threshold.	Kay *et al*, 1999 Scheffer *et al,* 2001; Ludwig *et al*, 1997; Chase-Dunn and Hall, 1997
Biological and social evolutionary theorists	Feedback. Evolutionary link between institutions, culture, resources and physical environment. Dichotomy between human and natural systems avoided through emphasis on feedback.	Berkes and Folke, 1998; Adger, 1999; Holling *et al*, 2002
Historical ecology	History. Impossible to understand complex systems without a historical analysis	Balee, 1998
Post-normal science	Uncertainty. Peer review to be extended to the community level to ensure quality and validity of conclusions.	Functowicz and Ravetz, 1990; Functowicz & Ravetz, 1992

Table 3: Approaches to epistemology relevant to natural resource management

Approach	Emphasis	Source
Social constructivist (in the broadest sense) Post modernist Relativist	Knowledge cannot be divorced from social experience, and cannot therefore objectively access an external reality. Environmental 'problems' are culturally constructed. 'One truth' is as good as another, and therefore one knowledge claim cannot be privileged over another. A common reality exists, however nobody can ever know reality exactly as it is, and therefore diverse world-views are simply different interpretations of a common reality.	Macnaghten and Urry, 1998 Symanski, 1994; Hannigan, 1995; Milton, 1996 Demeritt, 1994
Environmental ethics	Power. Inclusion of multiple worldviews as an antidote to Foucauldian impressions of science as all-encompassing.	Callicot, 1994; Gadgil *et al*, 2000
Environmental management	Ability of traditional/local knowledge to contribute toward conservation of biodiversity, rare species, protected areas and sustainable resource use. Adaptive management has lessons to be learned from traditional/local knowledge	Gadgil *et al*., 1993; Alcorn, 1989; Colding, 1998; Johannes, 1998; Mauro and Hardison, 2000; Berkes *et al,* 2000; Martello 2001; Berkes *et al,* 2003; Gadgil *et al.,* 2003
Scepticism	Efforts to 'bridge' different knowledge systems will lead to the compartmentalization and distillation of the non-dominant knowledge system. Integration allows the extension of scientific frameworks and concentration of power in the hands of scientists. Local knowledge is seldom relevant outside of the local	Feyerabend, 1970; Latour, 1987, 1988; Forsyth, 1999; Nadasdy, 1999; Lovell *et al,* 2002; du Toit *et al,* 2004

	context. Integration implicitly assumes that knowledge is an intellectual product that can be isolated from its social context	

Table 4: Case study profiles

Case study	Land tenure	Livelihoods	Relationship with natural resources	Biome/vegetation type
South Africa, Eastern Cape Province. Community names: Qongqota and Machibi (27° 28' E, 33° 00' S)	Communal, most have been subjected to resettlement at some point in the past	Animal husbandry is very important, arable field cultivation is on the decline, most families keep home gardens, collection of wild resources, state pensions and welfare grants, migrant labour.	isiXhosa identity is strongly foundered on interaction with ancestors. There are strong links between the spiritual world and environmental features, such as pools, intact forests, medicinal plants and ancestors graves. Relationship increasingly strained through interaction in formal economy and associated land use change.	Valley Bushveld/Xeric Succulent Thicket
South Africa, Richtersveld National Park (28º15' S, 17º 10' E)	Communal tenure, those who live outside the National Park hold a 30 year lease allowing access for grazing. The original inhabitants remain inside the park.	Semi-nomadic pastoralists (mainly goats and sheep), collection of wild resources, state pensions and welfare grants, employment in local mines, migrant labour	Fuel wood is the primary energy source. Bushmeat, fish, and wild fruits supplement diets. Natural streams and watering points are central to all pastoralist activities.	Succulent Karroo
Peru, South Andean Mountain Chain, Cusco region. Community names: Sacaca, Amaru, Paru-Paru, Cuyo Grande, Chawaytiri, and Pampallaqta Between 13°30'E 70°31'S and 14º20'E 71°21'S	Communal after Agrarian Reform in the 1960's.	Poly-agriculture at household, community and landscape levels, animal husbandry, collection of wild resources, barter interchanges, handicrafts and fabrics, migrant labour	Close relationship with natural resources through Traditional Andean Cosmology which links natural resources, processes and services, with spiritual beliefs and human landscape management and local practices	Mountain ecosystems. High diversity of ecological conditions following an altitudinal pattern. *Puna*, *Suni* and *Yunga* bio-cultural zones.

Table 5: Summary table of approaches followed by the South African and Peruvian case studies

Case study	Conceptual models used to deal with scale, and complexity	Methods for bridging Epistemologies	Approaches for dealing with uncertainty
South Africa	• MEA framework • Adaptive renewal • Nested institutional and ecosystem change	• Summaries of literature • Forum theatre • PRA workshops • Combining local and GIS mapping • Vegetation surveys • Water quality testing • Household surveys • Key informant interviews	Triangulation through: • Historical records • Review of existing literature • Combination of various qualitative and quantitative methods • Community validation of scientific knowledge • Community validation of their own knowledge through feedback meetings • Scientific validation of local knowledge through surveys and literature
Peru	• Complex Adaptive Hierarchical Systems • Traditional Andean Cosmology • MEA framework	• Local debate and learning groups • Video reports and registers • Collective participative mapping • Traditional Geographical Information System (TGIS) • Arariwas (Traditional Citizen's Juries) • Traditional Resources Registers (Potatoes and Medicinal plants) • Household surveys • Specialized knowledge guarders conversations • Field trips and resources surveys	• Acceptance of uncertainty and variability as inherent property of the Andean System, and then of the research process • Application of traditional space management principles to methodologies and tools Triangulation through : • Review of existing literature • Historical research • Analysis and use of customary practices and norms • Integration of Traditional and Occidental Taxonomic Systems for space and resources characterization • Oral traditional knowledge registration • Combination of quantitative and qualitative information