# The character of interdisciplinary research

EXAMINED THROUGH A SAMPLE OF SOCIO-ENVIRONMENTAL RESEARCH PROJECTS

AUSTRALIAN ACADEMY OF THE HUMANITIES

AUSTRALIAN ACADEMY OF SCIENCE

ACADEMY OF THE SOCIAL SCIENCES IN AUSTRALIA

AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING

ACOLA

AUSTRALIAN COUNCIL OF LEARNED ACADEMIES

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Australian Academy of Science

ACADEMY OF THE SOCIAL SCIENCES IN AUSTRALIA

ATSE

ACOLA is the interface of the four Learned Academies:
Australian Academy of the Humanities
Australian Academy of Science
Academy of the Social Sciences in Australia
Australian Academy of Technological Sciences and Engineering

ACOLA
AUSTRALIAN COUNCIL OF LEARNED ACADEMIES

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The Australian Academy of the Humanities advances knowledge of, and the pursuit of excellence in, the humanities in Australia. Established by Royal Charter in 1969, the Academy is an independent organisation of more than 500 elected scholars who are leaders and experts in the humanities disciplines.

The Academy promotes the contribution of the humanities disciplines for public good and to the national research and innovation system, including their critical role in the interdisciplinary collaboration required to address societal challenges and opportunities. The Academy supports the next generation of humanities researchers and teachers through its grants programme, and provides authoritative and independent advice to governments, industry, the media and the public on matters concerning the humanities.

www.humanities.org.au

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The Australian Academy of Science is a private organisation established by Royal Charter in 1954. It comprises ~450 of Australia's leading scientists, elected for outstanding contributions to the life sciences and physical sciences. The Academy recognises and fosters science excellence through awards to established and early career researchers, provides evidence-based advice to assist public policy development, organises scientific conferences, and publishes scientific books and journals. The Academy represents Australian science internationally, through its National Committees for Science, and fosters international scientific relations through exchanges, events and meetings. The Academy promotes public awareness of science and its school education programs support and inspire primary and secondary teachers to bring inquiry-based science into classrooms around Australia.

www.science.org.au

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ACADEMY OF THE SOCIAL SCIENCES IN AUSTRALIA

ATSE

## Academy of Social Sciences in Australia

The Academy of the Social Sciences in Australia (ASSA) promotes excellence in the social sciences in Australia and in their contribution to public policy. It coordinates the promotion of research, teaching and advice in the social sciences, promote national and international scholarly cooperation across disciplines and sectors, comment on national needs and priorities in the social sciences and provide advice to government on issues of national importance.

Established in 1971, replacing its parent body the Social Science Research Council of Australia, itself founded in 1942, the academy is an independent, interdisciplinary body of elected Fellows. The Fellows are elected by their peers for their distinguished achievements and exceptional contributions made to the social sciences across 18 disciplines.

It is an autonomous, non-governmental organisation, devoted to the advancement of knowledge and research in the various social sciences.

www.assa.edu.au

## Australian Academy of Technological Sciences and Engineering

ATSE advocates for a future in which technological sciences and engineering and innovation contribute significantly to Australia's social, economic and environmental wellbeing. The Academy is empowered in its mission by some 800 Fellows drawn from industry, academia, research institutes and government, who represent the brightest and the best in technological sciences and engineering in Australia. Through engagement by our Fellows, the Academy provides robust, independent and trusted evidence-based advice on technological issues of national importance. We do this via activities including policy submissions, workshops, symposia, conferences parliamentary briefings, international exchanges and visits and the publication of scientific and technical reports. The Academy promotes science, and maths education via programs focusing on enquiry-based learning, teaching quality and career promotion. ATSE fosters national and international collaboration and encourages technology transfer for economic, social and environmental benefit.

www.atse.org.au

By providing a forum that brings together great minds, broad perspectives and knowledge, ACOLA is the nexus for true interdisciplinary cooperation to develop integrated problem solving and cutting edge thinking on key issues for the benefit of Australia.

ACOLA receives Australian Government funding from the Australian Research Council and the Department of Industry, Innovation, Science, Research and Tertiary Education. www.acola.org.au

# FOREWORD

Since 2010, ACOLA has been undertaking a study funded through the Australian Research Council into the question of interdisciplinary research in the area of environmental sustainability. This multivalent program of research is designed to address two outstanding problems, one a key issue in research management, the other a national challenge. The former is the application of interdisciplinary research to the broad, problem-based research agendas of today and tomorrow. The latter issue – addressed as a test case for the methodological work conducted in the first part of the program – is how to use this understanding to find effective ways of approaching the array of challenges confronting Australia, with particular emphasis on sustainability.

ACOLA members have recognised that research aiming at addressing the major societal challenges and visionary, groundbreaking new discoveries will increasingly require an interdisciplinary approach. The need for interdisciplinary research will continue to grow, particularly in applied fields, yet the Australian research system at times presents it with many challenges that need to be overcome. Generally, funding bodies and research performers have operated in a world where research in single or closely related disciplines is the norm and interdisciplinary projects need to conform to policies and organisation structures for which they are ill suited. While a wide range of high quality discipline research needs to continue to be supported, as it provides the foundation for interdisciplinary programs, some changes in approach to funding and management are required.

More and more research is aimed at tackling the grand challenges of society and addressing complex problems which do not fall within the traditional academic disciplines. Consequently the need for an interdisciplinary approach, particularly for visionary research that attempts to break new ground, will continue to increase. The growing demand for interdisciplinary research is seen in every field.

At present, funding mechanisms (with the exception of the block grants to Universities) tend to be silo-based, and usually allocate funding on the basis of excellence defined in a narrow and field-specific fashion. The problem is made more difficult by the fact that many interdisciplinary proposals involve groups that are geographically separated and may require more time to reach their objectives than single-discipline projects.

This report, *The Character of Interdisciplinary Research: Examined through a sample of socio-environmental research projects,* prepared by Professor Michael Webber of the University of Melbourne, represents the second stage of a project funded through an ARC Learned Academies Special Projects (LASP) grant. The project outcomes began in 2011 with a report by Professor Gabriele Bammer from The Australian National University. The report, *Strengthening Interdisciplinary Research – what it is, what it does, how it does it and how it is supported* (ACOLA, 2012) examined the status quo in the field of interdisciplinary research in Australia, made a number of key findings and presented a set of six recommendations.

**Recommendations from** *Strengthening Interdisciplinary Research (2012)*

- The establishment of an agreed parsimonious classification which distinguishes the major kinds of interdisciplinary research.
- The establishment of standard reporting systems to fully describe different kinds of interdisciplinary research, allowing them to be understood, assessed and learnt from.
- The compilation of useful strategies into "toolkits", providing a range of options for conducting different aspect of interdisciplinary research, such as synthesising knowledge, building trust and engaging with end-users.
- The development of an effective system to collect data about the amount of interdisciplinary research of various kinds which is being undertaken.
- The development of an effective system to collect data about the quality of different kinds of interdisciplinary research. The assessment of the best ways of educating the next generation, including the value of starting with a base in a discipline and determining which skills are relevant.
- The convening of an ACOLA workshop with key individuals from government, industry, philanthropy and research organisations to develop action plans for strengthening interdisciplinary research.

That report served as a foundation for the more detailed context-based examination of interdisciplinary research related to environmental sustainability that has been undertaken by Professor Webber.

This report examines both intrinsic and external challenges across the whole field of interdisciplinary research into socio-environmental sustainability in Australia. Using a series of case studies, interviews, existing reports and an international seminar, he sets out to map not only the problems but also the strategies that have been developed to address those.

Broad findings include a series of institutional problems that those engaged in interdisciplinary research face, as well as specific characteristics of successful projects and comments on the opportunities that interdisciplinary research presents to influence transformational social change.

ACOLA welcomes feedback on these findings, particularly from practitioners in the field who have experienced the challenge of 'making interdisciplinary research work' so that the ongoing study can be thoroughly informed.

PETER LAVER AM FTSE
CHAIR, STEERING COMMITTEE

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# ABOUT THE PROJECT

## Making interdisciplinary research work

There are considerable benefits in encouraging interdisciplinary research, particularly where the objective of the research is to achieve useful economic, social, environmental or cultural outcomes. The real world does not always present its problems and opportunities conveniently aligned with traditional academic disciplines so mechanisms are needed to facilitate interactions and collaborations between researchers working in widely different fields.

Supported by the ARC Linkage Learned Academies Special Projects Funding this project addresses two outstanding problems: the application of interdisciplinary research to the broad, problem-based research and how to use this understanding to find effective ways of approaching the array of challenges confronting Australia.

The project comprises four components over three years:

1. Critical Examination of Interdisciplinary Research in Australia and abroad, was completed in February 2013 resulting in *Strengthening Interdisciplinary Research – what it is, what it does, how it does it and how it is supported*. The report made a series of recommendations, which formed the basis for the next phase of the project.
2. Interdisciplinary Research Applications for Sustainable Resource Utilisation and **3.** Sustainable Growth – Interdisciplinary Research Applications for Economic, Social and Cultural Prosperity were merged to deliver *The character of interdisciplinary research* (this report)
4. Lessons Learned for Interdisciplinary Research: Good Practice

A complex array of disparate but interlinked phenomena such as: population growth, the security of water and food supplies, energy use, urban infrastructure development, social harmony, and even refugee policy (with further complexity arising from the variability that may be induced by climate change) requires the integrated application of knowledge and understanding from all branches of academe (the natural sciences and technology, engineering, humanities, social sciences and the arts) to achieve workable solutions that will contribute to a sustainable future for Australia.

## Report aims

The aim of this report is to document good interdisciplinary research into issues of sustainability in Australia. It identifies good practices for interdisciplinary research in Australian universities and other research organisations, the hurdles to doing such research well and some strategies that have been used to overcome those hurdles. Drawing upon information about a sample of research projects and programs in the field of environmental sustainability at Australian universities to this report sought to:

- identify the breadth of interdisciplinary research programs and projects in Australian universities and other research organisations
- assess the extent to which ineffective policies and other barriers affect those research programs and projects
- observe good and bad practices and assess strategies for overcoming the hurdles to doing interdisciplinary research
- identify useful methods that researchers have employed to overcome some of the difficulties and barriers to interdisciplinary research
- document current achievements and the future opportunities for high quality interdisciplinary research into issues of sustainability.

# KEY FINDINGS

## Barriers and Challenges

General challenges include:

- Little training exists in the practice of interdisciplinary research
- Additional time is required within interdisciplinary projects to overcome multiple languages and methodologies, develop trust between researchers and relations with stakeholders
- A body of knowledge as to how to practice interdisciplinary research (within the field of sustainability) is still lacking
- It is not clear that large projects or centres are the most effective at delivering interdisciplinary research

Institutional challenges include:

- A disjunct (for younger researchers) between interdisciplinarity and career progress
- A lack of high-impact, prestigious interdisciplinary journals
- University structures (departments, faculties) that mitigate against broader inquiry
- Interdisciplinarity may inhibit career progress; the academic job market is organised into disciplines
- There is a lack of agreement about what constitutes quality in interdisciplinary research
- Competitive research funding is usually reviewed within disciplines

Broader, extrinsic challenges include:

- A peer review and research funding environment that is often not welcoming to interdisciplinary projects
- The multiple roles that interdisciplinary researchers are forced to play, as intermediaries, facilitators and scientists

## Characteristics of successful interdisciplinary research

The report identifies 13 key considerations for successful interdisciplinary research projects.

### 1. Leadership

The leadership group must be carefully chosen, ensuring that at least one member of the leadership group has project management skills. Interdisciplinary projects that involve several sub projects and several participants (with diverse motives) working towards a common goal over are complex operations.

### 2. Skills mix

The mix of disciplines represented in the project team must be chosen based on appropriateness to the project. The right mix of non-discipline skills is also essential such as project management, communications, facilitation and stakeholder management and data analytics and statistics.

Develop skills for the future, allow for succession, including the training and mentoring of junior researchers.

### 3. Team work

A good inter-disciplinary researcher should be: curious about, and willing to learn from, other disciplines (not suffer from disciplinary arrogance); flexible and adaptable; be open to ideas coming from other disciplines and experiences; creative; a good communicator and listener; able to absorb information and its implications rapidly; and a good team worker.

### 4. External input

Stakeholders and the public have information and skills that need to be combined appropriately with the information and skills of the researchers.

### 5. Ask the right questions

Spend a lot of time at the beginning getting the questions right.

### 6. Integrated findings

Successful projects factor into their design, at the beginning, how the findings of the different streams of research will be integrated. Different kinds of research proceed at different paces; thus, critical paths need to be understood for successful integration.

### 7. Size and scale

While there are plenty of pressures to enlarge projects, maintain an appropriate size. Large projects do not necessarily cohere; more people means more time spent on managing them; and additional people may take the project into inappropriate directions.

### 8. Meetings and communications

Consider the time, cost and means of communication to enable the most productive outcomes.

### 9. Plan for staggered outcomes

While projects can be scoped by defining research questions, implement projects by planning to deliver tangible products.

### 10. Supply and demand

Early decisions should be made about the role of end users or practitioners, whether they are to be central to the project and involved at all stages, on the leadership team or consulted at appropriate times.

### 11. Who will own the results?

Understand the role of commercialisation in the research program, if necessary ensure that the team has members who can facilitate. Protocols for intellectual property ownership should be agreed before the project commences.

### 12. The paperwork

Maintain documentation. A university and a funding agency will require lots of documents; in addition to these, however, the informal agreements with team members and end users need to be documented, as do the progress of individual sub-projects and the interactions between team members (and between the team and end users). Allow for these costs.

### 13. Managing the work-flow

Recognise that the team members have other responsibilities outside the project. The timing of contributions needs therefore to be explicitly negotiated between the leadership group and each team member, and documented.

## Achievements and Opportunities

Interdisciplinary research into environmental sustainability in Australia is still in the early stages. The Cooperative Research Centres and larger programs studied for this report are among the earliest large-scale research projects into socio-environments within Australia. Apart from specific technical expertise and research on the interface between agriculture and environmental management, this decade has really been one of learning how to do this kind of research, how to foster it and how to fund it. There has also been progress in developing tools for integration. That achievement is not inconsiderable. However, Australia would benefit from developing a long vision around interdisciplinary research needs.

# 1

# INTRODUCTION

THERE IS CONTINUED UNCERTAINTY ABOUT HOW TO CONDUCT INTERDISCIPLINARY RESEARCH, HOW TO PREPARE PEOPLE TO CONDUCT IT, AND HOW TO POSITION IT IN RELATION TO DISCIPLINARY RESEARCH. HOW SHOULD INTERDISCIPLINARY INVESTIGATIONS BE INITIATED, FUNDED, MANAGED, ASSESSED AND REWARDED? THESE UNCERTAINTIES REMAIN DESPITE A GROWING BODY OF INTERDISCIPLINARY RESEARCH AND SOME ATTEMPTS TO UNDERSTAND ITS CHARACTERISTICS.

In Australia, the Learned Academies have played an important role in seeking to describe the significance, role and conduct of interdisciplinary research. At the Australian Academy of Science 2002 symposium on Transition to Sustainability, Pearman *et al.* (2002) sought to identify the kind of science that would be needed to develop a sustainable Australia and the means of encouraging that science. They recommended the conduct of regional case studies of sustainability in newly-created centres which balance disciplinary and interdisciplinary focus, knowledge generation and application, a variety of methodologies, and different geographical foci; collaboration across universities and between the social and natural sciences; and an improved understanding of the barriers (including policy barriers) to this kind of research. After a review of projects on sustainability that had been conducted in Australia, the Joint Academies Committee on Sustainability of the National Academies Forum responded to this paper by commissioning Brinsmead's (2005) discussion of the methodological options for making integrated assessments of sustainability. Brinsmead used case studies to illustrate how to:

- develop an integrated understanding and description of material processes,
- conduct an integrated evaluation when diverse interests are included,
- develop an integrated design or an integrated policy that combines a number of alternative options into a single coherent strategy, and
- integrate the assessment process itself within its socio-political context.

Although his report was devoted principally to the 'how' of integrated assessment, Brinsmead also recommended a systematic review of national scientific and government institutions that influence the development of integrated assessments of sustainability.

The present project of the Australian Council of Learned Academies (ACOLA, the successor to the National Academies Forum) has stepped away from the details of interdisciplinary assessments of sustainability to consider the broader question of making interdisciplinary research work to achieve public policy goals. Phase 1 of this project identified ways of classifying interdisciplinary research (Bammer 2012) and proposed a program for strengthening and encouraging it. The Phase 1 report argued that some of the difficulties faced by interdisciplinary researchers and their projects are caused by university and government policies which do little to support interdisciplinary research. Effective policies should:

1. rest on good data and a simple measurement system that can accommodate change
2. reflect agreement on what constitutes quality
3. employ effective straightforward assessment mechanisms, which:
    a. resolve current debates and contribute to existing evaluations
    b. deal with the challenges for assessors in evaluating people and projects that fall outside areas they know well
    c. deal with harsh assessments by experts from component disciplines
    d. accommodate evaluation of impact
    e. set reasonable expectations and accommodate experimentation and failure
    f. identify a college of peers and exploit the benefits of peer-review
4. enhance supportive funding, remove barriers and avoid perverse incentives.

Without seeking how to prescribe how interdisciplinary research be done, she also recommended that toolkits be developed that assist interdisciplinary researchers to synthesise knowledge, build trust and engage with end users.

This report, Phase 2 of the ACOLA project, is thus intended to implement some of Bammer's recommendations in the context of sustainability. A decade after Pearman *et al.*'s (2002) recommendation that interdisciplinary research centres be established to conduct regionally-focused studies, there is now sufficient experience in Australia of such centres and other experiments in conducting interdisciplinary research into sustainability to:

1. identify cases of interdisciplinary research programs and projects in Australian universities and other research organisations. These cases are drawn from different categories of research. What kinds of interdisciplinary research about sustainability are done in Australia? The cases include programs and projects that might be deemed more successful as well as ones deemed less successful, and include brief reference to overseas examples;
2. assess the extent to which ineffective policies and other barriers affect those research programs and projects;
3. observe good and bad practices and assess strategies for overcoming the hurdles to doing interdisciplinary research;
4. identify useful methods that researchers have employed to overcome some of the difficulties and barriers to interdisciplinary research. This includes techniques used to establish trust and ways in which end-users and researchers collaborate;
5. document current achievements and the future opportunities for high class research into issues of sustainabiity.

These conclusions are drawn from research projects and programs in a variety of Australian universities and research organisations. The questions asked of each project / program included:

1. what is the interdisciplinary research aiming to achieve? (Is it problem-driven or curiosity-driven? To what degree is each present?)
2. what is being 'combined' (which disciplines? which practitioner knowledges? which end-user perspectives? different epistemologies, languages, cultures?)
3. what is the context in which the interdisciplinary research is occurring?
4. what is the decision-making process?
5. how is the interdisciplinary research undertaken?
6. what is the impact or outcome?
7. who evaluates the outcome? According to them, what is the evaluation?
8. what policies and other barriers inhibit / encourage those research programs and projects? What other issues influenced the outcomes of the projects, for good or ill?
9. what have been good and bad practices? What strategies are used to overcome the hurdles to interdisciplinary research?
10. what are current achievements and the future opportunities for high class research into issues of sustainabiilty?

Data have been collected not only from project leaders but also from junior researchers, who are doing the actual work.

The units of analysis are thus case studies of research programs and projects. They are not, except incidentally, case studies of university practices. In some universities, I studied several projects; in others one; some universities are not represented in the sample.

The case studies were identified in several ways:

1. I conducted a Google search with the key words "XXX interdisciplinary research" and identified centres or projects. [XXX denotes the name of the university or a common abbreviation, such as UWA.]

This information was recorded and some inferences drawn from it; I used it to inform the case studies.

2. In some universities, I selected one project or program on sustainability that was identified in the Google search. I selected a variety of kinds of programs: some university-initiated, some bottom-up; some more technical, and some more social; some programs, some individual projects.
3. I also sought to match comparison cases. When talking to a person involved in one project or program, the interviewee might mention a similar program in another university and explain how that program was different from the one we were discussing. I often followed up these suggestions.
4. A call was made to the Learned Academies to nominate fellows and projects or programs that might be of use or interest in this program. I followed some of these nominations.
5. Programs and projects directly focused on climate change or adaptation to climate change were not targeted. Of course, all research into sustainability is now informed and given relevance by past and likely future changes to our climate. The principle of selection was this: if a project stated its aim as 'managing water under conditions of climatic variability' and provided a rationale that referred to variability (perhaps greater variability in the future), then it belonged to the target population; if a project stated its aim as 'adapting to climatic variability' and used as a vehicle water management, then it was excluded from the population. Research on the specific causes of climate change and on modeling scenarios of future climates was excluded.

This search procedure is biased against research conducted by CSIRO, government agencies and non-university research groups. The principal reason for this exclusion is scale. University-based projects are sufficiently variegated without invoking yet another source of variation (though several of the sampled projects do include these other agencies as participants). Australia's national research agency, CSIRO, has, over the past decade, made massive organisational changes in refocusing its work on issues of national importance rather than disciplines. The experience provides a unique opportunity to understand the benefits and prices of doing this kind of research, one that could furnish by itself book-length studies of institutional change and research outside disciplines.

Disciplines are social constructions. The definitions of individual disciplines have changed over time, as disciplines have merged or been subdivided; disciplinary boundaries are different in different cultures, too. So, what counts as interdisciplinary in one place or time may not count as interdisciplinary in another; and what one person considers to be interdisciplinary may not be so to someone else. My principle in accepting programs and projects as interdisciplinary is that they are self-identified as such: if the documentation and the person I interviewed stated that this was interdisciplinary research, then I have accepted this. Self-identification is, after all, one of the principal stabilisers of such social constructions as disciplines.

To a lesser extent, I have also drawn upon the environmental projects that were awarded seed-funding by the University of Melbourne Interdisciplinary Seed Funding Scheme. This is not a sample – it is the entire set of projects funded in 2010 – 2012 – so it is not subject to my biases. It is of course subject to the biases, whatever they were, of the committee that chose these projects over other applications. The proponents in these projects were not interviewed, but there does exist documentation about their aims and their project leaders (see Rickards 2012 and www.sustainable.unimelb.edu.au/content/views/seed_funding, accessed 19 September 2012).

I have also drawn, occasionally, upon my own experiences. I am a geographer, and have

## Table 1. List of case studies, with sources

| Name of Program / Project | Interviewees | Documentary Sources |
|---|---|---|
| Melbourne Sustainable Society Institute [Melbourne] | Professor Craig Pearson<br>5 March 2012<br>Dr Lauren Rickards<br>7 March 2012 | www.sustainable.unimelb.edu.au<br>Rickards L 2012 *Melbourne Interdisciplinary Collaboration Exploration*, available at www.ri.unimelb.edu.au<br>*MSSI Annual Report 2011*, available at www.sustainable.unimelb.edu.au |
| Primary Industries Adaptation Research Network [Melbourne] | Dr Lauren Rickards<br>7 March 2012 | piarn.org.au |
| University of Melbourne Interdisciplinary Seed Funding Scheme | Dr Lauren Rickards<br>7 March 2012 | www.sustainable.unimelb.edu.au<br>Rickards L 2012 *Melbourne Interdisciplinary Collaboration Exploration*, available at www.ri.unimelb.edu.au<br>*MSSI Annual Report 2011*, available at www.sustainable.unimelb.edu.au |
| Centre for Water Sensitive Cities [Monash] | Professor Ana Deletic<br>12 March 2012 | www.watersensitivecities.org.au<br>Wong T H F *et al.* 2011 An inter-disciplinary research program for building water sensitive cities, 12th International Conference on Urban Drainage, Porto Alegre/Brazil, 11-16 September 2011 |
| Plant Movements across the Indian Ocean [Monash] | Dr Priya Rangan<br>16 March 2012 | Kull C A *et al.* 2011 Adoption, use and perception of Australian acacias around the world *Diversity and Distributions* 17: 822-836<br>Kull C and Rangan H 2008 Acacia exchanges: Wattles, thorn trees, and the study of plant movements Geoforum 39: 1258-1272 |
| Food flows [ANU] | Dr Rob Dyball<br>22 March 2012 | Porter J *et al*. 2011 How will growing cities eat? Nature 469 (7328): 34 |
| Sustainable Farms Project [ANU] | Professor Steve Dovers<br>23 March 2012 | Dovers S 2005 Clarifying the imperative of integration research for sustainable environmental management *Journal of Research Practice* 1: 1-19<br>Sherren K *et al*. 2011 Lessons from visualising the landscape and habitat implications of tree decline – and its remediation through tree planting – in Australia's grazing landscapes Landscape and Urban Planning 103: 248-258<br>Dovers S *et al.* 2011 CERF Significant Project 'Sustainable Farms' Final Report fennerschool-research.anu.edu.au/sustfarms/downloads |
| Integrated Catchment Assessment and Management Centre [ANU] | Professor Tony Jakeman<br>23 March 2012 | icam.anu.edu.au<br>Jakeman A J *et al*. (eds) 2008 *Environmental Modelling, Software and Decision Support: state of the art and new perspectives* Amsterdam: Elsevier |
| Regional Landscape Change [Ballarat, Deakin, Monash, Melbourne, UNSW] | Professor Peter Gell<br>5 April 2012 | crnballarat.com<br>Battarbee R *et al*. Human Impact on freshwater ecosystems. In Matthews J A (ed) *Sage* Handbook of Environmental Change, Vol 2, London: Sage 47-70<br>Dick J *et al*. 2011 A history of aquatic plants in the Ramsar-listed Coorong wetland, *South Australia* Journal of Paleolimnology 46: 623-635 |
| Landscape Logic [Tasmania, ANU, RMIT, Charles Sturt, CSIRO] | Professor Allan Curtis<br>13 April 2012 | www.landscapelogic.org.au<br>Lefroy T, Curtis A, Jakeman A and McKee J 2012 *Landscape Logic: Integrating Science for Landscape Management* Collingwood Vic: CSIRO |
| Farms, Rivers, Markets [Melbourne, Monash, Murray-Darling Freshwater Research Centre] | Wrap-up seminar, Latrobe-Wodonga<br>12 April, 2012<br>Dr Nick Bond<br>19 April | Langford J ed 2012 Farms, Rivers, Markets: Overview Report Melbourne: University of Melbourne<br>www.frm.unimelb.edu.au/default.htm |

| Name of Program / Project | Interviewees | Documentary Sources |
|---|---|---|
| Community Vulnerability and Extreme Events [Sunshine Coast] | Professor Tim Smith<br>19 April | www.usc.edu.au/university/faculties-and-divisions/faculty-of-arts-and-business/staff/032359.htm<br>Community vulnerability and extreme events: development of a typology of coastal settlement vulnerability to aid adaptation strategies (ARC Discovery, 2010 to 2012) (Baum S W, Smith T F and Arthurson K D) |
| Investment Framework for Environmental Resources (INFFER) [Western Australia] | Professor David Pannell<br>23 April | www.inffer.org<br>Pannell D J *et al.* 2012 Integrated assessment of public investment in land-use change to protect environmental assets in Australia Land Use Policy 29: 377-387<br>Roberts A M *et al.* 2011 Agricultural land management strategies to reduce phosphorus loads in the Gippsland Lakes, Australia Agricultural Systems 106: 11-22 |
| SE Queensland Urban Water Security Research Alliance [Queensland] | Dr Kelly Fielding<br>24 April | www.urbanwateralliance.org.au/index.html<br>Beal C *et al.* 2011 A novel mixed method smart metering approach to reconciling differences between perceived and actual residential end use water consumption. Journal of Cleaner Production doi:10.1016/j.jclepro.2011.09.007<br>Beal C *et al.* 2011 Using smart meters to identify social and technological impacts on residential water consumption. Water Science and Technology: Water Supply 11: 527-533<br>Bickford G and Lehmann R 2011 Review of the Urban Water Security Research Alliance Research www.urbanwateralliance.org.au/publications.html#reports |
| National Primary Industries Research Development and Extension Framework [Melbourne] | Dr Rob Day<br>24 April | www.daff.gov.au/agriculture-food/innovation/national-primary-industries |
| Advanced Water Management Centre [Queensland] | Professor Jurg Keller<br>30 April | www.awmc.uq.edu.au/water-recycling-research-program<br>Keller J 2010 Urban wastewater management in a resource-constrained world *ATSE Focus* August 2010 7-10 |
| Vulnerability to fuel prices in Australian cities [Griffith] | Dr Jago Dodson<br>1 May | www.griffith.edu.au/environment-planning-architecture/urban-research-program<br>Dodson J and Sipe N 2008 Shocking the suburbs: Oil vulnerability in the Australian city Sydney: UNSW Press |
| Sustainable tourism [Western Sydney] | Dr Robyn Bushell<br>10 May 2012 | Staiff R *et al.* (eds) 2012 *Heritage Tourism: Place, Encounter & Engagement* London: Routledge |
| National Centre for Groundwater Research and Training [Flinders, Charles Sturt, James Cook, Latrobe, Monash, QUT, ANU, UNSW, Queensland, Western Australia, South Australia, UTS, CSIRO, Geoscience Australia] | Professor Jennifer McKay<br>15 May 2012 | www.groundwater.com.au |
| Urbanism, climate adaptation and human health [Canberra, ANU, Queensland, Melbourne, Western Sydney, Curtin, James Cook, Qld Institute of Medical Research] | Professor Anthony Capon<br>31 May 2012 | www.csiro.au/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/Climate-Health-Cluster.aspx<br>Bambrick *et al.* 2011 Climate change and health in the urban environment: Adaptation opportunities in Australian cities Asia-Pacific Journal of Public Health 23: 67S-79S |

worked for over 40 years in departments where social and natural scientists have to work together and create common endeavours. In the past three years I have worked with other geographers, hydrologists and earth scientists on the problems associated with managing the supply of water to Shanghai. This is funded by the ARC Discovery Program, 2011-2014.

Finally, I included discussions about interdisciplinary research in Canada, Germany and the UK. The Canadian and UK experience is based on documents. In August 2012, I participated in a discussion of German-language interdisciplinary environmental research at the University of Cologne (and followed that up with a literature review). These are, of course, only a small selection of possible cases (there is a wider discussion of international experience of interdisciplinary research in Bammer 2012), but they provide some comparisons with the Australian cases.

Tables 1, 2 and 3 contain a list of cases studied. In qualitative research, the principles of sample selection are similar to those familiar to scientists: the sample size should be large enough to reflect the variations within the population and individuals should be chosen in an unbiased manner. As to size of the sample: subject to the constraints of budget and time, I sought to select cases until I had exhausted the variability in context, size of project, degree of formality, and disciplinary involvement. As to representativeness: the cases cannot be said to have been selected at random. An attempt was made to reduce my bias in selecting cases, by selecting from a wide variety of universities and by using university home pages and a Google search. However, this search was supplemented by cases I was referred to by interviewees, by cases that seemed comparable to cases already included and by a deliberate attempt to gain variety [for example, smaller projects and larger programs; inter-university collaborations and single institution projects; projects about environmental management, health, cities]. Of the people approached, 74 per cent agreed to talk to me, a gratifyingly high proportion. This process has led to a sample of cases that, while not random, nevertheless reflects the range of interdisciplinary research about sustainability that is being conducted in Australian universities.

Table 1 indicates the variety exhibited by the cases. Some are small, poorly funded projects that existed for only a few years; some are larger ARC-funded projects; others are formally established centres that have existed for half a decade or more; there are university-established centres and programs that are meant to foment interdisciplinary research; yet others are large, government-funded research centres intended to tackle particular problems. Some of these domains of variation influence success; but there are other differences that are not indicated on this table. The analytical sections of this report seek to identify the characteristics of projects and programs that influence their success.

In addition, I consulted two reports on interdisciplinary research, one in the UK and one in Canada, an evaluation of interdisciplinary research within CSIRO and participated in a seminar on interdisciplinary research in German-language institutions, see Table 2.

## Table 2. List of additional sources

| Name of Program / Project | Interviewees | Documentary Sources |
|---|---|---|
| Changing Knowledge and Disciplinary Boundaries Through Integrative Research Methods in the Social Sciences and Humanities | | Griffin G *et al.* 2006 Interdisciplinarity in interdisciplinary research programs in the UK, www.york.ac.uk/res/researchintegration/Interdisciplinarity_UK.pdf |
| Interdisciplinary research in the health sciences in Canada | | Hall J G *et al.* 2006 *Canadian Medical Association Journal* 175: 763-771 |
| Interdisciplinary research within CSIRO | | Syme G 2005 Integration initiatives at CSIRO: reflections of an insider *Journal of Research Practice* 1(2): 1-19 |
| Interdisciplinary research in German-language institutions | 30 August 2012 | igc2012.org/frontend/index.php?page_id=592&v=List&do=15&day=135&ses=52654#anker_session_52654 and igc2012.org/frontend/index.php?page_id=592&v=List&do=15&day=135&ses=52655#anker_session_52655 |

Note: In addition to the data listed for each individual program or project, I also used Google Scholar to obtain a listing of the publications of one or more of the participants in the program.

## Table 3. List of projects funded by the University of Melbourne Interdisciplinary Seed Funding Scheme 2010-2012

| Project | Participants |
|---|---|
| 2012 | |
| The oral and geological record of natural hazards of Timor Leste and the development of a practical risk management strategy | Steven Boger, School of Earth Sciences, Faculty of Science<br>Robyn Sloggett, Centre for Cultural Materials and Conservation, School of Historical and Philosophical Studies<br>Sara Soares, School of Earth Sciences |
| Understanding Uptake: How Trust, Cognition and Statistical Transparency Influence the Adoption of New Models in NRM Decision Making | Yung En Chee, School of Botany<br>Mark Burgman, School of Botany<br>Ann Nicholson, Clayton School of Information Technology, Monash University<br>Fiona Fidler, School of Botany<br>Libby Rumpff, School of Botany<br>Peter Parbery, Department of Primary Industries (Vic Government) |
| Youth leadership and empowerment in rural east Timor: exploring a creative arts approach to sustainable community development | Violeta Schubert, Development Studies<br>Lindy Joubert, Architecture & Arts<br>Helen Hermann, Psychiatry, Centre for Youth Mental Health, School of Population Health<br>John Hajek, Languages & Linguistics<br>Margaret Kelaher, School of Population Health |
| Conceptions of human-nature relationships and sustainable action: Development and preliminary testing of an interdisciplinary theoretical framework | Kathryn Williams, Resource Management and Geography<br>Monica Minnegal, Social and Political Science<br>Jennifer Boldero Psychological Sciences<br>Peter Dwyer, Resource Management and Geography |
| Place, health and liveability | Carolyn Whitzman, Architecture, Building and Planning<br>Billie Giles-Corti, McCaughey Centre, School of Population Health<br>Lu Aye, Infrastructure Engineering<br>Dominique Hes, Architecture, Building and Planning<br>Melanie Davern, McCaughey Centre, School of Population Health<br>Iain Butterworth, Vic Department of Health |

| Project | Participants |
|---|---|
| **2011** | |
| Towards Achieving Environmentally Sustainable Supply Chain Management | Sherah Kurnia, Department of Information Systems<br>Mahbubur Rahim, School of IT, Monash University<br>Priyan Mendis, Civil and Environmental Engineering<br>Prakash Singh, Management and Marketing<br>Damien Power, Management and Marketing<br>Danny Samson, Management and Marketing |
| Climate Knowledge and Sustainable Lifestyle: Cultural Dynamics of Climate Change | Yoshihisa Kashima, Department of Psychological Sciences<br>Dr Ailie Gallant, School of Earth Sciences<br>David Karoly, School of Earth Sciences<br>Daniel Little, Department of Psychological Sciences<br>Angela Paladino, Department of Management and Marketing<br>Peter Rayner, School of Earth Sciences<br>David K. Sewell, Department of Psychological Sciences<br>John Wiseman, Melbourne Sustainable Society Institute |
| Institutional Resilience in Bushfire Prone Areas: Learning from Experience | Alan March, Faculty of Architecture, Building & Planning<br>Louise Harms, Social Work<br>Daniel Samson, Department of Management and Marketing |
| A social learning tool for educating stakeholders and assisting decisions on water allocation in the Murray Darling Basin | John Langford, Infrastructure Engineering<br>Graham Moore, Department of Civil and Environmental Engineering<br>Margaret Ayre, Department of Agriculture and Food Systems<br>Gerry Learmonth, Engineering and Applied Science, University of Virginia<br>John Freebairn, Economics<br>Ruth Nettle, Department of Agriculture and Food Systems<br>Andrew Western, Department of Civil and Environmental Engineering<br>Chris Arnott, Alluvium Consulting Pty Ltd<br>Phil Wallis, Uniwater, Monash University<br>Graham Steed, G R Steed & Associates |
| Urban Placemaking: social equity and cultural diversity | Ruth Fincher, Department of Resource Management and Geography<br>Maree Pardy, Gender Studies<br>Kate Shaw, Faculty of Architecture, Building and Planning |
| **2010** | |
| Limits of resilience – integrating empirical research with theory | Barb Downes, Resource Management and Geography<br>Fiona Miller, Resource Management & Geography<br>Jon Barnett, Resource Management & Geography |
| A triple bottom line review of the Building an Education Revolution initiative | Clare Newton, Architecture, Building & Planning<br>Kenn Fisher, Rubida Research<br>Sue Wilks, Architecture, Building and Planning<br>Robert Crawford, Architecture, Building and Planning<br>Ajibade Aibinu, Quantity Surveying & Construction<br>Dianne Chambers, Computer Education<br>Toong-Khuan Chan, Construction Management and Technology<br>Dominique Hes, Architecture, Building and Planning |

| Project | Participants |
| --- | --- |
| MUtopia – A Collaborative-Interdisciplinary Platform For Visualisation, Simulation And Testing Innovative Ideas Of Future Sustainable Urban Development | Priyan Mendis, Civil and Environmental Engineering<br>Hector Malano, Civil & Environmental Engineering<br>Abbas Rajabifard, Geomatics<br>Ian Johnston, Civil & Environmental Engineering<br>Colin Duffield, Civil & Environmental Engineering<br>Lu Aye, Civil & Environmental Engineering<br>Andrew Western, Civil & Environmental Engineering<br>Robert Crawford, Faculty of Architecture, Building and Planning<br>Brian Davidson, Melbourne School of Land and Environment<br>Tuan Ngo, Civil & Environmental Engineering<br>Hemanta Doloi, Faculty of Architecture, Building and Planning |
| Social Accountability for Sustainable Development | Tom Davis, Public Policy, Social and Political Sciences<br>Paul Smyth, School of Social & Political Sciences<br>Kate Macdonald, School of Social & Political Sciences<br>Jens Zinn, School of Social & Political Sciences<br>Nick Crofts, Nossal Institute<br>Jon Barnett, Dept. of Resource Management & Geography<br>John Tobin, Melbourne School of Law |
| Social characteristics of sustainability of rural and regional communities | Craig Pearson, Melbourne Sustainable Society Institute<br>Yoshi Kashima, Behavioural Science<br>Dean Lusher, Behavioural Science<br>Leonie Pearson, Life and Social Sciences, Swinburne University<br>Jenny Lewis, Social and Political Sciences<br>Sam Wilson, Melbourne Sustainable Society Institute |
| Revealing Hidden Waters – Socio-cultural perspectives on water planning, management and practice: an inter-disciplinary study of water on the margins of Melbourne | Annie Bolitho, Melbourne Sustainable Society Institute<br>Anna Hurlimann, Urban Planning<br>Natalie Jamieson, Office of Environment Programs<br>Kathryn Bowen, National Centre for Epidemiology and Population Health, Australian National University |
| Public Understanding of Bushfire Risk: Translating Science into Practice | Ruth Beilin, Resource Management and Geography<br>Karen Reid, Resource Management & Geography<br>Rebecca Ford, Resource Management & Geography<br>Helena Bender, Resource Management & Geography<br>Kevin Tolhurst, Forest & Ecosystem Science |

Source: www.sustainable.unimelb.edu.au/content/views/seed_funding, accessed 19 September 2012.

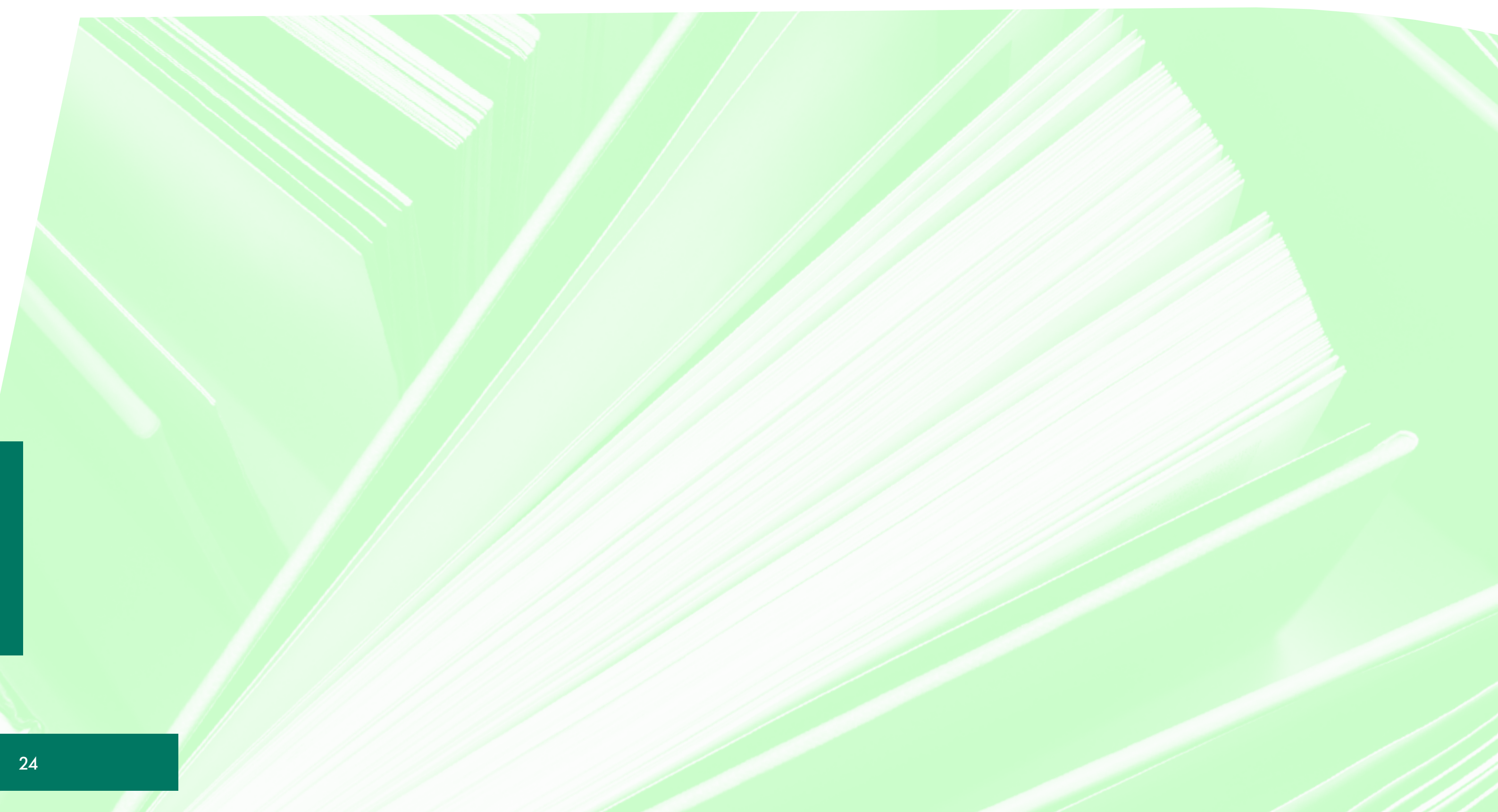
Using the information listed in Tables 1, 2 and 3, I followed standard guidelines for qualitative data collection and analysis (Miles and Huberman 1994). The analysis is not exploratory, since there are specific questions to be answered and there exist hypotheses about some of the characteristics of projects that affect outcomes. Nevertheless, the analysis proceeded according to familiar qualitative methods: assemble rich data about each case; combine induction and hypotheses to create categories of projects and programs; use deep immersion to infer the relationship between categories and outcomes; seek to be reflexive – returning to the cases in order to assess the validity of tentative conclusions and examining the relationship between the stories told by the data and the research questions. Miles and Huberman emphasise the following tests for evaluating the methods of a research project:

Objectivity/Confirmability: is the study relatively neutral, freed from unacknowledged researcher bias, explicit about inevitable bias?

Reliability/Dependability/Auditability: are the methods of study consistent and reasonably stable over time and across researchers and methods?

This study was conducted by a single individual [the author] and all interviews and data collection were undertaken by him. The data were collected within a short period [March – May 2012]. I conducted interviews using a standard open-ended format, with a set of predetermined topics:

1. What is the name of the project? End / start dates?
2. Funding?
3. What is the interdisciplinary research aiming to achieve? (Is it problem-driven or curiosity-driven? To what degree is each present?)
4. What is being 'combined' (which disciplines? Which practitioner knowledge? Which end-user perspectives? Different epistemologies, languages, cultures?)
5. What is the context in which the interdisciplinary research is occurring? Institutional? Pressures / constraints? Bottom-up / top-down?
6. What is the decision-making process? Governance structure?
7. How is the interdisciplinary research undertaken?
8. What is the impact or outcome?
9. Who evaluates the outcome? According to them, what is the evaluation? And according to you?



10. What policies and other barriers inhibit / encourage those research programs and projects? What other issues influenced the outcomes of the projects, for good or ill?
11. What have been good and bad practices; what strategies are used to overcome the hurdles to interdisciplinary research?
12. What are current achievements and the future opportunities for high class research into issues of sustainability in Australia?

I took notes in all interviews; transcribed them within one day; provided a copy to the interviewees, inviting their comments; and incorporated those comments. The interview and recording process was thus reliable and consistent over the course of the project.

Before each interview I collected public information about the research program or project and read some published papers, to inform my questioning and the subsequent discussion. I supplemented this information with other sources that the interviewees provided, such as annual reports, particular publications, and brochures. I invited interviewees to provide such supplementary information. There are inevitable differences in the visibility of projects, particularly between those that involve the collaboration of only a couple of people and those that are well-funded centres for research; but I have sought to obtain sufficient information to characterise each case – and where I needed to, I asked interviewees for it. There is greater variation between cases in such supplementary data than in interviews; but still it is not large.

A copy of all the data, including interview notes, has been stored securely. However, some interviews contained opinions and statements that interviewees did not want attributed to them. Such opinions cannot be usefully separated from the specific person who made them; therefore these data are confidential.

# 2

# INTERDISCIPLINARY RESEARCH ABOUT SUSTAINABILITY IN AUSTRALIA

IN THIS REPORT, RESEARCH ABOUT SUSTAINABILITY MEANS RESEARCH CONCERNED WITH THE ABILITY OF OUR SOCIETY TO CONTINUE TO EXIST IN THE LONG RUN IN SOMETHING SIMILAR TO ITS PRESENT FORM, INSOFAR AS THAT DEPENDS ON OUR ENVIRONMENT. IN THE LONG RUN, SOCIETIES CAN CONTINUE TO FUNCTION ONLY IF THEY MEET CERTAIN CONDITIONS (MOST OF WHICH WE DON'T UNDERSTAND), SUCH AS CLASS RELATIONS, FORMS OF GOVERNANCE, INTERGOVERNMENTAL RELATIONS, INVESTMENT AND EDUCATION.

These are not the issues with which this report is concerned. Rather this report investigates research into the environmental bases of sustainable societies – the relationship between such environmental variables as precipitation, runoff, evapotranspiration and water management; or temperature, soil conditions, slopes and forestry practices; or solar radiation, atmospheric physics, pollution regulations and urban planning on the one hand, and the long run well being of societies on the other.

The environment is constructed by biophysical and social processes, rather than simply being the external setting for the social world of humans, though the degree of human influence ranges from almost total (in an inner city) to relatively little (in an uninhabited outback); both the stuff of the environment (what you see or sense) and the processes that operate on that stuff are more or less social, less or more biophysical. Humans, both as individuals and as social groups, are partly constituted by their environments; we have evolved and we continue to behave within constraints set by biophysical processes. In an important sense we are biophysical processes. Equally, those biophysical processes are now inextricably linked to human practices, as the concept of the anthropocene emphasises (Crutzen and Stoermer 2000). The lesson of global warming, biodiversity loss, interference with the nitrogen and phosphorus cycles, ozone depletion, ocean acidification and freshwater use is that nowhere on earth is now outside human influence. By 1997 it was estimated that humans had directly transformed nearly 45 per cent of the land surface, contributed about 20 per cent of atmospheric $CO_2$, used about a half of accessible surface fresh water, contributed over 50 per cent of terrestrial nitrogen fixation and caused over 20 per cent of all bird species to become extinct in the previous 2000 years (Vitousek *et al.* 1997; see also Rockstrom *et al.* 2009). So water management, forestry practices, pollution regulations and urban planning are environmental variables. It is above all this co-evolving nature of the human-environment assemblage that determines the need for interdisciplinary research: ecologists, geomorphologists, atmospheric physicists, engineers, lawyers, economists, sociologists and geographers must contribute to understanding our socio-environment.

There do exist institutionalised fora in which such integration can occur. Most particularly, there exist departments or institutes of environmental studies, ecological economics and environmental history; examples include the Fenner School at ANU and The Australia Institute. Departments of agriculture and geography have performed a similar integrative role (the benefits of an integrated understanding of the socio-environment were recognised long ago). But most ecological economists and environmental historians, and many environmental scientists, are individuals working within broader departments – of economics or history, even environmental studies. In this respect, most of the people who work in interdisciplinary projects about sustainability are housed within individual departments such as chemistry, psychology, botany or sociology. Research of both forms (within dedicated institutes and across established departments) is represented in this report.

This section documents some of the research on sustainability that is being conducted in Australia. Principally, I am concerned with two questions: What is interdisciplinary research aiming to achieve? What is being 'combined'? This discussion points to some gaps in the topics that are researched and the disciplines that contribute to the research.

## 2.1 What is interdisciplinary research on sustainability in Australia aiming to achieve?

The projects are directed at four principal empirical topics.[1]

First, even though programs and projects directly aimed at understanding the causes of, impacts of and solutions to climate change were excluded from the sample, nevertheless climate change represented a principal theme of many projects. The range of questions is huge:

1. Which primary industry systems are vulnerable to climate change? Why? What is their adaptive capacity? How can adaptive capacity be increased? How can an enterprise move from having adaptive capacity to taking actions to adapt? What adaptation technologies, options and understanding are needed implement these actions?
2. What is the extent of knowledge about climate and climate change possessed by people? How is that knowledge related to the creation of a sustainable lifestyle? What are the cultural dynamics of climate change?
3. What will be the impacts of climate change in cities? How will these be related to the health of Australia's population (through, for example, heat stress)? What will be the health equity effects of anticipated climate changes and how should these be mitigated through health promotion, disease prevention and health services?
4. How should we design cities to be more sensitive to the constraints on water supply that cities face? What are socially and technically appropriate technologies to treat water for re-use or release? How should urban water regimes be governed?
5. At what scale are variations in vulnerability important – the nation, smaller communities, the household? Which households and which communities are likely to bear the uneven impacts of climate change the most?
6. Do we need to re-imagine our institutional arrangements for living together in the face of climate change and climate variability? Do we need new planning frameworks? Increased real time monitoring? Institutional change for water management? Can we create institutions that are less vulnerable to the frailties of human decision taking?

A second group of projects investigates the supply of water, food and energy and seeks ways to secure that supply, sustainably. These include studies aimed at the policy, cultural, economic and legal implications of sustainability of water, food and energy:

1. How to improve the allocation of water to wetlands through a decision-support system.
2. How to reduce the demand for water through the grid – storm water harvesting and reuse, rainwater tanks, residential water use, and / or demand management? What are the technical, economic and social constraints on the adoption of these methods?
3. How to improve the quality of water at source, particularly the safety of purified recycled water; how to raise the quality of water and water treatment across the water cycle.
4. What are the dimensions of vulnerability to fuel prices in Australian cities, especially in view of the fact that poorer households tend to live on the edges of Australian cities?

1 Almost all projects embrace innovative forms of representation, usually involving geographic information systems and methods of visualising the results of simulations and scenarios; this research is not separately reported on here.

5. What are resilient urban food systems and what is their contribution to promoting population health in a changing climate?
6. What new kinds of farming systems do Australian farmers need to adopt to cope with an increasingly variable climate?
7. What steps should we be taking to develop biofuels as an energy source within Australia?

Third, research on landscape management, biodiversity and conservation often involves the connection between biodiversity and society: pests and invasive species; threatened species and habitats; and ecosystem processes and services. However, the range is vast:

1. How do ecosystems respond to social and biophysical stresses? What are response and recovery times?
2. What is the political ecology of exchanges of biological material across oceans? What biological material has moved, where and when? Under what impulses? And with what effects on socio-environments?
3. What tools are needed to improve environmental management in Australia? Can role-playing games be used to improve water and environment management? Can evidence-based tools assess the technical and social feasibility of proposed environmental interventions? Do water markets create or mitigate environmental problems? What integrated assessment models and decision support systems promote the sustainable development of groundwater or are needed for modern river operating systems?
4. What accounting tools are appropriate to measure sustainability – at the national level (environmentally-relevant measures of GDP, for example) and at the level of individual enterprises?
5. Historical and future landscape change, ecosystem services and resilience are topics that involve the fields of biodiversity, conservation, as well as land use and planning. How can we use information about the past and scenarios of the future to equip regions and regional communities to adapt to environmental change in economically-viable and environmentally-sustainable ways? Can we integrate production and conservation in grazing landscapes so as to reduce the rate of paddock tree loss through active clearing or simple neglect?

What are the issues of vulnerability, risk, sensitivity and uncertainty that are faced in the integrated management of groundwater? And how are they to be managed? What is the degree of institutional resilience in bushfire prone areas?

Cities and towns are the focus of the fourth group of interdisciplinary research projects. Urban-focused research into sustainability raises some particular questions, including:

1. How to incorporate social equity and cultural diversity into planning, particularly planning for environmental variability and change.
2. What is the role of the urban transport system in creating or reducing pollution, making or adapting to climate change and improving or making worse our health? How can we raise the safety and integrity of infrastructure, improve the delivery of physical infrastructure, and manage our transport assets more efficiently and equitably?
3. How should we use knowledge about human behaviour in changing environments to inform governance systems about the implications of planning decisions and frameworks for human health?
4. Other topics, already mentioned, include: water sensitive urban design and treatment technologies; urban water governance; urban climatology; the health impacts of climate change in urban areas; and resilient urban food systems to promote population health in a changing climate.

These are empirical research questions. But they also involve theoretical questions, and most projects propose or develop new theoretical tools with which to conceptualise the issues under investigation.

Bammer (2012) recommended that analyses of interdisciplinary research investigate whether it is problem-driven or curiosity-driven. This is not an important distinction in these projects. Virtually everyone claimed that their research is driven by social need. In a broad sense, everyone considered that they were contributing to the creation of a more sustainable socio-environment, by producing more knowledge about the manner in which the socio-environment works, improving the technologies that mediate the material flows between human and nonhuman worlds, or enhancing the capacity of individuals, environmental managers and corporations to make decisions that protect the integrity of the socio-environmental system. The real questions to the researchers concern the extent to which projects are initiated and driven by end-users (such as funding agencies or environmental management agencies, which can direct research towards real world problems) as opposed to project researchers (who understand what fundamental knowledge may be within reach); and whether the projects' aims are immediate or longer term.

Several projects were initiated principally by researchers. These include: Plant Movements across the Indian Ocean; Food Flows; Sustainable Farms Project; Regional Landscape Change; Farms, Rivers, Markets; Community Vulnerability and Extreme Events; Vulnerability to Fuel Prices in Australian Cities. These are often two or three year projects, perhaps because of funding restrictions. At least some of them represent cynical attempts to acquire funding or other resources through environmental research rather than to understand socio-environments by means of those resources. Many projects combine the interests of researchers with the needs of funding agencies or environmental managers, often developing over an extended period of collaboration. Such is the Centre for Water Sensitive Cities; Integrated Catchment Assessment and Management Centre; Landscape Logic; Investment Framework for Environmental Resources; Advanced Water Management Centre; and Sustainable Tourism. The Primary Industries Adaptation Research Network falls into this category, too. Some of these are long term (Centre for Water Sensitive Cities; Landscape Logic; Advanced Water Management Centre) while others are sustained through a sequence of shorter term projects (Integrated Catchment Assessment and Management Centre; Investment Framework for Environmental Resources; and Sustainable Tourism). A few projects were initiated principally by funding and management agencies, most notably the SE Queensland Urban Water Security Research Alliance; National Centre for Groundwater Research and Training; and Urbanism, Climate Adaptation and Human Health. These projects tend to be long term and large scale. Nevertheless, whether initiated by researchers, agencies or some combination of these, this research is directed at three general questions.

The first question is: how does the socio-environmental system work? (How did it work in the past? How has it changed? What will the future look like?) This research is largely directed at understanding the risks to human beings (and only to a lesser extent, other populations) of this unfolding of the socio-environmental system. One particular form of these risks is their inequitable impact. Climate change is a large component of this question, though people are increasingly aware of the significance of other fluctuations in climates (such as associated with the ENSO signal) and of the manner in which human beings and environmental processes combined to create what we understand as the Australian landscape.

The second question is: what technologies exist or can be created with which to manage existing socio-environments and to adapt to possible futures? 'Technology' does not mean only a machine or chemical process; rather it comprises a 'socio-technical assemblage' – a combination of people, organisations, machines and processes that together manage human interactions with the world around them: their extraction of resources, their processing, and the disposal of their wastes. At the one end of such technologies lie the chemical processes for purifying water developed in the Advanced Water Management Centre – our traditional understanding of technology. At the other end lie some of the designs and equipment installations of the Centre for Water Sensitive Cities, which place more emphasis on the manner in which cities and houses are designed; the decision-support systems created by the Integrated Catchment Assessment and Management Centre; and the planning and urban design strategies advocated by the project on Urbanism, Climate Adaptation and Human Health.

And the third question is: how can we manage the socio-environment in a more sustainable way? Usually, this comes down to projects seeking to provide farmers and environmental managers with better information about the way in which the socio-environmental system works: the design of many projects implies that better information leads to better decisions. The Sustainable Farms Project sought to provide farmers with digestible information about the demographics of paddock trees so that they could manage paddocks for the long term survival of a treed landscape. The project on Regional Landscape Change is trying to understand how landscapes evolved, so that environmental managers have a better idea about what might be a 'natural' landscape in a region. The project on Community Vulnerability and Extreme Events seeks to provide information about who within a region is vulnerable to extreme events, and what those dimensions of vulnerability are; this ought to enable planners to understand (and so mitigate) the social risks created by extreme events. Landscape Logic used environmental sciences, such as ecology and hydrology, to inform environmental managers about the fallacies of some well-established management practices in Australia. The Investment Framework for Environmental Resources is a method for providing relevant and accurate information to inform decisions about investments in environmental assets, such as lake rehabilitation. It is by no means clear that it is scientific information that is always the resource in shortest supply when management decisions are made: one topic that is conspicuous in its absence is the politics and sociology of environmental decision taking.

Particular projects focus on only part of the socio-environmental system – this region, that time, this ecosystem, that river, this city. But in aggregate the research spans much of the socio-environmental system, even if there is little that attempts to present this aggregate picture, outside undergraduate textbooks. I make four observations about these research projects.

First, the study sites are located within the Australian coastal rim: from southeast Queensland to Canberra and Adelaide, with southwest Western Australia as an outlier. Even though projects from James Cook University and Charles Darwin University would provide coverage of northern Australia, nevertheless, the focus of research is highly concentrated on (as well as in) the 'big southeast corner'.

Secondly, research on urban issues represents a relatively small proportion of Australia's interdisciplinary environmental research portfolio. The Centre for Water Sensitive Cities, the project on Community Vulnerability and Extreme Events, the SE Queensland Urban Water Security Research Alliance, the Advanced Water Management Centre, the project on Vulnerability to Fuel Prices in Australian Cities, the Sustainable Tourism project and that on Urbanism, Climate Adaptation and Human Health are all directly and principally focused on urban areas – fewer than half the projects, even though I deliberately chose some urban projects. Similarly, the 17 (seed) projects funded by the Melbourne Sustainability Institute in

2010, 2011 and 2012 contained only five directed specifically at urban issues (six were specifically rural and the remainder neutral – they were directed at the population at large). In comparison, nearly three quarters of us live in cities of over 100 000 population (though not all of their environmental impact is constrained within urban boundaries).

Thirdly, I deliberately ensured that the sample contained economists and medical researchers, for example by searching within departmental home pages. But, apart from one case in the sample, there is little interdisciplinary research about sustainability and health in Australia. Likewise, most of the economics seems to be agricultural (agricultural economics contributes to Farms, Rivers, Markets, and the Investment Framework for Environmental Resources). Much of the dollars and cents work within environmental research is actually accounting. A survey of the projects funded by the Melbourne Sustainable Society Institute reveals just how acute is this shortage of medical and economic participants in research on environmental sustainability: out of 17 funded projects (with 96 named participants), only one involved an economist and only four involved researchers in medicine or health sciences. Section 3 of this report identifies some of the constraints that may inhibit university-based researchers in some disciplines from collaborating in interdisciplinary research projects; such non-university organisations as The Australia Institute do involve economists in their interdisciplinary research.

Finally, there is also a bias in the institutions from which research on environmental sustainability emanates. I deliberately sampled projects in the new universities that evolved out of the former institutes of technology. Nevertheless, they account for a strikingly high a proportion of projects. Excluding the funding schemes and collaborative networks, the list of projects and programs contains 42 instances of names of universities from which researchers contribute (this number counts universities not researchers). The big research-intensive universities figure large in this list (20 of the participations). But 13 (or 31 per cent) of the participations are by researchers at the former institutes of technology: Ballarat, Deakin, RMIT, CSU, Sunshine Coast, Western Sydney, QUT, UniSA, UTS, Canberra and Curtin.

It is not clear why interdisciplinary environmental research at new universities should form so large a share of the total portfolio. One hypothesis is that Australia's research-intensive universities are competing on a global scale, and reward staff success at that scale – success being measured as refereed publications in international journals about global scale issues. Such a structure of rewards means that staff research interests in the research-intensive universities are biased towards that scale, rather than to purely domestic interests. (Individuals have their specific interests; this is an argument about a tendency not a rule.) So there is a niche of local, domestic concerns that researchers in new universities are filling. Perhaps a similar hypothesis about the structure of rewards could explain the three research gaps.

## 2.2 A brief contrast with Canada

A brief comparison with Canadian interdisciplinary research on environmental sustainability makes some of these characteristics clear. McMahon and Oddie (2007) describe conceptual and empirical research about the Montreal, Toronto and Vancouver regions and then identify themes that characterise emerging Canadian research.

In contrast to Australia, Canadian research has a strong urban focus. (About 46 per cent of Canadians live in cities of more than one million people; about 63 per cent in cities of over 200 000 people. Both proportions are lower than in Australia.) At the University of British Columbia, for example, the Centre for Human Settlements and its Task Force on Healthy and Sustainable Communities spawned a series of reports that directed attention away from 'pure and wild nature' towards urban resource extraction and exploitation, waste generation and release. One result was the concept of ecological footprint (Rees 1992). In Montreal, the survival of social democracy at the municipal level is reflected in community-based and academically supported research projects that explore public engagement and urban environmental governance. In Toronto, debates about the preservation of urban green space, the problems of sprawl and the rehabilitation of the Great Lakes are predicated on the recognition that much of what happens in rural areas has its basis in the demands of urban people and their modes of social organisation. Such an integrated sense of the urban-rural, socio-natural environment is much less evident in Australia.

McMahon and Oddie also identify three emerging research topics. The first is 'globally inflected health concerns and related urban issues of environmental and food security' (McMahon and Oddie 2007: 49). In Canada health is one of the principal dimensions of research into sustainable cities. In Australia, the projects on Community Vulnerability to Extreme Events, on Vulnerability to Fuel Prices in Australian Cities and on Urbanism, Climate Adaptation and Human Health fall into this category. A second theme concerns the impacts of the actual environmental performance of infrastructural investment on sustainable development and metropolitan environments. Third is a continuing development of the concept of a bioregion to embed it within research on the flows of matter and energy that sustain communities, on urban agriculture and food security, and on the politics of sustainability within planning on the ground. The Centre for Water Sensitive Cities, the SE Queensland Urban Water Security Research Alliance and the project on Food Flows have similar concerns, as do several of the small projects funded by the Melbourne Sustainable Society Institute. But there is less effort devoted to such themes in Australia than in Canada.

## 2.3 What is being 'combined'?

Bammer (2012) advocated classifying interdisciplinary research according to eight criteria. Three of these form the basis for the discussion in this subsection:

- Number and diversity of perspectives combined,
- Ways disciplinary insights are combined,
- Degree of engagement with end-users to achieve policy, practice or technological innovation.

It is common to identify the simplest form of cross-disciplinary research as 'multi-disciplinary' (Dovers 2005). This is research in which the insights and methods of several disciplines are combined to provide a picture of a region or problem that is more comprehensive than a single discipline could provide. Such research provides multiple angles of view, like a collection of chapters written by different disciplinary practitioners who had not otherwise interacted. Alternatively, multidisciplinarity is a simple way of characterising research by identifying the disciplines and epistemological commitments of the participants in interdisciplinary research about environmental sustainability.

Appendix 1 contains data about the disciplines that participated in the projects. On average, each project had three or four disciplines represented among its participants, though several had six or seven. About a half of all discipline-project representations are accounted for by six disciplines – geography, ecology (with botany or biology), planning (and architecture), agriculture (which includes agricultural economics), environmental management (or resource management or environmental engineering) and hydrology (and water engineering). The other disciplines that are represented in about five of the 35 projects are psychology (and psychiatry), civil engineering (which includes transport engineering) and health sciences. Some of the collaborators are based in quite closely related disciplines (such as urban planning and economic geography), others in quite disparate disciplines (such as chemical engineering, psychology and law).

Apart from the small part played by health sciences and medicine in these projects, there are other gaps. None of the big social sciences (outside psychology) and virtually none of the large material sciences (outside the biological group) are strongly represented in these projects.

Chemists, geologists, sociologists and political scientists worked on a small number of projects, but there were no philosophers or physicists. With the exception of ecology, and to a lesser extent psychology and health sciences, Australian university-based interdisciplinary research on environmental sustainability is carried by a few small disciplines (like geography and hydrology) or the applied disciplines of planning, agriculture and engineering. This disciplinary composition of interdisciplinary research on environmental sustainability entails a pair of consequences.

One of these is a commitment to a largely pragmatic view of society and its environments. By and large, these projects understand society as a collection of rational (if not always fully informed) individuals, sometimes formed into competing interest groups and supervised and guided by a benign state. Much social science, though, entertains different understandings of society, that place a higher priority on structures and critique. Critical social theory, gender and other theories of difference, creative thinking about the constitution of socio-environments, the political economy of industrial-capitalist growth trajectories, sophisticated understandings of political and bureaucratic processes: none of these appears in these projects in more than a minor way. There is almost no engagement with different epistemologies or scientific cultures (Rickards 2012 noted the same characteristic of the University of Melbourne seed funding scheme).

In this respect, these projects of interdisciplinary research on environmental sustainability reflect a biased understanding of the constitution of socio-environments. This is not a criticism of the individual projects, or the social scientists, for their views are certainly part of the main stream; it is a critique of the composition of the research effort. And this means that there is little engagement between more critical and structural understandings of society and practical, immediate problems. There is little such engagement anywhere – critical / structural and mainstream social sciences are like two solitudes – but here is one forum in which such engagement could have occurred.

The second consequence is a limited engagement with transdisciplinary research. Much research into sustainability is intended to have practical application: to lead to behaviours that are *more* sustainable. We want to know how things work; but we also want to identify ways of making things work better. However, neither scientists nor policy makers cause things to work better. Environmental change is the consequence of the decisions of farmers, factory managers, car drivers, urban planners, architects, construction engineers and the like: the people who implement decisions, within contexts set by the socio-economic system, policies and biophysical processes. Therefore, if recommendations are to have practical, beneficial outcomes, they must be attuned to the world views of those decision makers and relevant to their socio-economic circumstances. In other words, those decision makers – or at least representatives of them – need to be engaged in the research process. A similar argument applies to policy makers: they need to be engaged, too. Transdisciplinary research, then, is research that involves decision makers, policy makers and researchers from more than a single discipline. 'Involve', at its most meagre might mean consultation; at its most comprehensive, it means that practitioners participate in the design, conduct and evaluation of the research – in the co-production of knowledge (Herweg *et al.* 2010; Pohl *et al.* 2010).

The relative position of expertise and public understandings of the way in which the world operates has long been debated in science and technology studies. (See the summary in Jasanoff 2003.) One interpretation of this debate is that useful information is held by both experts and the public. Indeed, scientists and others have to be constituted as experts by some kinds of social process – recognised as expert by a court of law, for example, or dignified by being heard by government departments. On the other hand, social processes of recognition and hearing themselves are influenced by scientific knowledge: successful prediction is one of the keys to being constituted an expert. A key question for interdisciplinary and transdisciplinary research into sustainability is how to combine these different knowledges: under what circumstances does lay knowledge form a useful element of a 'total' understanding? Under what circumstances does expert knowledge trump lay knowledge? There has been virtually no debate about this question in interdisciplinary research on socio-environments within Australia – and none within these projects.

Many projects did contain elements of transdisciplinarity. One of the directors of the Centre for Water Sensitive Cities is a consulting engineer. The Sustainable Farms project involved farmers. The work of the Integrated Catchment Assessment and Management Centre is designed in consultation with water managers; INFFER has a similar practice, as does the Sustainable Tourism project. Environmental managers participated to a degree in both the Regional Landscape Change and Landscape Logic projects. Government agencies and their needs help give direction to the SE Queensland Urban Water Security Alliance and the Advanced Water Management Centre. The National Centre for Groundwater Research and Training has an advisory board of practitioners. The project on Urbanism, Climate Adaptation and Human Health involves health professionals and managers. In these projects, the needs of managers provided foci for the research – defining the problem and, sometimes, prescribing the circumstances of decision makers who would use the results of the research – but then typically the researchers got on with the job and produced results. People, including farmers, were generally objects to be studied rather than practitioners who could contribute to the research. Sherren *et al.*'s (2010) remark about the Sustainable Farms project, that

> … our stakeholders have been invited to shape the research agenda during yearly workshops, but otherwise their involvement has been limited to hosting case sites and acting as subjects in social science methodologies

is typical of the strategies followed in even the most participatory of projects. Understood as an approach characterised by the continuous exchange of experience and knowledge among all interested and relevant actors throughout the project, the integrative development of a common conceptual framework and methodology, and extended periods of joint fieldwork (Herweg *et al.* 2010), more radical forms of transdisciplinary practice are little represented. They are not regarded as valuable or they have not proved necessary.

## 2.4 Conclusion

Australian research spans much of the socio-environmental system, but with some gaps. The southeastern coastal rim is over-represented, at least in relation to land area. There is a relatively small presence of urban issues. With the exception of ecology, and to a lesser extent psychology and health sciences, Australian interdisciplinary research on environmental sustainability is carried by a few small disciplines (like geography and hydrology) or the applied disciplines of planning, agriculture and engineering. Furthermore, there is almost no engagement with different epistemologies or scientific cultures or with transdisciplinary research. We know little about the reasons for these peculiarities of interdisciplinary environmental research in Australia. They do, however, limit the range of research, its potential innovativeness and its ability to contribute to the development of socio-environmental theory.

# 3

# INFLUENCE OF POLICIES AND OTHER BARRIERS

THIS SECTION IDENTIFIES SOME CONSTRAINTS UPON INTERDISCIPLINARY RESEARCH IN AUSTRALIA ON SUSTAINABILITY. IT ADDRESSES FOUR PRINCIPAL GROUPS OF QUESTIONS:

- WHAT IS THE CONTEXT (POLICY, POLITICAL AND INSTITUTIONAL) IN WHICH THE INTERDISCIPLINARY RESEARCH IS OCCURRING?
- WHAT IS THE IMPACT OF THE RESEARCH AND WHO EVALUATES IT?
- WHAT IS THE PROGRAM / PROJECT STRUCTURE?
- WHAT HAVE BEEN THE PROBLEMS OR BARRIERS THAT THE PROJECT OR PROGRAM ENCOUNTERED?

## 3.1 The context

Three kinds of context are important: the state of (and changes in) the socio-environment; new understandings of the manner in which research can or should be conducted; and an increasing understanding amongst policy makers about the value of interdisciplinary research. All play their part in influencing the design, conduct and success of the projects.

Research on sustainability reflects perceived need. Society needs knowledge about various elements of the socio-environment, but that need is translated into research funding and the other resources that are required to conduct interdisciplinary research by the perceptions of policy makers, funding agencies, university administrators, and individual researchers. Even the research funded by the ARC is steered into directions of national need through the national priority system and the perceptions and biases of reviewers and disciplinary panels. Research and research centres sponsored by state governments or federal ministries – such as the SE Queensland Urban Water Security Alliance and the Advanced Management Water Centre – illustrate the intermediating role of the research gatekeepers. The complexity of socio-environmental processes and the social value of interdisciplinary research on sustainability inspire many people – there are plenty of problems that people want solved, without inventing your (the researcher's) own; funding makes these aspirations real.

Research on environmental sustainability in Australia in the 21st century has been overwhelmingly driven by two considerations. One is the drought of 2003-2012 (the dates are different in different parts of the country). This is popularly understood to have been the worst drought on record, at least in terms of its financial impact on farmers (ABC 2003). Climatic variability – has been recognised as an environmental condition to which both rural and urban Australians needed to adapt, ever since Federation. Another driver is closely related – the threats posed by climate change. Since the IPCC's *First Assessment Report* was released in 1990, most scientists have accepted both that the globe is warming and that a principal cause is human. Nine of the 18 individual projects listed in Table 1 are directly focused on one or other of these problems, and several of the others are informed by them.

The Advanced Water Management Centre makes the reasoning clear:

> "It all began with the 'Millennium drought', before which abundant clean water was taken for granted. Scarce rain in South East Queensland and across most of the densely populated regions across the country increased pressure on our water supplies and awareness of the value of water. In addition to conservation measures, a diversification of water supply options and the concept of providing water fit-for-purpose are being gradually implemented across the country. In 2008 the AWMC established the Water Recycling Research Program to investigate the recovery of what constitutes the biggest part of wastewater (>99%). … In 2010, the Water Recycling Research Program then extended the scope of its activities to other urban water sources such as drinking water and storm-water, continuing and extending its multidisciplinary approach and collaborations with other research entities..." (www.awmc.uq.edu.au/water-recycling-research-program, accessed 19 September 2012).

The impact of these two concerns on environmental research is measured by publication statistics. A search of Google Scholar on the term "'climate change', Australia, interdisciplinary environmental sustainability research" revealed 19 200 items (some of these are duplicates, and not all are about Australia or authored by Australian-based researchers). By contrast, if the search is limited to materials published before 1992, only 215 items are listed. A search of "drought, Australia, interdisciplinary environmental sustainability research" reveals 6 260 items, only 107 of which were published on or before 1992. By contrast the number of items returned by a search on "salinity, Australia, interdisciplinary environmental sustainability research" halved between 2010 and 2012 (Pannell and Roberts 2010 provide a trenchant discussion of the rise and fall of salinity as a politically expedient socio-environmental issue between 2000 and 2007).

Other projects investigate and propose methods to make socio-environmental management more rational, or more in accordance with beliefs about environmental processes. These include the Integrated Catchment Assessment and Management Centre, Regional Landscape Change, Landscape Logic and Investment Framework for Environmental Resources. Like the National Primary Industries Research Development and Extension Framework, these projects respond to efficiency concerns, the translation of knowledge into environmental management practice. Some, like Regional Landscape Change (and Plant Movements Across the Indian Ocean), are more engaged at the research end of this strand, seeking to understand what the pre-European environment actually was like, to provide a baseline to which to managers might aspire; others, like Investment Framework for Environmental Resources, use existing research to develop an investment decision tool. The context for these is the increasing emphasis upon efficiency as a criterion of public sector investment and decision taking.

The remaining three projects aim at more localised threats to the socio-environment – providing a secure food supply to cities, managing farm landscapes sustainably, and encouraging sustainable behaviour among tourist operators. Sometimes the threats are perceived by local governments (as in Sustainable Tourism), at other times by the researchers (as in Sustainable Farms). The methods and theories deployed by these projects are much more sophisticated than they would have been ten or twenty years ago, nevertheless the topics would be familiar to environmental scientists of that era.

The influence of such perceived needs upon interdisciplinary research into environmental sustainability in Australia is unsurprising.[2] (Likewise, it is unsurprising that two of the University of Melbourne's seed funded projects concerned the risks of bush fires.) More surprising is the lack of intersection between most of these projects and current debates that animate social science, such as those over democracy, participation and inequality. (These concerns do appear in two projects – on Community Vulnerability and Extreme Events and Vulnerability to Fuel Prices in Australian Cities.) Such concerns also appeared in the portfolio of projects seed-funded by the University of Melbourne, though these projects have not yet gained competitive funding. This gap contrasts with the methods and results of the Victorian Women's Trust (2007).

The second context for interdisciplinary research on environmental sustainability is the model of research funding. This combines relatively small-scale funding of researcher-initiated projects with large-scale funding of research centres. Both kinds of project are represented in Table 1. Some projects, such as the Centre for Water Sensitive Cities, grew from small to large scale (it received CRC funding in 2012). However, there is a clear trend towards the concentration of research into university-based research centres (Turpin *et al*. 2011), manifest in the Cooperative Research Centre program, established in 1991. Insight Economics (2006) indicates that at any time there exist about 50 CRCs, each receiving on average over $ 70 million, spread over five years. In comparison, total ARC funding in 2006-2007 on Discovery Projects was $ 314 million, at an average of about $ 334 000 per project, spread over a maximum of three years. The 50 CRCs receive annually from the CRC program, universities and CSIRO a sum that exceeds the total expenditure on all

2 Whether the current interest in climate change and variability will survive the ending of the federal government's commitment to the National Climate Change Adaptation Research Facility in 2013 and the more normal rainfall of 2011 and 2012 is an open question.

ARC Discovery Projects. (The ARC itself in 2006 spent another $ 100 million on Centres of Excellence.) CSIRO, with its Flagships program, has joined the trend.

Turpin *et al.* (2011) argue that such research centres were regarded as a mechanism for concentrating research into funding programs rather than discrete projects, enticing universities to collaborate with each other and with other research institutions and industry, and encouraging new research management structures that by-pass what were seen as traditional and inflexible university bureaucracies. The first reason refers to the simplification of the management of funding programs (such as ARC) rather than to making research more effective at generating results. The second and third do address a perceived need: encouraging researchers – in different disciplines within universities, in different universities, in other research organisations and out in the 'real world' – to collaborate. Whether these two reasons imply that the new organisations have to be large is not obvious.

The effect is clear. There is a group of small projects and centres that subsist on ARC Discovery grants, university subsidies (including the implicit subsidies of salaries and infrastructure) or contract funding. Operating at a quite different scale are the large centres, which have varied sources of funding, long lives, and multiple projects run by separate teams. They incorporate researchers from a variety of universities and other research centres as well as having formal structures for the participation of end-users. Lying between these two extremes are some projects that were set up for specialised purposes: larger and better funded than the small projects, they nevertheless have quite short lives; examples are the projects on Regional Landscape Change, Landscape Logic and Farms, Rivers, Markets. Among both the small and the mid-sized projects are examples in which academics were asked by their universities to create projects to access collaborative funds or to create collaborations with other universities.

Since the population of researchers on environmental sustainability in Australia is relatively small, these large, multi-university collaborations imply that some researchers have a presence in many projects. Tony Jakeman, director of ANU's Integrated Catchment Assessment and Management Centre, leads the Integration and Decision Support Program of the National Centre for Groundwater Research and Training as well as being a project leader in the Landscape Logic project; the Centre for Water Sensitive Cities and the Advanced Water Management Centre are partners in the SE Queensland Urban Water Security Research Alliance. Such cross-directorships may reduce the variety of approaches taken by large projects.

Turpin *et al.* (2011) claim that the trend toward a centres model was not only driven by the promise of government funding. Another driver, they say, was the demand for problem-oriented, cross-disciplinary organisations which lay outside the traditional discipline-based structures of universities. The disciplines of planning and geography were not doing the job, or were perceived to be not doing it. An early example was the Centre for Resource and Environmental Studies at ANU, now the Fenner School. Centres could challenge the cultures of academic disciplines (Garrett-Jones *et al.* 2010). Centres reflected a dawning awareness of the need to institutionalise the transfer of research results from research organisations to end users. And centres embodied a realisation that complex, real-world problems like environmental sustainability can only be tackled through interdisciplinary or transdisciplinary approaches. Thus, the third context for these projects is a growing emphasis on interdisciplinarity. The University of Melbourne's Sustainable Society Institute and its Interdisciplinary Seed Funding Scheme are recognitions, however belated, of this trend.

These are the three contexts in which the research projects and programs operate. Some projects are designed explicitly – or even established primarily – to tap into these contexts. Even so, several projects, including some that became large, emerged gradually and principally from an interest in a particular problem. The detailed design of the project then reflects the evolution of a protracted negotiation between individuals with specific skills and knowledges about the best way in which to combine their interests and capacities to address some aspect of the problem. Such are the ARC Discovery Projects listed in Table 1. But so also are several of the other projects, such as the Centre for Water Sensitive Cities; the Investment Framework for Environmental Resources; the project on Urbanism, Climate Adaptation and Human Health. Such projects, and others like them, reflect an enduring interest in real, complex problems; sometimes they evolve into a form that reflects the contexts, perhaps through financial encouragement, or simply through the increasing availability of information about potential collaborators. But always they reflect the specific skills and capacities of the core participants.

## 3.2 Impacts of the research

Each project has its specific impacts – a piece of knowledge, a decision made differently, a different action. The particularities of these impacts are too detailed to document here. Instead, this subsection describes the sorts of impacts and the kinds of benefits that the research is perceived as delivering.

One important benefit is an increase in the sum total of environmental and management knowledge. This knowledge is encoded in journal papers or books, in software, in reports to government agencies or corporations, in verbal advice to managers, in seminars, or in community focus groups. In virtually all projects, this knowledge is both scientific and managerial. A special form of knowledge is an increased understanding of what we do not know: the unknown unknowns. All self-aware research contributes to a better understanding of the gaps in knowledge, and it is that understanding that leads people to continue to do research. Research can solve problems; but it also creates them.

A great deal of effort is expended to translate knowledge into practice. In some cases, this was a relatively smooth process, especially if research is tailored to a client's problems and if the output is presented in a manner that facilitates adoption: client-pulled innovation. Other projects seek to encourage adoption by including environmental managers within the research group or having industry partners on the board of management. Conferences and master classes, education materials for professionals (including course notes and resources) are produced and so are papers in policy-related and industry journals, like *Water* and *Urban Planning and Research*.

Adoption by end users, especially industry professionals working in government departments, is a difficult problem. Some projects study adoption processes, though commonly among the general public or farmers rather than among professional environmental managers. In many government departments, research results are not always welcome: information reduces flexibility about decision making; established systems within departments may not be compatible with the proposed innovation; some managers resist change, especially when it is proposed by academics; decision makers are often pressured to make decisions too quickly. Recently, in many departments, especially Commonwealth departments, staff turnover means that no one is expert in the field; teaching new managers about a project causes delays.

The application of knowledge and the involvement of end users on the one side may be linked to the integration of disciplinary contributions into a coherent whole on the other. One interviewee thought that the project s/he worked on failed to integrate its findings. The research was meant to be applied, but no agency stakeholders were engaged in the project to force the project leaders to ask integrated questions that would necessitate integrated research practices. So, in the end, the project did not deliver useful outcomes.

The projects train PhD students. Several projects sought to broaden students' awareness of work in and research questions arising from other disciplines, through master classes or summer schools that introduce them to environmental research in other departments and provide an experience of interdisciplinary research. These are ancillary to the main program of research of the students, which remains anchored within a single department, but they do introduce research students to interdisciplinary research and provide an opportunity for networking. Except, perhaps, for the Fenner School with its explicit commitment to interdisciplinary research, most programs and centres followed a similar practice: encourage students to think of problems about sustainability, but work within a single discipline, publish in its journals and focus on its labour market. The organisation of disciplines appears to inhibit supervisors from involving PhD students in explicitly interdisciplinary research problems.

These impacts are of value first to the participants themselves. People consistently stressed that the work of the project or centre was of practical value and could contribute to sustainable socio-environments. (This is what the farmers, environmental managers and consumers value too.) Everyone had to produce papers, preferably in highly ranked journals and they had to bring in additional funding, because these are how universities measure success. But for virtually all the participants, it was the science and / or its application that counted. Interdisciplinarity contributes to better science or social science and to more appropriate application. Researchers could meet new and interesting people from other disciplines, people who could bring a new perspective. Sometimes, it was as fun. It delivered prizes (Investment Framework for Environmental Resources won the 2009 Eureka Prize of the Australian Museum for interdisciplinary research), peer-recognition and desired positions. But in the end, people did it for the results.

Typical of the evaluations done by the participants themselves is Landscape Logic (2011).[3] The report describes the evaluation of the project by the participants and those who had interacted with it as potential end users. About a fifth of these people thought that the project had been a complete or partial failure; 60 – 70 per cent thought it a moderate or complete success; the others did not know. What worked was: engagement between researchers and end users; and the research itself. There were administrative failures (within the project); people questioned whether the benefits would last once the money had dried up; it may have been costly for what was achieved.

The audiences for interdisciplinary research into environmental sustainability are many. We are all stakeholders – we pay for it, and we have to live in the socio-environments that management practices deliver. Public information about research programs is limited, and usually restricted to comparisons of economic benefits and costs (such as Insight Economics 2006). But generally stakeholders include: government departments that provide the funding, without being a potential user (for example, the Commonwealth Department of Innovation, Industry, Science, Research and Tertiary Education might fund an environmental project, but not expect to apply its results); government departments that provide funds and anticipate use of the findings (such as a state department of environment); government departments and other environmental agencies (including NGOs) that do not fund but do expect to use the findings; specialised funding agencies, such as ARC and CRC; CSIRO, in its position as a funding agency and research organisation; the universities that host the projects and programs.

Typical of the evaluations done by or for such stakeholders is the review of the SE Queensland Urban Water Security Research Alliance (Bickford and Lehmann 2011). This review described the problems of

3 Dovers *et al.* (2011) is a shorter and less self-critical evaluation of the Sustainable Farms project.

managing water resources and supplying water to south east Queensland and the contributions that the Alliance had made in resolving those problems. It summarised the benefits to the government of Queensland from its investment in the Alliance, in terms of leveraging additional funds and knowledge gained. It described the research capacity developed through the funding and identified future research needs. Apparently, stakeholders believed that the Alliance had been an effective model in delivering the research program and had shared resources and information among the researchers. Bickford and Lehmann concluded that the government would gain more benefit if the research findings of the various themes were more closely integrated and if there were more transfer of knowledge to the government's agencies. Other agencies have different degrees of concern about impacts and measures of them, and often, the main evidence of a funding agency's evaluation is repeat business: a good centre is one that is growing.

## 3.3 Program/project structure

Interdisciplinary research is undertaken within a variety of structures. These include small projects, of two, three or four people who have found a common interest and work together to resolve a problem or question. Others are large, formally established centres, sometimes even incorporated. They have different decision making processes and different structures of governance.

In smaller projects, principals are typically equal. ARC Discovery projects involve investigators from the same university, or investigators who used to work together. The Sustainable Farms Project also worked in this manner, as does Investment Framework for Environmental Resources. These people know each other well, outside the research environment. They discuss the project as equals and share responsibility for decisions. The only small project that involved people widely separated from each other was the Food Flows project in the Fenner School at ANU (and that was a mandated cooperation).

Even so, disciplines are not always equal in such projects. Funding application processes imply that one discipline's problems are commonly taken as the core problematic, to which other disciplinary interests are subsumed. (Projects that are not funded through peer-evaluated funding models may not be susceptible to this problem.) For example, an ARC Discovery project from the Centre for Water Sensitive Cities involved engineers and a geographer; the three people were a team, working together. But the funding application was written as an application within the category of human geography, with the engineers as investigators who contributed particular expertise. Similarly, the project about Community Vulnerability and Extreme Events combined the interests of economic geography and planning, environmental management and public health and was envisaged as combining these areas of study equally. But the application was written as a piece of economic geography. The project about Plant Movements across the Indian Ocean involved a geographer working in environmental history, a biogeographer and a person working on botanical systems. ARC applications, however, were written as social science, pitched at using science to help answer problems of environmental history. In these framings, one discipline's problems are taken as central and the others as contributing to that problematic; the other disciplines are not regarded by the application process as core to the project. Only participants who trust each other can relegate their research questions for the purposes of an application for funds, believing that once funding is gained, those questions will once again become central to the project.

Smaller projects, in which principals operate as equals, virtually all originate within a single institution. Often the research questions arise out of chance remarks, or develop over long periods of discussion. Even some larger projects, such as the Centre for Water

Sensitive Cities, evolved in this fashion. This is a powerful reason for the existence of programs such as geography or institutions such as the Fenner School, that facilitate interaction between researchers with different backgrounds and research training. Such institutions provide a space for developing trust and mutual interests without adding to people's workloads (which multi-disciplinary seminar programs do). Conversely, both kinds of institution risk loss of disciplinary depth.

In larger projects and programs, governance structures are more formal, with a designated chief, head or chair. Typically, such larger projects were subdivided into themes or subprojects, by problem or discipline. In the former case, the research program could explode into a series of more or less linked projects. In the latter case, the program typically dissolved into a series of linked, discipline-specific projects, with little interdisciplinary work. Both approaches are common in large, multi-institutional programs and centres, but they also occurred in some single university projects (such as Farms, Rivers, Markets and the SE Queensland Urban Water Security Research Alliance). Multi-institutional collaborations, including Regional Landscape Change, Landscape Logic and the National Centre for Groundwater Research and Training, all had this structure. Landscape Logic (2011) commented that the relationship between team members and the management committee remained an issue throughout the project, as did the relationship between the different sub projects. Two centres – Integrated Catchment Assessment and Management Centre and Advanced Water Management Centre – operate like a university department, with a single head directing multiple strands of work.

The large projects, programs and centres face the problem of integrating the results from the various strands of research (or sub programs) into a coherent, interdisciplinary synthesis that answers the original research question. Even otherwise apparently strong programs, such as the SE Queensland Urban Water Security Research Alliance, struggled to integrate the research of separate teams (Bickford and Lehmann 2011). In the strongest projects, one person (or a small group of two or three people) had a vision, which drove the entire program. That core group then operated by inviting other contributors, almost as consultants, to provide answers to specific questions. In effect, this structure mimics the manner in which small projects operate. Such a structure provides the strength of a unified vision, especially if the group contains people from several disciplines, though it risks depending on a few people. It also excludes collaborators from the interdisciplinary synthesis, threatening their commitment to the project. Sometimes – and these were often the most effective projects – this vision drove the growth of a small scale project into a large centre.

Several research projects have been or threaten to be less effective at integrating their research themes into an interdisciplinary answer to a question about environmental sustainability. In the weakest of these, the chief essentially acted as a chair or administrator, securing funding, organising the paper work, and delegating responsibility for the various research sub projects to other people. In such arrangements, the separate themes develop separately. The chair may be weak or one or more of the theme leaders particularly strong. Such projects can produce good science, but little useful interdisciplinary insight into sustainable socio-environments.

These structures and outcomes invite the question: are big projects, programs or centres 'good'? CRCs and other large centres face diseconomies of scale. There is the cost of managing a large enterprise, often with disparate kinds of research programs, large numbers of more-or-less full time employees and a variety of end users. It may be easier and cheaper for a government department to manage a program of 50 CRCs than a program of 5000 Discovery projects, but there is a cost that is devolved to the CRCs. The most prominent diseconomy may, however, be the problem of integrating the results of the disparate sub programs into a single coherent whole (Landscape Logic 2011): large centres and research programs may be administratively convenient, but perhaps not deliver the best interdisciplinary research. A second diseconomy is that of enfranchising the staff within the sub programs: it is easy for a core management group to disperse funds to sub programs in a way that appears unfair and / or opaque, quite contrary to the ethos of many academic departments.

## 3.4 The problems and barriers facing interdisciplinary research into sustainability

During this century, interdisciplinary research into environmental sustainability in Australia has faced a context that is generally encouraging. It is recognised both that society needs to understand more about climate change and climatic variability and that this need has to be met at least in part through interdisciplinary research. But the interviewees observed that the institutional environment places barriers in the way of this research. Two problems are inherent in interdisciplinary research, at least at this stage of its development; but others are institutional and could be addressed by changes in policies or procedures of managing research.

The first problem, common to many of the projects, is the additional time that needs to be invested in interdisciplinary as compared to within-discipline projects. Separate disciplines have different languages, hierarchies of concepts, methodological precepts, standards for evidence, understandings of problem. Different disciplines have different expectations about the freedom of post doctoral fellows to choose their own research priorities. All these differences have to be negotiated, until the participants have a common language, similar concepts, methods, standards, problem statements – at least for the purposes of the project. An interdisciplinary project has to develop its own methodological and theoretical basis, out of the contributions of the team members. At present, different environmental problems apparently entail different combinations of discipline (though in practice influenced by networks of friendship and connection), which means that much of this groundwork needs to be done anew by each project. There is no disciplinary history that provides quick and commonly understood bases from which to develop the project and implement it. This all takes time and makes interdisciplinary research messier and slower than within-discipline collaborations.

Many projects underestimate the time needed to get the teams working together (Landscape Logic 2011). Pannell *et al.* (2006) describe a project to synthesise research about the adoption of conservation practices. The team comprised a psychologist, three sociologists and two economists, who spent two or three years arguing about concepts and findings before even beginning to write the paper. Yet in the end, they discovered that they agreed about almost everything; it just took several years to find the language to work that out, and then to find the shades of grey that were under-appreciated in standard disciplinary frameworks.

Nor is this negotiation simply about formal, disciplinary matters of language, concepts, methods, standards and problems. It is also interpersonal. Individual researchers have to be convinced about the need to collaborate and to align their goals with the goals of the project. This may mean accepting research priorities that are different from those that obtain in a single-discipline project – for example, stepping back from the frontiers of stream ecology to integrate known ecology with known hydrology. The team has to own the project as a group; the members must trust each other to be able to do the research, to want to do the research, to apply appropriate standard of work, to be nice to each other.

One way to reduce these costs is to collaborate with friends or long-term

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colleagues. This is an argument in favour of interdisciplinary research institutes, such as the Fenner School, or wide-ranging departments like agriculture or geography. One interviewee commented that cross-disciplinary links need to form over time in an unpressurised environment, in which people can discuss issues not related to a project through which they develop a level of trust and camaraderie before tackling the problem at hand. (There are, though, downsides to such institutions.)

Writing up the results of interdisciplinary research is also time consuming. At this stage all the ambiguities and sleights of hand that covered over some disagreements, all the incompletely specified concepts and understandings have to be made absolutely clear. Writing demands a clarity of thought that reveals the gaps in procedures and ideas. Superimposed on the demand for clarity are the different writing practices of different disciplines. Even within the single project, papers on different topics might need to be principally written by people from different disciplines (and targeted at different kinds of journals).

Collaboration with stakeholders also needs additional time (Sherren *et al.* 2010). Integrating end users into the research process, engaging them with agenda setting and the actual research process are important means of ensuring that recommendations are adopted. But stakeholders have to be part of the process of negotiating the project's language, concepts, methods, standards and problem statements. The priorities of stakeholders may change over time, causing research programs to be redirected (as happened when public attitudes to recycled drinking water became clearer); and they may have politically-inspired reactions to findings. If the representatives of stakeholders change over time (if, for example, government departmental staff leave or are promoted), all those initial negotiations may have to be repeated. And if adoption is complex, then industry partners need to commit to the time for training and the researchers need to budget the time to do this. Researchers in the Sustainable Farms project concluded that the time and costs of engaging with stakeholders may simply be unjustified in projects below the size of a CRC.

For larger projects, there is also the time and cost of management meetings. If projects are large, meetings of the management group must be formal, minuted and communicated to other members of the project. If the project or program is multi-institutional, these meetings also require travel. As Landscape Logic (2011) commented, the spatial separation of research teams also creates problems when trying to create partnerships. Such meetings eat into people's busy lives; but skimping on them is a recipe for dictatorship or disintegration.

The second intrinsic problem for interdisciplinary research now is the lack of procedural precedent. Several interviewees claimed that there is no large, well-established body of off-the-shelf precedent upon which researchers can draw. The corpus of interdisciplinary research into sustainability is small and the number of thoughtful reflections on the experience of the researchers is even smaller. There is no 'methods course' upon which participants can draw. Few researchers had actually read reflections from their predecessors and each research team thus essentially begins anew.

Therefore, each interdisciplinary project has to reinvent a disciplinary mix, agree on methods and standards, and identify a means of integrating the results of individual investigations into a coherent whole. The researchers have to do this and coordinate with stakeholders. Furthermore, participants can have no *a priori* understanding of a project's format and direction, once all the negotiations have been concluded. Cooperation with close colleagues means that participants can anticipate what project tasks will be, even if the specific sites, methods and theoretical frames are still to be worked out. But cooperation with people from different disciplines precludes such expectations. To an important extent, therefore, researchers who propose an interdisciplinary project cannot know what they will have to do.

Consequently, the standards of quality in interdisciplinary research into sustainability are not settled. There exist disagreements about the quality of individual pieces of work in all disciplines; and in social sciences, at least, this extends to disagreements about the quality of strands of research. But is interdisciplinary research into sustainability a matter of solving specific problems or is problem solving a means of assembling cases that are to be integrated into a coherent theory of socio-environmental sustainability? Is interdisciplinary research into sustainability a way of merging insights from individual disciplines (which implies that disciplines are fundamental) or it is trying to present a new form of knowledge, that transcends and ultimately challenges the disciplinary organisation of knowledge? Answers to these questions range from the completely traditional (disciplines are the basis for all academic knowledge and the logical frame on which to hang departmental structures) to the radical (disciplines are merely a way of dividing up knowledge that was convenient in the past but is now dysfunctional). Without agreement on such fundamental questions (or some of them), interdisciplinary research into sustainability will lack a sufficient body of precedent to resolve the issues of time and negotiation.

These two problems are intrinsic to interdisciplinary research – problems which only experience and reflection can resolve. German experience corroborates this account (Herweg 2010; Pohl 2010). The following problems are institutional, however, and can be rectified.

The academic job market is organised into disciplines. Disciplines are not merely ways of cutting up knowledge; they are social organisations through which jobs and resources are distributed. Interdisciplinary research is antithetical to that structure. For some people, this conflict is not a problem: established figures with influential positions within their discipline can afford to practise radical research experiments; cutting edge theoretical advances in one discipline sometimes require skills from another discipline (political ecologists may need to work with 'real' ecologists, for example); scientific or engineering advances may be marketable only after social research about adoption. But for other researchers, particularly junior academics and PhD students, interdisciplinarity may inhibit career progress.

In all disciplines the unit of output is a published paper or scholarly book. Quality is assessed by measures such as the impact factor of a journal or the citation rate of a book or paper. Funding – research opportunity – depends on these measures of success. This means working on topics with many active researchers and belonging to a community of scholars working on that topic. This is summarised in the phrase 'cutting edge'. It means empirically rich and theoretically well informed research, in which the terms 'empirical' and 'theoretical' are both defined internally by the disciplinary society (or peers). According to one interviewee: a paper is only publishable in a mainstream psychology journal if it pushes theoretical boundaries. Of necessity, interdisciplinary research lies outside this range; especially, cutting edge, theoretically informed, discipline-specific publications are exactly the kind of written output that practitioners and environmental management agencies do not want. Practitioner journals are not high impact publications that earn prestige for a faculty or university. This clearly poses problems for researchers who are not well-established within the hierarchy of their discipline. There are several issues (see also Griffin *et al.* 2006).

The first problem is that reputations and ultimately career prospects are determined by the societies that are their disciplines. Work published outside a discipline's journals, especially if it is not at the leading edge of the discipline's research trajectory, counts for little. If research is completed and published slowly then people's counts of papers and citations drop – they appear unproductive. If research is applied, it may be devalued. Researchers from big, prestigious disciplines – economics, psychology, environmental engineering, ecology – who publish in a smaller arena – geography, sociology, environmental change – find their citation counts dropping. Leaving a cohort of people recognised as working on a particular disciplinary problem risks recognition and citations. As several interviewees noted, a specialised research focus is the way to negotiate this game – or a certain level of seniority and peer-recognition that obviates the need to continue to compete.

The second problem is that deans and heads of department manage units that compete with similar units in other universities. That competition is over 'quality' and 'prestige', often measured by citations, PhD graduations or evaluation by peers, and is, in turn, driven by a similar competition between universities, that the ERA process only exacerbates. Therefore, even if individuals are prepared to bear the costs of interdisciplinary research in order to conduct research that is socially and environmentally relevant, their heads and deans may not. Deans prioritise their own faculties; interdisciplinary research is likely to annoy the dean and implies that the researcher is not entirely committed to the faculty and its goals (Rickards 2012).

The third problem is that universities, to varying degrees, manage their administrative processes through faculties. In an important sense, the University of Melbourne is a federation of faculties. In such a university, coordinating the appointment of staff in another faculty, paying people in another faculty, supervising graduate students in another faculty – all of these incur substantial investments of time. Incentive funds (such as central funds to faculties to recognise large numbers of ARC grants) flow only to the faculty of the first-named chief investigator. According to the interviewees, other universities face similar administrative problems.

> Soft money for interdisciplinary environmental research is easy to find; but staff are therefore on soft money, which breeds insecurity; so good staff leave for more secure positions.

Fourthly, outside interdisciplinary institutes and broad ranging departments, young staff who work in interdisciplinary research centres or programs are hired outside a formal departmental job market. However, teaching within universities is still generally organised through departments; and it is teaching that provides the bulk of the income that universities receive from the federal government. Unlike research income, teaching income is deemed sufficiently secure for departments, faculties and universities to base decisions about the number of tenured or tenurable staff on it. This means that staff working outside departments, such as those working in centres or programs devoted to interdisciplinary research, generally work outside the tenure system. A general complaint from younger staff – and from their sympathetic older colleagues – is lack of security, the feeling that jobs depend on the whim of funding agencies. Soft money for interdisciplinary environmental research is easy to find; but staff are therefore on soft money, which breeds insecurity; so good staff leave for more secure positions.

Thus, the most commonly cited disbenefits of participating in one research program are telling (Landscape Logic 2011): insufficient scientific output from the research and too much focus on producing non-peer reviewed publications. Unfortunately, the evaluation does not classify these responses by age or stage of career. Even so, most participants did evaluate their participation positively: 68 per cent stated that being part of of the program had positive effects on their career by creating new networks, exposing researchers to new methods and different scientists, providing experience in specific techniques in working and communicate with other disciplines.

For these reasons, several interviewees felt that PhD students should be firmly ensconced within a traditional discipline. For some, this was a matter of attaining sufficient specialisation and depth of research to attain standing in their own discipline. For others, the issues were more pragmatic: interdisciplinarity is harder, longer and more complex; universities are not designed to assist it; reviewers and examiners do not work easily in an interdisciplinary space; department heads recruit on the basis of mastery even if they say that they want breadth (Rickards 2012). Yet this means that no one is being trained in interdisciplinary work: once they become mature scholars, able to bear the costs of interdisciplinarity, they will have to reinvent interdisciplinary procedures.

The second institutional problem is reviewing. In the past, few journals were prepared to publish interdisciplinary papers about sustainability; that, however, is now less of a problem, even if the journals have yet to attain high impact scores. Now, the principal problem is that of finding qualified reviewers. The issue occurs in two arenas.

The first arena is that of the journal. If a paper is written by specialists from disparate fields who have spent years learning a common language to produce a paper that is outside the expertise of any one member of the team, then it is likely to be outside the expertise of any one reviewer – unless that reviewer has also conducted similar research. The relative scarcity of interdisciplinary research into sustainability means that such reviewers are hard to find. For example, hydrologists might find a paper woolly, the concepts imprecise, the data speculative and subjective whereas social scientists regard it as theoretically naïve and too concise; both consider that the problem statement misses the point. In part, this problem arises from the span of knowledge brought to bear on the research question; however, it also reflects lack of agreement about what constitutes quality in interdisciplinary research. (The same problem applies to interdisciplinary PhD theses.)

Secondly, lack of qualified reviewers raises problems in adjudicating applications for competitive research funding. Interviewees were universally scathing about processes at the ARC. Research projects are divided into five interdisciplinary groupings, or panels, which separate humanities; social sciences; physics, chemistry and earth sciences; mathematics and engineering; and biological sciences, all of which are critical components of projects about sustainability. An interdisciplinary project has no natural home in one of these panels. Within panels, projects are reviewed by disciplinary experts, who evaluate on the basis of the norms and criteria of their discipline (and perhaps identify their discipline as competing with other disciplines represented in that panel). There is no interdisciplinary arena within which interdisciplinary research into sustainability could properly fit, so people massage their applications (prioritising one discipline and making other contributions subsidiary to it). It is hard to conceive of a panel for interdisciplinary projects about sustainability, but even were one to exist qualified reviewers would still be scarce.

The third institutional issue is that of funding. Apart from shortage of funds, the organisation of funding also presents problems for interdisciplinary research into sustainability:

1. The ARC provides less funds than are requested and it does not pay chief investigators for their time. This means that ARC projects are conducted by full or part time research assistants or research fellows, under the general guidance of chief investigators. This both slows research and reduces the amount of conceptual effort within a project. In general, ARC research projects progress too slowly for policy relevance: academics as free labourers cannot work fast enough for policy relevance, which means that much policy-relevant research is undertaken by commercial organisations, which may be quick but superficial according to several interviewees.
2. Other government funding is subject to shifts in priorities. For established centres and research programs, the principal challenge is political influence over funding priorities. These shift rapidly and are not logical scientifically. Governments expect that new capacity can be generated quickly and then shed once the political priority has shifted. In fact, capacity takes time to build: sharp shifts in priorities impose high transaction costs. And three – five year funding cycles imply that centre managers must always worry about maintaining a research capacity. One commented that the biggest risk for a centre is that it builds capacity only to find that funding insufficient to maintain it.
3. If research is applied, researchers often need to involve several management agencies. But it is difficult to obtain their cooperation over funding. Such agencies often have specific industry or discipline bases which have to be coordinated before they agree on funding. Insofar as such work does not fall into the categories

of the national competitive grants system, it receives little recognition within the department, faculty, university or ERA.

4. In at least one centre, universities competed to maximise their share of project funds.
5. Medical research, including biotechnology, receives slightly more funding than all other science, social science and humanities research in Australia. Medical disciplines can dominate any field of research, distorting the overall direction of Australia's research effort.

The final institutional problem is that interdisciplinary researchers occupy multiple roles. Turpin *et al.* (2011) and Garrett-Jones *et al.* (2010) commented that people employed in CRCs occupy grey areas, having responsibilities to the CRC and to a university or government department. They also pointed to tensions between work for a discipline and work for an interdisciplinary project. Few respondents raised these as problems (though Landscape Logic 2011 identifies a conflict between personal goals and team goals). However, some respondents did identify a tension between their training as research scientists and the work that was required in a transdisciplinary project (compare Pohl *et al.* 2010).

People who conduct interdisciplinary and transdisciplinary research into sustainability have to play three roles. First, they are scientists, who are supposed to provide knowledge that is validated according to the norms of natural and social sciences. Secondly, they are intermediaries, whose task is to interrelate epistemological, conceptual and practical elements that were not related before, achieving a consensus about a problem, its causes and its solution. The evidence is that such negotiation is within the capacity of well-meaning scientists (though it does take time). They have to articulate disciplinary concerns in such a way that a common interest emerges. Thirdly, they are facilitators, helping the process of communication between the various disciplinary concerns and end users. The problems are that natural and social scientists are not trained in these second or third roles, and that they take time away from the first role (which researchers think of as their 'real job').

## 3.5 Conclusions

Since the mid 1990s in Australia it has been recognised that society needs to understand more about environmental change and variability, and money has followed this recognition. That perceived need is superimposed on longer term concerns about efficiency and rational management and various, more localised threats to environmental sustainability. Secondly, for whatever reason – administrative convenience, encouraging cross-university collaboration or challenging inflexible university bureaucracies – governments, university administrators and funding agencies have come to believe that much of the country's research effort should be concentrated into large centres. Even though small, investigator-initiated projects continue to be funded, the centres are drawing government, university and CSIRO research funds from small projects towards large centres. Thirdly, cross-disciplinary research has become newly fashionable. These are not isolated circumstances; rather, they operate in conjunction, promoting the kind of interdisciplinary, cross university, end-user participatory research centres about environmental sustainability that dominate the list of projects and programs in Table 1.

Interdisciplinary research into sustainability increases the sum total of environmental and management knowledge and to some degree has translated that knowledge into practice. However, adoption by end users, especially in government departments, is sometimes frustrated by resistance to research and high rates of staff turnover (though some projects also fail to deliver practical results). Though projects do train PhD students, there is little training in the practice of interdisciplinary research, nor agreement that this is desirable under current administrative practices in universities. In general, the knowledge, practice and training are regarded as valuable by most people who are familiar with interdisciplinary research projects.

Interdisciplinary research is undertaken within a variety of structures. In smaller projects, principals are typically equal and colleagues. Even so, institutional pressures may force participants to make some disciplines subsidiary to others. Larger projects and programs are commonly subdivided into sub projects, and governance structures are more formal, with a designated chief, head or chair. The large projects, programs and centres face the problem of integrating the results from the various sub programs into a coherent, interdisciplinary synthesis that answers the original research question. These structures have to balance the strength of vision that a core group could provide against excluding collaborators from the interdisciplinary synthesis, threatening their commitment to the project. It is not clear that large projects or centres are the most effective at delivering interdisciplinary research.

Despite the generally supportive environment, the favourable evaluations of participants and a gradual increase in knowledge about how to manage such projects, there does exist a range of problems and barriers to interdisciplinary research into sustainability. The first of these is the additional time that needs to be invested in interdisciplinary as compared to within-discipline projects – to negotiate languages, hierarchies of concepts, methodological precepts, standards for evidence, understandings of problem, to develop trusting relationships between team members, to resolve different styles of writing results, to collaborate with stakeholders, to manage. The second is the lack of an established corpus of knowledge about how to do interdisciplinary research into sustainability, which translates into a lack of standards of quality in interdisciplinary research into sustainability. These two problems are intrinsic to the current state of interdisciplinary research, though a sustained program of reflection and training could reduce their impact.

But the institutional environment in Australia, as in some other countries, also discourages interdisciplinary research. The academic job market is organised into disciplines which determine the reputations and ultimately career prospects of researchers and devalue research located on the discipline's borders. Deans, heads of department and university administrative structures are commonly antithetical to interdisciplinary research. Junior research positions within interdisciplinary research centres are often insecure. There is a lack of people qualified to review interdisciplinary applications for funding or research papers. Funding procedures also inhibit interdisciplinary research. Rather than merely creating schemes to fund interdisciplinary research into sustainability, it is desirable to remedy some of these disincentives, perhaps using some of the institutional innovations identified by Kueffer *et al.* (2012).

# 4

# GOOD AND BAD PRACTICES: TOOLS FOR INTEGRATION

ALL RESEARCH PROJECTS FACE PROBLEMS OF MANAGING TIME, BUDGETING, ORGANISING SUPPLIES AND SUPERVISING JUNIOR RESEARCH STAFF. PROJECTS WITH SEVERAL CHIEF INVESTIGATORS FACE ADDITIONAL PROBLEMS – OF AGREEING ON EXACTLY WHAT IS TO BE DONE, ON PRIORITIES AND ON WHO IS TO DO WHAT.

If projects are interdisciplinary, there are further problems, particularly associated with integrating the work done by the scientists who come from different disciplines and overcoming (or at least minimising the effects of) the barriers noted in section 3.4. This section explores the practices deployed by interdisciplinary researchers to overcome these, focusing especially on strategies that are used to overcome the hurdles to interdisciplinary research into sustainability. The section lists practices that at least some interviewees found useful, as well as practices that proved harmful to the interdisciplinary research projects. It does not discuss strategies for overcoming the problems that are inherent in all research projects, except insofar as they are exacerbated in interdisciplinary research. Nor does it discuss the manner in which governments, funding agencies and universities should reorganise to facilitate interdisciplinary research into socio-environments: the previous section identified the problems that these institutions create and should eliminate. This section is, rather, devoted to providing information, drawn from the practical experience of actual research projects, that may be useful to those who succeed the current generation of interdisciplinary researchers.[4]

My fundamental conclusion is that any interdisciplinary research project relies in the first place on its leadership. There has to be one individual – and certainly no more than three or four – who form the core leadership group. These people have to conceptualise the entire project, visualise the manner in which basic research and application are linked, and understand at least the central principles of all the detailed research that is to be undertaken. Someone or a small group has to understand the entire project and drive all its activities towards the goal of answering the questions that the project is designed to answer. (It is a valid project to discover what are the important questions about an environment. For such a project, the driving question is: what are the important questions? However, answering those important questions is itself a separate project.) Several respondents made this recommendation explicitly; in other cases, junior members of the project expressed frustration at the lack of a core conceptualisation of the project as a whole.

Of course, the project may subsequently be divided into parts, components that need to be completed. Individuals may be put in charge of those components. But this has to be a devolved responsibility. An interdisciplinary project cannot be a federation of sub projects that are somehow to be 'brought together' at the end. There cannot be a committee of management representing all the different sub projects. That way lies disintegration. There may be good science produced in such federal projects, but the difficulties in integrating them into an interdisciplinary whole are formidable, as the experience of several of the large projects in this sample indicates.

I now extend the comments of the respondents. If the project involves industry partners and other stakeholders, such as environmental managers, farmers, planners or ordinary individuals, then at least one representative of those groups should belong to that central leadership group. There should be at least one practitioner in the leadership group, but not so many that the group

4 Most recommendation was made by at least one interviewee, though I have of course assembled them into a coherent argument. Others are inferences drawn by me from what I interpret as problematic practices in one or more of the sampled projects. I have, in effect, conducted an evaluation of the sampled projects, aided by the interviewees' comments; thus it would be invidious to cite specific examples. Some recommendations were disputed by some interviewees (indeed different members of some projects drew different inferences from their experiences).

contains more than three or four people. But the practitioner, too, has to understand the entire project and assist in driving it. The practitioner is not a representative of other practitioners; just as the scientists in the leadership group are not representatives of other scientists. The leaders are simply individuals, bringing diverse viewpoints into the leadership of the project, but operating as a coherent whole, with a common vision of the entire project – its purposes, its methods and its intended outputs.

This form of organisation means that the leadership group should be formed before the project itself begins. That is, the leaders must all be involved in the initiation, design and funding applications for the project. They must negotiate all the misunderstandings and differences that arise from disciplinary identify before the project is proposed. The leadership group cannot be formed out of the project members once the project is underway (for example, after funding is obtained).

Such leadership must not mean that other voices within the project are not heard. A common complaint from people who were not project leaders concerned lack of communication with 'the top'. The leadership group must talk frequently and openly with other members of the project, including stakeholders – soliciting their views, reflecting on findings and progress to date, listening to their ideas, and responding to their comments. Such discussions may imply that changes in the project's direction, methods and pace are necessary. Nevertheless, such decisions must be made by the leadership group itself, after listening to everyone else. Frequent, open discussions with the team members help create trust between the leadership group and everyone else and help motivate the team members; but they do distract from everything else that people have to do: so such meetings should be frequent, but not too frequent.

The leadership group, then, has to drive the entire project. In addition to maintaining its vision of the project and ensuring that the project remains true to this vision, the leaders have also to make some important decisions when designing the project. The key decisions, according to the respondents, are:

Ensure that at least one member of the leadership group has project management skills. Interdisciplinary projects that involve several sub projects and several participants (with diverse motives) working towards some common goal over three to five years are complex operations. Someone must have appropriate training; if not, it needs to be organised (perhaps through a skilled project manager).

Arrange that the mix of disciplines represented in the project team is appropriate, rather than simply convenient or politically expedient. Also ensure that an appropriate mix of other skills is represented in the team – good scientists, good communicators, facilitators for focus groups or discussions with stakeholders, statisticians and geographic information systems specialists, and so on. But do not presume that the team members represent disciplines (they are only one example of the scientists in the discipline) and do not identify them as belonging to a discipline (they are part of this interdisciplinary project).

Especial attention needs to be devoted to service roles. Such tasks may include specialised statistics, GIS, adoption, background information (such as projections about climate, demography, GDP and its sectoral composition). These tasks provide skills that the team does not have, or information that is needed by the project but is not to be the target of specific research. However, such tasks may need research too, to apply the skill or the information to the specific needs of the project. Recognising that skills other than academic ability are important, too. According to Bruce *et al.* (2004), a good interdisciplinary researcher should exhibit:

- Curiosity about, and willingness to learn from, other disciplines (not suffer from disciplinary arrogance);

- Flexibility and adaptability;
- An open mind to ideas coming from other disciplines and experiences;
- Creativity;
- Good communication and listening skills;
- An ability to absorb information and its implications rapidly;
- The characteristics of a good team worker.
- And remember that expertise does not lie wholly within the scientific team. Stakeholders and the public more generally have information and skills that need to be combined in an appropriate way with the information and skills brought into the project by the scientists. Expertise needs to be conceptualised within the project and the appropriate roles of lay and scientific personnel need by the identified and planned early in the project.
- Spend a lot of time at the beginning getting the questions right.
- Know, right at the beginning, how the findings of the different streams of research – the different disciplines even – will be integrated. The following section identifies models for this; but the leadership group must have chosen one or more of these during the design phases of the project. And recognise, while doing this, that different kinds of research proceed at different paces; thus, critical paths need to be understood.
- Keep the project at an appropriate size. There are plenty of pressures to enlarge projects – including such performance indicators as total funding, total research publications, staff employed. But large projects do not necessarily cohere; more people means more time spent on managing them; and additional people may take the project into inappropriate directions.
- Make allowances for the time that has to be spent in communication, and the cost of bringing everyone together for these meetings. Skype may be a help, reducing both the time and the cost of meetings, but productive and constructive meetings may take days.
- Plan the project around tasks with tangible products. Projects can be scoped in general terms, by defining research questions. But bringing the research questions down to practical activities, such as journal articles, workshops, specific field investigations and the like, serves to form groups around those tangible activities and forces the groups to begin to cooperate across disciplines. Rather than arguing about what concepts mean, in abstract terms, the groups argue about specific decisions and activities.

> ...provision should be made for specialised papers, perhaps limited in focus to a small part of a single discipline. Such publications meet the professional needs and preferences of different researchers and raise participants' measured research productivity.

Such so-called 'boundary objects' as journal articles pressure the collaborators to produce a condensed, simplified, organised and agreed text that summarises some findings. Many authors may be involved in the writing process, but the article presents a coherent voice and a single image of the project. Writing journal articles attracts the attention of all members of the team.

Nevertheless, provision should be made for specialised papers, perhaps limited in focus to a small part of a single discipline. Such publications meet the professional needs and preferences of different researchers and raise participants' measured research productivity.

- Make early decisions about the role of end users or practitioners, whether they are to be central to the project and involved at all stages or rather consulted at appropriate times. In effect, this represents the question whether the research is to be driven by supply or demand – in effect, whether the leadership group itself contains end users. If the project is supply-driven, then ensure that the outputs are appropriate to the intended market (at an appropriate level of complexity, for example). Allow for the time spent in consultations with end users, and the cost of this. And if the project is to be transdisciplinary, then start the processes of communicating with end users right at the beginning, and keep it going, otherwise stakeholders will disengage from the project.
- Equally, make early decisions about the role of commercialisation in the research program, and then ensure that the team has members who can facilitate this. Agree on ownership of intellectual property.
- Maintain documentation. A university and a funding agency will require lots of documents; in addition to these, however, the informal agreements with team members and end users need to be documented, as do the progress of individual sub projects and the processes of interaction between team members (and between the team and end users). Allow for the costs of this.
- Recognise that the team members have other responsibilities than to the project. They may have responsibilities to families, other research projects, teaching, administration: they are generally volunteers to the project. The timing of contributions needs therefore to be explicitly negotiated between the leadership group and each team member, and documented. Especially recognise that the members of the team are in a labour market where specific credit systems operate and they need to satisfy the requirements of those systems. The leadership group has a special responsibility to ensure that junior team members have access to appropriate career paths.

The leadership group has to make these decisions, but also explain them and explicate them in detail. The need and purpose of decisions have to be clarified. Especially important is explaining why interdisciplinarity is needed for this project.

These requirements imply that it is bad practice to combine separate bids for funds (a problem that afflicted a couple of the projects in the sample). Combining the teams from two bids leads to problems in bringing the two groups of people together and making their different interests cohere. It is also bad practice to combine what are essentially different projects under one banner in order to achieve some scale threshold, or meet some other external, arbitrary criterion. Indeed, the practice of creating large centres that then undertake multiple projects produces a level of administration within the centre for no scientific benefit: it is mere administrative convenience for someone else. The different projects just compete with each other for influence over the entire project – and ultimately, for resources.

It is another implication, recognised by several participants, that integration should not be a separate sub project. Commonly, larger projects are broken into several specific research tasks (sub projects) plus one other task, called integration. This practice has flaws, two of which are serious. First, members of each sub project do not think of integration as their task. Second, integration cannot occur until the work of the sub projects is completed. Instead, integration of the findings of different projects and integration of findings with methods of application should occur all throughout the project. The project is a coherent whole; it needs to be treated as such by everyone in the team, all the time. That implies that the sub projects ought not be based in individual disciplines; rather, individual sub projects need to be integrated too.

In turn, this means that there have to be a spaces for sharing. Some of these might be material spaces (tea rooms did serve an academic purpose) and informal, where people from different sub projects and / or different disciplines can get to know each other – where they can begin to cohere in the way that a department coheres. Others might be more formal: seminars, conferences, project meetings. The evidence is that collaborations work best when the collaborators know each other well; providing spaces where people can meet and talk is one way of assisting this. Co-location is useful, even if not always possible. Other spaces may be non-material, including the opportunity to collaborate in producing outputs, for example. However, even the formal spaces need to allow space for informal interaction between the members of the project. People have to identify with the project as a whole, not simply with their sub project; they have to learn the language and language styles of other disciplines; they have to come to understand the difficulties faced by and the contributions of everyone else.

As participants observed, one important space is for sharing data. There must be a central location at which all project data (including documentation of plans and agreements) are stored and to which all team members have access. (It must be backed up.) There must be protocols about the replacement of this information when new data becomes available. Such a location could also form the basis for a public web site, which implies the need for a web master. But if there is a public web site, then it needs to provide interpretation suited to a general reader as well as simply data and scientific publications.

Another space is needed for training. Various forms of training might be appropriate – for example in specific skills or management. However, other kinds of training are also important. Many of the interdisciplinary researchers in the sample have not read about the experiences of other interdisciplinary researchers nor about the theoretical and empirical work that has been published about how to do it. Nor, in general, had they much prior experience of working with people in other disciplines. But these are skills, and the leadership group needs to ensure that the team members acquire them, rather than hoping that they learn on the job. Some specific skills include (Pohl *et al.* 2010):

1. Recognising that the world is sensed and understood in different ways by different people, and knowing what some of the principal dimensions of difference are likely to be.
2. Understanding that relations between people and institutions are, in addition to their ostensible purpose, also relations of power and prestige. Such power relations influence participation.
3. Being able to think about how to integrate different interests, paradigms, practices, values and interpretations in search of solutions to the research problem.
4. Appreciating the significance of collective learning processes, such as meetings and informal spaces where people can talk outside established hierarchies. The team members and the end users have to trust each other, one component of which is being self-reflexive about position, style and findings. And the members have to be able to manage conflicts.

There must also be space for succession. Whether for the specific project, the centre or interdisciplinary research into sustainability as as whole, the present generation of leaders has sometime to be replaced. The leadership group should provide for this. Respondents recommended a variety of practices. Offer appropriate training and experience for junior people to move up into more senior roles. Make contingency plans for the replacement of project members, especially the leadership group. Provide a space to inculcate PhD students into the ethos and benefits of interdisciplinary research, as well as its pitfalls and barriers. Several of the barriers identified in the previous section arise from people's training and socialisation as members of a discipline; those barriers can only be overcome if that training is revised. It is the responsibility of this generation of interdisciplinary research leaders to ensure that this happens.

A special case of succession planning is providing for future funding. In an environment where funding priorities change drastically and quickly, people who run centres or long-term projects must try to find ways to ensure funds in the long term. This may involve a mix of funds from governments, private institutions and funding agencies. The long term future also depends on an appropriate mix of basic and more applied science, which means mixing ARC Discovery projects with projects that are more applied.

In the real world, all good practices are constrained by resources. The two most limiting of these are time and money. So: good practice is to meet often and talk lots; but those activities eat into the time that people have to spend preparing lectures, going to meetings, supervising graduate students and doing all the other tasks that comprise the working life of a modern academic. Indeed, many of the poor practices that were observed arise from attempts to economise on time and money. The underfunding of Australia's universities as compared to OECD peers is one of the most severe constraints on the practice of a resource-intensive activity like interdisciplinary research.

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# 5

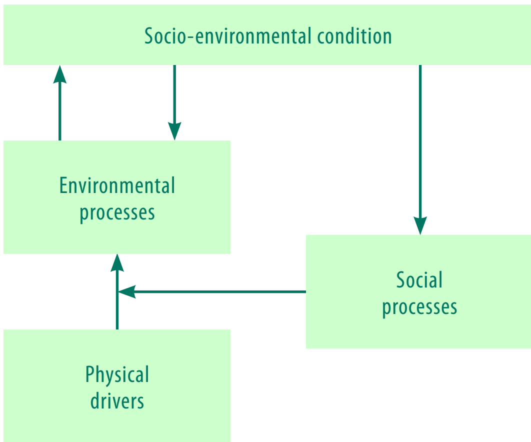
# MODELS FOR INTEGRATION

SOCIO-ENVIRONMENTAL CONDITION MIGHT BE SUMMARISED BY A SET OF VARIABLES – MEAN NUMBER OF GRAMS OF PLASTIC PER SQ KM; ESTIMATED NUMBER OF SPECIES; AVERAGE LIFESPAN OF HUMAN BEINGS; GINI COEFFICIENT OF PERSONAL INCOMES.

The list is potentially endless, even for a single parcel of land. It has to be replicated across all the parcels of land in the world, and aggregated into regions such as catchments or cities, up to provinces, nations and the entire world. The variables interact: plastic deposition affects species diversity (the environmental variables interact); lifespan is affected by inequality (the social variables interact); human lifespan depends on grams of plastic (social variables depend on environmental variables; the number of species depends on inequality (environmental variables depend on social variables). The well being of the entire social economic system thus reflects a myriad of variables that are measured at a lot of different locations and spatial scales. Understanding the trajectory of this system through time is the goal of environmental research; helping to steer the system to a 'better' trajectory is the ultimate purpose.

To comprehend the system we divide it into bits – groups of variables, places, time slices and kinds of interactions. The result is a model: a representation of (a part of) the socio-environmental condition. The proto-typical model of a socio-environment is shown in Figure 1. In this model everything that goes on is classified as a condition (the outcome variable, or state of the world), a process (in turn divided into social and environmental) and a driver (a process that is outside social effect). At the scale of a farm, climate is a driver; at the scale of the world, climate is an environmental process that depends on physical drivers (solar system, laws of physics) and social processes (burning fossil fuels). At the human time scale, geological conditions are a driver. The arrows indicate causality: the drivers, influenced by social processes, cause the environmental processes; in turn, environmental and social processes cause the socio-environmental condition; and that condition influences social and environmental processes. Notice the simplifying assumption that social processes do not affect socio-environmental conditions directly, but only through the way in which they mediate environmental processes. Understanding the socio-environment represented by Figure 1 is an interdisciplinary task, for it involves social and environmental processes together.

## Figure 1. Prototype model of a socio-environment




Inside each process box, however, are scientific and social scientific understandings of the relevant processes. On the environmental side, much of this understanding is encapsulated in models – hydrological models, ecological models, chemical models – that each have a structure of conditions and processes similar to that of Figure 1 (only more complex, and often populated with numbers). Bringing all these understandings together is also an interdisciplinary task.

Inside the social box, conditions are more fraught, and it is important to understand the nature of the difficulty if interdisciplinary research is to have any hope of long term success. The human activities that influence environmental processes include: driving to work on Monday morning; applying fertiliser today at this rate; chopping down an invasive tree; turning off the air conditioner. Or they might be more general: growing wheat in the Wimmera; restoring wetland ecological conditions in Kakadu; subdividing farm land for urban expansion; imposing a carbon tax. Each of these activities has effects on socio-environmental conditions that, in principle at least, we could trace. (In the exposition that follows, these activities are called 'Level 1 social processes'.) One approach to environmental management is to use this thought to identify the important controls over socio-environmental conditions (in an area) and then to seek to proscribe those activities that cause deterioration in those conditions. This strategy is common. But it fails, because people engage in the activities that they do engage in for reasons – and regulation does not remove those reasons.

Behind the activities of human beings are the conditions that lead people to make the decisions that they do, given their goals and constraints. In a deeper sense, these conditions, goals and constraints drive the activities that influence environmental processes. They include, for a farmer: the structure of costs and prices for agricultural commodities; their knowledge about fertiliser uptake by wheat; attitudes to claims about climate change; degree of community or family pressures to conform to group decisions; capital constraints imposed by bank lending policies and family responsibilities; availability of labour; farming goals. An environmental management agency or a corporation has a similar set of influences – attitudes, knowledge, constraints of various kinds, goals of profitability or environmental restoration, and so on. Politicians, making decisions to allocate funds to the activities that affect environmental processes, have these kinds of influences as well as the need to get re-elected. Like farmers and managers, they also face influences from outside and interact in complex and poorly understood ways. (These are 'Level 2 social processes'.)

Understanding the interior of the social process box thus requires understanding how all these factors influence human activities. We have some knowledge of these links for farmers and corporations, but it is partial and hardly extends at all to knowledge about people as individual citizens. Furthermore, it is knowledge that is highly contested. The conditions of production of social science include three problematic circumstances: we do the research on ourselves; we cannot conduct many experiments that approximate the conditions of real decisions; and we normatively judge the states of society that we observe. The effects are that social theories are influenced by the observer's position in that society, that observations are generally consistent with different views about how the world operates and that states of society are judged. If social science were produced by a species of super beings then we would know a lot more about how societies operate. In other words, attempting to understand the background reasons for human activities leads to a pair of problems for interdisciplinary research on sustainability: the relationships between these backgrounds and specific activities are not always well understood; and in any event those understandings are often contested. (Even the simplifications involved in producing Figure 1 are often contested in social science and humanities.)

Furthermore, there is another level at which these issues need to be contemplated. Consider the conditions, goals and constraints that influence people's activities. Where do these come from? This question invites an even deeper level of analysis that includes as variables such factors as: the nature of the socio-economic system (capitalism with an orientation to free trade and market dominated exchange or a variation on this); an orientation towards participation (or more direct methods of producing outcomes); an understanding of nature as subordinate to human needs (or of us as subordinate to nature); and so on. As we think about sustainability in the longer run – perhaps in terms of 50 years – then these must be considered as variables (they are 'Level 3 social processes'). Theories of the relationship between these variables and the conditions, goals and constraints are even more rudimentary and even more hotly contested than theories of the relationships between conditions, goals and constraints on the one hand and human activities on the other.

All scientific members of an interdisciplinary team need to understand these conditions of social science. They need also to understand how they arise (we research ourselves; we generally cannot experiment; we judge societies) rather than resort to disdain for social science. It is also imperative that the interdisciplinary understanding of the socio-environment that is under investigation be one that reflects honestly (rather than partially) social scientific knowledge. There has been a variety of attempts to do this; they are the focus of this section of the report.

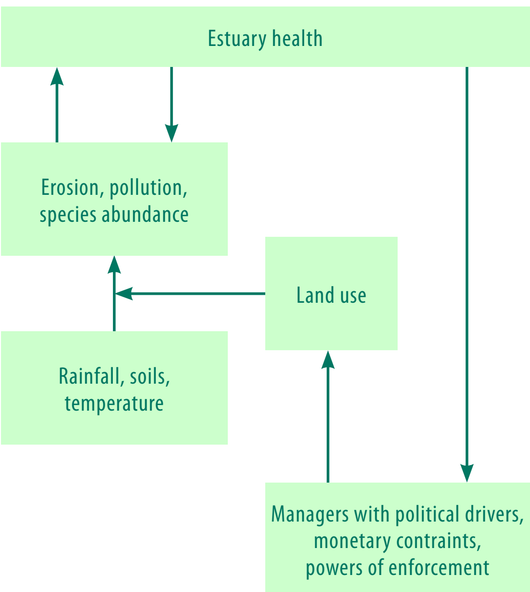
There are three possible approaches to this task. All model the Physical drivers → Environmental processes → Socio-environmental condition pathway of Figure 1 through some form of system. Specific variables are identified in each box and causal links between them are posited; the links might be deterministic or probabilistic. There may also be feedback loops (A → B → A). These models of physical processes may involve a single discipline or be interdisciplinary. If the research is about sustainability, then any approach must include at least the Level 1 social processes. These are also generally modeled as systems. The first approach to modeling Figure 1 in practice is to regard this system as the complete system and to ignore the possibility of Level 2 and Level 3 social processes; but this is incomplete. The second approach is to extend the first approach by considering Level 2 social processes, and to attempt to estimate how at least some of the conditions, goals and constraints influence the behaviour of at least some of the agents who act on the system. Such might be, for example, the procedure of psychologists or economists. We are, however, far from being able to consider social systems holistically. The third approach extends the second by considering Level 3 social processes. These are, however, so incompletely known and so subject to political debate and struggle that they cannot be modeled in a formal way. Commonly, some forms of expert judgement need to be used in this task.

Within the field of interdisciplinary research into sustainability, there exist five standard ways of implementing Figure 1 in practice. These are: actor based models, agent based models, Bayesian nets, collaborative conceptual models and scenarios. Practitioners of these methods argue that they are perhaps most suitable for delineating the interactions in a socio-environmental system, and the causes and effects that occur; the specific numeric results that flow from quantifying the models are regarded as less important. This is called modeling for insight rather than modeling to predict. They also generally agree that including social processes within such models is an enormous and difficult task, often extremely expensive. Some models naturally encourage public or expert participation; others are essentially the constructs of modelers (who might or might not consult experts or the public when constructing their model).

Whichever kind of model is used to implement the socio-environmental model, certain general principles need to underpin the modeling (Brinsmead 2005). For example, the models need to include all the features, strategies and context that affect outcomes, but only those features. The separate models need to be coherent; for example, should refer to the same areas and time frames as well as including common variables. Levels of detail need to be similar in the different models, but sufficient to differentiate strategies and outcomes. These requirements are common to the various integrating tools.

In actor based models, society is divided into categories of actors, such as land users, fishers and catchment managers. For each of these categories, a perception graph is produced that summarises those actors' views about how the socio-environmental system works, how their actions affect it, and the goals and constraints that influence their actions. Catchment managers might, for example, visualise the problem of managing a catchment for estuary health like Figure 2. As compared to Figure 1, the social process box has been divided into two – one representing the managers and the other land users. (In computerised versions of actor based models, such as www.dana.actoranalysis.com, there are no feedback loops of the kind represented by the arrow from Estuary health to Managers.) The perceptual map of land users, as a category of actor, would be represented by a different model; and other actors might be represented too – fishers, residents, and so on. The perceptual maps of different actors can then be combined as the basis for research into the specific land uses that influence environmental processes, the specific pathways of these effects, the interactions of the environmental factors, and so on. Such combination would, for example, represent the influence of other goals and constraints on land users' behaviour as well as the effect of catchment managers' actions.

### Figure 2. Actor based model of catchment managers' perceptions of managing for estuary health




In other words, actor based models:

1. encourage participation;
2. can consider Level 2 social processes, but with primitive forms of interaction between the different actors and no interaction between the individuals within each category of person;
3. can support expert judgment and quantified observational results;
4. lack explicit means of incorporating observational results into the model's data;
5. (without the feedback loop of Figure 2) represent a model of decision making rather than of system behaviour.

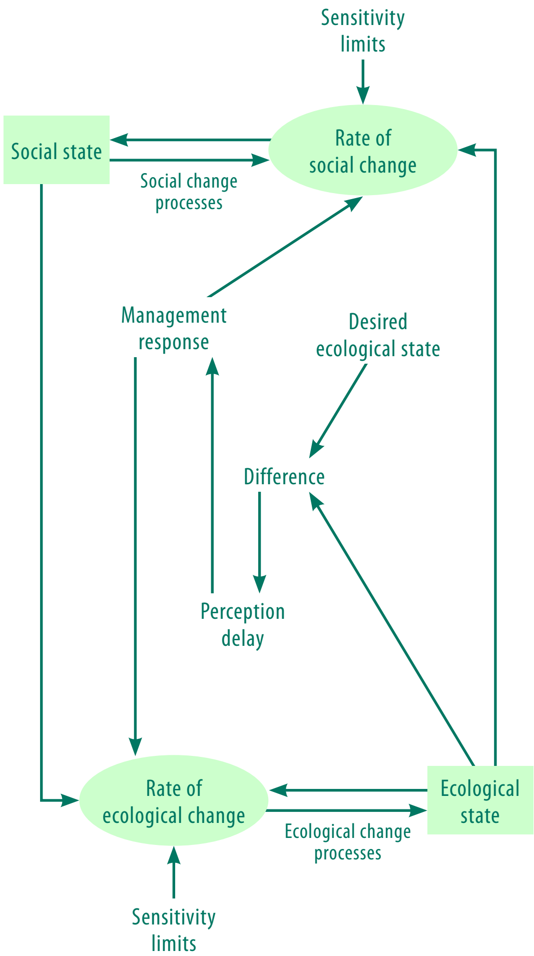
Pahl-Wostl (2005) provides an accessible introduction to such modeling.

This form of model can be taken in two different directions: collaborative conceptual models and Bayesian nets.

Collaborative conceptual models extend actor based models in two ways. See Newell (2012) for the theoretical basis of the modeling strategy; Newell *et al.* (2008) for an outline of the way a collaborative conceptual model is built in practice; and Proust *et al.* (2012) for its application to the Urbanism, Climate Adaptation and Human Health project. First, a strong systems dynamics framework, including feedback loops, is added. Secondly, the participants who construct their own, individual perceptual maps of the system are required to collaborate in pairs to produce a joint map. The resultant maps are combined into a 'Jumbogram' that is used to design data collection that in turn refines the perceptual maps of the system and provides the basis for evaluating the effects of management decisions.

Figure 3 illustrates the general model structure for a socio-environmental system that is separated into two parts. The change in each depends on the rate at which change processes operate. That rate depends on managerial actions, the state of the socio-environment, and on the pace at which the socio-environment can adapt. Managerial actions are driven by the difference between the actual state of the environmental and an externally defined desired state, with a delay that depends on the length of time required before differences between desired and actual states become apparent. There are strongly developed feedback loops; in Figure 3, these are between an actual state and some desired state; but they could be between the actual environmental conditions faced by an organism and its optimum conditions.

## Figure 3. General system structure used in collaborative conceptual modeling



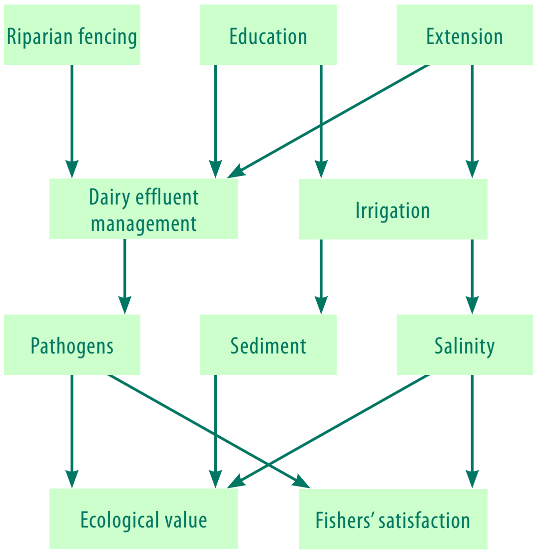

Source: after Newell *et al.* (2008). Sources and sinks in the original have been omitted.

Collaborative conceptual models:

1. rely on participation;
2. are capable of including Level 2 social processes, more strongly represent forms of interaction between the different actors than actor based models, though in practice include little interaction between the individuals within each category of person;
3. can support expert judgment, lay participation and quantified observational results;
4. lack an explicit mechanism through which to incorporate data into the model;
5. represent feedbacks between actual and desired states of the socio-environment; thus they could be used to manage or to study socio-environmental dynamics (though management should be represented as more complex than simply responding to the difference between the actual and the desired state of affairs).

The second direction in which to extend actor based models is Bayesian nets. These formed the basis for the integration of socio-environmental variables in the Landscape Logic program. Kragt (2009) provides a beginner's guide; Polino and Henderson (2010) a guide to their use in natural resource management; and Polino (2010) illustrates their application to the management of estuaries in Tasmania. Figure 4 provides an example of a net that represents the relationship between management and land uses (top row of rectangles), activities that are threatening the quality of water in a river (second row), the specific materials that determine the quality of water (third row) and measures of that quality (ecological and use values). In some applications, measures of end users' satisfaction (including satisfaction with the quality of the environment) are combined into one measure (willingness to pay); but separate measures of outcomes are permissible.

## Figure 4. Example of structure of a Bayesian net for river management




Source: Adapted from Polino and Henderson (2010).

There are two contrasts between this and the two models already considered. First, the directions of causality are all one way: there are no (and cannot be any) feedback loops. This makes Bayesian nets difficult to use in studies of ecological dynamics. Secondly, there are specific and powerful ways of incorporating data into the model. The modeling starts by incorporating prior knowledge about relationships between causes and effects – for example, about the efficacy of extension activities on changing irrigation practices and effluent management, about the relationships between these and indicators of water quality, and about the relationships between measures of water quality and ecological value and fishers' satisfaction. These are expressed as conditional statements, such as: if irrigation is in this form, then the possible values of salinity have particular probabilities. When new data are collected, Bayes' theorem is used to update these conditional probabilities.

Bayesian network models:

1. are neutral about participation;
2. only poorly consider Level 2 social processes;
3. can support expert judgment, lay participation and quantified observational results;
4. are built around an explicit mechanism through which to incorporate data into the model;
5. do not represent feedbacks between actual and desired states of the socio-environment; thus they are most appropriately used for management.

Agent based models represent one of the most interesting developments in social sciences in the past couple of decades. Society is regarded as being composed of individuals of different types: some are people (who, perhaps, work and consume); some are firms (which hire labour, produce and sell); some are other species of being (which have an array of possible activities). There are many individuals in each category. Within each category, individuals behave in particular ways: they can do certain things, they choose to do activities with probabilities that depend on given rules (which change as individuals learn). They can interact with each other, and with individuals of other types: they might work for a firm, earn wages, buy produce from other firms. Social categories, such as wages and prices, are determined according to rules, commonly market clearing. Such models have been used in studies of segregation, class formation and income inequality, and they demonstrate how complex social structures can emerge from interactions between individuals. They offer a powerful approach to the study of Level 2 social processes and some purchase on Level 3 processes.

Agent based models have also been used in studies of environmental management. To illustrate the method, consider forest management for the control of invasive species (Perez and Dragicevic 2010). One category of individuals comprised beetles (the mountain pine beetle, which infests forests in British Columbia). Each individual beetle has certain possibilities of flight, chooses (probabilistically) a tree in that range according to tree health and size, lays eggs and then has a certain probability of dying in winter. Pine trees are also a category of individual. Each tree has a particular capacity to repel beetles, depending on age, health, size and other characteristics. The third category of individual comprises forest managers. Managers can cull stands of pine that are infested, according to certain rules about degrees of infestation and sanitary cordons about infested stands. Since the decision rules of each agent are probabilistic, any single calculation of the model is just one possible outcome; so such a model is run multiple times to find probabilities that particular end states will occur, under different management rules.

Other environmental applications study similar management decisions, or border controls. These have simplistic social behaviour. However, such models could, at least in principle, be extended to examine the co-evolution of social and environmental subsystems. Such models would be for experimental and scientific purposes rather than management.

Agent based models:

1. do not encourage participation;
2. can examine Level 2 social processes and perhaps Level 3;
3. may use expert judgment and previous observations, but only in the stage of model construction and evaluation (testing);
4. contain is no explicit mechanism for incorporating data;
5. include feedbacks between the system state and its change: the models can be used for management and – in more complex forms – for examining the dynamics of socio-environmental systems.

Whereas agent based models are a bottom-up, disaggregated way of modelling social systems, scenarios are top-down, the most aggregated of the methods described in this section. They are plausible descriptions of how the future may unfold. The underlying philosophy of scenario building is that social systems are too complex – or at least, we understand too little of them – for predictions, even probabilistic predictions, to be useful or meaningful. So a scenario is simply one possible future. It is therefore most suitable for analyses that involve the medium to long term – at least a decade.

To illustrate, suppose that we are interested in the supply of and demand for water through a river to a city. The hydrologists provide models that indicate the probabilities with which different flow volumes obtain throughout the year, perhaps modified in the light of projected climate change. The social modelers then have to predict what water is extracted upstream and what water is demanded by the residents and industries of the city. Such predictions could be based on the past history of demand (through regression or time series) or it could reflect different ways in which society could evolve. Perhaps we might suppose that little changes, except that economic and technical change proceeds much as in the last 20 years: then what would that future society look like and what would be the demand for water? This is a business-as-usual scenario. Another scenario might be built around assumptions that economic growth slows and people start to economise on the use of resources such as water; institutional arrangements for sharing water throughout the basin are implemented. A third scenario might assume that economic and population growth is fast, profligate of resources and uncooperative about resource use. In each of these scenarios, a consistent story has to be built about the nature of society, especially as it affects the demands for water. The final scenario set then includes both the scenarios of social change and the predicted hydrological characteristics of the river.

Scenarios, in other words:

1. encourage participation;
2. can reflect Level 2 social processes and perhaps Level 3;
3. may use expert judgment, lay inputs and previous observations, at the stage of scenario building;

4. have no explicit mechanism for incorporating data;
5. may incorporate feedbacks between the system state and its change, if the scenarios are carefully constructed: the models can be used for management but the dynamics of socio-environmental systems are really assumed through process of the scenario building.

Such scenarios form the basis for identifying possible climate futures: the scenarios embody assumptions about economic growth, population and emissions, for example, and then examine what the effects on atmospheric carbon dioxide might be, and from that what future climates might look like.

These are all important tools in the repertoire of those who would understand or manage socio-environmental systems. The choice among them depends on the definition of the problem that is to be solved. In practice, simple and robust models are most comprehensible and easiest to implement. But that does require that the researchers and managers hold an appropriate model of society in their heads as the basis for understanding how Level 1 social processes occur. More complex models, especially those that analyse Level 2 and 3 social processes are for the moment more applicable to research into the dynamics of socio-environmental systems than to management – at least until we understand social evolution better. What is most important, perhaps, is not to confuse simple models as embodying what is really known about social dynamics. All models are wrong; some are useful.

# 6

# CONCLUSION: ACHIEVEMENTS AND OPPORTUNITIES

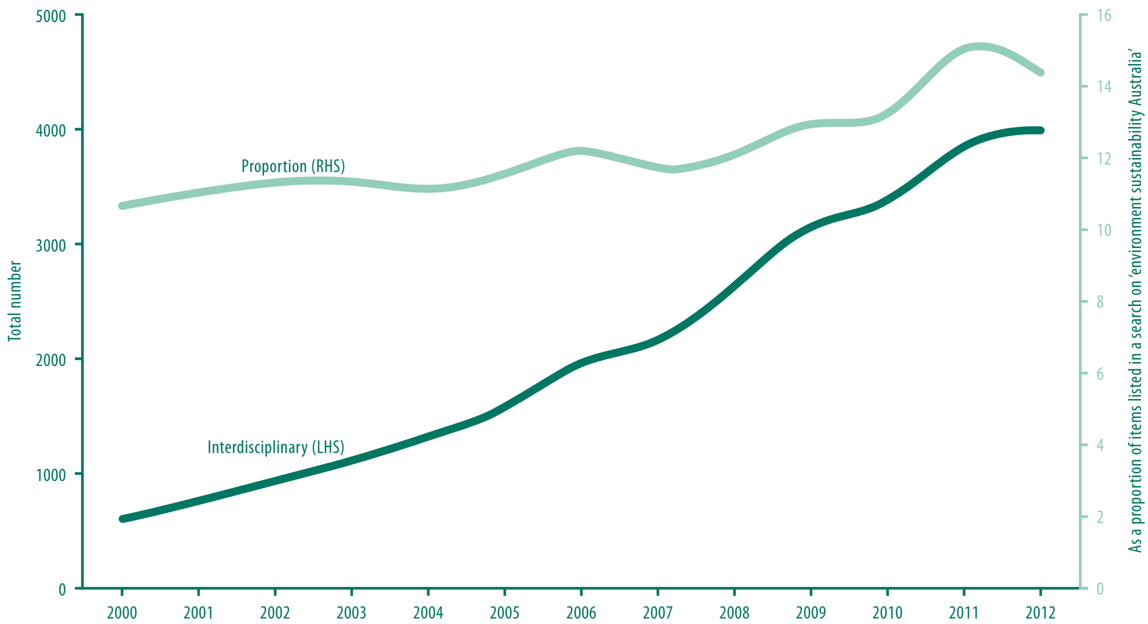
INTERDISCIPLINARY RESEARCH INTO ENVIRONMENTAL SUSTAINABILITY IN AUSTRALIA IS IN ITS INFANCY. FIGURE 5 SHOWS THE RESULTS OF A SEARCH ON GOOGLE SCHOLAR FOR PAPERS, BOOKS AND ARTICLES ON THE TOPIC "INTERDISCIPLINARY ENVIRONMENT SUSTAINABILITY AUSTRALIA".

In 2000, less than 600 items were found. An analysis of a sample of these indicates that approximately 90 per cent of those 600 were literature reviews, calls for more such research, exhortations to do more teaching on this topic, and papers about other topics that happened to mention the keywords (either in the title of a reference or in passing). By 2012, this number had risen to 4000 (which represents a doubling about every six years). About half of all items about "interdisciplinary environment sustainability Australia" were published after 2009. Interestingly, the proportion of interdisciplinary items among all items on "environment sustainability Australia" has been rising steady (as Figure 5 also shows), from about 10.5 per cent in 2000 to nearly 15 per cent in 2011.

The CRCs and larger programs listed in Table 1 are among the earliest large scale research projects into socio-environments within Australia. Apart from specific pieces of technical expertise and some research on the interface between agriculture and environmental management (much of the information from which has been integrated with the results of single-discipline research), this decade has really been one of learning how to do this kind of research (Section 4), how to foster it and how to fund it (Section 3). There has also been a deal of progress in developing models for integration (Section 5). That achievement is not inconsiderable.

There have been gaps in the aggregate of research and much of the effort has been carried by a few small disciplines. Furthermore, there is almost no engagement with different epistemologies or scientific cultures or with transdisciplinary research. But these gaps are perhaps to be expected for, despite the generally supportive environment, the favourable evaluations of participants and a gradual increase in knowledge about how to manage such projects, there does exist a range of problems and barriers to interdisciplinary research into sustainability. Though some of these problems are intrinsic to the current state of interdisciplinary

## Figure 5. Number of items on "interdisciplinary environment sustainability Australia" listed in Google Scholar, by year



research, the institutional environment in Australia, as in some other countries, also discourages interdisciplinary research.

Thus the opportunities and needs for future research are large. Participants in existing projects generally accept that outcome-oriented research has to be interdisciplinary. Not many problems can be solved by a single discipline. The most critical problems according to the interviewees are:

- Climate change, the overwhelming socio-environmental issue facing Australia and Australians. There remain questions about the pace and directions of change, as well as about making projections at a fine spatial scale, but the deepest questions refer to possible actions. How can we prevent conditions from becoming catastrophic in the future? How does society need to change in order to adapt to the future conditions? Some specific related issues include:
    - low carbon cities and urban land use;
    - epidemiology: context-dependent health outcomes;
    - *the nature of energy use: its production, distribution and consumption, particularly in relation to electricity and carbon pricing;*
    - *food security in a changing climate.*
- We need to understand more about how specific kinds of socio-environments work:
    - the ecological dynamics of estuaries
    - biodiversity and native vegetation, informing ecological judgments by social and economic perspectives;
    - water quality, compensating existing information about quantity;
    - the ecological character of the Murray-Darling Basin.
- We need a lot more research about conditions and processes within cities. The salience of cities in public debate may be increasing, but unevenly in space and time. Research problems include the relationship between urban form and energy use.
- There are some specific problems of the socio-environment that require research:
    - alternative futures for resource dependent communities;
    - land use planning for climate change and bushfires: in high risk areas, preventing subdivisions and concentrating populations into villages; the forest – agriculture interface as an issue of ecological integrity;
    - diffuse source pollution.

Rostrom *et al*. (2009) identify an even broader range of issues.

Issues such as these need to be understood in their complexity. Policy is often unsophisticated, reflecting research based on a single discipline that fails to comprehend the multiplicity of drivers. Consider, for example, the problem of farmers' adaptations to climate change. Farmers need to adapt their practices to be sustainable in the light of changing climates. But climate is only one of the factors that influences the sustainability of a farm: a sustainable adaptation to a changing climate must also be appropriate to changing markets, the personnel who are working on the farm and the life history, experiences and education of the farm family.

The key climatic variable is perhaps variability. The socio-environment has to be managed for conditions of long term variability. Some responses to variability have been proposed recently, such as groundwater buffers and cropping opportunistically. But we still rely on imported models and try to create regularity rather than adapting to variability. There will inevitably be a drought more severe than any we have experienced. One of the tools through which to approach issues of variability and the conditions of specific socio-environments within Australia is environmental history. So far, much of that work is limited to archives, and so constrained to the period of written history. But there is much scope for research that combines paleo-botany, biogeography, political ecology, linguistics and archeology to understand the period of human occupation of Australia, as well as research about plant and animal movements between Australia and its neighbours. Another tool through which to approach variability is resilient design: constructing social environments in such a way that the risks of environmental change are ameliorated (though such design is still based on an understanding of potential variability).

Many respondents expressed the need to make coherent what is known about Australia's socio-environment and what research is needed. In part, this plea is expressed through details about research needs. More important is the need to articulate a long term vision about sustainability and the information needed to manage towards it. There is a lot of interdisciplinary research about environmental sustainability now (though perhaps not enough), but much of it is related to short term perceptions about what are environmental problems. Despite the early recommendations of Pearman *et al.* (2002), there is no long term vision about Australia's research needs in this field. Such a vision might reduce the fluctuations of funding to particular topics; it would also put individual projects within a broader frame of reference; and it might serve to prepare research capacity for the problems that are only now emerging (rather than only those that are presently seen as urgent).

Such a vision would provide for basic science and community needs. Both kinds of research are important and necessary. But the points along the continuum need to be linked. Interdisciplinary research into socio-environments in Australia does reflect some community needs – especially through funding agencies, and to a lesser extent through stakeholder engagement in research projects. But science directs what the community can have. The community needs to be enabled to express needs, hopes and plans that help direct what the science should do.

That long term research vision would have to address the central problem of socio-environmental sustainability in Australia. That problem concerns how to induce societies to make the changes that are required to move to a low carbon future, one that manages its socio-environment more sustainably. That is what is unknown; and that is what the failures of government and of international processes such as Copenhagen teach us that we do not know. This is research on creating transformational social change, fundamental political change. The need for such research brings the social sciences into the centre of interdisciplinary research on sustainability, alongside the long-standing contributions from natural sciences.

# APPENDIX 1

## Disciplines represented in interdisciplinary projects about environmental sustainability

| SAMPLE (TABLE 1) | Geography | Botany / Biology / Ecology | Planning / Architecture | Agriculture | Environmental mngt / eng | Hydrology / Water eng | Geomatics / GIS | Climatology | Psychology / Psychiatry | Law | Economics | Chemical eng | Civil eng (incl transport) | Control eng | Health & medicine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary Industries Adaptation Research Network | | 1 | | 1 | 1 | | | | | | 1 | | | | |
| Interdisciplinary Seed Funding Scheme | | | | | | | | | | | | | | | |
| Centre for Water Sensitive Cities | 1 | | | | | 1 | | | | | | | | | |
| Plant Movements across the Indian Ocean | 1 | 1 | | | | | | | | | | | | | |
| Food Flows | 1 | 1 | | 1 | | | 1 | | | | | | | | |
| ICAM | | 1 | | | | 1 | | | | | | | | | |
| Sustainable Farms | | 1 | | | | | 1 | | | | 1 | | | | |
| Regional Landscape Change [CRN] | 1 | 1 | | | 1 | 1 | | 1 | 1 | | | | | | |
| Landscape Logic | 1 | 1 | | | 1 | 1 | 1 | | | | | | | | |
| Community Vulnerability and Extreme Events | 1 | | 1 | | | | | | | | | | | | 1 |
| Farms, Rivers, Markets | | 1 | | 1 | | 1 | | | | 1 | | | | 1 | |
| INFFER | | | | 1 | 1 | | | | | | | | | | |
| Urban Water Security Research Alliance – values | 1 | | 1 | | 1 | | | 1 | 1 | | | 1 | | | |
| Advanced Water Management Centre | | | | | | | | | | | | 1 | 1 | 1 | |
| Primary Industries RDEF | | 1 | | | | | | | | | | | | | |
| Urban and regional oil vulnerability | 1 | | 1 | | | | | | | | | | | | |
| Fostering Responsible Tourism Business Practices | | | 1 | | | | | | | | | | | | |
| National Centre for Groundwater Research and Training | 1 | | | 1 | 1 | | | | | 1 | | | | | |
| Urbanism, climate adaptation and human health | | 1 | 1 | | | | | | | | | | 1 | | 1 |
| TOTAL 18 projects | 9 | 10 | 5 | 5 | 6 | 5 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| ID SEED FUND FROM MSSI | | | | | | | | | | | | | | | |
| Boger | | | | | | | | | | | | | | | |
| Burgman | | 1 | | | | | | | | | | | | | |
| Schubert | | | 1 | | | | | | 1 | | | | | | 1 |
| Williams | 1 | | | | 1 | | | | 1 | | | | | | |
| Whitzman | | | 1 | | | | | | | | | | 1 | | 1 |
| Kumia | | | | | | | | | | | | | 1 | | |
| Kashima | | | | | | | | | 1 | | | | | | |
| March | | | 1 | | | | | | | | | | | | |
| Langford | | | | 1 | | 1 | | | | | 1 | | 1 | | |
| Fincher | 1 | | 1 | | | | | | | | | | | | |
| Downes | 1 | 1 | | | | | | | | | | | | | |
| Newton | | | 1 | | 1 | | | | | | | | | | |
| Mutopia | | | 1 | 1 | | 1 | 1 | | | | | | 1 | | |
| Davis | 1 | | | | | | | | | 1 | | | | | 1 |
| Pearson | | | | | | | | | 1 | | | | | | |
| Miller | 1 | | 1 | | | | | | | | | | | | 1 |
| Reid | 1 | | | | 1 | | | | | | | | | | |
| TOTAL 17 projects | 6 | 2 | 7 | 2 | 3 | 2 | 1 | 0 | 4 | 1 | 1 | 0 | 4 | 0 | 4 |
| GRAND TOTAL | 15 | 12 | 12 | 7 | 9 | 7 | 4 | 2 | 6 | 3 | 3 | 2 | 6 | 2 | 6 |

Note: the table counts disciplines represented in each project, not participants.

| | Human ecology | Microbiology | Pedology / Soils | Sociology / Social work | Geology | Management / OR | Anthropology | Forestry | History | IT / Information Systems | Development Studies | Linguistics | Political Science | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| | | | 1 | | | | | 1 | | | | | | 6 |
| | | | | | | | | | | | | | | 0 |
| | | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | | 2 |
| | 1 | | | | | | | | | | | | | 5 |
| | | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | | 3 |
| | | | | | 1 | | | | | | | | | 7 |
| | | | 1 | | | | | | | | | | | 6 |
| | | | | | | | | | | | | | | 3 |
| | | | | | | 1 | | | | | | | | 6 |
| | | | | 1 | | | | | | | | | | 3 |
| | | 1 | | | | | | | | | | | | 7 |
| | | 1 | | | | | | | | | | | | 4 |
| | | | | | | | | | | | | | | 1 |
| | | | | | | | | | | | | | | 2 |
| | 1 | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | | 4 |
| | | | | 1 | | | 1 | | | | | | | 6 |
| | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | | | | | | 71 |
| | | | | | | | | | | | | | | |
| | | | | | 1 | | | | 1 | | | | | 2 |
| | | | | | | | | | | 1 | | | | 2 |
| | | | | | | | | | | | 1 | 1 | | 5 |
| | | | | | | | 1 | | | | | | | 4 |
| | | | | | | | | | | | | | | 3 |
| | | | | | | 1 | | | | 1 | | | | 3 |
| | | | | | 1 | 1 | | | | | | | | 3 |
| | | | | 1 | | 1 | | | | | | | | 3 |
| | | | | | | | | | | | | | | 4 |
| | | | | | | | | | | | 1 | | | 3 |
| | | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | | 5 |
| | | | | | | | | | | | | | 1 | 4 |
| | 1 | | | | | | | | | | | | 1 | 3 |
| | | | | | | | | | | | | | | 3 |
| | | | | | | | | 1 | | | | | | 3 |
| | 1 | 0 | 0 | 1 | 2 | 3 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 54 |
| | 3 | 2 | 2 | 3 | 3 | 4 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 125 |

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