SUBMISSION ON PUBLIC SUPPORT FOR SCIENCE AND INNOVATION

Comments on the Productivity Commission Draft Research Report - November 2006.

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The main comment is how we can creatively and constructively deal with the big issues that require research and innovation beyond the traditional frameworks and scientific discipline boundaries of today. There is currently no process to consider big issues effectively although the previous objectives for the CRC program were the closest to providing a process to achieve this. I fully support a return to these objectives (draft finding no 9.4 of the report).

The primary big issue that requires attention is sustainability. We have been very effective in conducting more reductionist research and commercialising the outcomes but when it comes to common goods and services and the impact of activities on sustainability it often becomes too hard. The difficulties are: there is too much spillover so that funding sources are not interested, the task is seen as too large and unmanageable, there is a major challenge for science to address interdisciplinary issues, and, we have too few mechanisms to handle the issue of the "tragedy of the commons" (the latter issue is discussed in Hardin, 1968). Having made excellent progress on the components of larger issues, the real need is for a process to deal with them and innovative answers or we will have increasing 'unintended outcomes' from tackling issues piecemeal with only partial knowledge or, more commonly by delaying actions until it is too late. These needs are well beyond commercial interests and rewards.

This submission provides a focus for the big issues, some suggested ways forward to address it and recommendations for the draft report.

1. Sustainability

All Australian governments have signed on to Ecologically Sustainable Development (ESD) principles and their implementation. ESD is not necessarily equivalent to sustainability but is close enough to move forward without debating new paradigms. While varying interpretations of sustainability exist, the concept is seen as the most appropriate principle by which to assess proposed actions to ensure minimal harm now and in the future, to develop maximum productivity and consider the fairness and ethics of actions.

A useful definition of ESD is: "Ecologically sustainable development means using, conserving and enhancing the ***community's resources*** so that ***ecological processes*** on which life depends are maintained and the total ***quality of life***, now and in the future, ***can be increased***" (ESD Steering Committee 1992).

Important principles are given in bold italics above and form the basis for how an effective approach may be considered. They require an emphasis on stewardship, holistic and integrated approaches to interactions and consideration of fairness and quality of life which is broader than profitability and environmental management which is what sustainability has commonly been reduced to.

Sustainability as a concept has been around for a long time but is only recently becoming prominent as a goal and process for societies. In a review of the Master of Business Administration Degree courses in Australian institutions (Tilbury, Crawley & Berry 2005), very few courses regarded sustainability seriously enough to warrant being considered 'leading edge' in an international focus. Government grants have been given in some cases (Lane 2005) to fund the development of suitable modules on sustainability to incorporate into these courses.

Thus there is merit in sustainability being specifically considered in the report. Sustainability comprises the interactions between social, economic environmental and ethical aspects of whole ecosystems.

2. Adaptive management

Given that we need to consider sustainability at the ecosystem level where the ability to understand interactions, drivers and uncertainty of the outcomes, then we need a process to integrate research with management at multiple levels and scales. Adaptive management is a suitable process. This following section is adapted from Coastal CRC (2007).

Adaptive management can be defined as “a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs”. British Columbia Forest Service (no date). Adaptive management has been strongly promoted in the major International Millennium Ecological Assessment project and is expressed as “The mode of operation in which an intervention (action) is followed by monitoring (learning), with the information then being used in designing and implementing the next intervention (acting again) to steer the system toward a given objective or to modify the objective itself.” Alcamo, et al. (2003).

Adaptive management was developed from operations research and management science in the 1970s. It has been used as a formal process for managing experimentation for complex, adaptive and uncertain issues requiring collaborative effort. The early developments placed considerable emphasis on building systems models to consider the whole system and the inter-relationships because the difficulty in mounting, managing and securing funding was very high. To avoid continually repeating past mistakes and approaches that haven’t worked, developing science that can deal with such large experiments will be required. Examples are how to manage the release of unintended genetically modified organisms into the environment, new pest invasions, climate change, restoration of degraded ecosystems, lifestyle diseases and cancer that are multi-factor driven, quality of life, governance etc.

Adaptive management is the preferred choice for changing management practices and developing policies when the risk of trial-and-error methods is too high, too expensive or not feasible and decisions cannot be postponed until more certain data to inform decisions is available. It is required where there are uncertain and unknown responses to decisions and management actions. It may lead to changes in goals, as further information is known, which in turn may trigger changes in priorities, structures, power, and institutional relationships. Such changes produce uncertainty and stress, and a common response is to resist the changes that produce those effects. By providing a structured basis for collaborative efforts of different stakeholders to work together and achieve common objectives through applying the concept of “learning by doing” to a range of issues, developments and initiatives then improved outcomes will occur.

Some reasons to adopt adaptive management in a formal process are:

- Complex adaptive systems are non-linear and can switch to alternate and undesirable states once critical values are exceeded. New ecosystem states have different processes operating and uncertain outcomes and implications
- Many examples of big mistakes from poor decisions on partial and selected knowledge - not holistic
- Ad-hoc trade-offs and unintended consequences cause unnecessary ongoing costs
- Diverse thinking and multiple disciplines are required to deal with big issues
- Expectations of scientists, policy people, community and politicians are unrealistic of each other

- Effective democracy means involvement by informed citizens – a new governance

A number of benefits from the use of the Adaptive Management process can be identified as:

- Participatory adaptive decision making
- Synthesis of knowledges and more rational decisions
- Adaptive management processes can be scaled to the complexity of the issue and the diversity of stakeholders
- Process for adjustment of goals and targets based on learning and knowledge from involvement will result in continual improvement
- Institutional arrangements and experimental policies can be improved based on evidence

However, the process is commonly ignored and considered too costly in time. There is scope to improve it and reward science and innovation for tackling the more difficult ecosystem level issues using best-available processes.

3. Synthesis of knowledge

An important step required for ecosystem level issues being evaluated and managed through adaptive management processes is how to synthesise various types of knowledges. The following section is from Shaw (2006). Humans work best when focussed on specific issues. For complex issues encompassing social, economic, environmental and ethical aspects, it is very difficult to provide holistic and integrated views of the processes operating, comprehensive views of the decision options and the likely implications of various management actions for adaptive decision making. Integrated approaches are required to overcome the disadvantages of the fragmentation of society into segments of responsibility and of science into disciplines. This is of particular importance if we are to progress towards long-term sustainability.

A knowledge synthesis approach with a focus on ecosystems (comprising environmental, social and economic aspects) that allows the strengths of expert, experiential, historical and intuitional knowledge to be synthesised to achieve an integrated view that will allow the best long-term sustainable decision and actions possible in the circumstances.
The approach comprises six steps:

1. **Setting directions.** Scoping the issue, refining the brief, setting goals, agreeing on beliefs, ethics and accountability and the methods of interaction;
2. **Framing**. Framing the issue as ‘what if’ scenarios. This moves the focus to solutions for unknown futures, rather than disputes on processes, and develops a common basis for communication;
3. **Collages**. Experts and stakeholders provide collages of their understanding of processes and likely linkages, with the group developing and refining the linkages and their relative importance;
4. **Conceptual picture**. A shared and refined, conceptual mental picture of the feedbacks and interactions, together with management options and their possible consequences is developed from the synthesised knowledge. Convergence rather than consensus is the basis allowing for revision and adjustments with evolving information;
5. **Prediction**. Each participant provides their probabilistic prediction of the most likely outcomes of selected and agreed ‘what if’ scenarios, based on their knowledge, intuition and the tools they use. A numerical Bayesian process is used to capture the intuitive judgements of the participants. This often neglected aspect balances innate wisdom with scientific data and knowledge to contribute to the best possible outcome. It enables myths and partial knowledge to be addressed with reduced conflict;

6. **Expected outcomes**. A synthesis of the most probable scenario outcomes including the range of responses, their uncertainty, implications, possible resilience and response times.

The process used to locate the lost US submarine *Scorpion* in 1968 is an exemplary approach for seeking the best decision to a complex issue where the necessary information to locate the submarine was very limited. While such a goal as locating a submarine has very defined boundary conditions, the principle of synthesising the available information and involving various experts and scenarios has not been surpassed. It has preceded the development of various published methodologies with its own mix of tools.

The process has been outlined by Suroweiski (2004) and Sontag and Drew (1998). It involved collation, sorting and synthesis of all available information, identification of possible scenarios, use of diverse experts to give their own 'best bet' judgement on the probability of each component scenario occurring. This was done as simple bets with small rewards to maintain strong involvement to quantify the intuition and experience of the experts for Bayesian analysis of the probability of most likely locations.

From this, a probability map of the likely locations of the submarine on the seafloor was compiled from which optimal search routines were used (Richardson and Stone 1971) to search for the submarine. The submarine was located some 200 metres from the grid square of highest probability based on the analysis of the responses of the experts to the various scenario components. This was an excellent result and the process can be extrapolated to complex issues to provide the probability of different events happening which can minimise unintended consequences.

The expected benefits of a knowledge synthesis process are:

- A framework and process that can be readily implemented to seek a synthesised view of an issue, 'what if' scenarios, identify implications and consider proposed development or conflicting resource use or needs or other complex issue in a constructive manner.
- The possibility to anticipate future related issues through the process and 'what if' scenarios before it is too late.
- A convergence approach means existing tools and approaches can be incorporated and a new magic trick is not being invented.
- An excellent opportunity for younger people to understudy experts, and for retired people as mentors, and to learn through participation in real life issues over a short period of time.
- A roving and flexible team can deal with local issues jointly involving local stakeholders where the relevant skills are not locally available.
- Ownership of the issue by all participants through creative involvement and spreading of knowledge through people and group networks.
- Compilation of the various collages will become a valuable resource for approaching related issues in a shorter time period.
- The interaction and process can be scaled to the complexity and conflictual nature of the issue.
- No major new infrastructure required since it uses people in existing institutions and stakeholders. An ongoing core group who build up the experience, collages and facilitation of the approach will make a major difference to the effectiveness of the process longer term since it may be a rather intense and interactive process of diverse interests.
- Directly incorporating governance and ethical aspects with science, expectations and intuition to derive the 'best' possible outcomes

Wilson (1998) in his book *Consilience: the unity of knowledge* offers good reasons to consider this approach of linking knowledge together and overcoming the barriers.

4. Overcoming barriers

The government policy on science and innovation has a strong focus on economic return from investment in R&D. While this is the norm for some research directions, it does not address the pressing complex issues as discussed earlier. To seek the outcomes required from research in other than specific economic terms will require a team approach.

4.1 The role of scientists in the innovation cycle

Figure 1 as a model for how the world of science works indicates that considerable activity is needed beyond science if research outputs are to be used effectively. To bridge the gaps and overcome the barriers means a cooperative team approach with others besides scientists. Some important aspects are:

- seeking a common point of reference across the differing cultures and languages
- proactively seeking and engaging contributors apart from science to reach the goal and
- overcoming the barriers to diverse interaction. These interactions were outside the normally expected behaviour patterns of the science participants.

Figure 1. The value chain for science in relation to the rewards that scientists receive for their work compared to what is needed if the gaps are to be successfully addressed, from (Shaw 2003).

Gibbons et al. (1994) and Nowotny et al. (2001) outline a knowledge paradigm to achieve a level of integration to achieve effective outcomes.

4.2 Scientific discipline boundaries

Scientists are rewarded for publications usually within highly ranking referred journals. In past efforts with the Coastal CRC, some of the participating scientists in the CRC were considered by their non-CRC peers to have put their career on hold by participating in the CRC where multi-disciplinary large projects were the norm. While ARC has initiated grants for multi-disciplinary projects, it is very limited and needs to be expanded to be able to tackle bigger and more complex issues by involving several disciplines over longer time frames. There needs to be alternative reward systems and probably incentives besides the current rewards systems of scientific excellence within a discipline that encourage team approaches to enable the big pressing issues to be tackled in a timely and holistic manner.

I fully support the draft finding 9.5 on alternative and shorter term CRC models as one way to do this alongside an alternative reward system and an incentive scheme.

4.3 Stakeholder involvement

Seeking outcomes for difficult and complex ecosystem level issues and the development of 'trigger' and proactive management options to minimise collapse of systems into less desirable states and to minimise unintended outcomes from partial solutions requires multiple stakeholder engagement. This will be difficult but necessary. Table 1 identifies the different paradigms that need to be managed to achieve this desirable outcome.

Table 1. Operational differences for various groups involved in natural resource management modified from Adams and Hess (2001) with the inclusion of a scientist column (Shaw 2003).

Operational setting	Scientists	Community	Corporations	Government
Institutions	teams	associations	markets	public service
Regulator	peer review	values	prices	Votes, law
Dynamic	sharing & recognition	reciprocity	competition	representation
Tools	publications & networks	networks	contracts	programs
Focus	production of knowledge	equity, cohesion	efficiency, productivity	order, redistribution

5. Recommendations

1. Draft findings 9.4 and 9.5 are fully supported and could even be enhanced in the report with some of this further material as appropriate.
2. Incentives be provided by government funding agencies to encourage scientists to collaborate, involve stakeholders and tackle the large complex issues of society in a holistic and integrated way based on synthesis of knowledge and more ongoing projects with review dates for possible further funding depending on progress
3. Alternative rewards systems be developed to allow inter-disciplinary science careers to be equally rewarded but allowing scientists the freedom to tackle the scale of issue raised in this paper
4. Specific allocation of research funding to develop multi-stakeholder based teamwork to address the achievement of outcomes beyond science as illustrated in Figure 1
5. Addressing sustainability, society and quality of life issues where there is market failure will require a new paradigm of process, interactions and priorities if these major issues are to be approached in a worthwhile manner to achieve the outcomes desired by society. Some of the tools to do this, which have been outlined in this paper, will be required as well as governance and institutional arrangements to encourage participation.

6. References

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