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A framework for applying the concept of ecosystem services to natural resource management in Australia

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SUMMARY: Ecosystems are declining worldwide, largely due to ignorance of their value to humans and inadequate social and economic mechanisms to encourage individuals to invest in maintaining them. The concept of Ecosystem Services is becoming popular as a way to encourage discussion about the dependence of humans on nature and what that means socially and economically. Ecosystem services are transformations of natural assets (soil, water, air, and living organisms) into products that are important to humans. Examples include: provision of clean air and water; maintenance of soil fertility; maintenance of liveable climates; pollination of crops and other vegetation; control of potential pests; provision of genetic resources; production of food and fibre; and provision of cultural, spiritual and intellectual experiences. The value of ecosystem services to humans comes from their role in supporting our lives, their cheapness, and our limited ability to replace them with human-engineered alternatives. The problems we have in maintaining them come about because our economic systems don't cope well with goods and services that are publicly owned. This paper describes a framework for identifying the services coming from ecosystems around Australia, for analysing the ecological, social and economic problems and opportunities presented, and for exploring new ways to encourage investment in maintaining ecosystem services. The framework focuses on co-learning between scientists, economists and community members, and emphasises the need to communicate the results in ways that support decision-making at all levels. Since water and waterways underpin all ecosystem services, this approach also offers a framework for defining the health of waterways and managing them for healthy, productive and sustainable human communities.

THE MAIN POINTS OF THIS PAPER

- Waterways and their associated ecosystems provide a set of services that support and fulfil human life.
- Delivery of these *ecosystem services* is declining worldwide, largely due to ignorance of their value to humans and inadequate social and economic mechanisms to encourage individuals to invest in maintaining them.
- The value of the ecosystem services to humans comes from our dependence on them, their cheapness, and our limited ability to replace them with human-engineered alternatives.
- This paper proposes a framework to address these problems. It focuses on assessment of ecosystem services from ecosystems around Australia, analysis of the ecological, social and economic problems and opportunities presented, and exploration of new approaches to encouraging investment in maintaining ecosystem services.

1. INTRODUCTION

The health of rivers and streams is usually defined in terms of biological and ecological outcomes of physical processes (Young, 2001). These outcomes include the provision of habitats for organisms living in the streams and on flood plains, the extent and nature of food webs among these organisms, and the primary production achieved within these food webs. It is reasoned that the biological components of waterways are sensitive to changes in physical processes and thus can serve as indicators of whether the system is functioning in the way that we want it to.

Although our understanding of how to diagnose unwanted outcomes from waterways is improving rapidly, there is less consensus about what those outcomes should be. For example, debate about environmental flows is raging within Australia yet what proportion of our communities understand what environmental flows mean to them personally? Central to the notions of ecosystem health and ecologically sustainable development are a consideration of human needs and responsibilities. We seek healthy and sustainable ecosystems to support ongoing human existence, fulfilment and prosperity, and to meet our obligations to other species and future generations. Although the responsibilities of humans are often discussed, the needs that we bring to our relationship with nature are less clearly articulated.

Many economists and ecologists argue that this lack of clarity about human dependence on the environment is a major force underpinning environmental decline (Pearce & Moran 1994). It also limits public support for better environmental management. For example, experts can agree that ecosystems of all sorts around the world are in poor and declining condition with respect to the purification and delivery of water (World Resources Institute, 2000), but the majority of people do not understand what this means for them in their day to day decisions. Hence, ecosystems continue to be given low value in economic decisions and there is limited political will to address the issues.

The concept of Ecosystem Services offers a framework for considering the provision of life-support and life-

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fulfilment to people by nature. It prompts us to ask what these services are and what is happening to them, or will happen under different approaches to land-management, how much of the services is needed to maintain lives and lifestyles, and what the possibilities, costs and benefits are of substituting technological alternatives for ecosystem services (see Section 3).

In this paper, we discuss the concept of ecosystem services and how it is being applied to engage communities around Australia in dialogue about natural resource management. In particular, we summarise a new approach to assessing what ecosystem services come from a range of Australian ecosystems. A companion paper (Shelton et al. this volume) reports on the first major assessment of ecosystem services (in the Goulburn Broken Catchment of Victoria).

2. WHY ARE ECOSYSTEMS DECLINING?

There is mounting evidence that ecosystems around the world are declining in terms of the species that live in them and the services that they provide for humans (Daily, 1997; World Resources Institute, 2000). The experts consulted by the World Resources Institute concluded that within a few decades virtually all of the world's ecosystems will have suffered significant negative impacts from human activities. There are many immediate causes of this trend, but underlying these causes is the fact that humans give a relatively low value to ecosystems compared with the value given to activities that potentially degrade them. The literature gives several reasons for this trend:

- People generally are not well informed about the benefits that come from ecosystems and the potential to lose those benefits under some management regimes (Daily, 1997);
- People assume ecosystem services to be endlessly regenerating;
- Many of the components of ecosystems are publicly rather than privately owned, meaning that private markets that might give price signals when resources decline do not emerge and that decline of ecosystems due to other economic activity is not factored into costs in those markets (Heal, 2000);
- The economic systems used in most countries emphasise values and preferences of individuals (consumer sovereignty) more than the values of communities (Costanza and Folke, 1997);
- Many ecosystem services are not approaching critically rarity, so marginal losses are not given high importance;
- Many changes in ecosystems have long lead times, meaning that symptoms of decline are not apparent until years or decades after critical thresholds are passed;
- There is a widespread assumption that ecosystem services can be replaced cost-effectively by technological alternatives;
- There are few mechanisms or incentive for investment in ecosystem services (Heal 2000).

Most of these trends can be addressed through better documentation of what the benefits of ecosystems are to people, what impacts human activities are having, and what the costs and benefits of technological substitution are. The way that the concept of ecosystem services is being applied in Australia and the USA is aimed at addressing these issues.

3. WHAT ARE ECOSYSTEM SERVICES?

Since the middle of the 19th Century, scientists have been challenging the idea that the world's resources are infinite (Mooney and Ehrlich, 1997), but it has taken some time to develop a concept relating the needs of humans to the amounts and types of natural resources that might be needed.

Ecosystem services have been defined by Daily (1997) as *the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life*. Mooney and Ehrlich (1997) trace the development of the concept. Ecosystem function, as it pertains to service delivery for humans, was first described in a 1970 report (*Study of Critical Environmental Problems*), which coined the term *environmental services*. Holdren and Ehrlich later refined the list of services, using the terminology *public service functions of the global environment*. Westman, in 1977, simplified this to *nature's services* which was finally refined to *ecosystem services* by Ehrlich and others in 1981 (Mooney and Ehrlich, 1997).

Ecosystem services include: provision of clean air and water; maintenance of soil fertility and structure; maintenance of liveable climates; pollination of crops and other vegetation; control of the vast majority of potential pests, diseases and weeds; provision of genetic resources; production of goods like food and fibre; and provision of cultural, spiritual and intellectual values (Daily, 1997; Binning et al. 2001). These services meet most of the fundamental needs that humans have, including subsistence, protection, understanding, leisure, creation, identity and freedom (Max-Neef, 1991).

Putting the concept of ecosystem services into practice in policy and planning requires answers to several key questions (PCAST 1998; Daily 1999):

- What ecosystems provide which services?
- Who benefits and over what scales of time and space?
- What are the impacts of humans upon the supply of services?
- How is the supply of services related to the condition of ecosystems?
- How much damage has been done already?
- What is needed to repair damaged ecosystems?

- Where are the problems geographically?
- How interdependent are ecosystem services?
- How reliant are the services on biological diversity?
- How much can technology substitute for ecosystem services?
- Given likely future technology, what area of natural ecosystems will be needed to support human life into the future?

4. APPLICATION OF THE CONCEPT OF ECOSYSTEM SERVICES IN AUSTRALIA

As part of the Sidney Myer Centenary Celebration 1899-1999, The Myer Foundation provided seed funding for a project on ecosystem services involving CSIRO and a wide range of land managers, community groups, industry, land management agencies, scientists and economists. The Ecosystem Services Project began in 1999 and will run at least until 2003. It aims to:

- engage policy developers, decision makers, and implementers throughout;
- assess what services are provided by a range of Australian ecosystems;
- assess who benefits from the services, where;
- explore and analyse change under different scenarios (including interactions between ecological, economic and social processes);
- investigate new institutional, market, and policy structures to encourage accounting of, and investment in, natural assets; and
- develop and test guidelines for performing such assessments in Australia and elsewhere.

To achieve these aims, a process beginning with a stakeholder-driven inventory of ecosystem services and continuing with interlinked ecological, social and economic analyses is being implemented (**Figure 1**). The process is one of learning between scientists, economists, industry, communities and agencies, facilitated by a major investment in communication throughout. To facilitate this two-way learning, we need language that allows people with arrange of experiences, backgrounds and qualifications to engage. Talking about *services* inevitably focuses our attention on the receivers of those services. Thus, we argue that ecosystem services need to be identified and discussed in terms related to people's perceptions and needs for services from the environment rather than scientific or economic theory.

This limits the set of ecosystem services that we deal with to those that people without specialist ecological knowledge can recognise (sometimes with a little help) and see the importance of. Thus, "production and maintenance of fertile soil" can be recognised by most people because they know fertile soil is needed for growing crops and maintaining natural bushland. While "nutrient cycling", "organic matter decomposition", or "mineralisation" are important processes that underpin the delivery of services to people, they probably are not understood or appreciated by most non-scientists. We would deal with them when analysing how delivery of services might be affected by changes in management practices, but not as part of the list of higher-level services we focus on in our assessments.

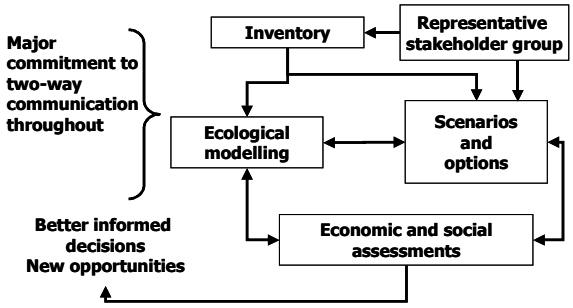

Figure 1: *Key elements of the approach to assessing and valuing ecosystem services as applied by The Ecosystem Services Project.*

Figure 2 was developed as a way to simplify ecological complexity and to focus people's thinking about the relationship between natural capital (natural assets), ecological goods and other products, and the services that emerge through transformations between assets and products. In this framework, ecosystem services contribute to the economic and social well-being of people in two ways:

- Through the use of natural assets to provide an ***inputs to production***. For example, fruit production is dependant on the service of pollination, which in turn is dependent on the natural asset of biota to provide insect pollinators. Similarly, crops are dependent on the service of nutrient cycling, which uses the natural asset of soil.
- By ***maintaining natural assets*** through regenerating the assets (e.g. maintaining soil health through nutrient recycling) and through the assimilation of by-products arising from production processes or from consumption of goods (e.g. assimilation of carbon dioxide from industry by vegetation or detoxification of chemicals by soil micro-organisms).

Through additional funding (notably from Land and Water Australia, the Rainforest Cooperative Research Centre, the University of New England, the Cotton Cooperative Research Centre and the Rural Industries Research and Development Corporation) and collaborations with various organisations, agencies and individuals, seven case studies are underway around Australia emphasising different parts of the assessment approach and different ecosystem services depending on ecosystems and land uses (**Figure 3**). The agricultural case study in the Goulburn-Broken Catchment of Victoria is the most advanced. CSIRO has entered into a full partnership with the Goulburn-

Broken Catchment Management Authority, and additional support is being provided by Land & Water Australia.

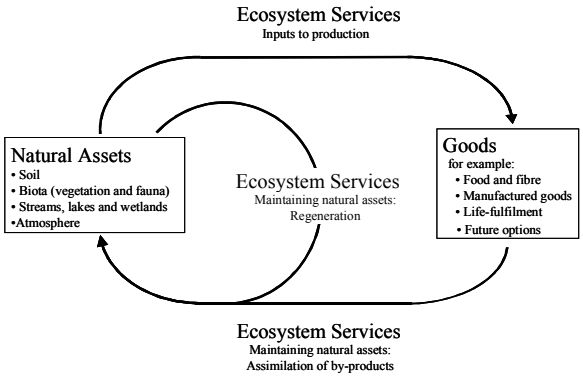

Figure 2: *Conceptual framework defining ecosystem services in terms of three types of transformations: (1) Transformations of natural assets into products valued economically and in other ways by people in a catchment; (2) transformations of the by-products of Type 1 ecosystem services back into natural assets; (3) internal transformations among natural assets to maintain those assets.*

5. METHODS FOR INVENTORY

The first step in the Ecosystem Services Project is an inventory of ecosystem goods and services (**Figure 1**). There have been relatively few assessments of ecosystem services at a catchment or similar geographic scale anywhere in the world (see Daily 1997 for some examples). The methods developed for the Australian Ecosystem Services Project are described by Shelton et al. (this volume). These have been applied in the Goulburn Broken Catchment of Victoria (Binning et al. 2001).

6. ECOLOGICAL ANALYSES AND ECONOMIC ASSESSMENTS OF ECOSYSTEM SERVICES

The debate about how to value natural assets and the goods and services that flow from them has been central to the development of the discipline of ecological economics, especially over the past decade. Texts have been written on the concept of value and expert panels have been convened to seek a unifying definition. The consensus seems to be that it is not possible to develop a single unifying definition of value and that it is more constructive to recognise and understand the different perceptions within society and how they relate to one another (Bingham et al. 1995; PCAST, 1998; Bockstael et al. 2000).

Economic value is seen by some as just one of many values that nature can have, while others argue that properly carried-out economic valuations encapsulate all societal values (Pearce and Moran, 1994). Some commentators suggest that applying economic valuations to nature enhances rather than slows its degradation, while others argue that the solutions to environmental degradation lie in economic assessments. With respect to ecosystem services, the choice of which services to value is in itself a value judgement usually made on the basis of economic and social values (Bingham et al. 1995).

The economic value of ecosystem goods and services should relate to their contribution to human welfare. Techniques for economic valuation seek to measure people's perceptions of this contribution. Often this is done in terms of their willingness to pay for getting goods and services or their willingness to accept compensation for losing them. It is important to acknowledge the distinction between *price* and *value* in such exercises. Prices are strongly influenced by supply and demand. Thus, diamonds fetch a higher price than water because they are rarer. Consider, though, our willingness to pay if water became scarce, or our willingness to accept compensation for losing our water. Economic assessments should be considered in the context of the comparisons and decisions being made, and care should be exercised in extrapolating beyond that context (Bockstael et al. 2000).

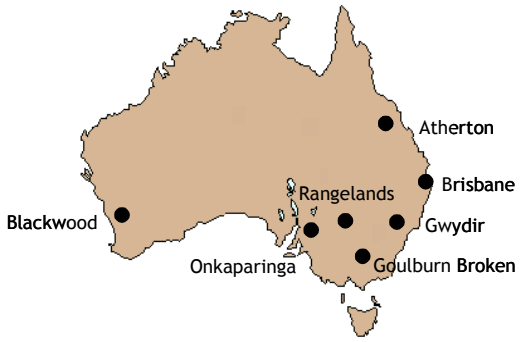

Figure 3: *Locations of existing case studies in the Ecosystem Services Project.*

Willingness to pay for goods traded in markets is revealed by prices that people are prepared to pay. Willingness to pay for goods not traded directly in markets can be inferred, for example, from the amount people pay for real estate that supplies services like pleasant views (hedonic pricing method) or from expenditure on travel to natural places (travel cost method). The choices people make about complex issues involving economic, social and environmental issues can be analysed (choice modelling) to reveal the value they place on the environmental components (Bennett, 1999). Alternatively, people can be asked directly what they will give up to keep the service or would accept as compensation to lose it (contingent valuation).

Perhaps the most challenging question raised by a focus on ecosystem services (see Section 3) is how much technology can or should substitute for ecosystem services. The cost of replacing ecosystem services with human-engineered systems can be used as a measure of the economic value of the services if three

conditions are met: (1) the human-engineered system provides the same quality, type and amount of benefits that the ecosystem provides; (2) the human-engineered system must be the least-cost alternative to the ecosystem; (3) people are willing to pay the replacement cost (Bockstael et al. 2000).

These conditions are rarely met. The cost of replacing the ecosystem service of maintaining soil fertility in the USA, for example, is at least US$45 billion per year, estimated as the cost of fertiliser to replace the naturally-fixed nitrogen (Daily et al. 1997) Not only would people be unlikely to pay this amount but the need to totally replace this service is unlikely to arise. If we consider near-total loss of life-supporting ecosystem services like maintenance of atmospheric composition or provision of clean water, willingness to pay for the last bits is likely to equal all the money people have, and willingness to accept compensation for loss is likely to approach infinity. Such reasoning leads to very high estimates of value that are not very helpful for day to day decision making.

The more realistic challenge for ecologists and economists is to estimate the extent of substitution that might be necessary or possible within realistic timeframes. Detailed and objective assessments of the relative merits of ecosystem and technological services are rare but are increasingly needed (Hawken et al. 2000).

Examples of technology-ecosystem alternatives that we are investigating in case studies in the ecosystem services project include the substitution of water filtration and waste treatment facilities for the water filtering and waste assimilation services from ecosystems, substitution of pesticides and fertilisers for natural pest control and fertilisation services, substitution of levee banks for natural flood control services, and substitution of honey bees (an introduced ecosystem service) or hand pollination for natural pollination services provided by native pollinators (Cork and Shelton, 2000; Binning et al. 2001). In all cases there are compelling reasons to look more closely at the potentially large economic benefits of encouraging the ecosystem services.

We should not, however, conclude that technology is always the inferior alternative or that there is necessarily a trade-off between technology and ecosystem services. Improvements in management of ecosystems, and/or in the effectiveness or efficiency of technology, or decreases in costs of labour or materials can dramatically and quickly alter the comparisons and potentially could allow situations where ecosystem services and technology might work synergistically for improved human welfare.

Traditional approaches to economic valuation are based on the preferences (willingness to pay) of individuals. Because many natural assets and ecosystem services are publicly rather than privately owned, there is often little incentive or opportunity for individuals to invest in their protection and maintenance (Heal, 2000). With increasing focus on ecologically sustainable management, it is recognised by some economists that we need approaches that assess what is valuable to communities (Costanza and Folke, 1997). Such approaches require processes for informing communities what is potentially valuable to them, and this requires that scientists and economists step outside their disciplinary jargon and enter into dialogue in common language with community members. If this can be done then the dollar value of ecosystem services becomes secondary to the information on what they mean to communities – which becomes the basis for decision making. We are using the concept of ecosystem services as one way to break down the disciplinary boundaries, and we are employing new techniques like citizen's juries (Lenaghan, 1999) to inform and support decision-making at all levels.

7. EXPLORING NEW MECHANISMS FOR INVESTMENT IN ECOSYSTEM SERVICES

Efforts are under way in Australia and around the world to develop new markets for environmental goods and services (Binning and Young, 1997; Heal, 2000). We will not attempt to review these here. The essential requirements of such schemes are that investors are given some limited rights over ecosystem goods and services so that they can trade them, and that demand either exists due to rarity or is created by regulations defining acceptable levels of ecosystem goods and services (Salzman, 1997; Heal, 2000). Associated issues include definition of property rights, debate about what duty of care can be expected of current land owners, and the need for robust methods for measuring delivery of the ecosystem services in trading (Binning and Young, 1997).

A key issue raised by a focus on ecosystem services is the need to encourage investment in the full range of services rather than allowing imbalance to be introduced by haphazard investment in one or a few at a time. Models such as that depicted in **Figure 4** are being considered by various groups in Australia and overseas. In the Ecosystem Services Project we are exploring innovative ways to allow investors to contribute to and benefit from regional environmental "banks" that are guided by strategic planning for balanced environmental outcomes.

8. CONCLUSIONS

The benefits, or services, that come from ecosystems, meet the full range of essential human needs, from life-support to life-fulfilment. The delivery of these services is declining largely due to ignorance of what the values are, an unbalanced focus on what value means to individuals rather than communities, inadequate debate about the efficiency and effectiveness of substituting technology for ecosystems, and inadequate institutions

and mechanisms to encourage investment in maintenance of ecosystems.

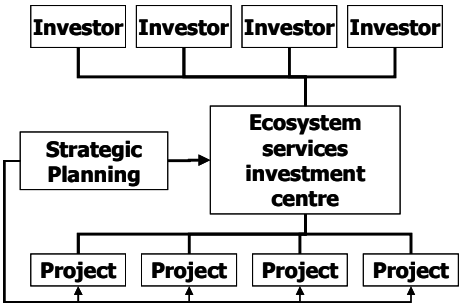

Figure 4: *Generic design for an investment framework to encourage balanced environmental outcomes at regional scales*

The framework presented here focuses on identifying the services coming from ecosystems around Australia, analysing the ecological, social and economic problems and opportunities associated with technological substitution, and looking for new approaches to encouraging investment. It includes a major focus on co-learning between scientists, economists and community members, and communication of the results to support decision making at all levels. Since water and waterways underpin all ecosystem services, this approach also offers a framework for defining the health of waterways and managing for ongoing maintenance of what humans should value in their relationship with wet environments.

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