Ecosystem Services From Healthy Oceans and Coasts

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Abstract

Ecosystem services (the benefits people derive from functioning ecosystems) are increasingly being recognized as essential to sustainable human well-being. Oceans and coasts provide a significant portion of ecosystem services. We need to significantly improve our understanding and modelling of the complex interconnections between ecosystems and sustainable human well-being to allow us to make better management decisions. Australia is a timely and unique test bed to facilitate these advances, with applications to a broad range of critical coastal and marine issues.

Background and Relevance

Ecosystem services are defined as those functions of ecosystems that support (directly or indirectly) sustainable human well-being (Costanza et al. 1997, Daily 1997). Table 1 is one of the first classifications of ecosystem services and their corresponding ecosystem functions. Since then, several other classification schemes have been put forward with variations on this theme (de Groot et al. 2002, MEA 2005, Costanza 2008, Sukhdev et al. 2010, Haines-Young and Potschin 2011, de Groot et al. 2012). Ecosystem services occur at multiple scales, from climate regulation and carbon sequestration at the global scale, to storm protection, recreation, and food supply at the local and regional scales. They also span a range of degrees of connection to human perception of the benefits, with services like storm protection being less directly connected, and recreational opportunities being more directly connected. Since the concept was introduced more than two decades ago, interest in ecosystem services and their valuation has exploded. The Millennium Ecosystem Assessment (MEA 2005) and The Economics of Ecosystems & Biodiversity (TEEB) report (Sukhdev et al. 2010) spurred increased interest in the concept. A recent search on the Institute for Scientific Information (ISI) website on the topic “ecosystem services” showed a total of more than 12,000 journal articles, with more than 1,400 published in 2013 alone.

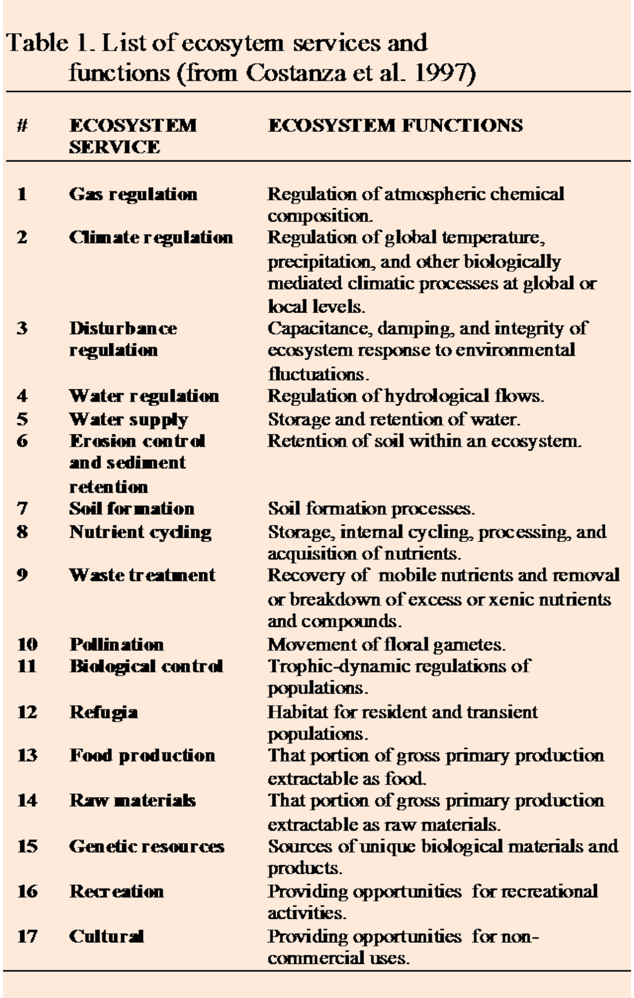

Table 1. List of ecosytem services and functions (from Costanza et al. 1997)

#	ECOSYSTEM SERVICE	ECOSYSTEM FUNCTIONS
1	**Gas regulation**	Regulation of atmospheric chemical composition.
2	**Climate regulation**	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.
3	**Disturbance regulation**	Capacitance, damping, and integrity of ecosystem response to environmental fluctuations.
4	**Water regulation**	Regulation of hydrological flows.
5	**Water supply**	Storage and retention of water.
6	**Erosion control and sediment retention**	Retention of soil within an ecosystem.
7	**Soil formation**	Soil formation processes.
8	**Nutrient cycling**	Storage, internal cycling, processing, and acquisition of nutrients.
9	**Waste treatment**	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.
10	**Pollination**	Movement of floral gametes.
11	**Biological control**	Trophic-dynamic regulations of populations.
12	**Refugia**	Habitat for resident and transient populations.
13	**Food production**	That portion of gross primary production extractable as food.
14	**Raw materials**	That portion of gross primary production extractable as raw materials.
15	**Genetic resources**	Sources of unique biological materials and products.
16	**Recreation**	Providing opportunities for recreational activities.
17	**Cultural**	Providing opportunities for non-commercial uses.

The non-market values of the various individual ecosystem services listed in Table 1 have been estimated in thousands of separate studies, for a range of different ecosystems (de Groot et. al 2012). An initial synthesis of this research estimated that the value of the world’s ecosystem services far exceeds the value of conventional marketed economic goods and services (Costanza et al. 1997; Costanza et al. 2014). It also concluded that marine and coastal systems provided the majority of this global value. This seminal 1997 Nature paper has been cited more than 4,000 times in the ISI web of knowledge. It was an early first estimate using relatively unsophisticated benefit transfer methods, whose limits were clearly acknowledged in the paper. Much work has been done since then and much additional work needs to be done.

Various new social institutions are also being developed to use information about the patterns, dynamics, and values of ecosystem services in order to better manage them. For example, Costa Rica and other countries have systems of payments to individual landowners for the ecosystem services their land produces when maintained in a conserved, forested state (Farley and Costanza 2010). Several regions, states and countries have assessed and estimated the value of their ecosystem services and natural capital, so that they can better manage these assets

(Batker et al. 2010, Liu et al 2010, UK National Ecosystem Assessment 2011, Kubiszewski et al. 2013).

In order for ecosystem services to occur, natural capital (natural ecosystems and their products that do not require human activity to build or maintain) must interact with other forms of capital that do require human intervention to build and maintain. These include: built or manufactured capital, human capital (e.g., human labour and knowledge); and social capital (e.g., communities and cultures) (Costanza et al. 2011). This interaction is shown in Figure 1 (Costanza et al. 2014). Thus, ecosystem services science (ESS) is inherently an integrated, transdisciplinary science that is concerned with the way these four forms of capital assets (built, human, social and natural) contribute to human well-being and the synergies and trade-offs among them. The challenge in ecosystem services analysis and valuation is to assess the relative contribution of the natural capital stock in this interaction and to balance our assets to enhance sustainable human well-being.

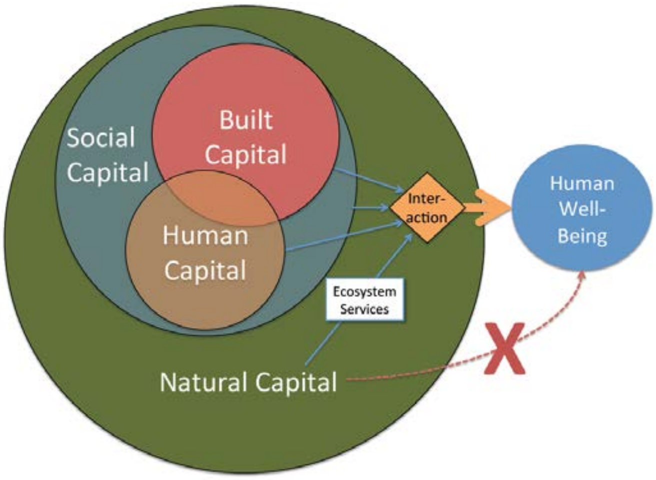

Figure 1. Interaction between built, social, human and natural capital required to produce human well-being. Built and human capital (the economy) are embedded in society which is embedded in the rest of nature. Ecosystem services are the relative contribution of natural capital to human well-being, they do not flow directly. It is therefore essential to adopt a broad, transdisciplinary perspective in order to address ecosystem services. (Costanza et al. 2014).

What is needed now is a more sophisticated and transferable ability to understand and model the complex connections between ecosystem functions and the benefits they provide to humans. This will allow us to assess the trade-offs—in terms of contributions to long-term human well-being—of protecting and restoring natural environments relative to other assets.

This is consistent with Marine Nation 2025 (http://www.aims.gov.au/opsag), which states that:

> “Innovative and cost effective ways to predict how biodiversity, ecosystems, society and the economy might change under future scenarios at the appropriate scale while understanding the limits of our predictive capacity will provide the basis for more effective management to support biodiversity conservation and sustainable resource use”

The science needs this implies were further elaborated in Marine Nation 2025 as:

> “The challenges faced by the science community in providing advice to government fall into three categories:
>
> **Need for appropriate data.** As highlighted elsewhere in this document, social and economic data of relevance to decision-making are lacking in some areas. For example, informed management of recreational fishing is hampered by lack of social data on recreational activity, economic data on value, and biological data on catch. Data on ecosystem health and function, particularly for pelagic and deep-sea

> environments are very limited. The impacts of multiple uses and cumulative threats are largely unknown, despite the intensity of human use of the marine estate, particularly in the coastal zone.
>
> **Need for new tools.** Robust, evidence-based decision-making requires management of large volumes of data and complex risk-based modelling coupling biophysical, economic and social models that include shifting baselines as the climate changes. The national data and computing infrastructure for this task are beginning to expand, as are innovative ways to combine and display information. A critical issue is that the tools need to produce robust, trustworthy and comprehensible advice of direct relevance to policy outcomes.
>
> **Need for new skills**. Working within the science-policy interface is fundamentally different from traditional scientific research. Scientists providing advice for policy or decision-making need to be able to communicate complex and fuzzy issues to non-experts in ways that can used to achieve policy outcomes. A challenge for scientists is that they are asked to respond to management questions at scales that are outside current knowledge, and within severe time constraints. In turn, decision-makers are asked to specify management goals and acceptable risk levels. Both positions are uncomfortable and require negotiation and flexibility."

Science Needs

Consistent with the science needs articulated in Marine Nation 2025, Ecosystem Services Science needs can be divided into three similar categories:

Need for appropriate data and monitoring

Our present knowledge and understanding of Australia marine natural values is relatively poor and very patchy in spatial coverage and quality. Most of the Australian marine habitats have not been systematically mapped and surveyed and the associated communities and biodiversity are undescribed. Consequently, the conservation values and status is unknown for large areas of Australia's marine environment. This problem needs to be addressed through the collection of appropriate continent-wide data, which can then facilitate the subsequent design and implementation of flora and fauna inventory surveys. These surveys need to be run in parallel and in deep collaboration with social and economic surveys to capture information, at appropriate scale(s), about the social and economic systems, which interact with the marine environment and their consequent impacts on human wellbeing (Figure 1). Particular attention needs to be paid to indicators that monitor interactions between the systems (the drivers and consequences of change) to ensure it will be possible to use such data in integrated models.

The success of marine monitoring programs requires that high-quality data and rigorous analysis feeds directly into current management processes. The design and implementation of the monitoring program must therefore be collaborative and sufficiently flexible to meet evolving management needs (Lindenmayer and Likens 2009). A key determinant of the utility of a monitoring program for management is the joint decisions of scientists and managers regarding what to measure, and the extent to which this includes systemic characteristics and processes. Thus, identifying and monitoring drivers of change in the relationships between the marine and coastal environments and societies that depend on these environments is essential (Bohensky et al. 2014). This is because firstly, to be able to interpret the data that we collect we need to understand mechanisms of change in the variables of interest (Biggs et al. 2011, Ferreira et al. 2011). Secondly, monitoring drivers over time enables management agencies to anticipate some outcomes, despite the uncertainty and complexity of marine systems. This points to the need for better integrated modelling.

Need for new participatory integrated modelling and valuation methods

Integrated models at multiple scales and their supporting data bases need to be developed, tested, and implemented. The process of developing, updating and applying the models needs to also involve participation by key ecosystem scientists, ecological economists, ecosystem managers, stakeholders, and students (c.f. Higgins et al. 1997, Costanza and Ruth 1998, van den Belt 2004). This approach to collaborative science, synthesis, and modelling, has been used successfully by ecological synthesis centres, including the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara (c.f. Farber et al. 2006), and the Australian Centre for Ecological Analysis and Synthesis (ACEAS) in Brisbane.

The models can be linked with spatial data (see above) allowing spatially explicit models of coastal and marine systems to be constructed (cf. Costanza et al. 2002, Costanza and Voinov 2003). Using GIS and remote sensing data, the models can be parameterised and used for any location on the planet. The spatial proximity of particular patches of an ecosystem relative to other systems and to human populations is an important characteristic in determining its functioning and value (Costanza et al. 2008). Integrated models need to allow adequate consideration of this effect in ecosystem services modelling and valuation.

The resulting models (in combination with GIS data and web-based outreach facilities) can allow a relatively sophisticated analysis of ecosystem service dynamics at any point or region on the globe. This will enable the concept of ecosystem services to be effectively used in a number of decision contexts. For example, the models can provide critical input to systems of payment for ecosystem services, for adding the value of ecosystem services into national income accounts, as the Australian Bureau of Statistics is currently attempting to do, and for analysing trade-offs in managing coastal and marines ecosystems, like the Great Barrier Reef. The models can then be used to predict potential outcomes of management and test the acceptability of management and opportunity costs of short-term versus long-term management options. A key consideration, however, is the engagement of local resource users, and the application of appropriate deliberative valuation techniques which can elicit their priorities for future management strategies. In Australia this is particularly important when engaging Indigenous resource owners, and tools have been developed for such situations (e.g. Skewes et al. in review).

Need for new skills and new institutions for managing ecosystem services

The translation of ecosystem processes into human well-being is mediated by a number of social institutions (social capital) that can yield very different outcomes. For example, innovative forms of private or public governance may yield higher rates of regeneration and better sustainability of renewable natural resources and ecosystem services from essentially the same ecosystem inputs. Add to that, the complex range of stakeholders and their demands, and the multiple spatial and temporal scales involved in seeing the challenges realistically, provide serious challenges and exceptional opportunities. Additionally, scenarios can be used to help inform actions that promote the likely survival of components of ecosystems and address likely or possible events causing challenges for managers.

Better understanding of the complex roles of social institutions in mediating the translation of ecosystem functions into various forms of ecosystem services and human well-being, and the design and testing of innovative public goods and common pool resource institutions for improving ecosystem management are critical needs. For example, given the common pool and public goods nature of most ecosystem services, we need institutions that can effectively manage ecosystem services by employing a more sophisticated suite of property rights regimes (Ostrom 1990, Costanza et al. 2001, Dietz et. al 2003). Further research into some of traditional land and sea management practices might offer insights for modern institutions. We need institutions that use a balanced combination of existing private property rights systems, and new property rights systems that can propertize ecosystems and their services without privatizing them (Barnes 2006, Barnes et al. 2008). For example, the “public trust doctrine” has been identified as the appropriate legal framework for the management of ecosystems with governments acting as trustees for the publicly owned commons (Wood 2014). Systems of payment for ecosystem services (PES) and common asset trusts can be effective elements in these institutions. However, these systems require careful design with participation by local stakeholders to account for complex system relationships and cultural contexts (Farley and Costanza 2010, Kinzig et al 2011). Australian examples include biodiversity and ecosystem service auctions in Victoria, the National Market Based Instruments (MBI) program, water markets, and biodiversity offsets at the state and national levels (Crossman et al. 2011).

In addition, the spatial and temporal scale of the institutions to manage ecosystem services must be matched with the scales of the services themselves (Costanza et al. 1998). Mutually reinforcing institutions at local, regional, and global scales over short, medium, and long time scales will be required. Institutions are needed to ensure the flow of information between scales, to account for different ownership regimes, cultures, and actors, and to fully internalize ecosystem costs and benefits.

This is particularly challenging where ecosystem functions, services and benefits flow across ecological and social boundaries, resulting in governance mis-matches. An example in the Great Barrier Reef is the linkages and trade-offs between agriculture, river and coastal water quality, reef health and tourism, where management regimes do not cover the associated ecosystem service trade-offs (Butler et al. 2013a). Similarly, Australia’s northern Economic Exclusion Zone (EEZ) borders Indonesia, Timor Leste and Papua New Guinea. Natural capital (e.g. fish stocks, marine turtles) in the Arafura and Timor Seas and the Torres Strait is shared by these nations, and trans-boundary ecosystem processes also provide ecosystem service benefits to multiple stakeholders. Trans-boundary diagnostics of the flows of benefits and costs have been carried out for this region (ATSEA 2012), but many issues are so complex that standard co-management structures are not sufficiently effective (Butler et al. 2013b, Butler et al. in review). This is partially due the lack of government capacity within these neighbouring nations to regulate legal and illegal users of marine resources, and stressors occurring ‘upstream’ in terms of value chains and hydrological processes (Butler et al. in review).

Novel institutional systems should be explicitly designed to assure that the poor are not excluded, since they are often heavily dependent on common property assets such as ecosystem services. Free-riding should be prevented (Farley and Costanza 2010). Finally, relevant stakeholders (local, regional, national, and global) should be engaged in the formulation and implementation of both the valuation exercises around ecosystem services and institutional design decisions. Full stakeholder awareness and participation contributes to credible and accepted rules that identify and appropriately assign the corresponding responsibilities in ways that can be effectively enforced (Ostrom 1990, Dietz et al. 2003, Costanza 2013).

In tropical northern Australia, Indigenous coastal tenure, rights, customs, aspirations and current programs in sea country management need to be fully considered in defining coastal and ocean ESS. Despite Indigenous customary ownership of large tracts of the coastal estate in tropical, northern Australia (~85% of the Northern Territory), and high levels of coastal resource use and cultural dependence - ecosystem services valuations for Indigenous coastal communities in Australia are few, and largely restricted to tropical rivers and coastal wetlands (Jackson et al. 2012). Valuations for coral reefs and other marine ecosystems are especially important and need more effort (Stoeckl et al. 2011, 2014). However, the values of iconic ‘cultural keystone species’ such as dugong and turtles are well-established, and in the Torres Strait they have catalysed governance transformations for other marine resources (Butler et al. 2012).

Among the many challenges to sustainability is the tendency for myopia and overconfidence in institutional decision-making (Catino 2013). Ecosystem services are typically diffuse, with many beneficiaries accruing gains over extensive time horizons. Natural capital and ecosystem services may be compromised because, relative to alternatives, their diffuse nature make them predisposed to a suite of psychological frailties documented in behavioural economics, including availability bias, status quo bias and time-inconsistent preferences (Kahneman et al. 1982, Hoch and Lowenstein 1991). Insulation against these frailties may be provided via clear and routine articulation of the nature and value of ecosystem services in institutional decision-making. The framing of choices may also offer an effective means for avoiding organizational and social regret (Thaler and Sunstein 2008).

Perspective

There is already substantial interest and work going on in Australia on ecosystem services (Cork et al. 2002, Australia21 2007, Australian Bureau of Statistics 2010; 2012, Crossman et al 2011). Pittock et al. (2012) and Alamgir et al. (2014) provide recent comprehensive reviews with Alamgir et al. (2014) noting that a gap exists in integrating climate change and associated impacts on ecosystem services. Internationally, the Ecosystem Services Partnership (ESP- www.es-partnership.org) includes most of the individuals and groups around the world working on ecosystem services. The ESP can be a vehicle for engaging additional participants and agencies, sharing output, and communicating results.

The Marine Ecosystem Services Partnership (MESP - http://www.marineecosystemservices.org) is a working group of ESP. The MESP strives to provide up-to-date and easily accessible data for the use of policy makers, environmental managers, researchers, and marine ecosystem stakeholders. In its first iteration, the MESP database held over 900 entries of economic valuation data representing over 2000 values. The MESP strives to be a community of practice through which data users and managers can work collectively to better integrate ecosystem services data with marine policy needs. This collaboration is aided with the use of tools such as the valuation mapper – a dynamic map allowing users to burrow down through different types of data by inputting spatial and thematic queries. MESP will improve the estimation, dissemination, and use by decision makers of social and natural science data about marine ecosystem services by

- easing access to ecosystem valuations by creating a centralized and submission-enabled data repository that is spatially explicit.
- improving communication between valuation researchers and policy makers.
- utilizing web-based tools to better target areas where new research is needed

- providing contextual and up-to-date perspectives for understanding valuation data in relation to environmental management decisions.

Australia is unique in its position as a single nation state, managing a whole continent and its marine jurisdiction. It has not done this well. With the exception of the Great Barrier Reef Marine Park all other marine protected areas are what have come to be called “residue”, i.e. unwanted areas, areas that no one else, particularly fishers and miners, consider desirable (Pressey et al., 2000; Edgar et al., 2011). States are given jurisdiction over a three nautical mile (five km) edge to the coast. Kirkman (2014) gives a description of the process and science behind selecting South Australia’s MPAs. From state waters to the outer boundary of the Economic Exclusion Zone (EEZ) the Commonwealth has jurisdiction. The commitment to, and establishment of a National System of Marine Protected Areas (or NRSMPA) (ANZECC 1998, 1999) and also, efforts by the Commonwealth to undertake ecosystem-based, bioregional, integrated ocean planning, both provide excellent opportunities for existing (and new) spatial datasets (on ocean values and human uses) to inform future valuation of Australia’s ocean ecosystem services.

The national bioregional planning framework template for the NRSMPA is the Integrated Marine and Coastal Regionalisation of Australia (or IMCRA). Under IMCRA, 58 mesoscale, bioregions have been identified for Australia’s coastal waters, based on a broad range of biophysical parameters (IMCRA 1998). In contrast, the Commonwealth marine reserves uses the 41 provincial-scale bioregions as the template for a MPA network in Commonwealth waters. Significantly, these mesoscale and provincial bioregions are the result of scientific analysis that has classified Australia's marine environment, into broadly similar ecological regions. Goals and Principles seek to draw on available science while recognising from the outset that Australia’s knowledge of the biodiversity in some areas is not well developed. A significant proportion of each marine region is far offshore, very deep, and has not been the subject of detailed study or data gathering. In these circumstances, existing detailed and peer-reviewed data should be supplemented with information drawn from known linkages between biodiversity and the physical environment. Key inputs into the process should include:

- existing scientific information underlying IMCRA, e.g. bathymetry, geomorphic features, distribution of endemic biota
- additional regional information on habitats, species distribution and ecology
- data on the location and distribution of human activities in a marine region
- views of ocean users and stakeholders in each marine region, including trans-boundary stakeholders
- consideration of the contribution that existing spatial management measures can make to the National Representative System of Marine Protected Area (NRSMPA) and
- consideration of potential management effectiveness (e.g. feasibility of compliance).

A planning framework for the systematic development of a comprehensive, adequate and representative (CAR) National Reserve System (NRS) for terrestrial and inland aquatic systems is provided by the Interim Biogeographic Regionalisation for Australia (IBRA). IBRA is endorsed by all levels of government as a key tool for identifying areas for conservation under *Australia's Strategy for the National Reserve System 2009–2030*. (Taken from: http://www.environment.gov.au/topics/land/nrs/science-maps-and-data/ibra/australias-bioregion-framework). IBRA is progressively updated as new scientific knowledge or new protected areas are added, making it a dynamic tool for monitoring progress towards building a CAR reserve system

There is currently no similar repository for marine data, collected by jurisdictions. Significantly, a wide range of biophysical spatial datasets (oceanography, marine habitats, fish assemblages, etc.) and habitat surveys and mapping has been undertaken by the states and territories, scientific organizations and the Commonwealth to identify MPAs and also, establish, validate and refine bioregion boundaries.

As such, there is a potential and opportunity to extend IBRA to include relevant data obtained for regional marine ecosystems across Australia. By combining the information about protected areas in Australia with the IBRA region, the level of protection of Australia's various marine ecosystems can be measured. Assessing the level of protection assists governments to decide how to best prioritise funding and other resources to meet national protection targets. In building the NRS, the main priority is to address the key gaps in comprehensiveness at the national scale. Most important of these is the protection of ecosystems that are currently poorly reserved or not protected at all. Knowledge of the ecosystem services provided by these ecosystems is critical in national priority-setting.

Another potential major stream of ocean data for ES valuation, is the Integrated Marine Observing System (or IMOS), Australia’s largest ocean data observations system and data portal. Established in 2007, the IMOS, through the AODN, provides a comprehensive range of publicly accessible, real-time data on oceanography, fisheries, and increasingly, biological data (such as, reef surveys, movements of marine mammals, etc.) [https://imos.aodn.org.au/imos123/]. The Australian Ocean Data Network (AODN) includes data from the six Commonwealth Agencies with responsibilities in the Australian marine jurisdiction (AAD, AIMS, BOM, CSIRO, GA and RAN). Further national effort is needed in ocean data warehousing, particularly ensuring key coastal data by State/Territory agencies, marine industries, where possible, are made available.

Strategic monitoring of indicator species or ecosystems and inventories of those ecosystems is a start towards obtaining a nationwide ESS that can indicate the value of ecosystem services. Mapping the coast and underwater habitats can be used for a multitude of purposes and should be of high priority.

Due to the ‘public goods’ nature of the ES of coastal and ocean ecosystems, the potential for private incentives to sustainably manage their ecosystem services is limited. With this ‘market failure’ and by their inherent nature, ecosystem services are typically under supplied by the market system (Brander et al. 2012). As a result, oceans are generally undervalued in both private and public decision-making, relating to their use, conservation and restoration. Environmental planning and problem solving also requires much better science communication between everyone, including scientists, key stakeholders, and the community (Dennison 2008). Given these challenges, a greater focus on scientific communication and the development of ecological and economic models that help to predict the risks of inaction and direct economic valuations (such as Brander et al. 2012) are advocated.

In response to the inherent uncertainty in our ability to predict ocean ecosystem evolution and response to different management policies, a shift is required from optimization-based management to an adaptive co-management paradigm (Folke 2003). Over the last several decades, environmental risk assessment and decision-making strategies have become increasingly more sophisticated, information-intensive, and complex (using approaches such as expert judgment and cost–benefit analysis). In this 2nd phase of management, environmental decision-making tools such as comparative risk assessment (CRA) and multi-criteria decision analysis (MCDA), coupled with adaptive management - provide structured, participatory methods for comparing and also, identifying optimal, management alternatives

(Linkov et al 2006). These tools are being increasingly used for river catchment and water planning (Straton et al. 2011). In identifying and deciding ocean management actions and options, an integrated ecosystem goods and services (EGS) and ecosystem-based management (EBM) approach, will be essential to explore ‘trade-offs’ among EGS to different user groups/stakeholders. A basic approach to prioritising adaptation under conditions of uncertainty that considers ecosystem services is set out by Lukasiewicz et al. (2013b).

Realisation

Making sustainable ecosystem management into a key *economic* goal will have a huge impact. It will allow us to move beyond the counterproductive “economy *vs.* the environment” debate to thinking about how best to balance our portfolio of assets to produce sustainable human well-being (Costanza et al. 2000, Costanza and Jorgensen 2002). However, only a different approach to thinking about and managing the future will realize this potential.

Scenario planning.

Solving complex problems requires an adequate understanding of how the system in question works and a vision of shared goals for the system (Costanza 2001). Even with adequate scientific understanding of any system, evidence may be ignored in management and policy. One important reason is the lack of a shared vision of the goals.

To overcome this roadblock to solutions, a broadly shared vision needs to be built about the world that societies want to live in. In essence, this is what democratic governance should do. Unfortunately, current versions of democracy give too much weight to special interest groups (Gilens and Page, 2014) whose visions and goals are not consistent with those of the broader public, including the scientific community. One of the (perhaps intended) consequences of the rampant if minority anti-climate science movement, in the English-speaking world in particular, is to paint science as just another interest group, with a vested interest in exaggerating problems to increase research budgets.

Scenario planning (Ringland and Schwartz, 1998; Peterson et al., 2003) is one tool that can help to build a shared vision. Scenario planning differs from forecasting, projections, and predictions in that it explores plausible rather than probable futures (Peterson et al., 2003). Although aspects of the depicted futures may come to eventuate, these futures are best viewed as caricatures of reality from which we can learn (Bohensky et al. 2011).

Scenario planning is based on four assumptions (DTI, 2003):
1. The future is unlike the past, and is significantly shaped by human choice and action.
2. The future cannot be foreseen, but exploring possible futures can inform present decisions.
3. There are many possible futures; scenarios therefore map within a 'possibility space'.
4. Scenario development involves both rational analysis and creative thinking.

Scenarios are best suited to exploring situations of high uncertainty and low controllability (Peterson et al. 2003). Global drivers of change in marine and coastal systems such as climate change and global governance are largely beyond the control of a particular region. A set of alternative scenarios provides a tool to explore the consequences of these uncontrollable forces and to formulate robust responses locally. Policy and value changes that may be required are then highlighted, and key branching points can be identified at which such changes can most affect outcomes (Gallopín 2002).

How could scenario planning be applied to the management of marine and coastal resources? Representatives of major stakeholder groups can come together to envision plausible futures for these areas. These scenarios would cover the full range of options, from business-as-usual development to more sustainable futures. In all cases the scenarios must be “plausible” – meaning that they should take scientific evidence into account but also have credibility with stakeholders; they combine rational analysis and creative thinking. Bohensky et al. (2011) is an example of this process for the Great Barrier Reef and its catchment, and the method has been successfully applied to Indigenous marine resource and livelihood planning (e.g. Butler et al. 2013c, Bohensky et al. 2014).

Scenario planning has been shown to work, even in very contentious situations, by bringing together stakeholders to think together about options for the whole system (Kahane, 2004). It allows participants to step out of their special interest mode and begin to build shared visions. Scenario planning is now embedded in the strategic thinking of some of the world’s most influential institutions, including the World Bank and United Nations Environment Program. Scenario planning was used in the Millennium Ecosystem Assessment to chart possible trajectories for the global community based on the rate and extent of ecological change and the interactions with management policies (Carpenter et al., 2005). Scenario planning need not be static; scenarios can be revisited and reworked as part of a long-term formal process—for example, the application of scenario planning to guide water management in the Netherlands from the 1950s (Haasnoot and Middelkoop, 2012).

Once a range of scenarios is created, it is often clear to all participants which options are most desirable, robust, and risk averse, given the underlying uncertainties about the future. The development of an evidence-based understanding of how the world works, combined with a shared vision how we want it to be, are powerful tools to tackle even the most complex and recalcitrant of problems.

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