SEVENTH FRAMEWORK PROGRAMME

Policy demands for value evidence on deep-sea environments

Rob Tinch, Sybille van den Hove and Claire W. Armstrong

Norwegian cold-water coral reef. Image courtesy Pål Buhl-Mortensen, Institute of Marine Research, Norway

HERMIONE
Hotspot Ecosystem Research and Man's Impact on European seas

Report on policy demands for value evidence

Table of contents

List of acronyms

AFMEC	Alternative Future Scenarios for Marine Ecosystems
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CBD	UN Convention on Biological Diversity
CFP	Common Fisheries Policy
CWC	Cold Water Coral
DECC	UK Department for Energy and Climate Change
DEFRA	UK Department for Environment, Food and Rural Affairs
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EKC	Environmental Kuznets' Curve
ELD	Environmental Liabilities Directive
ESF	Ecosystem Goods and Services Framework
EUMS	European Union Member States
GHG	Greenhouse gas
HERMES	Hotspot Ecosystem Research on the Margins of European Seas
HERMIONE	Hotspot Ecosystem Research and Man's Impact on European Seas
MA	Millennium Ecosystem Assessment
MCZ	Marine Conservation Zone
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NGO	Non-Governmental Organization
OSPAR	Oslo and Paris Conventions for the protection of the marine environment of the North-East Atlantic
OST	UK Office of Science and Technology
SP	Stated Preference
TEEB	The Economics of Ecosystems and Biodiversity
TEEB QA	The Economics of Ecosystems and Biodiversity Quantitative Assessment
TEV	Total economic value

UKCIP	UK Climate Impacts Programme
UKNEA	United Kingdom National Ecosystem Assessment
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNU-IAS	United Nations University Institute of Advanced Studies
WTP	Willingness to Pay

Report on policy demands for value evidence

Introduction

The deep sea, defined as water and sea floor areas below 200 meters, comprises 90% of the biosphere. As described in more detail by Armstrong et al (2010), the deep sea provides a whole array of ecosystem functions, goods and services, some of which contribute significantly to the global biogeochemical cycles, and hence to the well-being of humankind and ultimately to the suitability of planet Earth to our species.

But pressures on, and threats to, deep-sea ecosystems are increasing. Increasing human populations and demands for resources, coupled with over-exploitation of many more traditional resource bases, and rapid technological advance, make further exploitation of deep seas both possible and attractive. The main threats include deep-sea fishing, oil and gas extraction, minerals extraction, waste disposal and pollution, and cables and pipelines. There are also important threats arising through the indirect impacts of other human activities. Threats to deep-sea environments are addressed by, for example, Thiel (2003), Davies et al (2007), and van den Hove and Moreau (2007).

The potential for these threats to cause damage is exacerbated where the governance of deep seas is limited or ineffective, as is especially the case where the area lies outside national jurisdictions and is exposed to potential overexploitation due to open-access resources (Gjerde 2006a). The deep sea is in many respects both at the frontier of governance on Earth, and one of the last relatively unexplored and unfamiliar environments, viewed with fascination and awe by many humans. There are therefore specific challenges for valuation, governance, and the integration of the two.

There is increasing interest in estimating and using value evidence in marine contexts, including work commissioned by key stakeholders at international scale, for example by UNEP (UNEP 2006, van den Hove and Moreau 2007, Tinch and Mathieu 2010) and WWF (2008); in support of regional initiatives, such as UNEP's Plan Bleu for the Mediterranean (Plan Bleu 2010); and for national assessments and policy processes, for example the UK Crown Estate (see Saunders et al 2010a, 2010b; Dickie et al 2010), the UK government (McVittie et al 2008, Moran et al 2008; Hussain et al 2010; ABPMer 2007), and the Swedish Environmental Protection Agency (Swedish EPA 2008; 2009).

A previous report under the HERMIONE project (Armstrong et al, 2010) has explored the extent of human knowledge regarding the deep sea and its services, including what we know about the values of these services to humans. Systematic identification, qualitative description and quantitative measurements of the goods and services provided by deep sea systems is a work in progress, but information is becoming available and could be useful for various purposes.

In this report we consider valuation evidence in the context of the governance of deep seas, in particular focusing on the policy demand for different sorts of value evidence, and the

opportunities and barriers for greater use of value evidence to contribute to the sustainable management of deep sea systems.

Ecosystems, services, values and governance

The analytical framework for this report draws on four main themes:

- The 'ecosystem approach' to understanding and managing human interactions with the natural world
- The 'ecosystem services framework' for classifying and assessing the benefits that humans derive from ecosystems
- The valuation of these benefits, whether in economic terms or in other metrics
- The governance and management structures that can be used to control human use of natural environments.

These frameworks can all be applied in the deep-sea context, although the specific characteristics of deep-sea environments can influence the ways in which this is done. In particular, knowledge of the ecological processes and services of deep-sea ecosystems is often lacking, making valuation challenging, and governance structures may be weak or fragmented, limiting the scope for integrating value evidence within effective policy mechanisms. We consider the interaction of these elements and the implications for the usefulness of, and policy demand for, valuation evidence in deep-sea governance contexts.

Ecosystem approach

Many definitions of the 'ecosystem approach' have been put forward. In the framework of the Convention on Biological Diversity (CBD) for instance, the definition includes three important features:

- A **strategy for integrated management of land, water and living resources** that promotes conservation and sustainable use in an equitable way.
- **Based on the application of appropriate scientific methodologies** focused on levels of biological organization and encompassing the essential processes, functions and interactions among organisms and their environment.
- **Recognising that humans are an integral component of ecosystems**.

The concept extends the idea of 'integrated management', which considers the cumulative and synergistic impacts of activities, and the externalities between them, as opposed to a more traditional approach of sector-based management.

The ecosystem approach can fit well with adaptive management, which uses management intervention as a way of conducting strategic experiments to increase knowledge about a system. As defined by the Resilience Alliance[1], "adaptive management identifies

[1] http://www.resalliance.org/index.php/adaptive_management, accessed 07/10/2011.

uncertainties, and then establishes methodologies to test hypotheses concerning those uncertainties. It uses management as a tool not only to change the system, but as a tool to learn about the system. It is concerned with the need to learn and the cost of ignorance, while traditional management is focused on the need to preserve and the cost of knowledge."

Whatever the precise definition, the ecosystem approach is founded in the recognition of the interconnectedness of ecological processes and socio-economic processes. It is both a heuristic and a policy tool through which we endeavour to grasp the complexity of our relations to the socio-ecological system of which we are a part and attempt to render these relations more ecologically, socially and economically sustainable.

Ecosystem services framework

In recent years, and in particular since the publication of the Millennium Ecosystem Assessment (MA 2005), there has been a strong emphasis on the theoretical and practical development of approaches based on identifying, measuring and in some cases valuing the goods and services provided by ecosystems (Costanza et al. 1997; Daily 1997; Boyd and Banzhaf 2007; Fisher and Turner 2008; Luck et al. 2009; Mace et al. 2009; Haines-Young et al. 2009). These arguments do not seek to replace ethical justifications for conservation, but rather to complement them. The concept of ecosystem services captures the dependence of human well-being on natural capital and on the flow of services it provides (Daily 1997; MA 2003; MA 2005; Turner and Daily 2008). This development has occurred alongside a progression in biodiversity science, policy and management over the last two decades, shifting from a relatively simple framing in purely conservation terms focusing mostly on species and habitats, to a framing in terms of conservation, sustainable uses and benefit sharing[2] and a more systemic approach in terms of socio-ecological systems (Gallopin et al. 1989; Young et al. 2006).

There is no single 'best' way in which to classify ecosystem services, and the frameworks have evolved over the years, depending on the ecosystem and policy context. The most recent widespread application of the framework is the TEEB reports (TEEB 2010) and in numerous national ecosystem assessments (see EEA 2010, EEA 2011 for details). The forthcoming TEEB Quantitative Assessment (TEEB *in press*) was carried out at a global scale and the deep sea was not strongly represented, because it is one of the environments for which evidence on services and values is most lacking.

There is however increasing recognition of the important services provided by deep seas (see the summary in Figure 1). Earlier work under the HERMIONE project (Armstrong et al. 2010) catalogued the different services and the state of our knowledge regarding their biophysical and economic measurement. This underscored the particular importance of the

[2] For instance, the objectives of the Convention on Biological Diversity are: *"the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources (…)"*. (CBD, Article 1)

supporting services provided to other parts of the ocean and to terrestrial environments, and ultimately to all life on our planet. In the context of valuation, this is important, because many recent valuation protocols put supporting services to one side, focusing on the final services provided to humans, in order to avoid double-counting values. The principle is sound, but depends on the boundaries of assessment, and where we focus on the deep sea, without direct consideration of services arising outside deep sea systems, it is essential to consider the supporting services of the deep sea that maintain the ability of the other systems to provide the final services.

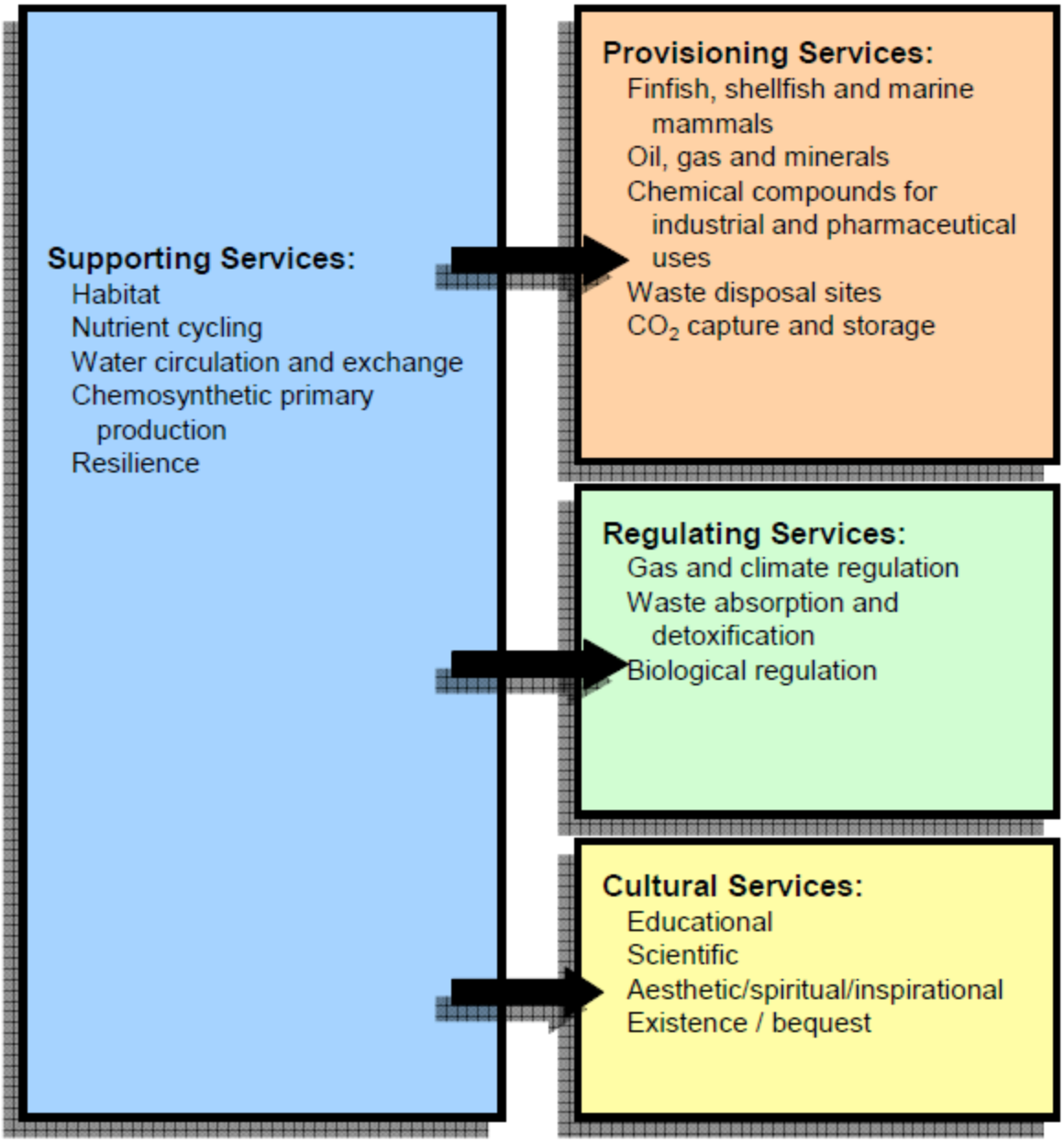

Figure 1: Summary of Deep Sea Ecosystem Goods and Services

Value frameworks

'Value' can have several meanings or interpretations. We may be concerned with market values, or with economic values, which are not limited to markets but do derive from individual human preferences. We may also be interested in attitudes, beliefs, and policy approval, including expressions of value that are not based in human preferences but in broader concepts of justice, morality or intrinsic values. Value can also be assessed through biophysical indicators, such as embodied energy, material flows, or risks of radical changes in the state of an ecosystem. For these measures, the underpinning human or moral considerations may be implicit. The approaches are not mutually exclusive, and multiple concepts may be useful, depending on the policy and cultural contexts and on the characteristics of the ecosystem, stakeholders and management structures. There can however be concerns about 'double counting' if a particular sources of value is represented by more than one indicator in a single assessment.[3]

Although 'the value of the natural environment' is a useful metaphor, and there have been attempts to assess it (see e.g. Costanza et al. 1997), the value concept of most practical interest and policy relevance is usually not 'the value' of the entire world, which is difficult to define let alone measure, or even a whole ecosystem, but rather the much more tractable value of relatively small changes in the quality or quantity of natural goods and services. This is true for monetary measures and also for other indices. Valuation generally is better suited to assessing the consequences of changes resulting from alternative management options, rather than for attempting to estimate 'total values' of ecosystems.

Monetary valuation methods attempt to express individuals' preferences for changes in the state of the environment in monetary terms. Non-monetary methods may aim to express preferences in units other than money, often involving deliberative and participatory approaches, which may focus on direct expression of preferences for outcomes. Alternatively 'valuation' may aim to explore how opinions are formed, and what beliefs and attitudes are towards objects and decisions of interest, without necessarily focusing on preferences or on benefits gained by humans. Methods are discussed in numerous sources – see for example chapter 5 of the TEEB 'Foundations' report (TEEB 2010a), or for a specifically marine context, Tinch and Mathieu (2010). Armstrong et al (2010) give an overview in the context of the deep sea.

Valuation can be applied bottom-up, within an ecosystem services framework, or top-down, focusing on states of the world (holistic assessments of ecosystems) under different options. The former is well suited to a service-by-service economic valuation, while the latter is well-suited to direct preference and policy approval assessments. In practice, work is often in between: most valuation studies do not assess the full range of ecosystem services but focus

[3] For example, if a monetary value for carbon abatement is used alongside a physical measure of the carbon saving, it is important to flag that these are not separate, additive benefits, but rather different ways of expressing the same benefit.

on just a few services that are amenable to valuation; and often several services may be bundled together for the purposes of valuation. This is true in particular where stated preference techniques are applied, because it can be difficult to focus the hypothetical scenarios, and respondents' reactions to them, on specific individual services. This 'embedding' effect means that it would be inappropriate to apply separate valuation to features that stated preference survey respondents have taken into account; in effect, the values expressed are for several services provided jointly.

Decision makers generally also need information about the physical and ecological consequences of decisions, and about where and when these consequences arise, and who is exposed to them. Value evidence can be useful but will not fulfil all those needs. Generally, therefore, value evidence forms one part of a more wide-ranging assessment.

Governance and management structures

A broad distinction can be made between governance and management (Olsen et al. 2006: 5) whereby governance "probes the fundamental goals and the institutional processes and structures that are the basis for planning and decision making," while management is "the process by which human and material resources are harnessed to achieve a known goal within a known institutional structure." These are clearly overlapping, with governance determining the tools and processes of management. **Error! Reference source not found.** illustrates some of the main tools that can be used for management of human use of natural resources and environments.

Table 1: Major governance mechanisms (adapted from van den Hove and Moreau, 2007)

Government	**Market place**	**Civil society**
Laws, regulations Enforcement, sanctions Property rights, standards, permits, quotas Taxation, subsidies, incentives Procurement and spending policies Planning and area-based management Education and outreach.	Profit-seeking behaviour: trading goods, services, permits Lobbying activities, advertising 'Green' products, eco-labelling Voluntary schemes. Ecosystem service valuation and environmental accounts.	Social norms and accepted behaviours Campaigning, lobbying Information, education, outreach Community leadership, issue framing Community led management and governance.

Actual and possible governance and management regimes are highly variable depending on jurisdictions, stakeholders, environments and threats. The applicability and effectiveness of mechanisms applied in the deep sea context is context-specific, depending on characteristics

of the issue, of the governance or management structures, and of the science-policy interfaces, actors and audiences involved. These features will also determine the necessary or possible role of value evidence.

Jurisdictions can play a crucial role in determining the applicability and effectiveness of different mechanisms, and this is particularly important for the deep sea, much of which lies outside national jurisdictions. Within national jurisdictions, governments may be able in principle to apply any mechanisms and management methods they see fit, although this can sometimes be limited by wider agreements – for example EU member states are limited by the constraints of the Common Fisheries Policy (CFP), Habitats Directive and Marine Strategy Framework Directive, in complicated ways. A member state wishing to constrain fishing activities in order to meet conservation objectives under the Habitats Directive, for example, is at liberty to impose any restrictions on its own vessels, but if restrictions are to apply to other MS vessels this falls under the CFP and agreement must be sought from the Commission. (European Commission 2007).

The United Nations Convention on the Law of the Sea (UNCLOS) provides the main framework agreement governing rights, duties, and activities throughout the oceans. There are deep sea areas within territorial seas, contiguous zones and Exclusive Economic Zones (EEZs). In the EEZ, states have sovereign rights for exploration, exploitation, conservation and management of all natural resources and over other economic activities, but such laws as exist beyond the EEZ are rather basic and difficult to enforce. Nations have been very good at taking advantage of their rights, and the 'high seas freedoms', but many have not yet fully implemented their duties to protect, conserve and cooperate (van den Hove and Moreau, 2007). The problem of open access to rich resources has resulted in some opportunistic behaviour, with actors depleting resources in one place and then moving on to another (Berkes et al. 2006); but until recently, law makers have not paid much attention to what goes on in the high seas beyond pelagic fishing activities (Gjerde, 2006b).

Overall, the deep-sea governance context forms what Gjerde (2006a: 37) calls a "web of obligations for states regarding biodiversity". However, Gjerde stresses that there are inadequacies with respect to the range of issues covered by existing conventions and institutions (a 'governance gap') and also in the implementation of such policies and legal requirements as exist (an 'implementation gap') (ibid.). Deep sea governance today is developing based on a framework of principles and methods that are under development and negotiation. The possible uses for value evidence should be understood in this context.

Uses of value evidence

Although it is clear that deep sea ecosystems, and the goods and services they supply to humans, are of significant value to us, that does not in itself justify the decision to attempt to elucidate or measure these values. This is only worth trying to do if it is somehow useful or interesting. The primary rationale for valuation is the need better to integrate natural and social sciences in managing the natural environment and in the policy-making process.

Against the possible gains from having estimates of values must be set the costs involved in calculating them. Methods must be sufficiently reliable to inform decisions on the natural environment, and the costs must not be disproportionate in the context of the possible gains from improved decision making (Allen and Loomis, 2004).

What can value evidence be useful for?

Value evidence for ecosystem goods and services can be useful for a range of purposes, including:

- to structure information about the ways in which humans benefit from, impact on, and depend upon ecosystems;
- to measure and account for these benefits and impacts;
- to understand and communicate our dependence on natural environments.
- to aid the understanding and resolution of value conflicts;
- to explore consequences of changing management strategies and practices;
- to support more efficient, effective and/or equitable decisions;
- to build a 'business case' for expenditures and investments;
- to provide the basis for certain management methods, for example setting payments for ecosystem services or environmental taxes;
- to inform legal processes relating for example to compensation for environmental damage.

In the deep-sea context, the main potential applications are:

Assessing and communicating the 'importance' of the deep sea: to answer the question "What does the deep sea do for us?", with the results being useful for general awareness raising or basic political strategy. This is fine for some services, or for specific areas, but when looking at the deep sea as a whole such assessments inevitably run into problems associated with the impossible baseline ("the deep sea stops existing") and there is no escaping the fundamental point that the deep sea plays a vital role in sustaining life on earth. Communicating this is of course important, but it is moot whether or not attempts to quantify such values are helpful at the global scale. Quantitative measurements of the importance of deep seas for specific services, industries or human populations, where there are alternative sources for the values, can however be useful.

Scenario evaluation for strategy development: involves exploratory assessment of one or more future scenarios. The interest is in general trends, outcomes and values for the areas under consideration under different possible future states of the world – often combining changed climatic conditions with changed socio-economic and technological characteristics of global or national societies (see Box 1 for a marine application). Value expressions can be used in scenarios as a kind of performance indicator, helping to understand the consequences of particular scenarios. This approach is taken by Dickie et al (2011), who make indicative projections of different future service values under four different scenarios for the UK marine environment. At the global scale, the key questions here relate to the long term consequences of open access to resources, and the possible gains from concerted international action to improve deep sea governance. This could be particularly useful at the strategic level, in further developing models for deep sea governance, and informing and securing international agreements on the issues.

Detailed policy and project appraisal: requires a more careful definition of baselines, and a more realistic focus on potential changes in levels of goods and services. The objective

here is to compare policy options in terms of service values, evaluated against an appropriate baseline, generally 'business as usual' management, though in some cases a 'status quo' baseline may be more practical. For example when considering options for siting deep sea protected areas and buffer zones, we would need to consider the state of the world without the project (the baseline) and compare it with the state of the world with the project. The values of interest are therefore not 'total' values of all services from the ecosystem, but rather the values of the change in services between baseline and project. Box 2 gives an example from the assessments for the UK Marine Bill.

Pricing decisions: there are many situations in which pricing can be used as a tool for environmental management. Possible applications include access payments or taxes for mineral or fossil fuel exploration, and payments for fishing permits. Valuation with a view to setting prices may need to take more account of how values vary over certain ranges of activity, since the level of the activity will be partly dependent on the price set. These instruments could be used in deep sea contexts, though they are clearly easier to implement within national waters than in a high seas context. For deep sea mining, the International Seabed Authority could adopt the role of competent authority for setting, collecting and spending taxes: the 1994 UN agreement relating to adoption of Part XI of UNCLOS provides for "the establishment of a system of taxation that is fair to the seabed miner and from which the international community as a whole may benefit" (Nandan et al 2002), though at present the mining code is not complete[4] and there are important barriers to reaching international agreement on such issues.

[4] http://www.isa.org.jm/en/documents/mcode

Box 1: Exploratory scenarios for marine ecosystems

The Alternative Future Scenarios for Marine Ecosystems (AFMEC: Viner et al 2006) explore how the UK marine environment, and human uses of it, may vary under different possible futures. These are based on four scenarios developed for the UK Climate Impacts Programme.

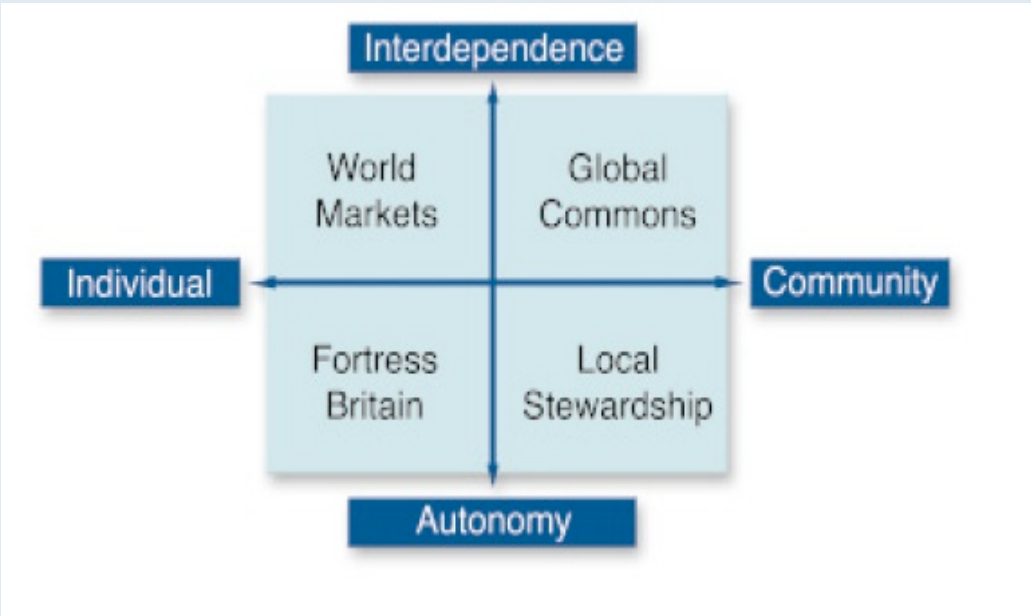

Figure 2: Scenarios used by UKCIP, OST, AFMEC (source: Viner et al 2006)

Similar approaches have been widely applied elsewhere: see for example Dickie et al (2011) for an application to the UK marine environment, making use of value evidence. The purpose of this exercise is not *prediction* of likely outcomes, but rather to create a vision of how the world *could* change in future, and what this might mean for particular sectors and environments. A key part of the process involves considering how the demand and supply for different resources and ecosystem services could change under the scenarios, and what that might mean for values. This can help to determine policies that could be robust to global changes that are entirely beyond the control of local or regional resource managers.

Box 2: Valuation and decision processes for designating protected areas

A full cost-benefit approach to appraising the creation and siting of marine protected areas would draw on a wide range of value evidence.

- Benefits of designation
  - Increased use values of conserved habitat, arising through enhanced ecosystem services
  - Increased non-use value of conserved habitat
  - Option values associated with increased range of future options
- Costs of designation
  - Use values forgone or displaced due to protection (e.g. fisheries, oil or minerals extraction, and so on)
  - Costs associated with implementing and policing the designation
- Benefits and costs must be assessed against the baseline of no protection
  - additionality and displacement effects should also be considered

Assessment could be implemented at different scales – for the individual specified site, for selecting from amongst a number of candidate sites, for the creation of a whole network of MPAs, and so on.

The governance and legislative context will also be important. In Europe, for example, the statutory obligation to implement marine Natura 2000 designations limits the scope to use value evidence, although some states have made use of values, including the UK which has used value evidence as an integral part of the impact assessment for the Marine Bill and as a means of taking account of socio-economic costs in determining the specific location of MPAs (see below). More generally, stakeholder and decision-maker buy-in will determine the extent to which value evidence is seen as credible, valid, and legitimate in the context of the decision problem.

One recent example is the Marine Conservation Zone (MCZ) provisions in the UK Marine and Coastal Access Bill, which involved a complex suite of value-based analysis (Defra 2009; McVittie et al 2008; Moran et al 2008; Hussain et al 2010; ABPMer 2007).

The analysis is applied at national scale – there is in fact little evidence at the individual site level. The study identifies 11 ecosystem service impacts and attempts to value seven of these based on production function and value transfer approaches. A separate stated preference (SP) survey is carried out for non-use values, but these are not treated as additional in order to avoid possible double counting: the case for conservation is argued on the basis of use values only, while noting that additional non-use values will exist.

The study suggests that establishment of a network of MCZs throughout UK waters has a positive BCR (Benefit-Cost Ratio) of between 6.7 and 38.9. Although this is an

Legal damage assessment: for example for oil spills or seabed pollution. This can be very similar to project appraisal in terms of the methods used – comparing the state of the world with and without an event – though it is retrospective rather than prospective. The burden of proof and level of accuracy or confidence required may be different. Again in the case of damage to deep seas outside national jurisdictions the governance situation is difficult. For example the 1992 Civil Liability Convention and the 1992 Fund Convention set out the rules in cases of oil pollution from shipping, but an incident affecting only the high seas would not have identifiable victims who could claim compensation. In addition, since the majority of problems relate to ships flying flags of convenience (Levantino 1982) the control is not perfect. The Deepwater Horizon spill in April 2010 has led to efforts to value the impacts, discussed briefly in Box 3.

Box 3: Valuations of Deep Water Horizon damages

The 2010 major incident at the Deep Water Horizon facility in the Gulf of Mexico has led to attempts to assess the environmental damages in economic terms.

The first rapid assessment (Costanza et al 2010) was a conservative estimate based only on impacts to the Mississippi delta, but taking into account a full range of ecosystem services. Assuming a 10 to 50 percent reduction in the ecosystem services provided by the Delta, they estimate a loss of $1.2 – $23.5 billion per year into the indefinite future until ecological recovery, or $34 – $670 billion in present value (at a 3.5 percent discount rate).

The assessment by Greater New Orleans, Inc. (2011) focuses on three components of direct impact to the market economy: fisheries, the losses due to moratoria on deepwater and shallow drilling, and damage to the 'brand' of Louisiana.

Research by Krupnick et al (2011) moves towards a full cost-benefit analysis of deepwater drilling. They stress that the lack of knowledge regarding the deep ecosystems and the way they respond to pollution make it very difficult to assess damages. Rather, there is a need for ongoing monitoring and assessment. Nevertheless, they present figures extrapolated from other major spills that suggest very significant environmental and economic damages.

The need for value evidence is clear, not only for legal damage assessment purposes, but also for appraisal of proposed policies such as moratoria on

Valuation for specific threats

The uses of valuation can also be associated with specific threats, resulting damages and relevant governance features. There is a limited range of direct threats to deep sea environments where valuation information can be useful in feeding into governance and management decisions, as described in Table 2.

Table 2: Valuation in relation to deep-sea threats

Threat	Governance features	Damages	Valuation
Fishing	• Open access problems • Overcapacity, fishing down foodwebs, fishing deeper as result of stock declines elsewhere • Inappropriate national subsidies for fishing • Multispecies fisheries and bycatch place technological limits on damage control • Restrictions on gear types, fishing methods, areas can reduce impacts • Voluntary agreements and labelling schemes can be applicable.	• To fish stocks directly • To non-target organisms • To food-webs (ecosystem overfishing) • To habitats • Climate change impacts of activities	• In principle, target stock impacts valued via future income forgone. Not adequate for severe depletion. Consider option values and food security. • Non-target organisms and habitat damages generally require non-market valuation. Values may be revealed / expressed via choices if labelling schemes or similar. • Consider full costs of fuel use, including climate change, especially since subsidies are common.

Threat	Governance features	Damages	Valuation
Oil and gas	• Main issue is determining access and benefit sharing • Safety and environmental standards are a major concern. • State control over location and techniques/standards	• Reduced stocks for future • Leaks and spills • Drilling fluids and muds • Direct habitat damage • End-of-life for infrastructure • Noise and impact on sensitive species • Climate change impacts	• Stocks can in principle be valued at market rates, noting the Hotelling rule[5] and existence of futures markets, though there is significant uncertainty. Option values could be high. Cost of alternative sources or energies could be used. • Leaks and spills can in principle be valued in terms of their short and long-term impacts on the marine environment and its services. In practice knowledge is imperfect and valuation challenging (Krupnick et al 2011). • Climate change and air pollution impacts are important and imply the net benefits of oil/gas are likely to be lower than market prices.

[5] Hotelling's rule (Hotelling 1931) states that, *ceteris paribus*, the prices of nonrenewable resources must increase at the rate of discount in order for supply and demand in the resource market to balance.

Threat	Governance features	Damages	Valuation
Minerals	• Main issue is determining access and benefit sharing • Safety and environmental standards are a major concern. • State control over location and techniques/standards	• Reduced stocks • Direct habitat damage • Mining wastes • End-of-life for infrastructure • Noise and impact on sensitive species	• As above. Costs of alternative sources of minerals may be considered.
Cable and pipes	• Location important – ideally covered by marine spatial planning but problematic outside national waters	• Habitat damage • Leaks (pipes) • Danger to/from fishing vessels • end-of-life waste	• Value of service difficult since small part of much larger system. Damage costs could be estimated, or costs of re-routing to avoid sensitive habitats.
Research and bioprospecting	• Access and benefit sharing issues	• Relatively few concerns regarding the environmental impacts	• For benefit sharing, methods based on expected or actual returns to investments.
Military activity	• Secretive, difficult to control in any way other than at national (or strategic alliance) level.	• Potential for damage to sensitive habitats • Accident risk, dangers to fishing, risk of pollution.	• Value of service hard to assess. Risks and damages can be assessed via impact on ecosystems and services.

Valuation in the context of Sustainable Development

The different uses of value evidence all play a role in the pursuit of sustainability. Figure 3 illustrates one conception of the interlocking principles of sustainable development. In each of the areas depicted, valuation, whether monetary or otherwise, has a role to play.

- **Living within environmental limits:** valuation of environmental damages and reductions in natural capital stocks, for compensation within a weak sustainability[6] framework, and for assessing risks and costs.
- **Ensuring a strong, healthy and just society:** evaluating needs and wants, winners and losers, and informing compensation options.
- **Achieving a sustainable economy:** measuring welfare and costs, informing incentives policies and the polluter pays principle
- **Promoting good governance:** communicating and informing values and attitudes, integrating values into governance instruments
- **Using scientific evidence responsibly:** direct information on public attitudes and values, sensitivity testing to account for uncertainty.

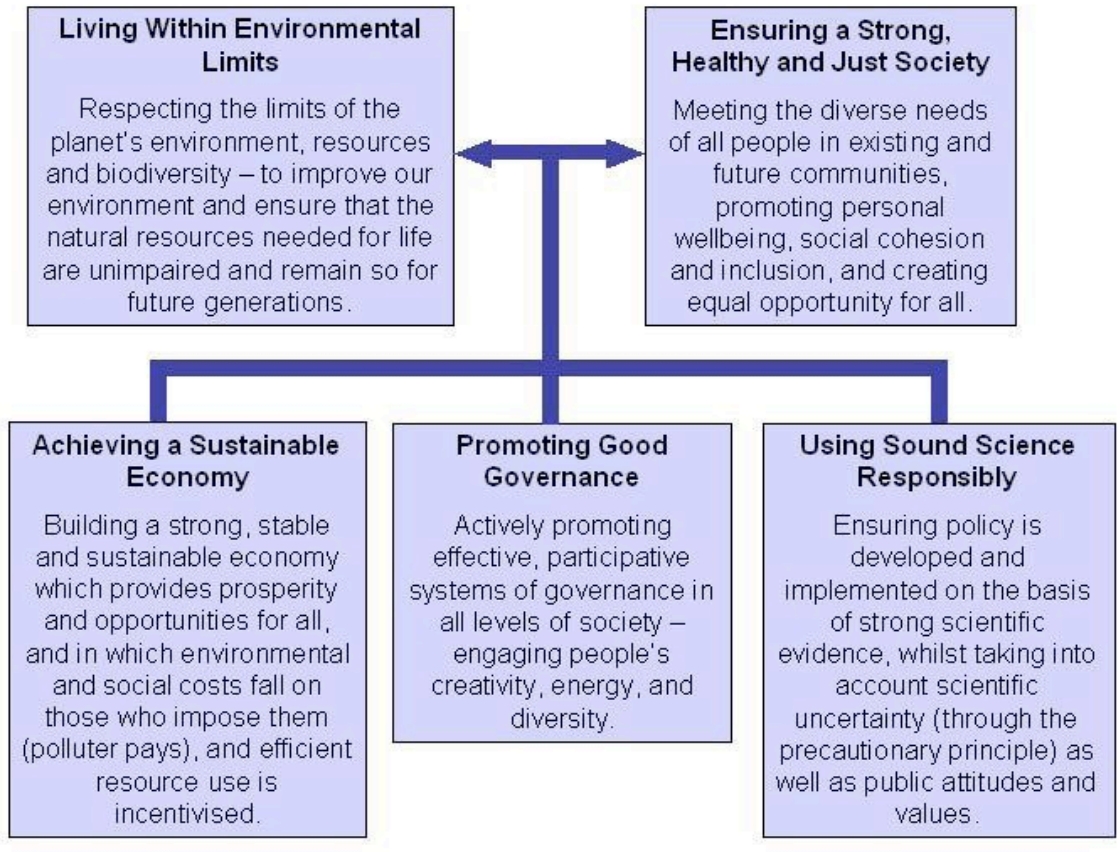

Figure 3: Guiding principles of sustainable development (Source: Defra 2005)

[6] A 'weak' sustainability criterion allows trade-off between different types of resources, for example replacing natural capital with manufactured capital. 'Strong' sustainability requires maintenance of stocks of each capital type and so rejects such trade-offs.

Tiers of value integration in decision processes

The recent TEEB synthesis report (TEEB 2010b) introduced the idea of a tiered approach to values in environmental assessment and management, where the integration of value evidence in decision making exists on different levels, from basic and general societal recognition of values, integrated in social norms, through formal demonstrations and assessments of values, to full use of value evidence as key components of management tools.

Recognizing value: in ecosystems, landscapes, species and other aspects of biodiversity. This is a feature of all human societies and communities, and it is sometimes sufficient to ensure conservation and sustainable use via voluntary, informal or formal structures. Where this is not the case, that does not necessarily mean that value is not recognised – rather, it may be that free rider / open access problems erode individual incentives and opportunities to nurture and protect. Some environmental laws and regulations (for example protected areas legislation) can be interpreted as formalising the recognition of values, and introducing the structures needed to combat the tragedy of the commons. This conception goes beyond that in the TEEB synthesis, and sees 'recognition' of values as applying to any situation in which humans individually or collectively organise in such a way as to protect or enhance natural systems without formal assessment or demonstration of what values are at stake.

Demonstrating value: is the process of assessing or measuring values, generally in order to inform decision making, in particular by policymakers and resource managers, but also by businesses and others. Demonstrating values aims to support decision-making that considers the full costs and benefits of a proposed use of an ecosystem, rather than just those costs or values that enter markets in the form of private goods. It can also highlight the costs of achieving environmental objectives and help identify more efficient means of delivering ecosystem services.

Capturing value: involves the introduction of mechanisms that incorporate the values of ecosystems into decision making, through incentives and price signals. This can include payments for ecosystem services, reforming environmentally harmful subsidies, introducing tax breaks for conservation, or creating new markets for sustainably produced goods and ecosystem services. Capturing value generally requires creation or clarification of (property) rights and obligations, including rights to access and use natural resources, and liability for environmental damage.

In our interpretation, it is also possible to see the hierarchy of recognition-demonstration-capture as reflecting temporal and spatial dynamics. In pre-industrial, low human population times, in situations in which resources were abundant and human impacts on resource bases largely negligible, recognition of natural values may have been generally unnecessary. Though historically humans clearly have recognised the fundamental role of nature in supporting their livelihoods, this has often been viewed in a supernatural context as depending on the whim of benign or malign spirits. As societies and technologies develop, better understanding of the role of natural services and of the ways in which humans impact

on them leads to a more sophisticated form of 'recognition', but demonstration of values only becomes necessary when population densities and technologies rise to the extent that difficult choices need to be made that in effect trade off different forms of value. This is likely to occur initially for local and pressing issues (sanitation, local air pollution), then for less immediate and/or more widespread effects (watershed degradation, ozone depletion) and only later, if at all, for global and long-term problems (climate change, biodiversity loss).

The move towards capture will depend on the severity of impacts, and on social, cultural and governance contexts. Capture seeks to achieve more efficient environmental outcomes in cost-effective ways, reducing transactions costs and harnessing the power of markets to exchange information about trade-offs and preferences. However a note of caution may be needed with respect to possible perverse impacts of a wholesale shift to a 'capturing' perspective. It is undoubtedly true in many cases that use of market-based instruments and incentives can help to address problems of overexploitation and free access to scarce resources. This can also damage the cohesion of voluntary and informal stewardship under the 'recognising' theme. Bringing natural services and environments into a market setting, and creation or clarification of property rights, will often involve overturning informal arrangements and can result in perverse outcomes. In the deep sea context, the concept of the "common heritage of mankind" may provide a conservationist ethic that could potentially be damaged by a system of payments for access to mineral resources, for example.

However capturing value does not always have to imply the use of tax- or subsidy-based instruments. Standards and quotas, for example, can also be motivated on the basis of value arguments (‘demonstrations’) and in some cases may be less antagonistic to ‘recognised’ values, even if they are implemented within a tradable framework. And some policies can in effect offer opportunities for value ‘capture’ without direct regulation of prices or quantities – for example, information provision or labelling schemes expand the choices available to consumers (they can now see, at the point of purchase, the difference between ‘dolphin friendly’ and ‘ordinary’ tuna, for example), and this permits behaviours and expression of preferences and values that would not be possible in the absence of this mechanism.

In effect this hierarchy of recognise – demonstrate – value applies more widely than to economic methods. Recognition is the direct appreciation of value by users, stakeholders or managers, and adoption of appropriate responses. But depending on governance/management structures, and the number of actors, mere recognition may not be enough. The Coase theorem[7] may apply where information and transactions costs are low, and the number of actors is small, but relaxing these assumptions means that free rider problems and tragedy of the commons can arise even if all the actors are fully aware of the values. Demonstrating is for a wider audience, where there is a need to show actors at

[7] Coase (1960) set out the situations under which a negotiated settlement to environmental externalities might be expected. These include clearly defined property rights, and low transactions costs relative to possible gains.

various levels what is at stake. Demonstration could be in economic terms, but could also be through opinion surveys, measurements of use levels and impacts, and/or purely science-based arguments about biological or physical quantities of ecosystem services.

Demonstration goes some way towards putting values into decision making, and the boundary with 'capturing' may be a little fuzzy. Methods such as cost-benefit analysis or multi-criteria assessment might generally be considered more 'demonstrating', but policies such as the requirement to use specified carbon values in public sector cost-benefit analysis (CBA) (as in the UK, DECC 2010) might be argued to shift to a form of 'capture'. Capture seeks to reach out from (some subset of) the decision and policy makers to change the incentives and behaviours of others, and this can draw on and use value evidence in various ways, including through the use of pricing incentives. But appeals to morality and citizenship, and the facilitation of the expression of values, are also forms of capturing value. Table 3 describes the relationships between governance methods and tiers of value purposes.

Table 3: Governance methods and the TEEB valuation 'tiers'

Governance method	**Recognising**	**Demonstrating**	**Capturing**
Laws and regulations	Evidence of recognised values; need for legislation suggests recognition not universal, or that transactions costs/ free rider problems hinder expression of values.	Potentially important input to law-making. Formal structures of impact assessment may call for values.	Not usually. Measures to influence incentives discussed below. But penalties and risk of detection combine to form incentives: theory of optimal deterrence (Kuperan and Sutinen 1998) calls for different fines to influence choice of transgression.
Property rights, permits, quotas	Evidence of recognised values and of market failure in their expression.	Values may help to set, levels, or can be done on purely scientific grounds. Values may demonstrate need for action, or justify resources.	To an extent, especially if the permits are tradable. Restrictions may influence what values can be expressed (e.g. are conservation NGOs allowed to buy up fishing rights?)

Governance method	Recognising	Demonstrating	Capturing
Area based methods	Demand/support for protection is evidence of value recognition, though this could be primarily non-use/ moral values, or use values (e.g. for fisheries benefits) or both.	Values can be used in determining which areas to protect – in terms of value of what is protected, or (more usually) in terms of how to achieve conservation goals at least cost. Values may justify policy and resources.	Not relevant in most cases: no direct attempts to influence incentives or behaviours, other than through direct protection.
Voluntary agreements	Central: voluntary agreement pre-supposes recognition of values by all parties; or at least by some, and ability to persuade others.	Can be important to making the case for agreement, and in negotiating terms, especially if there are side payments for compensation.	Potentially, in particular if side-payments are used as this can be seen as analogous to payments for ecosystem services.
International agreements	Central: voluntary agreement pre-supposes recognition of values by all parties; or at least by some, and ability to persuade others.	Value evidence can reduce asymmetric information, clarify winners and losers, provide a basis for side-payments / incentives, and clarify the stakes – costs and benefits of agreement.	Potentially important, in particular where side payments are used to compensate losers or provide technology transfer for protection of global commons.
Extended liability and mandatory insurance	Reflects a recognition that harm may be done	Demonstration of values/risks may motivate the policy; in operation, estimates of actual damages necessary. High seas problem of determining to whom damage has been caused (common heritage of mankind).	Making polluters liable for damages acts to internalise the risks.

Governance method	Recognising	Demonstrating	Capturing
Labelling	Central: labelling relies on recognition of values. Potential to use price differentials and market information as a valuation method.	Can be useful in demonstrating the need for a scheme and in securing funding/support.	Yes, to the extent that price differentials in products reflect values of consumers, and by creating opportunity to express values.
Lobbying	Use of private resources on lobbying is clear evidence of values of those spending time or money (and can be used as a crude valuation method).	Value-based arguments can be important. Lobbyists may come from a moral/absolute perspective, but nonetheless use economic and value arguments to good effect, targeting their audience (see e.g. eftec 2011)	To an extent, since contributions to lobby groups and charities represent a form of value capture. Level of actual legacies has been used as a valuation method for bequest values (e.g. in the UK NEA, Mourato et al 2010) .
Communication and education	Seek to expand recognition of key values and in that way lead to behavioural change.	Demonstration of the values may play a central role, though not necessarily in monetary or quantified terms.	Indirectly, if the provision of information enables people to express their values in new ways or avoid unknowing damage to their values.

Demand for and barriers to use of value evidence

The potential roles for value evidence in deep-sea governance may be clear, but the actual level of use is determined by a complex suite of case-dependent characteristics characterising the demand for value evidence and barriers to its use. These issues were explored through a workshop with three round-table discussions held as a fringe event at a 2010 OSPAR and UNEP Regional Seas meeting. The workshop aimed to explore relevant questions including:

- Do policy makers want information about the values to humans of deep sea ecosystem services and processes? Or is this seen as much less relevant than evidence on the biophysical nature and integrity of these processes, and their roles in supporting biogeophysical cycles and functions?
- Assuming information about values to humans is considered relevant, do policy makers want information on public attitudes and values regarding the deep sea? Or

is the perspective more paternalistic, with a desire for objective measurements of how deep sea functions and processes impact on human production and well-being without particular consideration for public views or preferences?

- What forms of information are in demand / useful? For example indicators of general awareness, conservation attitudes, monetary expressions of value, and so on? At what points in the policy and decision making cycles is evidence needed, and at what levels of accuracy? Is a literature review and value transfer approach acceptable or is there a need for consultation and primary value elicitation for each new decision?
- Do the answers to the above questions vary with the environmental issues? For example, is evidence on public attitudes and values seen as crucial for coastal planning, but largely irrelevant for deep sea governance?
- Do the answers vary with institutional settings, within single countries, across countries and international bodies? How much is determined by institutional settings, and how much by the views of individual bureaucrats?

The following sections of this report draw heavily on the workshop discussions, but also go beyond what was said through additional commentary and analysis. On some topics the workshop showed broad consensus, on others there was some divergence of opinion, and we have tried to reflect the different views and draw general conclusions below.

Policy demand for value evidence

Filling direct policy need

There are certain areas in which valuation evidence is most likely to be demanded and used, because it fits neatly a direct policy or management need. For example, in Europe the Marine Strategy Framework Directive has a requirement for "good environmental status", and measures to achieve this can require use of cost-benefit analysis. At the minimum, this must value direct goods and services and costs. However the door is open for attempts to assess less tangible values, and if these can be expressed in monetary terms it would help to ensure the inclusion of "forgotten costs".

Similarly, a workshop participant flagged up discussions on a protocol introducing environmental impact assessment (EIA) for development decisions in a transboundary context for the Caspian Sea. Monetary values in EIA would be very useful for this: decision makers already know about "importance", but changes and decisions are often driven by "hard economics". It is seen as important, therefore, when presenting information to certain decision makers, to express values in monetary terms – to explain what could be gained, compared with what would be lost.

The ecosystem approach was seen as a key driver for increasing interest in valuation, in particular since many bodies interpret the approach not from a conservation perspective, but more from the uses and services that the ecosystem provides (one NGO participant suggested a ratio of 4:1 in emphasis). Though it is not clear how ecosystem services are perceived outside particular academic and policy circles, the ecosystem services framework is generally found helpful in the context of presenting this gains and losses information to decision makers. This applies not only to provisioning but also to regulating, supporting,

cultural services, and to use and non-use values: it's a question of putting these intangibles on the same monetary terms for decision makers, otherwise they are likely to be overlooked.

Overall, there is a clearly perceived need for value evidence to help decision makers determine appropriate levels of environmental investment, and to help make the 'business case' for such investments. For Regional Seas, participants suggested that environmental valuation should be a priority – in monetary terms, specific to the region, and including non-use values. Evidence is also needed at national levels.

Legal compensation assessment

Another area identified as ripe for valuation evidence is legal compensation, for example for killing a seal or destroying a section of coral reef. There have of course been well-publicised examples of use of valuation techniques to inform compensation and legal damage assessments, most famously for the Exxon Valdez oil spill (Carson et al 2003). More commonly decisions are "based on vague notions of what is appropriate"; this may include an element of economic calculation – for example compensation for reef damage related to income from diving tourism – but better information on values and opportunity costs could be welcome here.

Meeting the needs of policy demand for value evidence

The integration of knowledge and science into policy making is complex. Knowledge itself is rarely perceived as the driving factor for policy; rather, the "time had to be right". Participants stressed the need to link to topics seen as particularly salient by politicians and policy makers – for example climate change, fish stocks.

The key audience for value evidence on ecosystem goods and services was seen as policy advisers, generally most receptive to arguments based on ecosystem goods and services. But for these arguments to be well-received they must be tailored to the audience.

The importance of clear translation of complex science into reliable and concise policy messages can not be overstressed. Form and accuracy are paramount, and for example the key role of "diluted" science (1-2 pages) was flagged in discussions. Good photographs and short videos (c.2 minutes) were seen as very useful, backed up with scientific facts. Scenarios were flagged as a key tool, representing 'before' and 'after' a decision, or what would happen if the situation in question were not addressed.

Kenyon (2011) confirms from personal experience in the Scottish parliament that in a practical policy-making setting, "easy access to impartial sources of expertise that can provide clear, concise and timely information is invaluable." Parliamentary staff and parliamentarians face a massively diverse range of subjects on a daily basis; timescales are short; but much of the information already 'out there' is not accessible, does not directly answer the question at hand, or is not impartial.

Stressing the importance of specific ecosystems within the wider marine environment, supporting fishing and other services, results in clearer communication with the policy side – even when dealing with complex conservation issues, such as cold-water corals, focusing on familiar impacts makes clearer arguments for politicians, and helps to set the specific conservation issue (e.g. CWCs) in a global context.

Valuation as a tool of participation

In any governance context, and a fortiori where dealing with governance outside national jurisdictions, a sense of participation and co-ownership of the process can be an important part of consultation and negotiation, leading to deeper involvement and commitment; but even where public involvement in decision making is minimal the public can still be a source of information about how to value changes in ecosystems and the goods and services they supply.

Vierros et al (2006) argue that successful implementation of the ecosystem approach is dependent on the identification of the different stakeholders involved, and their practices, expectations and interests. However they also stress that knowledge of these factors for marine areas beyond national jurisdiction is seriously lacking. They discuss the relative importance of different stakeholders in terms of:

- rights and continuity of the relationship to the resource
- historical and cultural relation to the resource
- unique knowledge and skills for the management of the resource
- losses and damage incurred in the management process
- degree of economic and social reliance on the resource
- degree of effort and interest in the management of the resource
- concern about equity in the access to and distribution of benefits from the resource
- compatibility of their activities and interests
- present and potential impact of their activities on the resource.

It is notable that many of these features are closely related to value arguments, and value evidence could be useful in development of any prioritisation scheme. In the context of the deep sea, relatively few stakeholders would score highly against the above criteria: current industrial interests, primarily. Conservation interests, and views and values of the general public, risk being under-represented under such an approach.

Perceived reliability of views

Compared to stakeholders, the general public was perceived as being more conservationist, but perhaps less knowledgeable about the fact that it was actually benefiting from goods and services from the deep sea. For very complex or uncertain situations, expert views can be seen as more reliable than public valuation for decision-making purposes. Nevertheless, public opinion generally is very important, and on a strategic level, focusing on the short-term consequences of each case, and implying the sense of urgency, was suggested as a means

of enhancing salience for policy advisers. Public attitudes to scientific information was flagged as having an important influence over policy advisers, with the IPCC report "climategate" given as an example: a single flawed prediction on glacier melt in one section of the report caused the media and general public to doubt the validity of the whole edifice of climate science.

Cultural dependence of policy demand for value evidence

The need for information, and the relevance of attitudes and values, varies according to the region and governance context. Where there is democracy, involved NGOs, and cultures of consultation and incorporation of public views in decision processes, awareness raising and discussion may help to clarify attitudes and values for deep sea decisions. But where people have little or no collective voice or formal input into decision processes affecting their day to day lives, it can be very hard to interact on such remote and unfamiliar topics. General awareness and knowledge of human-environment interactions was also identified as important here: the appropriate approaches to eliciting and considering values may be very different between a remote, less educated community and a wealthy, high-tech and media-savvy community.

In some cultures, politicians are thought to source information on public opinions 'directly' through contact with the public, press and pressure groups; there is no perceived role for the state in formal collection of public attitudes or values. In France, for example, the "Grenelle de la Mer" (French national consultation process) included working sessions involving a range of stakeholders, but not the general public; the main two groupings were commercial with a focus on sustainable (commercial) development, and conservation/preservation focused. There issues were considered discursively without quantitative assessment of values. In other countries, for example the UK, there has been a strong emphasis on the incorporation of value evidence in decision making, even where uncertainty makes valuation difficult (see Box 4).

Barriers to use of value evidence

The above considerations suggest a wide range of areas of possible application of value evidence in deep sea governance contexts, at different levels of integration in decision processes. The extent to which value evidence actually is used will depend on a number of factors, relating for example to the governance or decision context, the characteristics (background, expectations, knowledge, beliefs...) of the stakeholders and decision makers, the characteristics of the environmental goods and services under consideration, and the availability and reliability of value evidence. In the workshop discussions, a wide range of barriers and problems were discussed, along with some possible solutions. The discussion that follows draws on both these threads.

Governance weakness

In many deep sea contexts, there are overlapping competences or poorly defined governance structures. This can limit the scope for all forms of policy mechanism, but the effect is more marked for some. In particular, market based instruments can be hard to apply where there is no single authority responsible for enforcing a policy, collecting or disbursing payments. Quantity-based controls can be easier to implement if international agreement on resource allocation can be reached first. The effectiveness of any agreement is likely to be constrained by the incentives for acceding to it, and complying with it, at a national as well as individual actor level.

Lack of need for value evidence

One fundamental question is whether or not there is any need to use value evidence. Formally assessing values, whether monetary or in some other framework, can be time consuming and expensive. If key stakeholders and decision makers can reach agreement on appropriate courses of action, for example if scientific and/or moral arguments are seen as sufficient both to determine a course of action and to justify the potential costs of planned interventions, and key funders and necessary supporters are already convinced on the basis of these arguments, there may be no need for attempts at valuation. This may be seen as a case of spontaneous 'recognition' of value, or arguments used could be interpreted as 'demonstrations' of value, without there being any formal attempt to specify or measure the values at stake.

If, conversely, this is not the case, it becomes necessary to consider whether better evidence on values would help. This depends on it being feasible to derive value evidence (and, practically, to do this at affordable cost) and on this evidence being considered valid and legitimate.

Unfamiliarity with the context

The public's lack of relevant knowledge necessary to form opinions and values for important deep sea issues was raised as a key problem, noting that public opinion can drive policy. One response is to argue that experts most familiar with the issues are more likely to come up with appropriate responses than relatively uninformed members of the general public. But on the other hand, the experts may not be well-placed to assess what public views might be regarding different possible outcomes and trade-offs, including how much of scarce resources should be invested in dealing with a particular issue. Values can be seen as evidence of concern, and can be assessed through behaviour, for example membership of NGOs, even where there is no significant scope for expressing values through market behaviour, but awareness is an essential prerequisite. Here the role of NGOs and other 'information spreaders' is key. Although in many regions there is a strong awareness of some marine ecosystem goods and services, notably fisheries, tourism, transport, oil and gas, there is little in the deep sea context, and there is a clear need for awareness raising.

There were some suggestions that in the deep sea context efforts would be better addressed at assessing public attitudes, and using these to inform and influence policy processes, than in attempting to value deep sea systems or individual ecosystem services flowing from them. If looking at values, it is important to consider both use and non-use, although in many respects the non-use values of deep sea environments are at the far frontier of feasible valuation methods. In any event, full transparency on the values considered and the means of their assessment is essential.

On a related point, many participants were sceptical of the potential to measure non-use values in monetary terms – in general, but especially for the deep sea, because it is so unfamiliar, and not directly used at all by public. Of course non-use values do not require individual use, but two of the component categories assume use by others (altruistic values for other users today, and bequest values for future users) and even 'pure' existence value is likely to be enhanced by familiarity with the context. Generally, there is a question over what exactly is being 'measured' by non-use valuation, and a concern that this might be more a vague recognition of 'good causes' than a carefully assessed value for a specific environment. This is still value information, and non-use values might yield ordinal rankings of non-use features of outcomes, but might not be cardinal numbers suitable for comparison with other use values and costs. In the UK Marine Bill assessments (Moran et al 2008, McVittie et al 2008) the non-use values were kept separate, as a kind of 'back-up' argument – that is, the investment in protected areas could be justified on the basis of use-values alone, and then in addition there were substantial non-use values – in order to avoid any risk of double counting, and because this avoided any 'contamination' of the use value estimates with concern about the reliability of non-use value estimates.

Lack of knowledge on key relationships

There are many situations in which feasible value evidence would not necessarily be useful. For example, if the fundamental problem is ignorance of how the natural processes work, how management influences them, and how they feed through to ecosystem services, then the priority would be scientific research into these links. In the workshop, our fundamental lack of knowledge regarding many deep sea processes and services was seen as a brake on the applicability of valuation arguments. Valuation may simply not be seen as credible if we do not know enough about the fundamental features. For example, there was discussion of the consequences of the recent Deep Water Horizon oil spill on deep sea ecosystems: in essence, we do not know what the short and long term effects will be. The general public, and policy makers, are interested, and want to know what the impacts are, but the scientific evidence is not able to provide this information with any confidence. However it is clear that in the absence of evidence, people will have their own opinions and assumptions. This can be argued to cast doubt on the validity of stated preference studies or other methods of eliciting individual values: if it is not clear what assumptions people are making, then how do we know what values they are expressing? Clearly, value evidence should not be considered independently of the context of its derivation, in particular relating to the

information and uncertainty communicated to the valuers. It is important, therefore, to be transparent and to communicate about uncertainties both in producing and in passing on and using value evidence. This is particularly important in deep sea contexts where knowledge gaps are significant, in relation to processes, seabed habitats, biodiversity and the cumulative effects of human impacts, including climate change and ocean acidification.

Uncertainty in the science evidence is not an artefact, but a genuine reflection of our current state of knowledge. EEA (2010, p31) notes that "If, in a specific area, there is a lack of scientific knowledge about important relationships between environmental pressures, ecosystem functioning and the provision of ecosystem services, economic valuation will not add anything to our understanding of these relationships." This is true; but it is not the role of valuation to add to this understanding. Rather valuation relates to preferences or attitudes about outcomes or policies. So the next statement by EEA (2010, p31), "Nor can economic valuation in such a situation appraise policies that are directed at ecosystem conservation", in fact goes too far. Any decision-making process is going to have to deal with the fundamental uncertainties, and the relevant question is not whether valuation can resolve the uncertainties – of course it can not, but the lack of information is not solved by other methods of considering impacts either – but rather, can valuation provide useful input to a decision process faced with the uncertainty?

Fundamental uncertainties may rule out the application of formal cost-benefit analysis, or a reductionist approach to valuing individual ecosystem services under specific conditions. But it may be possible to go part of the way and still derive policy-relevant conclusions. Values and attitudes could be expressed for fuzzier possibilities, including about margins of safety, safe minimum standards, and precautionary investments. Box 4 presents examples of how valuation can be useful even where uncertainty is high, and the implications of uncertainty for valuation are discussed further below.

Presence of critical thresholds

The TEEB synthesis (TEEB 2010a) notes that some aspects of ecosystem functioning, such as ecological resilience or the proximity of tipping points, are difficult to capture in valuations. They suggest that in such cases relevant information should be presented alongside estimated values, and that adoption of safe minimum standards or precautionary approaches for decisions about critical natural capital is called for prior to any consideration of trade-offs. However this does not mean that all value evidence is irrelevant in such cases. The existence of threshold effects and the potential for catastrophic changes in ecosystems and losses of ecosystem services limit the scope of valuation, but do not negate its usefulness.

It is true that, when imminent ecological thresholds threaten vital natural resources, conservation is essential, and marginal valuation becomes inappropriate. A resource that is abundantly available, such as oxygen to breathe, will have low or zero marginal economic value (even though the total value is essentially infinite). An abundant fish resource may likewise command a lower price per fish than a depleted stock, because it will not be as

scarce. Generally speaking, as a resource or service becomes very scarce, it is likely to become very valuable; and in some cases, there may be some minimum level of provision that is essential to avoid catastrophic consequences. Figure 4 shows a caricature "demand curve for natural capital": at high levels, marginal values change slowly, and valuation is appropriate and easier; as provision falls, marginal values rise more rapidly, and valuation, while still possible, becomes harder, with higher likely errors.

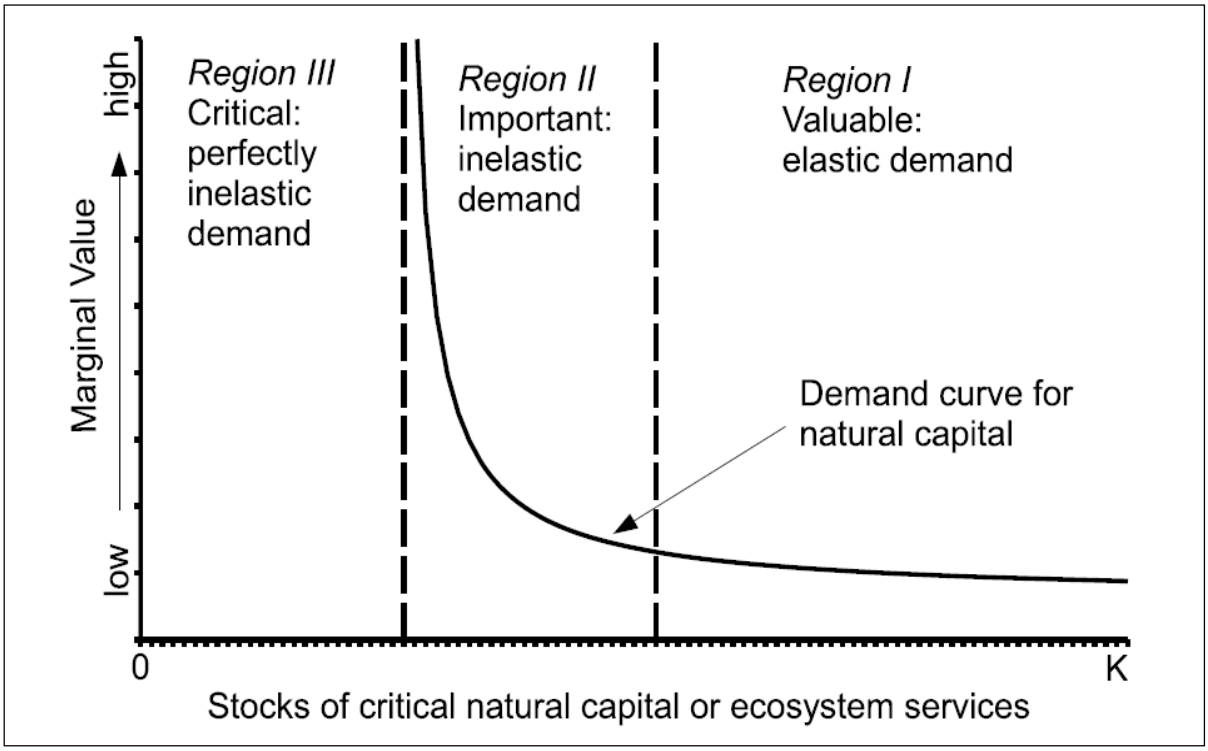

Figure 4: Demand curve for natural capital (source: Farley 2008)

This argument demonstrates the limits to the usefulness of monetary valuation as a guide to decision making and allocation at the marginal level within certain regions of the ecosystem-service value space. And market-based instruments depending on pricing (taxes, payments) are likely to be inapplicable, since they do not give certainty over quantity outcomes. But value evidence could nevertheless be important in demonstrating the need to avoid thresholds in any particular local or regional case, by estimating the consequences of crossing the threshold – only for large-scale, planetary life-support thresholds would valuation become literally meaningless. And market instruments that give quantity control (tradable permits, habitats banking) could be used to achieve certainty of staying within thresholds while reducing costs of control.

Valuation for precautionary management

Levels of uncertainty will impact on the relative usefulness of different types of value evidence, but some consideration of value will usually be possible and potentially useful. Uncertainty encompasses risk (where the probability of outcomes is known or can be

estimated) and ambiguity (where the sorts of outcomes are generally known but there is no reliable information by which to estimate probabilities), as well as radical uncertainty or ignorance (the 'unknown unknowns') (Stirling 2010). Uncertainty in deep sea ecosystem services assessment and valuation can be due both to imperfect knowledge of ecological and economic relationships in deep sea ecosystems, and to fundamental and irreducible randomness (for example in ocean currents or in fish stock-recruitment relationships).

There are different ways of dealing with risk/uncertainty within the valuation approaches. In practical terms, economic valuation and cost-benefit analysis deal with risk reasonably well, and with ambiguity to a limited extent, through the use of expected values and various forms of sensitivity analysis. But economic methods are quite limited under situations of radical uncertainty, where it is not possible to enumerate all of the likely consequences of a decision, nor its probabilities (Weitzman, 2009).

One response to such uncertainty is to include some level of insurance in management, trying to avoid the worst outcomes (Turner, 2007). It may be worth giving up some service, for example reducing fish catches, in order to reduce the risk of unpleasant surprises, such as fish stock collapses. This can be achieved by setting safe minimum standards and using a precautionary approach to management, ensuring that we do not risk crossing uncertain thresholds that could lead to potentially catastrophic and irreversible outcomes. In a deep-sea context, precaution could be required in particular in respect of

- rapid climate change, deep ocean links/feedbacks
- actions risking species extinction
- destruction of key habitats with either very slow or no recovery potential
- high fishing mortality on poorly understood stocks
- introducing persistent pollutants into deep sea environments

Even in such cases, however, deeper analysis of the issues may show that there is, after all, a role for value evidence. The Precautionary Principle can be stated in various forms, of which the best known is perhaps from the Rio Declaration: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (Principle 15 of the Rio Declaration on Environment and Development, UN 1992). This and other definitions have two key elements: the need for decision-makers to anticipate harm before it occurs or becomes likely, and the obligation to act to prevent or minimise the harm. Often, there is a form of 'get out' clause that allows for the cost of preventive action to be taken into account, as in the Rio definition ('cost-effective measures') or in blunter forms referring to 'disproportionate' costs. So although the Precautionary Principle might appear initially as beyond the scope of valuation, in fact value evidence is often important both in defining what constitutes harm, and in assessing acceptable levels of cost (including not only financial costs, but also other environmental impacts).

The European Community leaves additional scope for value evidence through paragraph 2 of article 191 of the Lisbon Treaty, which states that EU policy on the environment "shall be

Box 4: Dealing with uncertainty in valuation

In practice there may be limits to the use of values for numerous reasons. There may be a lack of scientific data on important relationships, so the objects of valuation are unclear, or the relationships between designation and changes in values cannot be determined. Or there may be a lack of valuation data for value transfer, and primary valuation research may be too time consuming or expensive. Valuation techniques may also be poorly adapted to certain forms of impact or service, and this can be a particular problem for deep-sea environments and services that are unfamiliar to most people.

But even if full CBA is not possible, value arguments can still be persuasive. In an assessment of high seas MPAs, Sumaila *et al.* (2007) only present monetary estimates for the opportunity cost of lost fish production in the short term. Longer term benefits, including fishery gains and reduced risks, are discussed but not quantified. The paper nonetheless presents a strong argument for protection: the estimated opportunity costs from a 20% closure of all high-seas pelagic and deep sea fisheries are just 1.8% of global catches, generating US$270 million annual profit loss from total high seas fishing profits of around US$1.35 billion. They note that about US$152 million per annum is currently paid as subsidies to high seas deep-sea bottom trawlers alone, suggesting that the true short-term losses would be lower.

The UK Marine Bill valuation study (Moran et al 2008, Hussain et al 2010, see Box 2) is a good illustration of the use of expert judgement to score likely impacts where we have some evidence of the total value of a service, but limited evidence of the impact on that service of a specific policy change. This kind of uncertainty is quite pervasive in studies of conservation decisions, and there are different approaches to it. Some studies push the scientific uncertainty into the valuation study, using stated preference studies of willingness-to-pay for conservation actions or results without actually modelling the ecological relationships. More recently, there has been a greater focus on use of ecosystem services frameworks, explicitly breaking impacts down to individual services and attempting to value them separately. This puts greater emphasis on issues of missing data, and the use of expert judgement is one way of trying to deal with this.

Intuitively it makes sense that we might expect more accuracy from letting experts make the judgements on scientific and ecological relationships, and limiting valuation tasks to clearly specified outcomes, but where stated preference is used this does depend on people being able to think of different impacts separately. If in fact there are strong linkages between impacts – for example, conservation of a particular species might not be possible without conservation of habitat and good environmental quality – then it may not be reasonable to expect respondents to overlook these linkages, and valuation of the species conservation is indeed likely to involve valuation of the conjoined changes. Where this is the case, even if the assessment framework breaks impacts down into all the component ecosystem services, it may still be preferable to use composite environmental values that are considered to cover several service categories.

taken, that environmental damage should as a priority be rectified at source and that the polluter should pay." The application of the Polluter Pays Principle presupposes that it is possible to determine how much damage has been inflicted, in order that the payment may be proportionate, and this clearly requires consideration of value evidence of some form.

Issues associated with legitimacy

Problems of legitimacy and reliability of value evidence were raised at the workshop. Values depend on individual views and this can be seen as a problem. In the case of coastal environments, it was noted that estimating direct use values is seen as relatively straightforward, in particular where markets exist, while for stated preference studies there is a huge spread in values. This could simply reflect different individuals having different values – and of course, market values are "averages", with some people willing to pay more for the goods, and some not buying in the market at all – but nonetheless the variance in stated preference values is often seen as casting doubt on the process.

Participants also noted the risks to legitimacy of process if different stakeholders have different opportunities to express their values and have them taken into account. The level of engagement and effort in interacting with governance institutions is often proportional to the level of vested interest in outcomes. In the deep sea, industrial interests have some control over data availability and presentation (e.g. Benn et al. 2010), and this was noted as a potential problem, with an identified risk that information could be spun to fit industrial interests and issues, with conservationists having less access to information and less ability to frame the debate.

Expression of 'illogical' values

Some workshop participants perceived a problem of divergence between a 'scientific', 'logical' approach and the more subjective world expressed through human values and attitudes. An example was discussed of a valuation study in the Netherlands, comparing a new island being created, with one being lost to the sea. Low values were expressed for the new island, and people were basically not that interested. Conversely, high values were expressed for the old one being lost. In ecological terms, however, the islands are of essentially equivalent value. This was thought to be due to the influence of assumed cultural, traditional, historical values for a pre-existing island that do not come in to play for a new area; it could also be seen as a kind of status-quo 'bias', similar to the commonly observed divergence between willingness to pay and willingness to accept compensation.

Such differences could be an artefact of the elicitation method, but could also be genuine – the divergence does not necessarily mean that the values are wrong. There may in fact be a wedge between how public value the change, and the 'eco-logical' value of the change. Seemingly 'irrational' public values may be perfectly rational, but directed at different end-points. This does lead to interesting issues regarding the scope and timing of the integration of value evidence: for example, different results might arise if value evidence were elicited for

general ecological objectives (with scientific/logical arguments used to determine details of implementation) or if valuation were applied to the individual components of a plan of action.

Equity and distribution

A particular problem of legitimacy is the dependence of (economic) value measurements on wealth and incomes. Wealth is recognised as having a big impact on values; the case of the 'value of (statistical) life' was raised at the workshop as an extreme example, and exemplar of the moral problems resulting: since economic value is based on preferences, expressed via willingness to pay (WTP), constrained by income, the amount wealthier individuals will be WTP in order to avoid some specified small risk of death will be higher than for poorer individuals. Grossing up leads to estimates of the value of statistical life that are significantly higher for industrialised countries than for developing countries, and the obvious moral quagmire that results. It is recognised that this is also the case for market goods – differences in values simply reflect underlying differences in income distributions – but this is not seen as resolving the problem. The fact that income constrains access to market goods is not a sufficient justification for using the same income to constrain access to environmental goods, and in fact bringing environmental goods into market structures, and using willingness to pay to determine allocations of environmental goods, can be seen as regressionary. One suggestion was the adoption of an alternative common scale, for example looking not at value directly but rather at value as proportion of income, in order to redress income inequalities. Such considerations are of course particularly important in the context of international agreements over the use of the high seas, given the huge disparities in incomes across the world.

Summary

The workshop participants saw much policy-led demand for improved valuation evidence, in particular to meet specific direct needs of policy. Communicating science evidence in an appropriate, clear, and timely form was central to filling this role. Set against this, however, is the "reality check" of several significant problems in valuation, especially in the context of deep sea environments that are unfamiliar to most people and imperfectly understood even by experts.

Overall, these factors mean that interpretation of value evidence requires many assumptions, and while this need not mean that valuation is a futile exercise, it does suggest that we should not rely on it as the sole approach to the issues, but rather need to address problems on all fronts. In practice, those engaged in valuation are well aware of these limitations, and as a rule stress the importance of seeing valuation in the context of supporting decisions, alongside a range of other evidence, and not as an alternative to deliberation.

Conclusions

Ensuring conservation and sustainable use of deep-sea ecosystems is a major challenge that will require concerted efforts from diverse stakeholders and the use of arguments from a broad spectrum of perspectives, including both conservation ethics and utilitarian arguments regarding ecosystem services. Deep-sea governance structures and tools are evolving and the specific roles of valuation evidence within them are yet to be defined. It will depend heavily on the people involved, and in this context the workshop discussions give some useful pointers.

Our workshop discussions primarily featured participants with quite conservation-oriented agendas, and their main need is to convince politicians of the importance of marine conservation. Overall they take a strategic approach: they are looking for convincing arguments, rather than value information per se. Factors such as ease of presentation and understanding, accuracy and clarity, and timeliness are important. Some of the well-discussed problems and limitations of valuation were recognised, as were some of the solutions.

- There is an overall emphasis on prioritising scientific understanding over public attitudes or values. More generally, there is often a sense of paternalism, with priority given to expert judgement – in some cases, even a sense that there is a physical measurement that is "right" and that public valuations are only correct to the extent that they follow this.
- Specifically for the deep sea, there is a view that unfamiliarity can lead to unreliable valuations – unlike the case of market goods or more familiar resources such as tropical coral reefs. This strengthens the focus on expert opinion, but also the need for awareness raising.
- However, there is recognition of the importance of public opinion to politicians and advisers in certain regions and institutional settings. This is translated in to emphasis on communicating the importance of deep sea environments to the general public, but not necessarily to a desire to quantify public values for deep sea environments.
- There are interesting points about the different applicability of arguments and of methods in different settings. Summarising, viability of arguments depends on political and governance contexts and processes. Applicability of methods depends on familiarity with the goods and services in question, and also on familiarity with participation and democracy: people being used to being asked and having their opinions taken into account, and being willing to engage with the valuation instrument.

As is to be expected in any group exercise, there were divergent opinions in some areas, and some actors were keen to see greater use of valuation evidence, seeking some of the benefits to argument and deliberation set out above; some were quite antagonistic, seeing conservation qua conservation as paramount, and rejecting the validity and accuracy of valuation arguments. Overall, however, most participants were somewhere in between – there is little appetite for valuation for its own sake, but a willingness to use it if and when it can help to advance the fundamental issues facing governance and management of deep sea systems. And this is perhaps as it should be: as we noted in our earlier report on deep

sea valuation (Armstrong et al 2010), valuation should be seen as one step in a continuum of ways of better organizing information to help guide decisions, but it is not an end in itself, and is only one tool in the decision-makers' tool box, to be used with skill and care, as and when appropriate.

Acknowledgements

The authors would like to thank all the participants at the workshop, and others attending the OSPAR meeting for useful discussions outside. Particular thanks to David Johnson (OSPAR) and Katrin Zimmer (Swedish EPA) for enabling the workshop to take place.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under the HERMIONE project, grant agreement n° 226354.

References

ABPMer, Risk and Policy Analysts, & Jan Brooke Environmental Consultant Ltd. (2007) Cost Impact of Marine Biodiversity Policies on Business - The Marine Bill Final Report, Defra, London.

Agyebeng, K. (2006) "Disappearing Acts – Toward a Global Civil Liability Regime for Pollution Damage Resulting from Offshore Oil and Gas Exploration". Cornell Law School Graduate Student Papers. Paper 11 http://scholarship.law.cornell.edu/lps_papers/11

Allen, B. and Loomis, J.B. (2004) Economic Value of Original Non-Market Valuation Research, American Agricultural Economics Association Meeting, Denver, Colorado, July 1-4

Armstrong, C, Foley, N, Tinch, R and van den Hove, S (2010) Ecosystem Goods and Services of the Deep Sea. Deliverable D6.2 of the HERMIONE project.

Benn AR, Weaver PP, Billet DSM, van den Hove S, Murdock AP, et al. (2010) Human Activities on the Deep Seafloor in the North East Atlantic: An Assessment of Spatial Extent. PLoS ONE 5(9): e12730. doi:10.1371/journal.pone.0012730

Berkes, F., Hughes, T.P., Steneck, R.S.,Wilson, J.A., Bellwood, R., Crona, B., Folke, C., Gunderson, L. H., Leslie, H. M., Norberg, J., Nyström, M., Olsson, P., Österblom, H., Scheffer,M., Worm, B. 2006. Globalization, Roving Bandits, and Marine Resources. Science 311 (5767): 1557–1558

Boyd, J. and Banzhaf, S. (2007) What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, 63(2-3): 616-626.

Carson, R.T., Mitchell, R.C., Hanemann, M., Kop, R.J., Presser, S. and Ruud, P.A. (2003) Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spill. *Environmental and Resource Economics*, 25: 257-286.

Coase, R (1960) The Problem of Social Cost. Journal of Law and Economics 3, 1-44

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naemm, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van der Belt, M. (1997) The value of the world's ecosystem services and natural capital, *Nature*, 387: 253-260.

Daily, G.C. (ed.) 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington. 392pp

Daily, G.C. (ed.) 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC.

Davies, A.J., Roberts, J.M. and Hall-Spencer, J. (2007) Preserving deep-sea natural heritage: Emerging issues in offshore conservation and management. *Biological Conservation*, 138: 299-312.

DECC (2010) "Updated short term traded carbon values for UK public policy appraisal". Available at:

http://www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/carbon%20valuation/1_20100610131858_e_@@_carbonvalues.pdf (accessed 05 May 2011).

Defra (2005): Securing the future, the United Kingdom Government Sustainable Development Strategy. http://www.defra.gov.uk/publications/2011/03/25/securing-the-future-pb10589/

Defra 2007, An introductory guide to valuing ecosystem services.

Defra 2009, Marine and coastal access bill impact assessment: Introduction to the House of Commons, Defra, London.Dickie I., Saunders J., Hull S., and Tinch, R. (2011) Valuing the Marine Estate and UK Seas: Dynamic Baseline Assessment – Final. Report prepared for The Crown Estate.

EEA 2010 (2010) "Scaling up ecosystem benefits". A contribution to The Economics of Ecosystems and Biodiversity (TEEB) study. EEA Report No 4/2010. http://www.eea.europa.eu/publications/scaling-up-ecosystem-benefits-a

EEA (2010) Ecosystem Assessments in Europe. Report prepared for the European Environment Agency in support to EEA work on European ecosystem assessments. Prepared by Marnie Graham, Maria Osbeck, Rasmus Klocker Larsen and Neil Powell. Available at: http://eureca.ew.eea.europa.eu/meeting_description/workshop-ecosystem-assessments-europe-12-13-october-2010/documents/2010_11_09_final-report.doc (accessed 26 September 2011).

EEA (2011) Ecosystem Assessments in Europe. Update – June 2011.

eftec (2006) Valuing our Natural Environment. Final Report. NR0103. Prepared for DEFRA. http://earthmind.net/rivers/docs/ukdefra-eftec-valuing-our-natural-environment.pdf

European Commission (2007): Guidelines for the establishment of the Natura 2000 network in the marine environment. Application of the Habitats and Birds Directives. http://ec.europa.eu/environment/nature/natura2000/marine/index_en.htm

Farley, J (2008) The role of prices in conserving critical natural capital. Conservation Biology, 22:6 pp1399-1408

Fisher, B. and Turner, R.K. (2008) Ecosystem services: Classification for valuation. Biological Conservation, 141(5): 1167-1169.

Gallopin, G, Gutman, P and Maletta, H (1989) Global impoverishment, sustainable development and the environment: a conceptual approach. *International Social Science Journal*, 121: 375–397.

Gjerde, K.M. 2006a. Critical Ocean Issues: Ecosystems and Biodiversity in Deep Waters and High Seas. UNEP/World Conservation Union (IUCN), Switzerland. Available at: http://www.iucn.org/dbtw-wpd/edocs/2006-007.pdf

Gjerde, K. 2006b. International Deep-Sea Governance: Key legal aspects. Presentation to the first meeting of the HERMES Science-Policy Panel, Brussels, 29 September 2006.

Greater New Orleans, Inc. (2011) A Study of the Economic Impact of the Deepwater Horizon Oil Spill. Part 1 (Fisheries), Part 2 (Moratoria) and Part 3 (Brand Damage).

Haines-Young, R., Potschin, M., de Groot, D., Kienast, F. and Bolliger, J. (2009) Towards a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting (Draft V1), Report to the European Environment Agency for Contract No: No. EEA/BSS/07/007, Centre for Environmental Management, School of Geography, University of NottinghamHotelling, H. (1931) The Economics of Exhaustible Resources. *J. Polit. Econ.*, 39:137-175.

Hull S., Saunders J., Dickie I. (2011) Valuing Change in the Marine Estate and UK Seas: Temporal and Spatial Assessment - Draft. Report prepared for The Crown Estate.

Hussain et al (2010) Hussain, S.S., Winrow-Giffin, A., Moran, D., Robinson, L.A., Fofana, A., Paramor, O.A.L., & Frid, C.L.J. 2010. An ex ante ecological economic assessment of the benefits arising from marine protected areas designation in the UK. *Ecological Economics*, 69, (4) 828-838.

International Oil Pollution Compensation Funds (2005) Liability and Compensation for Oil Pollution Damage: Texts of the 1992 Conventions and the Supplementary Fund Protocol.

Kenyon, W. (2011) A secondment to SPICe – the Scottish Parliament's Information Centre: A personal account by Wendy Kenyon. *In-land Magazine* (The newsletter of the Macaulay Land Use Reserch Institute, Aberdeen), Spring 2011, pp26-27.

Krupnick, A., Campbell, S., Cohen, M.A. and Parry, I.W.H. (2011) Understanding the Costs and Benefits of Deepwater Oil Drilling Regulation. Discussion Paper. RFF DP 10-62.

Kuperan, K.; Sutinen, Jon G. (1998) Blue Water Crime: Deterrence, Legitimacy, and Compliance in Fisheries. *Law & Soc'y Rev*. 32(2).

Levantino, B.T. (1982) Protection of the High Seas from Operational Oil Pollution: A Proposal. *Fordham International Law Journal*, 6(1):72-99. http://ir.lawnet.fordham.edu/ilj/vol6/iss1/3

Barney T. Levantino, Protection of the High Seas from Operational Oil Pollution: A Proposal, 6 Fordham Int'l L.J. 72 (1982), http://ir.lawnet.fordham.edu/ilj/vol6/iss1/3

Luck, G.W., Harrington, R., Harrison, P.A., Kremen, C., Berry, P.M., Bugter, R., Dawson, T.P., de Bello, F., DÃ-az, S., Feld, C.K., Haslett, J.R., Hering, D., Kontogianni, A., Lavorel, S., Rounsevell, M., Samways, M.J., Sandin, L., Settele, J., Sykes, M.T., van den Hove, S., Vandewalle, M. and Zobel, M., 2009.Quantifying the Contribution of Organisms to the Provision of Ecosystem Services. BioScience, 59(3): 223-235.

Luisetti, T., Turner, K., & Bateman, I. 2008, An ecosystem services approach to assess managed realignment coastal policy in England. CSERGE Working Paper ECM 08-04

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Current State and Trends Assessment. Washington: Island Press. Available at: http://www.maweb.org/en/condition.aspx

Mace, G., Bateman, I.J., Albon, S., Balmford, A., Church, A. and Winn, J., 2009. Conceptual framework and methodology, Report to the UK National Ecosystem Assessment.McVittie, A. & Moran, D. 2008, Determining monetary values for use and non-use goods and services: Marine Biodiversity – primary valuation, Final Report, Defra, London.

Moran, D., Hussain, S. S., Fofana, A., Frid, C. L. J., Paramor, O. A. L., Robinson, L. A., & Winrow-Giffin, A. (2008) The Marine Bill – Marine Nature Conservation Proposals – Valuing the Benefits, London, Defra.

Mourato, S., Atkinson, G., Collins, M., Gibbons, S., MacKerron, G. and Resende, G. (2010) Economic Analysis Report Cultural Services. Executive Summary. December 2010. UK NEA Economic Analysis Report.

Nandan, S., Lodge, M.Z. and Rosenne, S. (2002) The development of the regime for deep seabed mining. International Seabed Authority, Jamaica ISBN: 976-610-503-0.

OSPAR Commission (2000) Quality Status Report 2000, Region II – Greater North Sea. OSPAR Commission, London. 136 + xiii pp. Chapter 3. Human Activities.

Plan Bleu (2010) Les Notes du Plan Bleu: Environnement et Développement en Méditerranée. N° 17, Juillet 2010.

Ruckelshaus, M. and Guerry, A. (2010) 'Marine InVEST: a decisionmaking tool for mapping and valuing ecosystem services provided by coasts and oceans.' http://www.naturalcapitalproject.org/marine/MarineInVEST_Apr2010.pdf

Saunders, J., Tinch, R., and Hull, S. (2010a) Valuing the Marine Estate and UK Seas: An Ecosystem Services Framework. The Crown Estate, 54 pages, March 2010. ISBN: 978-1-906410-15-5.

Saunders, J., Tinch, R., Ozdemiroglu E. and Hull, S. (2010b) Valuing the Marine Estate and UK Seas: Initial Static Baseline Assessment. The Crown Estate, July 2010. ISBN: 978-1-906410-17-9.

Stirling, A. (2010). Keep it complex. Nature, 468: 1029-1031.

Sumaila, U.R., Zeller, D., Watson, R., Alder, J. and Pauly, D. (2007) Potential costs and benefits of marine reserves in the high seas. Marine Ecology Progress Series. 345: 305–310.

Swedish Environmental Protection Agency (2008) The economic value of ecosystem services provided by the Baltic Sea and Skagerrak: Existing information and gaps of knowledge. Report No. 5874.

Swedish Environmental Protection Agency (2009) *What's in the Sea for Me? Ecosystem Services Provided by the Baltic Sea and Skagerrak.* Naturvardsverket. Stockholm, The Swedish Environmental Protection Agency. Report No. 5872.

TEEB (2010a) The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington.

TEEB (2010b) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

TEEB (2011) The Economics of Ecosystems and Biodiversity: Quantitative Assessment (*in press*)

Thiel, H. (2003) "Anthropogenic impacts on the deep sea". In: Tyler, P.A. (ed.) Ecosystems of the World: The Deep Sea. Amsterdam, Netherlands: Elsevier.

Tinch R and Mathieu L (2011) Marine and coastal ecosystem services: Evaluation methods and their application. Report to UNEP-WCMC, Biodiversity series no. 33.

Turner, R.K. (2007) Limits to CBA in UK and European environmental policy: Retrospects and future prospects" Environmental and Resource Economics, 37: 253-269.

Turner, R. K. and Daily, G., (2008) The Ecosystem Services Framework and Natural Capital Conservation. *Environmental and Resource Economics*, 39(1): 25-35.

UNEP (2006) Marine and coastal ecosystems and human wellbeing: A synthesis report based on the findings of the Millennium Ecosystem Assessment. UNEP. 76pp

van den Hove, S. and Moreau, V. (2007) Ecosystems and Biodiversity in Deep Waters and High Seas: A scoping report on their socio-economy, management and governance. UNEP Regional Seas Reports and Studies No. 178. Switzerland: UNEP-WCMC.

van den Hove, S. and Moreau, V., (2007) Deep-Sea Biodiversity and Ecosystems: A scoping report on their socioeconomy, management and governance. UNEP Regional Seas Report and Studies No.184/UNEP-WCMC Biodiversity Series No. 28, 84 pages. Available at: http://www.unepwcmc.org/resources/publications/UNEP_WCMC_bio_series/28/Deep-Sea%20Biodiversity%20and%20Ecosystems_large.pdf

Vierros, M., Douvere, F. and Arico, S. (2006) UNU-IAS Report Implementing the Ecosystem Approach in Open Ocean and Deep Sea Environments. An Analysis of Stakeholders, their Interests and Existing Approaches. http://www.ias.unu.edu/binaries2/DeepSea_Stakeholders.pdf

Walser, M., Pohlmann, K. & Neumann, C. (2008) The Value of our Oceans - The Economic Benefits of Marine Biodiversity and Healthy Ecosystems. WWF Germany, Frankfurt am Main.

Weitzman, Martin L. (2009) On Modeling and Interpreting the Economics of Catastrophic Climate Change. Review of Economics and Statistics. Vol XCI:1

Young, O., Berkhout, F., Gallopin, G., Janssen, M., Ostrom, E., van der Leeuw, S., (2006) The globalization of socio-ecological systems: An agenda for scientific research, Global Environmental Change, 16: 304–316.