Part III

Assessment of Major Ecosystem Servismember)

1. Introduction to the concept of ecosystem services from oceans

Humanity has always drawn sustenance from the ocean through fishing, harvesting and trade. Today 44 per cent of th

Assessment, 2005; de Groot, 2011). The Millennium Ecosystem Assessment defines an ecosystem as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" and goes on to define ecosystem services as "the benefits that humans obtain from ecosystems" (p. 27). This definition encompasses both the benefits people perceive and those benefits that are not perceived (van den Belt et al., 2011). In other words, a benefit from ecosystems does not need to be explicitly perceived (or empirically quantified) to be considered relevant in an ecosystem services approach. Similarly, ecosystems and their processes and functions can be described in biophysical (and other) relationships whether or not humans benefit from them. Ecosystem services reflect the influence of these processes on society's wellbeing; including people's physical and mental well-being. While ecosystems provide services not only to people, the evaluations of services are, by definition anthropocentric.

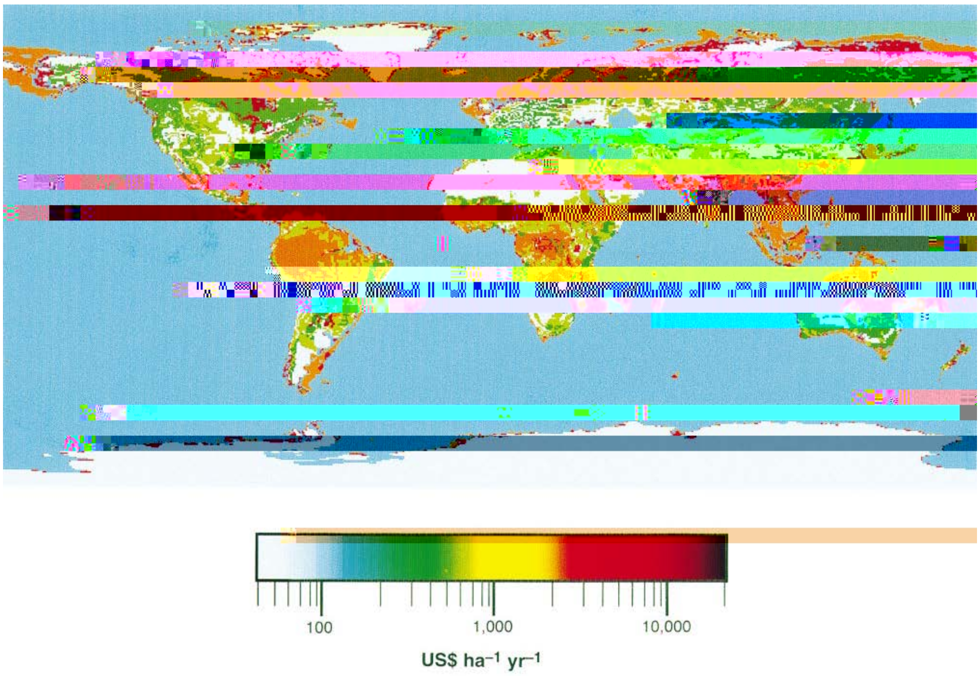
The deliberate interlinking between human and natural systems is not new, but over the past few decades interest in "ecosystem services" as a concept has surged, with research and activities involving natural and social scientists, governments and businesses alike (Costanza et al., 1997; Daily, 1997; Braat and de Groot, 2012) receiving a sustainable flow of ecosystem services, it is crucial to manage the scale of the ecosystem services approach has the potential to provide a new "currency" or organizing principle to consider multi-scale and cross-sectoral synergies and tradeoffs.

Several recently developed and evolving frameworks outline ecosystem services approach and its underlying connection between natural and human systems. Although the essence of the ecosystem services concept is the dependence of human well-being on ecosystems, there are diverse definitions of the concept, reflecting differing worldviews on how human systems relate to ecosystems. For example, ecological economists emphasize that human societies are a sub-set of

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) enhances this integration effort at sub-regional, regional and global levels (Larigauderie and Mooney, 2010; www.ipbes.net).

Although the concept has achieved broad acceptance, caution is needed in implementing ecosystem services approaches to avoid a simplistic or biased commodification of ecosystems that prioritizes some elements of nature that are economically useful to the detriment of overall ongoing preservation of those ecosystems for their intrinsic value. An unbalanced approach focused primarily on assigning monetary values can exacerbate power asymmetries and increase socio-ecological conflicts (e.g., Beymer-Farris and Bassett, 2012). Giving equal focus to non-market/non-use services within the ecosystem services framework is both a desirable approach and a strength of this method for decision-making (Chan et al., 2012). When ecosystem services are approached as an organizing principle, this includes the development of common units of measurement for decision support, beyond application of existing tools in the natural and social science toolboxes. It needs to be acknowledged that we don't, and may never, fully understand social-ecological systems to the point that people can confidently predict changes and impact or 'optimize' these systems. A precautionary stance regarding management and governance for maintenance of resilience of social-ecological systems is highlighted (Bigagli, 2015).

The ecosystem services approach gained momentum in the late 1990s, when monetary values associated with ecosystem services from natural capital were conservatively estimated (at a rate double that of global Gross Domestic Product (GDP)) to highlight the potential economic and societal value of previously unvalued ecosystem services (Costanza et al., 1997). These values were globally expressed with a single spatial dimension, a snapshot of which is shown in Figure 1. These values only provided a starting point of a necessary debate, as they relied on many and generally conservative assumptions about how to, in a broader sense, value services globally. Although they expressed these services in monetary values, the authors did not claim that these services were suitable for exchange in the market system (Costanza et al., 1997). A recent reassessment of these global values indicated that the values of global ecosystem services have increased with additional studies on ecosystem services, but these values simultaneously have decreased where natural capital has been converted to other types of capital (Costanza et al., 2014).



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 1. Global map of values of estimated ecosystem services in 1997. Source: Costanza et al., 1997.

An ecosystem services approach certainly isn't without controversy and critique is offered by neoclassical economists and ecologists (McCauley, 2006), albeit for different reasons. Some critiques of an ecosystem services approach are highlighting the utilitarian manner which this approach has been implemented services (e.g., nutrient cycling, primary production) and cultural services (e.g., area beyond the continental shelf edge, with benthic habitats generally lacking, and 3) focused on mangroves for supporting and provisioning services and coastal wetlands for regulating and supporting services. A primary focus on local or regional geographic location raises a concern for MCES, as biophysical events and conditions are generated further afield. For example, patterns of upwelling and migratory species will be influenced by benthic and oceanic conditions that might occur at some distance from the affected region and thus will be difficult to predict. As in other domains, decision-makers have to make decisions under conditions of high uncertainty with limited ability to conclusively consider all risks. An ecosystem services approach has the advantage of making visible the non-linear behaviour[6] of ecosystems and draw attention in decision-making to fundamentally different alternatives (Barbier et al., 2008). Such alternatives may lead to synergies (i.e., shared values across sectors as a basis for socio-ecological enterprises and poverty alleviation) or to difficult trade-offs between different uses or user groups. A valuation spectrum should include "all that is important to people", whether the people themselves perceive this or not (van den Belt et al., 2011) and regardless of whether the value is monetary, spiritual, cultural, or otherwise.

2. Evolving ecosystem services frameworks, principles and methods

An overview follows of accepted typologies, principles and methods currently used for assessing and measuring ecosystem services in the rapidly growing international literature. Although concepts and methodologies show a consistent pattern in local applications, no generally accepted classification of ecosystem goods and services for global accounting purposes exists (Haines-Young and Potschin, 2010; Böhnke-Henrichs et al., 2013). The complexity of such a task requires a pluralistic approach across temporal and spatial scales to make ecosystem services visible in decision making processes and to decision-relevant databases). Currently organized by country, further analysis of scale addressed by the valuation studies included may help progress toward a multi-scale approach. For example, completion of Table 1 for marine ecosystem services could be very useful for a future second United Nations World Ocean Assessment.

Table 1 Overview of thematic working groups of the Ecosystem Service Partnership (ESP), which would be useful to complete for a subsequent World Oceans Assessment.

Thematic working groups of ESP	Biomes	Scale
1. Ecosystem services assessment frameworks and typologies		

Figure 3. Process of ecosystem service assessments based on TEEB, redrawn after Hendriks et al., 2012.

2.1 The flow of ecosystem services

For this introductory chapter on ecosystem services, however, we elaborate on the cascading Haines-Young and Potschin (2010) framework. This framework is relevant because of its close alignment with the evolving United Nations System of Environmental-Economic Accounting (United Nations Statistics Division, 2013) and its effort to seek a consistent classification system and set of accounting principles (Boyd and Banzhaf, 2007; Landers and Nahlik, 2013).

Conceptual models, such as the Common International Classification of Ecosystem Goods and Services (CICES) (Haines-Young and Potschin, 2010), enable practitioners to differentiate between natural capital, i.e., the natural resources or ecological infrastructure, and the services that are derived from that infrastructure. This is presented in a framework cascading from biome to function/process, service, benefit and value (Figure 4). This framework is influenced by two perspectives: 1) the desire to account for ecosystem services and avoid double counting by economists and 2) an opportunity for natural scientists to rapidly communicate the value of particular ecological structures and processes. When applying this framework, supporting and cultural ecosystem services are easily ignored, and non-market[7] values are at best considered at the end of the cascade and more often are not considered at all; and the flow of ecosystem services is portrayed as linear or unidirectional,

The second step is to develop a model describing how the biophysical system produces or inhibits production of the metric of interest, and which key drivers modify that production. This step corresponds to step 1 in Figure 3. In the mangrove example above, if we are interested in the coastal protection function of mangrove forests and thus the above-ground density of the woody biomass, we ideally would have or develop a mangrove growth model that could predict how wave height and intensity, sunlight, rainfall, sedimentation, etc. affect production, and especially the inter-plant density, of the woody biomass. In order to do this modeling, for all potential functions (and services) of interest, one can draw on or develop species specific population models coupled with ecosystem dynamics models, although the parameters of the model may vary spatially and temporally. Once in place, these models then permit relatively simple sensitivity analyses that identify key drivers of change in the metric of interest.

Such models are always challenged by the availability of data, particularly in many developing countries. Thus, model development must proceed hand-in-hand with data discovery and, where possible, data-gap filling, so that models are tailored to the scale, resolution, and complexity of the data available for a region (Figure 5). Typically useful data include physical data on sea level, pH, temperature and wave height and intensity, and biological data on the demographics, densities, dispersal, and trophic dynamics of species. Although the data needs are similar at a global level across the major oceans, these data will vary by locale and temporally (sometimes seasonally). Availability of data and scientific understanding to properly paramatize such models in particular, depends on scale and differs between regions. Local/regional data for marine ecosystem services assessments are generally much more available for counties including, but not limited to Europe, North America, Australia/New Zealand, and Japan, and are very poor in most of Africa, Asia, and Latin America. A complete world assessment of ecosystem-g30.001 Tc 0.9(y)4.1(o)17 nysa.

Numerous examples of both types of decision-making exist. On the one hand is the more general, coarse-scale, often data-poor heuristic assessment, where decision-makers are primarily interested in whether service supply will go up, stay constant, or decline under a given management action. For example, model-building, including indigenous stakeholders, can be used to scope for changes over time in ecosystem service values in a non-spatial manner (van den Belt et al., 2012). On the other hand, more specific, fine-scale, often data-rich quantitative scenario development requires detailed assessments of who wins and loses under a given management action, and by how much, when and where. Examples include decisions on wave energy (Kim et al., 2012) and offshore aquaculture facility locations (Buck et al., 2004), considering specific tradeoffs.

At local and regional scales, often considerable but incomplete data are available, to make visible the biophysical supply of ecosystem services. Fundamental to such efforts are sufficient data to map the location and interaction of key biophysical attributes (such as wave energy, ocean temperature, species density and composition, quality and health of those species, etc.), and for some places around the world such data exist. However, for many regions of the world such data do not exist or are extremef-4(ame)9(n)64(m)4(m)4(-1(f-4(678)4(o)-2(mp) D)-1(e)-ih)-1(e)-besild
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Of particular importance is the multi-scale aspect of the ecosystem service approach, as it provides an invitation to consider a connection between local and global scales at different temporal/seasonal intervals (Costanza, 2008). Some ecosystem services are produced and consumed in situ (e.g., coastal protection), whereas others have clear global aspects (e.g., carbon sequestration, climate regulation, biodiversity, global fisheries and mineral extraction). Certain services are primarily seasonal (e.g., coastal protection), and others are provided or utilized year-round (e.g., food provision).

2.3 Demand for ecosystem services

The 'Benefits' and "Value' steps in the cascading framework (Fig. 4) represent the 'demand for ecosystem services' and indicate where drivers of management and decision-making can

- Non-rival goods can be used by many without being ‘used up’, e.g., one and the same fish can be admired by multiple divers, or clean coastal waters can be available
- A good is excludable if the use of it can be prevented, e.g., one needs permission to drill for minerals in the Exclusive Economic Zone.
- A non-excludable good is freely accessible to all, e.g. Storm protection provided by mangroves, seagrasses and reefs and dunes.

Most provisioning goods are ‘rival and excludable’ and therefore more suitable for valuation through markets, (e.g., fisheries in an Exclusive Economic Zone). However, some provisioning services are ‘rival but non-excludable’ (e.g., fisheries outside of caution. Table 2 provides a sample of references to local case studies of ecosystem services and their values associated with a sample of particular marine ecosystems. The development of such matrices is often referred to as a ‘rapid ecosystem service assessment (RESA)’ to identify where ecosystem services and valuation data are available and where data gaps exist. The 71 per cent of boxes that are grey and have no studies referenced represent ecosystem services provided by a particular

supporting services, such as habitat needed for spawning to ensure long term provisioning of protein.

Decisions on how best to manage marine resources frequently require consideration of the tradeoffs among a suite of possible scenarios. These tradeoffs generally entail values gained or lost with each scenario. Most commonly such values assigned are monetary. Historically, this has led to consideration of values that can be given a monetary worth, whereas services that are difficult to measure and value are often excluded from the decision-making process (TEEB, 2010a). Rodriguez et al. (2006) found that provisioning, regulating, cultural and supporting services are generally traded off in this respective order. This approach results in a focus on one or a few ecosystem services and in decisions that have an unequal distribution of costs and benefits across sectors of the population. Failure to include supporting and cultural services, specifically on par with provisioning services, may have unintended consequences.

In other words, understanding the flow of production (i.e., supply) and consumption (i.e., demand) of ecosystem services is complex, leaves room for cultural interpretation (Chan et al., 2012), and has distributive implications (Rodríguez et al., 2006; Halpern et al., 2011). However, tools are available - ranging from simple (for scoping purposes or in the face of poor data) to complex (for management purposes and when adequate data are available) - to assist in the development of scenarios and decision-support for this purpose.

2.5 Time preferences

Just as spatial analysis at multiple scales is crucial in understanding the supply of ecosystem services, the understanding of time scales and time preferences are important in assessing tradeoffs, especially with regard to the demand for ecosystem services. The perception of time is often culturally defined. Indigenous peoples often think in terms of multiple generations and time can have a spiritual element. For a market-oriented investor or government, time is captured in a ‘discount rate’. In essence, a high discount rate reflects a desire to consume resources now rather than later. From an economic perspective, this choice also determines how quickly an investment returns a profit. Long-term planning to safeguard the benefits of less visible, non-

2.6 The challenge of multi-scale integrated assessments for ecosystem services

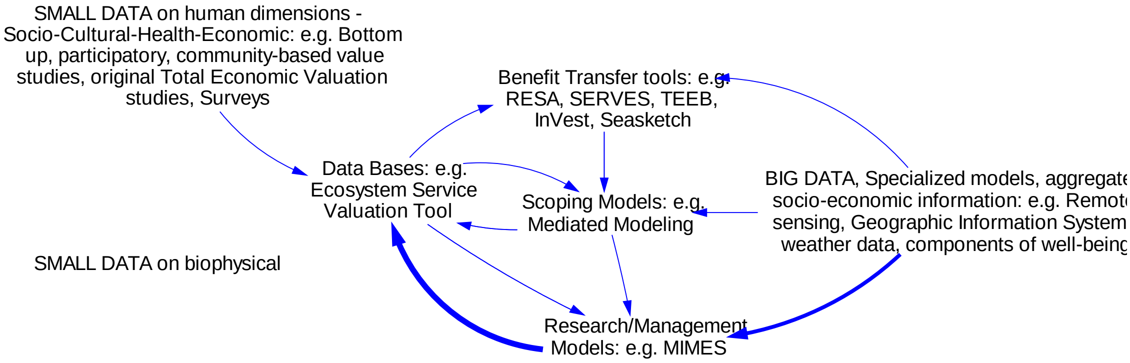
There are indicators that allow us to reflect on the health of oceans, e.g., the Ocean Health Index (Halpern et al., 2012) and retrospectively how ocean health is changing. A general indicator for ecosystem services from oceans is not available, nor may it be desirable as one indicator. Such an indicator would require integration across biophysical and human dimensions, with relevance across multiple scales and developing a transparent ability to consider tradeoffs with a forward perspective. This requires the gathering of data at local, regional, national and global scale, and in principle with three dimensions: space, time and values. Although not unique to the ecosystem services concept, the need to connect local to global scales through bottom-up and top-down governance is paramount.

Database management and modeling capacity are increasingly important to support decision-making at multiple levels of scale. This capacity needs to be 'fit for purpose' (i.e., it needs to answer specific questions by decision-makers in a timely fashion), as well as contribute to the development of knowledge across scales (i.e., be relevant beyond the boundary of an individual decision-maker). Currently, several tools are available, each emphasizing particular strengths, such as the ability (1) to communicate effectively with local stakeholders (e.g., Rapid Ecosystem Service Assessments (RESA), Seasketch (McClintock et al., 2012); (2) illustrate spatial aspects (e.g., InVEST (Lester et al., 2012; White et al., 2012); and (3) consider scenarios and changes over time, e.g., Mediated Modeling at the scoping (van den Belt, et al. 2012), research, and MIMES/MIDAS (Altman et al., 2014) at management levels. Table 3 illustrates some tools with differing strengths and weaknesses. A comprehensive overview of all tools is beyond the scope of this assessment.

Table 3. A subset of tools that can be included in an ecosystem services valuation 'toolbox'. The tools range from crude conversation starters (e.g. RESA) to spatially dynamic decision support frameworks (e.g. MIMES).

	Dimension	Rapid Ecosystem Service Assessment (RESA)	SeaSketch	InVEST	Mediated Modeling	MIMES
Context	Social/ values	Possible	Yes	Yes	Yes	Yes
Content	Spatial	Limited	Yes	Yes	No	Yes
	Dynamic/ changes over time	No	No			

These tools draw on local 'small data' and global 'big data' to various extents. Each case study has the potential to be used in education and add to the collective building of knowledge on ecosystem services. As discussed, multiple databases on ecosystem services and their values are already available (Appendix 1), many of which feature ecosystem-based management tools (e.g., http://ebmtoolsdatabase.org). Newly initiated local case studies, as well as the output from modelling tools and applications of TEEB-like processes, add to this body of knowledge, and draw on 'big data' sets. Bringing together the various databases, tools and knowledge gained from various applications is a priority for multiple stakeholders, such as policy makers, industry and non-governmental organizations The iMarine infrastructure is one example of an emerging "Community Cloud" platform which offers Virtual Research Environments that integrate a broad range of data services with scientific data and advanced analysis. Such scenarios then result in new datasets. This could be expanded to include protocols for an ecosystem services approach. Figure 5 illustrates a connection between: (1) 'big data', primarily spatial information relevant to the supply of ecosystem service and (2) 'small data', the transferable insights that can be gained from local case studies. These data are brought together in (modeling) tools, evolving (1) from scoping to management level and (2) from static to dynamic tools.
In the same way, but with a much more "bottom-up" and integrated emphasis, the European Marine Biodiversity Observation System (EMBOS: http://www.embos.eu/) offers the advantages of scale and expert identification of relevant organisms (taxonomy). This holistic approach is important since marine biodiversity provides many ecosystem services. However, biodiversity is undergoing profound changes, due to anthropogenic pressures, climatic warming and natural variation. Proper understanding of biodiversity patterns and ongoing changes is needed to assess consequences for ecosystem integrity, in order to be in a position to manage the natural resources.



3. Capacity-building and knowledge gaps

This section highlights knowledge gaps regarding the application of ecosystem services and discusses opportunities for capacity development. This concerns 'human capital', often interpreted as the 'ability to deal with complex societal challenges'. In the context of marine ecosystem services, this is reflected in the capacity to collect and use available data to make visible 'the benefits that people derive from ecosystems' relevant for effective decision-making at multiple scales. This includes effective global policies and agreements, education and awareness programmes. Assessing governance and institutional changes that are required at multiple scales is beyond the scope of this chapter, although it should be noted that a feedback to this effect is included in all of the ecosystem services frameworks.

There is a gap in social sciences and economics' ability to support ecosystem-based science. Application of an ecosystem services approach emphasizes the need for human dimensions of well-being, bridging natural and social sciences. Such integrative approach requires capability building in skills beyond existing disciplines. Generic skills that are needed to work within an ES framework, include: technical (e.g. modellers) and specialists (including scientists in specific disciplines), integrators

Demand for

sustainability of their local and global ecosystems and resultant services. However, collectively, it is crucial for people to understand that ecosystem services do not respect national and international boundaries, necessitating an integrated approach and a trading off with adjacent regions. If not accomplished in a transparent manner, this approach is likely to exacerbate regional conflicts. A simple example is the need for an understanding of ecosystem life processes by the community at large and the interdependence and cascading links between individual ecosystem services. Furthermore, it is vital to understand how this varies region-to-c 0 Tw 24.2 7i6.16.

Databases and tools available to Marine Stations and Meteorological Centres need to integrate and share data/tools/strategy. Time series are vital for biological/chemical/physical/geological datasets.

As original local studies of ecosystem services are expensive, guidance is needed for local stakeholders and decision-makers to progress from scoping to management tools. This includes a continuum of multiple discount rates relevant to the various ecosystem services (TEEB, 2010a). The users and resource dependents is key. Several networks (e.g., MEA, GEO-BON, IPBES, TEEB, Lisbon Principles) have developed and are further developing such principles and guides. A significant development in Europe is EMBOS (http://www.embos.eu/).

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