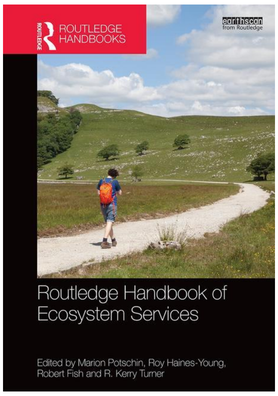

Routledge Handbook of Ecosystem Services

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Defining and Measuring Ecosystem Services

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DEFINING AND MEASURING ECOSYSTEM SERVICES

Marion Potschin and Roy Haines-Young

Introduction

The term 'ecosystem services' can mean different things to different people. On the one hand this is an advantage, because it can engage people in new conversations about the importance of biodiversity and the environment. In this sense 'ecosystem services' might be thought of as a *boundary object*, that is, an idea that can be adapted to represent different perspectives while retaining some sense of continuity across these different viewpoints (Abson et al., 2014; see also Briefing Note 7.1). On the other, that multi-faceted characteristic is a disadvantage once we come to measure and monitor these things called services: if we cannot agree what they are then people will not believe what is said about them or act on the evidence we collect. These problems of definition are amplified once we start to make a case for valuing or managing ecosystem services (see for example, Ojea et al., 2012) – that is, to apply the concept in a *normative* way.

This *Handbook* demonstrates the different ways that people think about ecosystem services; it is, in fact, a microcosm of the wider literature on the topic. Many authors start, quite legitimately, with the definition provided by the Millennium Ecosystem Assessment (MA, 2005) which describes them simply as *the benefits that ecosystems provide to people*. In contrast, others follow the guide of TEEB (The Economics of Ecosystems and Biodiversity), which views them as *the direct and indirect contributions of ecosystems to human well-being* (De Groot et al. 2010). Services, in other words, give rise to benefits; they are not the same thing. Despite these differences, however, both regard ecosystem services and goods as being synonymous. To add complexity to the debate, it is apparent that not all frame the idea in this way. The UK National Ecosystem Assessment (Mace et al., 2011), for example, suggests that it is 'goods' and 'benefits' that are one and the same, and that it is 'services' that are quite distinct (see also Mace et al., 2012; Mace, 2016). So what's the problem with all these different perspectives? In a sense, we all know what people are 'getting at', namely the importance that nature has for people. The difficulty lies in the fact that if we want to understand how ecosystems provide benefits to people, we need a way of characterising the ecological structures and processes and ecosystem characteristics that underpin them in ways that can be analysed. The aim of this chapter is to take the reader on a journey through the terminology surrounding the idea of ecosystem services, not to convince that there is a single, consistent way of thinking about them, but to provide a guide through a complex, and at times, puzzling terrain.

The ecosystem service cascade

A number of commentators have noted the problems of defining exactly what an ecosystem service is (see, for example, Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008; Fisher et al., 2009). Despite their differences, all agree that there is some kind of 'pathway' for delivering ecosystem services, which goes from ecological structures and processes at one end through to the well-being of people at the other. We have also represented this 'production line', describing it as a 'cascade' (Figure 3.1). Its purpose is to tease out more clearly the differences between these end-points and the steps between (Potschin and Haines-Young, 2011).

Conceptual frameworks such as the cascade serve a number of purposes. They can be used, for example, as a communication tool, a jumping-off point for discussion between experts and laypeople. Additionally or alternatively they can be used as a way of mapping out basic concepts so that they can be applied to solve problems; they identify the types of evidence that are considered relevant and so help place work on a stronger analytical footing. It is mainly for this last purpose that we use it here.

Thus, we suggest, the cascade model can help us think about the relationships between five key sets of ideas that define the ecosystem services 'paradigm'; that is, a way of looking at the world. We are clearly interested in ecosystems, and these are represented in the cascade model as the set of *ecological structures* and *processes* that we find in an area. Often we simply use some label for a habitat type, such as woodland or saltmarsh, as a catch-all to denote this box, but there is no reason why we cannot also refer to things such as 'the nitrogen cycle', with its various stores and transfers, as something that can also occupy the left-hand side of the diagram. In either case, given the complexity of most ecosystems, if we want to start to understand just how they benefit

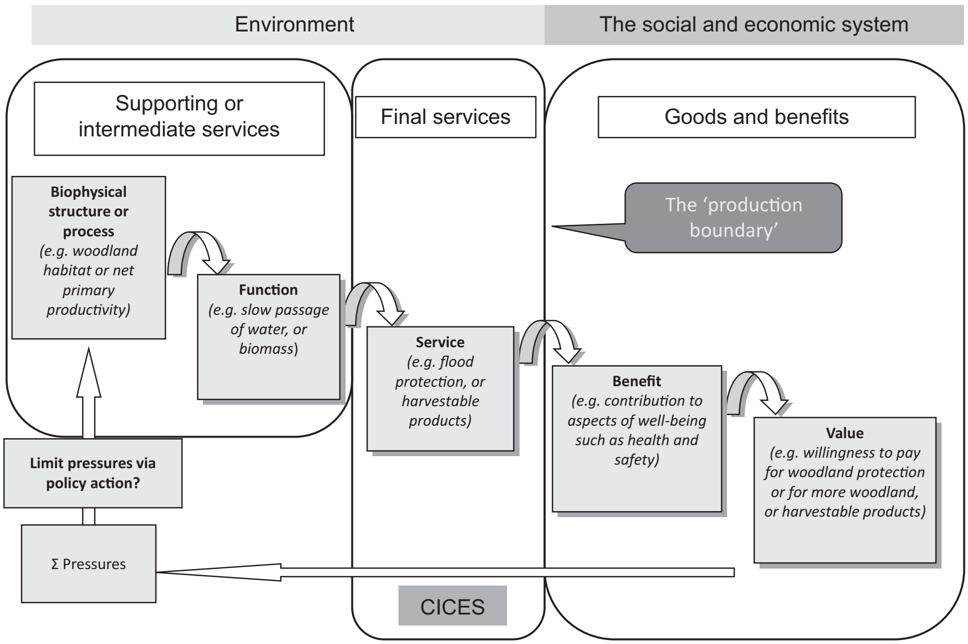

Figure 3.1 The cascade model.

Source: original, Haines-Young and Potschin, 2010; adapted from Potschin and Haines-Young, 2011 people, then it is useful to start to identify those properties and characteristics of the system that are potentially useful to people. This is where the idea of *functions* enter into the discussion. In terms of the cascade model, these are taken to be the subset of characteristics or behaviours that an ecosystem has that determine or 'underpin' its usefulness for people.

As Jax (2016) notes, the term 'function' is problematic for ecologists. For some (including those who prepared the MA) it is often just used as another way of referring to *ecological process*. Indeed, Wallace (2007) has gone so far as arguing that if ecosystem services, processes, structure and composition are adequately defined, the term 'function' is actually not required; Jax also suggests that we even might want to avoid it. However, there are, some advantages in thinking about what it is about an ecosystem that enables it to provide a service, and setting these characteristics or behaviours apart as a 'subset' can be helpful. We would suggest that it is especially helpful if we want to manage these properties in some way. In the case of woodlands, for example, their capacity to mediate runoff can be controlled by their canopy characteristics, and these are not solely determined by woodland type. Similarly, while the structural characteristics of wood that make it more or less useful for timber are determined by growth processes, these can be manipulated within the same woodland type to improve its ability to deliver a harvestable crop. Given the complex nature of ecosystem structures and processes, and that a single ecosystem may deliver a number of benefits, we need to try to be clear about just what capacities (properties, behaviours) make it useful to people; identifying these as 'functional' characteristics is, we suggest, therefore a necessary stage in understanding how ecosystems and people are linked.

Ecosystem services play a pivotal role in the cascade, which constitutes them as distinct from the functional characteristics of the ecosystems that make them useful, and the benefits that people ultimately enjoy. A defining feature of services is that they are, in some sense, the final outputs from an ecosystem. They are 'final' in that they are still connected to the structures and processes that gave rise to them; they are also final in the sense that they contribute directly to some product or condition that can be valued by people. Thus, to return to the woodland example, the standing crop of trees with particular structural characteristics is the service and the harvested, worked timber is the good or benefit. Following the logic used in the UK National Ecosystem Assessment, in the cascade *goods* and *benefits* are the things that have *value*, whether that value is expressed in monetary or non-monetary terms. 'Product' is another term that is sometimes used interchangeably with 'good'.

The distinction between functions, services, and goods and benefits can be clarified still further by recognising that a service may depend on a number of functional characteristics. For example, the utility of a standing crop of trees is dependent on a range of properties other than the characteristics of the woody material, such as the branch and stem characteristics of the stand, stem density and stand age. Similarly, a stand of trees can give rise to several different types of goods and benefits. In addition to its capacity to slow the passage of runoff, for example, those same trees can offer benefits in terms of shelter against winds, dust or noise, as well as a range of recreational activities.

A benefit is basically seen as something that can 'change people's well-being', which is understood to be things like people's health and security, or their social relations, or the kinds of choices they can make. These benefits are thus important to people, and that importance is therefore expressed by the values they assign to them. 'Value' is therefore the final box in the cascade model, on the right-hand side, and, as suggested, these values can be expressed in a number of different ways. Alongside monetary values, people can express the importance they attach to benefits using moral, aesthetic or spiritual criteria. And it is by reference to these values that people and societies chose to act (or not) to modify or manage the pressures on ecosystems and ultimately the benefits they deliver to society. This feedback is highlighted in the arrow running from values back to the left hand side of the cascade model.

Clearly, a limitation of the cascade model is that it seems to suggest a rather linear relationship between ecological structures and processes on the one hand, and benefits and values at the other. In the 'real world', of course, things are more complex and cannot easily be captured in a simple model such as this. Even for a single ecosystem, we can usually identify a network of linkages between a number of different ecological structures and processes, the different functions they support and the suite of benefits that ultimately arises. Nevertheless, the elements of the cascade do give us some of the vocabulary we need to represent and understand the richness of these relationships.

Using the cascade

The novelty of the ecosystem service paradigm stems from the willingness of researchers and practitioners to connect the study of biophysical and social systems. The cascade model can be seen as an entry-point into the discussion – as a tool for representing important elements in the production chain linking nature and people. In any real problem situation there will be many difficult judgements to be made about, for example, what counts as a function or a service or a benefit, etc., because how we interpret these ideas will change with the application context. As Boyd and Banzhaf (2007) memorably point out in their discussion of final ecosystem services: if we take potable water from a lake, the water is a final service, but if instead we eat the fish that live in the lake, then it is the fish and not the water that are the final ecosystem service. What the cascade model brings to these situations is, therefore, a framework that can structure our thinking. The ideas represented by the 'boxes' in the model are rather like words in a sentence which we can use to tell the ecosystem service story; each has meaning by virtue of the way we arrange the other 'words' (ideas) around them.

The point of the cascade model is not to put the world into tightly prescribed boxes, but to help more clearly understand the ways in which nature can influence people's well-being. Whatever terms we choose, the distinction between the contributions that an ecosystem makes and the way that well-being is changed is critical – hence our particular preoccupation with the service-benefit issue. The language used in the MA has helped all of us to make a start, but the basic concepts still need probing more deeply (cf. Lamarque et al., 2011; Portman, 2013).

We can see how the cascade model has helped people work through the logic of the ecosystem service paradigm by reference to some of the published literature. One of the key areas of analysis that it has encouraged people to think about concerns the patterns of supply and demand for ecosystem services. For example, Hansen and Pauleit (2014) have developed and modified the cascade to look at demand and supply relationships in relation to green infrastructure in urban settings, while Bürgi et al. (2015) have looked at the evolution of supply and demand interactions for ecosystem services over time in a Swiss landscape, to gain a deeper understanding of landscape history. Elsewhere, Martín-López et al. (2014) have used the cascade to undertake an empirical study of patterns of supply and demand in the Dõnana social-ecological system, in south-west Spain, while Geijzendorffer et al. (2015) have more generally reviewed some of the literature on the mismatch between the demand and supply. The latter concluded that to properly account for such mismatches studies should include multiple stakeholder groups with their different requirements, recognition that supply is not only determined by biophysical factors but also the services needed by people and hence management inputs, and temporal and spatial scale sensitivities.

Studies using the cascade to assist in understanding the services associated with particular ecosystems include those of Large and Gilvear (2014), who applied it to the analysis of 'riverscapes', and Liquete et al. (2011) in their work on mapping and assessing ecosystem services associated with freshwaters in Europe. In other applications, Plant and Prior (2014) used the cascade to develop a framework for statutory water allocation planning in Australia, while Zhang et al. (2015) applied the framework to help identify the components of plant diversity that are most correlated with ecosystem properties in a restored wetland in northern China, and Ratamäki et al. (2015) used cascade to explore pollination from a multi-level policy perspective.

There is considerable interest in the scientific policy communities in devising appropriate indicators of ecosystem services to 'mainstream' the concept (see Müller et al., 2016). Examples of the way the cascade has stimulated debate include that of Liquete et al. (2013a), who used it to propose three novel coastal protection indicators for European coastlines that cover the main anthropogenic pressures on the coastal zone. Maes et al. (2012b, 2013) have also used cascade to develop spatial indicators of potential and supply, with a view to identifying synergies and trade-offs between ecosystem service supply, biodiversity and habitat conservation, while van Oudenhoven et al. (2012) have used the cascade to develop a framework for indicator selection to assess effects of land management on ecosystem services in the southern part of the Netherlands. In the context of the work on indicators, a number of authors have attempted to make a link between the cascade and the DIPSIR framework (see Müller et al., 2016), including Hering et al. (2015) in their work on indicators for the management of Europe's water resources, and Honrado et al. (2013), who have identified a set of indicators that can sit within the DPSIR framework by looking at the relationships between the cascade concept and the environment factors assessed in Environmental Impact and Strategic Impact Analyses. As Maes et al. (2012a) argue, the policy relevance of work on ecosystem services, indicators and mapping is especially important, and have proposed a stepwise framework to support EU policies in a more effective way.

From such work it is clear that, despite its simplicity, the cascade can provide a foundation for building a number of different assessment approaches. Thus Chapman (2014) has proposed a modified cascade to support monitoring and assessment work linked to an adaptive co-management program in western Kenya; the suggested framework helped decision makers identify programme need, program activities, pathway process variables, moderating process variables, outcomes, and programme value.

In other published work, van Zanten et al. (2014) have used the cascade to explore the impact of the Common Agricultural Policy (CAP) on European agricultural landscapes and ecosystem services. These authors have adapted the cascade to help analyse the influence of commodity markets and policies on the behaviour of land managers and the influence of consumer demand on flows and values of the ecosystem services that originate from the agricultural landscape. In other developments, Cordier et al. (2014) have used the cascade to design a framework for ecosystem services monetisation in ecological-economic modelling. Their aim was to ensure that monetary valuation techniques are better able to contribute to the understanding of the impact of economic activities on changes in ecosystems services and the impact of these changes on economic activities. Applications of the cascade in a broader modelling arena include the work of McVittie et al. (2015), who use the cascade in operationalising an ecosystem services-based approach using Bayesian Belief Networks (BBNs) in the context of modelling the dynamics of riparian buffer strips, and Landuyt et al. (2013), who consider the relevance of the cascade to BBNs more generally.

In contrast to its use as an empirical, analytical framework, the cascade has been used to develop broader theoretical understandings. Pagella and Sinclair (2014), for example, have used an earlier version of the cascade to build a typology for understanding the different types of mapping tools. From their review of over 40 published studies they concluded that the major gaps in relation to our understanding of ecosystem services were the lack of analyses at scales relevant to management interventions; understandings of the pathways linking supply and use of services; synergies and trade-offs between services and the inclusion of stakeholder knowledge and uncertainty. Elsewhere, Vihervaara et al. (2013) used the cascade to categorise ecosystem service research in relation to the themes of the International Long Term Ecological Research (ILTER) network, and Kronenberg (2014) has used the cascade to look at what the current debate on ecosystem services can learn from the past in the literature dealing with 'economic ornithology'. Huang et al. (2015) have also considered agro-ecosystems, but this time from a multi-functional perspective. They observe that these systems have been studied by two scientific communities, and that while they have the same interest in understanding these landscapes from a holistic perspective an analysis of the literature suggests there has been limited interaction and exchange. Each group faces research challenges according to independently operating paradigms. These authors propose a conceptual framework based on the cascade that they suggest could stimulate a dialouge about how to analyse bundles of ecosystem services and the nature of multi-functional agriculture, and provide insights into strategies such as land sharing and land sparing.

Finally, the cascade has stimulated other theoretical approaches or readings of the links between ecosystem services and human well-being. Buchel and Frantzeskaki (2015) used the cascade as a starting point to develop a method that can be used to 'translate' ecosystem services for people using an urban park in Rotterdam. They suggested a modification to the cascade to distinguish cultural ecosystem services from other types of service, because, they argued, fundamentally they arise from the perception of nature, rather than from nature itself.

A modification to the cascade has also been suggested by Spangenberg et al. (2014, 2015) so as to include the notion of the potential of a system to generate ecosystem services. They argued for a 'reverse application' of the underlying cascade logic, so as to understand the 'full cycle of ecosystem services generation and management'. This, they suggest, is particularly helpful in a planning context, where we need to identify uncertainties, the legal and participative foundations of decision-making, and the potentially conflicting private and public interests. Von Haaren et al. (2014) go on to describe a 'practice-oriented' ES evaluation model (PRESET) as a reaction to the cascade, again specifically adapted to the requirements of local and regional planning.

The studies that have used the cascade illustrate the motivation for proposing it, namely to help focus thinking and stimulate discussion. While the cascade can be criticised because there are 'missing links', it never was proposed as a complete picture of the world. Rather, as we have suggested here, it is intended as a heuristic, a way of starting the kinds of conversation that people with different perspectives need to have in relation to the idea of ecosystem services. For particular applications, frameworks for showing the links between people and nature will need to be more fully specified – but in the case of the general use of the cascade, simplicity is perhaps a virtue.

Classifying ecosystem services

The fluid nature of the concept of ecosystem services can be an advantage in stimulating discussion, but it poses problems when we try to measure them, or design a system for classifying them so that we can report results clearly. An illustration of some of the difficulties that can arise is provided by Ojea et al. (2012), who looked at the problems that arise in the context of valuing the water services associated with forests from overlapping and ambiguous definitions in the MA classification. Elsewhere, Wong et al. (2015) have highlighted the difficulty of operationalising ecosystem services unless measurable 'endpoints' that unambiguously represent final ecosystem services can be identified. These kinds of difficulty are compounded by the fact that, even assuming that such endpoints can be agreed upon, the naming of services is often different between initiatives and service categories that appear in one system are not always included elsewhere.

In an attempt to provide a framework that could at least be used to translate between the systems, work was undertaken as part of the development of the revision of the System of Environmental and Economic Accounting (SEEA), led by the United Nations Statistical Division (UNSD). It resulted in the so-called Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin, 2013), which aimed to help people identify what constituted a final ecosystem service and navigate between the different typologies that have evolved around the ecosystem service concept, and especially to report in a standardised way (e.g. La Notte et al., 2012). While developed initially in an accounting context, it has been taken up more widely by the ecosystem services community, and is, for example, the framework being used in the EU *MAES* Process, which aims to map ecosystem services at the European scale in order to meet the commitments made under Action 5 of the EU's Biodiversity Strategy to 2020 (Maes et al., 2014). In other work, Crossman et al. (2013) suggest that such a classification might be seen as part of a more general systematic approach or 'blue print' for mapping and modelling ecosystem services. In looking to develop these more standardised approaches, Busch et al. (2012) have argued that it is especially important to develop classification systems, such as CICES, that are 'geographically and hierarchically consistent' so that we can make comparisons between regions, and integrate detailed local studies into a broader geographical understanding.

The CICES framework

The evolving nature of the science of ecosystem services and the way it is practiced, together with a field that brings together a range of disciplines, each with their own terminology, means that the design of a classification system that meets all needs is a major challenge. The development of CICES illustrates many of the issues involved, and the fact that we must probably think of the creation of a classification system as a process rather than a design problem that can be solved in a single step.

CICES was created through a consultative process, initially as part of the efforts to design integrated environmental and economic accounting systems, but latterly by involvement of the wider ecosystem service community. A key initial consideration in 2009, when the process began, was that wherever possible the system should have resonance with other widely used classifications, especially in relation to terminology. Thus CICES took as its starting point the typology of ecosystem services suggested in the Millennium Ecosystem Assessment (MA, 2005), and refined it to reflect some of the key issues identified in the wider research literature. For example, it explicitly attempted to identify what are considered to be 'final services', and was designed around the idea of a hierarchy, to accommodate the fact that people worked at different thematic as well as spatial scales.

The version of CICES that is now widely used was published in 2013, and is known as 'version 4.3' (Table 3.1).[1] At the highest or most general level are the three familiar categories used in the MA: provisioning, regulating and maintenance, and cultural. Below these major 'Sections' in the classification are a series of 'Divisions', 'Groups' and 'Classes'. Figure 3.2 shows the way in which the hierarchical structure works for Provisioning Services.

Ecosystem accounts, like more general ecosystem assessments, have to be based on a well-defined and credible metrics which are often specific to particular geographical situations or ecosystem types. For the purposes of reporting or comparison these may need to be aggregated and generalised. The hierarchical structure illustrated in Figure 3.2 allows users to go down to the most appropriate level of detail required by their application, but then group or combine results when making comparisons or more generalised reports. Thus moving down from Section, through Division, Group and Class the 'service' is increasingly more specific, and these detailed service types are nested within the broader categories that sit above them. In the classification

Table 3.1 The Common International Classification of Ecosystem services (CICES,V4.3).

Section	*Division*	*Group*	*Class*	*MA*	*TEEB*
Provisioning	Nutrition	Biomass	Cultivated crops	Food	Food
			Reared animals and their outputs		
			Wild plants, algae and their outputs		
			Wild animals and their outputs		
			Plants and algae from in-situ aquaculture		
			Animals from in-situ aquaculture		
		Water	Surface water for drinking	Water	Water
			Ground water for drinking		
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Fibre, timber, ornamental, biochemical	Raw materials, medicinal resources
			Materials from plants, algae and animals for agricultural use		
			Genetic materials from all biota	Genetic materials	Genetic materials
		Water	Surface water for non-drinking purposes	Water	Water
			Ground water for non-drinking purposes		
	Energy	Biomass-based energy sources	Plant-based resources	Fibre	Fuels and fibres
			Animal-based resources		
		Mechanical energy	Animal-based energy		
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	Water purification and water treatment, air quality regulation	Waste treatment (water purification), air quality regulation
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals		

Section	*Division*	*Group*	*Class*	*MA*	*TEEB*
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems		
			Dilution by atmosphere, freshwater and marine ecosystems		
			Mediation of smell/noise/visual impacts		
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	Erosion regulation	Erosion prevention
			Buffering and attenuation of mass flows		
		Liquid flows	Hydrological cycle and water flow maintenance	Water regulation	Regulation of water flows, regulation of extreme events
			Flood protection	Natural hazard regulation	
		Gaseous / air flows	Storm protection		
			Ventilation and transpiration	Air quality	Air quality
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Pollination	Pollination
			Maintaining nursery populations and habitats		
		Pest and disease control	Pest control	Pest regulation	Biological control
			Disease control	Disease regulation	
		Soil formation and composition	Weathering processes	Soil formation (supporting services)	Maintenance of soil fertility
			Decomposition and fixing processes		
		Water conditions	Chemical condition of freshwaters	Water regulation	Water
			Chemical condition of salt waters		
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	Atmospheric regulation	Climate regulation
			Micro and regional climate regulation	Air quality regulation	Air quality regulation

(*Continued*)

Table 3.1 (Continued)

Section	*Division*	*Group*	*Class*	*MA*	*TEEB*
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	Recreation and ecotourism	Recreation and tourism
			Physical use of land-/seascapes in different environmental settings		
		Intellectual and representative interactions	Scientific	Knowledge systems and educational values, cultural diversity, aesthetic values	Inspiration for culture, art and design, aesthetic information
			Educational		
			Heritage, cultural		
			Entertainment		
			Aesthetic		
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	Spiritual and religious values	Information and cognitive development
			Sacred and/or religious		
		Other cultural outputs	Existence		
			Bequest		

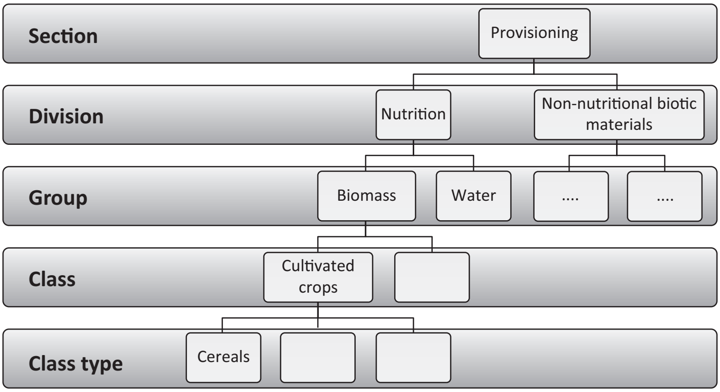

Figure 3.2 The hierarchical structure of CICES.

system there is therefore 'dependency', in the sense that the characteristics used to define services at the lower levels are inherited from the Sections, Divisions and Groups above them. There is also a sense of 'taxonomy' in that elements within the same Group or Class are conceptually more similar to each other, in terms of the ways they are used by people, than they are to services elsewhere in the classification; Table 3.2 sets out the basic definitions at the Section level. At any level in the hierarchy the categories are intended to be exclusive and non-overlapping, so that CICES can be regarded as a classification system rather than an arbitrary nomenclature.

Table 3.1 sets out the basic structure of CICES and also shows the equivalences with the categories used in the typologies of the MA and TEEB.[2] In many cases there is a fairly simple read-across at the group level, but there are categories included in CICES, such as bioenergy, that are not explicitly covered by the others.

The problem of abiotic ecosystem outputs

A key problem with any classification system is to set its boundaries – what should CICES cover and what should it exclude? A key difference that emerged during the consultation was the extent to which the notion of ecosystem services included abiotic outputs such as hydro or wind power, minerals such as salt and so on. On the one hand people argued that although such things were produced by 'natural processes', the fact they were not dependent on *living* processes, meant that the classification would 'water down' the importance that 'biodiversity' had in any future assessments. The position was reinforced by the argument that if abiotic output from nature were included where would we stop – should fossil fuels, for example, also be included? The danger here, people felt, was that if these were included their 'values' as 'ecosystem services' would outweigh many of the others. The counterargument was that many people, especially the 'public' who might be consulted during an ecosystem assessment, would not see the distinction between the biotic and abiotic outputs of ecosystems so clearly. By excluding renewable energy sources such as wind and wave power, for example, would we not tend to exclude a whole category of things that 'nature can do for us'?

The argument about whether abiotic ecosystem service outputs should be included in CICES or any other classification system is a complex one, which is not made easier by the fact that, in all the systems currently used, 'water' is generally included as a provisioning service. Although living processes certainly affect both quantity and quality issues in both the MA and TEEB, water is regarded as a provisioning service, notwithstanding the fact that the 'material' output is largely generated by abiotic, hydro-physical processes.

Table 3.2 Definition of the major categories of ecosystem services used in the CICES V4.3 Classification (after Haines, Young, and Potschin, 2013).

CICES Section	*Definition*
Provisioning	All nutritional, material and energetic outputs from living systems. In the proposed structure a distinction is made between provisioning and material outputs arising from biological or organic materials (biomass) and water. Materials can include genetic structures. The Division for energy makes a distinction between biomass based energy sources, where the organic material is consumed (e.g. fuel wood) and power provided to people by animals.
Regulating and Maintenance	All the ways in which living organisms can mediate or moderate the ambient environment that affects human performance. It therefore covers the degradation of wastes and toxic substances by exploiting living processes. Regulation and maintenance also covers the mediation of flows in solids, liquids and gases that affect people's performance. as well as the ways living organisms can regulate the physico-chemical and biological environment of people.
Cultural	All the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people. Cultural services are primarily regarded as the physical settings, locations or situations that give rise to changes in the physical or mental states of people, and whose character are fundamentally dependent on living processes; they can involve individual species, habitats and whole ecosystems. The settings can be semi-natural as well as natural settings (i.e. can include cultural landscapes) providing they are dependent on in situ living processes. In the classification we make the distinction between settings that support interactions that are used for physical activities such as hiking and angling, and intellectual or mental interactions involving analytical, symbolic and representational activities. Spiritual and religious settings are also recognised. The classification also covers the 'existence' and 'bequest' constructs that may arise from people's beliefs or understandings.

In CICES V4.3, abiotic ecosystem outputs were, in the end, excluded from the classification, although a parallel table covering these elements was provided; it applied the same classification logic to define provisioning, regulating and cultural outputs as for the services dependent on living processes. There was no attempt to restrict this list to only those abiotic outputs that were 'renewable' within the human time-frame, or to exclude 'sub-soil' assets. At this stage, however, the provisional classification of abiotic outputs is merely intended as a 'marker', to highlight the fact that we still probably need to develop a more all-encompassing vocabulary for discussing the trade-offs and synergies between the different types of output that ecosystems can provide.

Supporting services

A key difference between CICES and the typology used by the MA, for example, it that it does not include 'supporting services'. This is not because those developing CICES felt that they were unimportant, but because for them the problem was to identify the 'final' outputs from ecosystems that might form the basis of valuation and assessment. As Figure 3.1 suggests, CICES attempts to classify services which sit at the interface between the biophysical and socio-economic components of an integrated 'socio-ecological system'.

In any ecosystem assessment, once the important final services had been agreed upon or identified, then discussions about sustainability and appropriate management strategies would have to focus on the underlying ecosystem structures and processes, and the functional characteristics that give rise to them. Thus the final services are seen as the entry-points for these kinds of discussion, and it was felt that broad labels like 'nutrient cycling' or 'primary production' were not particularly helpful in this respect; for most final services there are probably multiple structures, processes and functions that 'support' them. This is not to say that some kind of agreement about how we describe these processes and functions is unnecessary – only that it is probably part of another 'conversation'.

There is, however, one aspect of the debate about supporting and intermediate services that is relevant to the structure of CICES, and it relates to the difficulty of specifying what a final service is in a particular situation. The difficulty was illustrated above in the discussion about if and when a lake's water or its fish were the final service. Thus there are other services listed in CICES that could be regarded in some situations as having an underpinning role, such as soil formation or pollination. The point here is that while the classification makes space for them, largely on the basis of customary practice, in any particular assessment a judgement has to be made about their status. Pollination might indeed be regarded as a final service if, for example, its value or importance were being compared with some alternative that depended on human intervention. Alternatively, it might be regarded as a 'supporting service' or ecological function delivered by a particular ecosystem if the harvestable fruit crop was being used to sum up the value of all the relevant ecosystem outputs (including pollination) necessary for its production. The responsibility of avoiding 'double counting' is down to the user of the classification and the purpose to which it is put – not only the designer.

Distinguishing services, goods and benefits

A particularly difficult problem that the design of CICES illustrates for those interested in classification systems for ecosystem services is the distinction between services and benefits. For those who regard services *as* benefits there is of course no problem. For those who argue that that there is a difference between them there is a problem of terminology, because services are defined as the 'activity or function of an ecosystem that *provides* benefit' while benefits are taken to be 'the many ways that human wellbeing is enhanced through the processes and functions of ecosystems via ecosystem services' (cf. Mace et al., 2012, italics ours). The problem with a consultative process such as that which led to CICES is that different people mixed the approaches and in some areas there is a blurring of categories.

In the discussion of the cascade model (see above), we suggested that final services were at the 'production boundary' where the link to ecological structures, processes and functions was broken. This is easy to visualise in the case where a crop is harvested. Thus the wheat growing in a field is the 'service' (in the sense that it is the result of all the activities or functions in the biophysical part of the socio-ecological system), while the grain in the combine harvester is the good (or benefit) – the thing that can be valued. The 'production boundary' is also easy to imagine when waste streams are reconnected to ecological processes to take advantage of 'bio-remediation services'. It is more difficult to visualise in the case of some other regulating services, especially cultural ones.

It is in the area of cultural services where many of the issues surrounding the problem of distinguishing services and benefits can be illustrated. In order to resolve the different positions in the consultative process, the design of CICES took a mixed approach by using the notion of 'environmental settings' to frame cultural services at the higher levels in the classification, and the more familiar terms used to refer to cultural services, such as 'recreation' or 'education', at the class level. As Chan et al. (2012) have noted, the classification of cultural services is particularly challenging, and these authors suggested that they might be regarded as the 'ecosystems' contributions to the non-material benefits (e.g. capabilities and experiences) that arise from 'human–ecosystem relationships' (Chan et al., 2012, p.9). This is also the approach taken in the UK National Ecosystem Assessment, where these 'contributions' are attributed to the locations (settings) or ecological features (e.g. species) that generate some benefit by virtue of some set of cultural practices (see also Church et al., 2014 and Tratalos et al., 2015). Thus 'walking' might generate the benefit of 'recreation' or 'spiritual fulfilment' in a woodland or coastal setting; the cultural practice of 'bird watching' might similarly generate a number of cultural benefits. These examples illustrate that for the non-material ecosystem outputs the 'production boundary' is crossed when the output is linked to some kind of relationship that people have with an ecosystem which then changes their well-being in some way. As Chan et al. (2012) argue, these non-material cultural benefits can include capabilities and experiences; by extension, to the non-material regulating services equivalent regulatory benefits would include such things as protection from storms or mediation of the ambient environment in which people live. An attempt to use a previous version of CICES in this way, to look at the interface between services and benefits, is provided by Staub et al. (2011) in an insightful study undertaken by the Swiss Federal Office for the Environment.

Developing our classification systems

Costanza (2008) has argued that multiple ways of classifying ecosystem services are needed, and usefully pointed to how they might be described in terms of spatial scale, or according to characteristics such as excludability and rivalness. It is indeed the case that we need to develop much richer vocabularies for describing the ways people and nature are linked. As for CICES, the purpose of stabilising the framework in 2013 as 'version 4.3' was to encourage people to test it in a practical way, so that future refinements could be informed by evidence rather than just opinion. Coming from an initiative that saw ecosystem accounting as 'experimental' meant that it was accepted that ideas need to be tested and refined.

In terms of its application, CICES has been used as the basis of the German TEEB study (Naturkapital Deutschland – TEEB DE, 2014) as well as the German National Ecosystem Assessment, NEA-D (Albert et al., 2014). Elsewhere it has been refined at the most detailed class level to meet the requirements of ecosystem assessment in Belgium (Turkelboom et al., 2013). Saastamoinen et al. (2014) have used it to classify ecosystem services associated with the boreal forests of Finland. Accounting applications include those of Schröter et al. (2014). Elsewhere, CICES has been used to look at the basis for developing or comparing indicators of ecosystem service supply and demand; examples include the work of Castro et al. (2014), Kosenius et al. (2013) and von Haaren et al. (2014). And, in other work, Bürgi et al. (2015) have used CICES to examine how ecosystem service output has changed for a Swiss landscape since about 1900; the classification framework was used to code the reports from achieve sources about whether things that we would now regard as ecosystem services were documented as important in past periods. However, while these applications of CICES suggest that the current framework is appropriate for many uses, it is clear from the work of Armstrong et al. (2012), and Liquete et al. (2013b), for example, that it may need to be adapted to ensure that it is suitable for the assessment of marine and coastal ecosystems, or integrated more closely with typologies for describing underlying ecosystem function. The recent development of the FEGS system by the US-EPA (see Landers et al., 2016) also suggests that there may be some scope to look at the way services, benefits and beneficiaries are aligned in different classification systems so that a more complete picture of the service cascade can be established.

Conclusion

Although the idea of ecosystem services is simple in concept, its application in management and policy is complex. If we are to deliver the practical benefits of managing natural capital in ways that can help sustain human well-being, it is clear that to overcome some of these challenges we need to find a means of describing and measuring ecosystems and their services consistently. Thus a discussion of how to define and classify services is not simply an academic matter, but rather central to any efforts to operationalise the ecosystem service paradigm. A critical discussion of the cascade model and the attempts to develop a Common International Classification for Ecosystem Services (CICES) is, we suggest, an important part of this evolutionary process.

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Notes

1 www.cices.eu
2 A simple tool for helping people make the translation is available at: http://openness.hugin.com/example/cices

References

Abson, D.J., von Wehrden, H., Baumgärtner, S., et al. (11 authors) (2014). Ecosystem services as a boundary object for sustainability. *Ecological Economics*, vol 103, pp 29–37.

Albert, C., Neßhöver, C., Wittmer, H., Hinzmann, M., and Görg, C. (2014). Sondierungsstudie für ein Nationales Assessment von Ökosystemen und ihren Leistungen für Wirtschaft und Gesellschaft in Deutschland. Helmholtz-Zentrum für Umweltforschung – UFZ, unter Mitarbeit von K. Grunewald und O. Bastian (IÖR), Leipzig.

Armstrong, C.W., Foley, N.S., Tinch, R., and van den Hove, S. (2012). Services from the deep: steps towards valuation of deep sea goods and services. *Ecosystem Services*, vol 2, pp 2–13.

Boyd, J., and Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, vol 63, no 2, pp 616–626.

Buchel, S., and Frantzeskaki, N. (2015). Citizens' voice: a case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands. *Ecosystem Services*. Available online since January 2015, doi:10.1016/j.ecoser.2014.11.014

Bürgi, M., Silbernagel, J., Wu, J., and Kienast, F. (2015). Linking ecosystem services with landscape history. *Landscape Ecology*, vol 30, no 1, pp 11–20.

Busch, M., La Notte, A., Laporte, V., and Erhard, M. (2012). Potentials of quantitative and qualitative approaches to assessing ecosystem services. *Ecological Indicators*, vol 21, pp 89–103.

Castro, A.J., Verburg, P.H., Martín-López, B., et al. (7 authors) (2014). Ecosystem service trade-offs from supply to social demand: a landscape-scale spatial analysis. *Landscape and Urban Planning*, vol 132, pp 102–110.

Chan, K.M., Satterfield, T., and Goldstein, J. (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics*, vol 74, pp 8–18.

Chapman, S. (2014). A framework for monitoring social process and outcomes in environmental programs. *Evaluation and Program Planning*, vol 47, pp 45–53.

Church, A., Fish, R., Haines-Young, R., et al. (15 authors) (2014). *UK National Ecosystem Assessment Follow-on. Work Package Report 5: Cultural Ecosystem Services and Indicators*. UNEP-WCMC, LWEC. Available at: http://uknea.unep-wcmc.org/Resources/

Cordier, M., Agúndez, J.A.P., Hecq, W., and Hamaide, B. (2014). A guiding framework for ecosystem services monetization in ecological–economic modeling. *Ecosystem Services*, vol 8, pp 86–96.

Costanza, R. (2008). Ecosystem services: multiple classification systems are needed. *Biological Conservation*, vol 141, no 2, pp 350–352.

Crossman, N.D., Burkhard, B., Nedkov, S., et al. (14 authors) (2013). A blueprint for mapping and modelling ecosystem services. *Ecosystem Services*, vol 4, pp 4–14.

de Groot, R.D., Fisher, B., Christie, M., Aronson, J., Braat, L., Haines-Young, R., et al. (12 authors). (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In Kumar, P. (ed.) *The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations*. Earthscan, London and Washington DC.

Fisher, B., and Turner, R.K. (2008). Ecosystem services: classification for valuation. *Biological Conservation*, vol 141, no 5, pp 1167–1169.

Fisher, B., Turner, R. K., and Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, vol 68, no 3, pp 643–653.

Geijzendorffer, I.R., Martín-López, B., and Roche, P.K. (2015). Improving the identification of mismatches in ecosystem services assessments. *Ecological Indicators*, vol 52, pp 320–331.

Haines-Young, R. and Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D.G and Frid, C.L.J. (eds) *Ecosystem Ecology: A New Synthesis*. Cambridge University Press, Cambridge, pp 110–139.

Haines-Young, R., and M. Potschin (2013). *Common International Classification of Ecosystem Services (CICES)*, Version 4.3. Report to the European Environment Agency. Available at: www.cices.eu

Hansen, R., and Pauleit, S. (2014). From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *Ambio*, vol 43, no 4, pp 516–529.

Hering, D., Carvalho, L., Argillier, C., et al. (20 authors) (2015). Managing aquatic ecosystems and water resources under multiple stress – an introduction to the MARS project. *Science of The Total Environment*, vol 503, pp 10–21.

Honrado, J.P., Vieira, C., Soares, C., et al. (7 authors) (2013). Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. *Environmental Impact Assessment Review*, vol 40, pp 14–24.

Huang, J., Tichit, M., Poulot, M., et al. (6 authors) (2015). Comparative review of multifunctionality and ecosystem services in sustainable agriculture. *Journal of Environmental Management*, vol 149, pp 138–147.

Jax, K. (2016). Ecosystem functions: a critical perspective. In Potschin, M., Haines-Young, R., Fish, R., and Turner, R. K. (eds) *Routledge Handbook of Ecosystem Services*. Routledge, London and New York, pp 42–44.

Kosenius, A.K., Haltia, E., Horne, P., Kniivilä, M., and Saastamoinen, O. (2013). *Value of ecosystem services? Examples and experiences on forests, peatlands, agricultural lands, and freshwaters in Finland*. PTT Working Papers 244. Pellervo Economic Research, Helsinki.

Kronenberg, J. (2014). What can the current debate on ecosystem services learn from the past? Lessons from economic ornithology. *Geoforum*, vol 55, pp 164–177.

La Notte, A., Maes, J., Thieu, V., Bouraoui, F., and Masi, F. (2012). Biophysical Assessment and Monetary Valuation of Ecosystem Services. JRC Science and Policy Reports, Publications Office of the European Union.

Lamarque, P., Quétier, F., and Lavorel, S. (2011). The diversity of the ecosystem services concept and its implications for their assessment and management. *Comptes Rendus Biologies*, vol 334, no 5, pp 441–449.

Landers, D., Nahil, M., and Rhodes, C. R. (2016). The beneficiary perspective – benefits and beyond. In Potschin, M., Haines-Young, R., Fish, R., and Turner, R. K. (eds) *Routledge Handbook of Ecosystem Services*. Routledge, London and New York, pp 74–87.

Landuyt, D., Broekx, S., D'hondt, R., et al. (6 authors) (2013). A review of Bayesian belief networks in ecosystem service modelling. *Environmental Modelling & Software*, vol 46, pp 1–11.

Large, A.R.G., and Gilvear, D.J. (2014). Using Google Earth, a virtual-globe imaging platform, for ecosystem services-based river assessment. *River Research and Applications*. doi: 10.1002/rra.2798

Liquete, C., Maes, J., La Notte, A., and Bidoglio, G. (2011). Securing water as a resource for society: an ecosystem services perspective. *Ecohydrology & Hydrobiology*, vol 11, no 3, pp 247–259.

Liquete, C., Zulian, G., Delgado, I., Stips, A., and Maes, J. (2013a). Assessment of coastal protection as an ecosystem service in Europe. *Ecological Indicators*, vol 30, pp 205–217.

Liquete, C., Piroddi, C., Drakou, E.G., et al. (7 authors) (2013b). Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. *PLoS One*, vol 8, no 7, e67737.

MA (2005). *Ecosystems and Human Well-being: Current State and Trends*. Island Press, Washington, DC.

Mace, G. (2016). Ecosystem services: where is the discipline heading? In Potschin, M., Haines-Young, R., Fish, R. and Turner, R. K. (eds) *Routledge Handbook of Ecosystem Services*. Routledge, London and New York, pp 602–605.

Mace, G., Bateman, I., Albon, S., et al. (11 authors) (2011). Conceptual framework and methodology. In *The UK National Ecosystem Assessment Technical Report*. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Mace, G.M., Norris, K., and Fitter, A.H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology & Evolution*, vol 27, no 1, pp 19–26.

Maes, J., Egoh, B., Willemen, L., et al. (14 authors) (2012a). Mapping ecosystem services for policy support and decision making in the European Union. *Ecosystem Services*, vol 1, no 1, pp 31–39.

Maes, J., Paracchini, M.L., Zulian, G., Dunbar, M.B., and Alkemade, R. (2012b). Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. *Biological Conservation*, vol 155, pp 1–12.

Maes, J., Hauck, J., Paracchini, M.L., et al. (10 authors) (2013). Mainstreaming ecosystem services into EU policy. *Current Opinion in Environmental Sustainability*, vol 5, no 1, pp 128–134.

Maes, J., Teller, A., Erhard, M., et al. (45 authors) (2014). *Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy 2020.* 2nd final report, European Union, February 2014.

Martín-López, B., Gómez-Baggethun, E., García-Llorente, M., and Montes, C. (2014). Trade-offs across value-domains in ecosystem services assessment. *Ecological Indicators*, vol 37, pp 220–228.

McVittie, A., Norton, L., Martin-Ortega, J., et al. (6 authors) (2015). Operationalizing an ecosystem services-based approach using Bayesian Belief Networks: an application to riparian buffer strips. *Ecological Economics*, vol 110, pp 15–27.

Müller, M., Burkhard, B., Hou, Y., et al. (6 authors) (2016). Indicators for ecosystem services. In Potschin, M., Haines-Young, R., Fish, R., and Turner, R. K. (eds) *Routledge Handbook of Ecosystem Services*. Routledge, London and New York, pp 157–169.

Naturkapital Deutschland – TEEB DE (2014). *Naturkapital und Klimapolitik – Synergien and Konflikte. Langfassung. Technische Universität Berlin, Helmholtz-Zentrum für Umweltforschung – UFZ, Leipzig.* Available at: www.naturkapital-teeb.de

Ojea, E., Martin-Ortega, J., and Chiabai, A. (2012). Defining and classifying ecosystem services for economic valuation: the case of forest water services. *Environmental Science & Policy*, vol 19, pp 1–15.

Pagella, T.F., and Sinclair, F.L. (2014). Development and use of a typology of mapping tools to assess their fitness for supporting management of ecosystem service provision. *Landscape Ecology*, vol 29, no 3, pp 383–399.

Plant, R., and Prior, T. (2014). An ecosystem services framework to support statutory water allocation planning in Australia. *International Journal of River Basin Management*, vol 12, no 3, pp 219–230.

Portman, M.E. (2013). Ecosystem services in practice: challenges to real world implementation of ecosystem services across multiple landscapes – a critical review. *Applied Geography*, no 45, pp 185–192.

Potschin, M., and Haines-Young, R. (2011). Ecosystem services: exploring a geographical perspective. *Progress in Physical Geography*, vol 35, no 5, pp 575–594.

Ratamäki, O., Jokinen, P., Sørensen, P.B., Breeze, T., and Potts, S. (2015). A multilevel analysis on pollination-related policies. *Ecosystem Services*, online.

Saastamoinen, O., Matero, J., Horne, P. et al. (7 authors) (2014). Classification of boreal forest ecosystem goods and services in Finland. Publications of the University of Eastern Finland. *Reports and Studies in Forestry and Natural Sciences* Number 11, University of Eastern Finland, Faculty of Science and Forestry, School of Forest Sciences.

Schröter, M., Barton, D.N., Remme, R.P., and Hein, L. (2014). Accounting for capacity and flow of ecosystem services: a conceptual model and a case study for Telemark, Norway. *Ecological Indicators*, vol 36, pp 539–551.

Spangenberg, J.H., von Haaren, C., and Settele, J. (2014). The ecosystem service cascade: further developing the metaphor. Integrating societal processes to accommodate social processes and planning, and the case of bioenergy. *Ecological Economics*, vol 104, pp 22–32.

Spangenberg, J.H., Görg, C., Truong, D.T., et al. (6 authors) (2015). Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. *International Journal of Biodiversity Science, Ecosystem Services & Management*, vol 10, no 1, pp 40–53.

Staub, C., Ott, W., Heusi, F. et al. (12 authors) (2011). *Indicators for Ecosystem Goods and Services: Framework, methodology and recommendations for a welfare-related environmental reporting*. Federal Office for the Environment, Bern. Environmental studies no. 1102: 17 S.

Tratalos, J. A., Haines-Young, R., Potschin, M., Fish, R., and Church, A. (2015). Cultural ecosystem services in the UK: lessons on designing indicators to inform management and policy. *Ecological Indicators* (in press).

Turkelboom, F., Raquez, P., Dufrêne, M., et al. (19 authors) (2013). CICES going local: ecosystem services classification adapted for a highly populated country. In Jacobs, S., Dendoonker, N., and Keune, H. (eds) *Ecosystem Services*. Chicago.

van Oudenhoven, A.P.E., Petz, K., Alkemade, R., Hein, L., and de Groot, R. S. (2012). Framework for systematic indicator selection to assess effects of land management on ecosystem services. *Ecological Indicators*, vol 21, pp 110–122.

van Zanten, B.T., Verburg, P.H., Espinosa, M., et al. (15 authors) (2014). European agricultural landscapes, common agricultural policy and ecosystem services: a review. *Agronomy for Sustainable Development*, vol 34, no 2, pp 309–325.

Vihervaara, P., D'Amato, D., Forsius, M., et al. (18 authors) (2013). Using long-term ecosystem service and biodiversity data to study the impacts and adaptation options in response to climate change: insights from the global ILTER sites network. *Current Opinion in Environmental Sustainability*, vol 5, no 1, pp 53–66.

von Haaren, C., Albert, C., Barkmann, J., de Groot, R.S., Spangenberg, J.H., Schröter-Schlaack, C., and Hansjürgens, B. (2014). From explanation to application: introducing a practice-oriented ecosystem services evaluation (PRESET) model adapted to the context of landscape planning and management. *Landscape Ecology*, vol 29, no 8, pp 1335–1346.

Wallace, K.J. (2007). Classification of ecosystem services: problems and solutions. *Biological Conservation*, vol 139, no 3, pp 235–246.

Wong, C.P., Jiang, B., Kinzig, A.P., Lee, K.N., and Ouyang, Z. (2015). Linking ecosystem characteristics to final ecosystem services for public policy. *Ecology Letters*, vol 18, no 1, pp 108–118.

Zhang, Y., Wang, R., Kaplan, D., and Liu, J. (2015). Which components of plant diversity are most correlated with ecosystem properties? A case study in a restored wetland in northern China. *Ecological Indicators*, vol 49, pp 228–236.

Briefing Note 3.1 Ecosystem functions: a critical perspective

Kurt Jax

Different meanings of "function" in an ecosystem services context

The term "function" is used in different ways within the environmental sciences literature (see Jax 2005 for details). In an ecosystem services context, "ecosystem function" is frequently part of the frameworks used to describe the relationships between ecosystems, human benefits and well-being, e.g. the "cascade model" (Figure 3.1). Here it is usually situated on the "supply side" of the scheme and forms part of the biophysical part of the framework. In these frameworks the notion of function is used in two major meanings. First, as denoting ecosystem processes that give rise to specific services, and second, the capacity (or potential) of ecosystems to provide services to humans.

The first meaning corresponds to that used in the Millennium Ecosystem Assessment (MA, 2005, p. 895) and e.g. by Wallace (2007), or Luck et al. (2009). Luck et al. (2009, p. 249), for example, state: "Ecosystem process: Synonymous with ecosystem function. The interactions among biotic and abiotic elements of ecosystems that lead to a certain result." Other authors, however, understand ecosystem function in terms of a capability: "[W]e explicitly define ecosystem functions as 'the capacity of natural processes and components to provide goods and services that satisfy human needs [. . .]'" (de Groot et al., 2002, p. 394). In the TEEB report, "ecosystem function" is characterised as "the subset of the interactions between biophysical structures, biodiversity and ecosystem processes that underpin the capacity of an ecosystem to provide ecosystem services" (Kumar, 2010, p. xxxiii), i.e. not as the capacity itself but as something that underpins the capacity. In the graph within the same report (de Groot et al., 2010, p. 17), it even refers to "the subset of biophysical structure or process providing the service", thus not referring to a capacity any more at all. Potschin and Haines Young (2011, p. 578) take up the original definition by de Groot and state: "'[F]unction' is being used [. . .] to indicate some capacity or capability of the ecosystem to do something that is potentially useful to people." In all these latter definitions, "functions" already include a normative dimension, i.e. ecosystem functions have a specific purpose, involving the identification of nature's benefits for humans, and ultimately human well-being. Likewise, Bastian et al. (2012, p. 9), emphasise a traditional meaning of "functions" as "tasks which an area [or ecosystem] is to fulfil" for humans, i.e. as "purposes".

A critical evaluation of the concept in an ecosystem services context

As above described, different ideas on what "ecosystem function" means exist. Based on the analysis above, the main meanings of "ecosystem function(s)" found in the literature are:

- (any) ecosystem processes (and other ecosystem properties) (merely descriptive);
- selected processes (and other ecosystem properties) underpin ecosystem services;
- selected processes (and other ecosystem properties) that are ecosystem services;
- capacities/potentials of an ecosystem to provide ecosystem services;
- selected processes (and other ecosystem properties) that underpin the capacities/potentials to provide ecosystem services;
- the "tasks" of ecosystems for the benefits of humans.

One problem that obviously arises from this diversity of meanings is the danger of terminological confusion. The same word ("ecosystem functions") signifies different things. If the specific meaning is not explained or becomes clear from the context, this can (and does) lead to confusion and communication problems.

A second problem for some definitions of "ecosystem function(s)" is how to operationalise the concept, especially when understanding ecosystem function as denoting capacities to provide ecosystem services. While the idea of separating the potential of delivering ecosystem services from its actual delivery is very useful and practically relevant, hardly any of the papers referring to ecosystem functions as a capacity explain in some more detail what is meant by "capacity" or "potential" and how it might be operationalised (but see e.g. Schröter et al., 2014).

Describing ecosystem functions in the sense of ecosystem processes (and sometimes other ecosystem attributes) is, in contrast, quite straightforward and close to the everyday work of ecologists. The degree to which the concepts used must be operationisable depends on the specific task at hand. It might not be necessary when the ecosystem services concept is just used for didactic purposes (e.g. as arguing for the usefulness of nature), but will certainly be needed for quantitative ecosystem services assessments.

Conclusions

Given the high ambiguity of the term "ecosystem function(s)" in an ecosystem services context, the term should be either defined explicitly and then used consistently (!) or be avoided entirely. Examples of ecosystem services frameworks which, for the sake of clarity, explicitly avoid the term as denoting one of their basic concepts are those of Wallace (2007), Bastian et al. (2012), and Schröter et al. (2014).

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References

Bastian, O., Haase, D., and Grunewald, K. (2012). Ecosystem properties, potentials and services – The EPPS conceptual framework and an urban application example. *Ecological Indicators*, vol 21, pp 7–16.

de Groot, R.S., Wilson, M.A., and Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, vol 41, pp 393–408.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., and Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, vol 7, pp 260–272.

Jax, K. (2005). Function and "functioning" in ecology? What does it mean? *Oikos*, vol 111, pp 641–648.

Kumar, P. (ed.) (2010). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Earthscan, London and Washington DC.

Luck, G.W., Harrington, R., Harrison, P., Kremen, C., Berry, P. M., Bugter, R., Dawson, T.P., de Bello, F., Diaz, 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*, vol 59, pp 223–235.

MA (2005). *Ecosystems and Human Well-being: Synthesis*, Island Press, Washington DC.

Potschin, M.B., and Haines-Young, R.H. (2011). Ecosystem services: exploring a geographical perspective. *Progress in Physical Geography*, vol 35, pp 575–594.

Schröter, M., Barton, D.N., Remme, R.P., and Hein, L. (2014). Accounting for capacity and flow of ecosystem services: a conceptual model and a case study for Telemark, Norway. *Ecological Indicators*, vol 36, pp 539–551.

Wallace, K.J. (2007). Classification of ecosystem services: problems and solutions. *Biological Conservation*, vol 139, pp 235–246.