Intermediate Ecosystem Services: An Empty Concept?

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The term 'intermediate ecosystem service' is widely used in the literature as a way of indicating specific ecological characteristics that in one way or another underpin the output of a 'final' ecosystem service. Such usage is consistent with some widely-used definitions of what ecosystem services are, including, for example, that of *The Economics of Ecosystem and Biodiversity* (TEEB)[1], which suggests that these are features of nature that contribute to human well-being and hence are valued by humans. However, what constitutes a final service is context specific (Fisher et al., 2009). In this note we consider whether the concept of intermediate ecosystem services continues to be useful in describing the phenomena that underpin ecosystem services, and suggest that it is not. Instead, we highlight an alternative perspective and terminology that is now evident in the literature.

By way of illustrating the notion of an intermediate service, a classic example is provided by Boyd and Banzaf (2007). They cite the case of the quality of a water body, which could be regarded as a direct, final service if the water is used as drinking water. However, from the perspective of recreational angling, clean water is an 'intermediate' component that contributes to this benefit through the final service of a 'fish stock' that more directly supports the activity of fishing. That ecosystem services are underpinned by a number of ecological components is not in dispute here. Rather, the issue concerns the difficulty of using the concept of intermediate services in an ecologically meaningful way. We suggest the term has perhaps more to do with economists deciding what to include or exclude from valuations and to avoid the problem of 'double counting' in valuation than of describing the ecological phenomena that underlie the generation of ecosystem services (La Notte et al 2017; Johnston and Russell, 2011).

Whether ecosystem services have an underpinning or final role is clearly context dependent (e.g. Boyd and Banzaf's example above). This is also the position put by Fisher et al., (2009) and adopted, for example, by Saarikoski et al. (2015). Further, the problem is not simply one of re-labelling the same phenomena, because the specifics of the ecological phenomena apparently covered by the term may change depending on whether they have an intermediate or final role. In the case of water quality, for example, the physical and chemical characteristics of the water body that makes it suitable for drinking purposes are not necessary the same as those that contribute to the benefit of angling. To say that we are somehow looking at the 'same thing' in a different context (as in Figures

[1] http://www.teebweb.org/resources/glossary-of-terms/

2-5 of Saarikoski et al., 2015, for example) seems to obfuscate our understanding of the biophysical conditions necessary for different kinds of services.

The importance of making a distinction between a 'final' service and what underpins it ecologically is illustrated by the way Saarikoski et al. (2015), for example, conceptualise pollination. In boreal forests, 'berries' (lingonberries and blueberries) are regarded as a final service, and pollination one of the ecological factors that contribute to their output. While Boyd and Banzaf (2007) argue that pollination is an ecosystem function, Saarikoski et al. (2015) prefer to refer to it as an intermediate service because terms such as 'process' or 'function' may be 'confusing to wider audiences' (Saarikoski et al. 2015, p 154). However, such a position seems at the same time to undermine the goal of 'analytical clarity' which these authors also champion; as Danley and Willmark (2016) argue, ambiguity around the notion of ecosystem services is not necessarily a virtue. In fact, pollination can in some contexts be legitimately regarded as a final service, as in the case of understanding the factors responsible for the 'yield gap' that arises from pollinator deficiency in types of small holder agriculture found in developing countries (Garibaldi et al. 2016). Here the final service (i.e. the contribution that pollinators make to human well-being) is represented by the *difference* in yield that the availability of pollinators make to final output. Thus, the status of pollination as an ecosystem function or a final service depends critically on one's analytical perspective. If berries are the things that are being valued then pollination is wrapped up with all the other contributions that nature makes to their production in the final estimate; if we are interested in the value of pollinators, then it is the marginal difference to yield they make which is 'final service'. This would apply whether we are dealing with small holder agriculture or boreal forests. As Schröter et al. (2012) have argued the 'last contribution' of an ecosystem might be an appropriate way of identifying an ecosystem service – but this clearly depends on what specific outputs are being considered.

The need to understand the particular ecological capacities that give rise to a final service, and how variations in these capacities affect the level of service output, can be captured in the notion of an 'ecological function' in the cascade model (Potschin and Haines-Young, 2016). While the concept of an ecological function has been challenged because of the different meaning associated with the term (e.g., Fisher et al., 2009; Jax, 2005, 2016; Wallace, 2007), it does at least have the merit of encouraging the identification of the *pre-conditions* required for a service (or a set of services) to be generated. Jax and Wallace both feel that the term 'function' is unnecessary, and that we simply need to understand the ecological structures and processes that characterise a given ecosystem. Whatever set of labels is used, however, we would argue that it is helpful to identify the sets of ecological components and their associated states that are critically associated with particular services because we might then be better placed both to manage them and understand how synergies and trade-offs arise within bundles of services.

It is also important practically to distinguish between these critical functional characteristics and the more general ecological structures and processes that give rise to them. Consider, for example, the case of woodlands. The ecological characteristics that determine the capacity of a forest stand used for timber are not necessarily the same as those that affect its suitability for the regulation of mass movements or its use as a cultural setting for recreation. Examples that illustrate such contrasts in functional properties include the biomechanical properties of trees (Price, 2015) and the characteristics of forest stands that afford protection against snow avalanche (Bebi et al. 2009). None of these tree or forest properties identified in these cases are 'services' in the sense implied by the notion of ‘intermediate services’, nor are they some general set of ecological structures and processes associated with a particular ecosystem, as implied by the more general notion of ‘supporting services’. Rather, we suggest that to understand how services arise, it is useful to distinguish between what determines these capacities as clearly as we can, and that the notion of an ‘ecological function’ is helpful in this respect. The richness of the literature on functional traits and the insights it provides on the capacities of ecosystems to generate different ecosystem services (e.g., de Bello et al., 2010; Lamarque et al., 2014; Lavorel et al., 2011) further illustrates the need to be clear about what constitutes these ‘underpinning’ elements. The analysis of Díaz et al. (2013) provides a number of examples of the way various species traits underpin different specific functions that influence specific ecosystem properties and their associated benefits to people.

The identification of the functional traits of species that underlie or determine specific ecosystem properties is an important avenue for understanding how (final) ecosystem services are generated, and is obscured by labelling them intermediate services. Since the identification of such traits depends on the utility of those properties for people, rather than whether they necessarily represent an adaptive advantage to the species (cf. Diaz et al. 2013), we suggest that more emphasis should be placed on species traits in the broader set of ecological structures and processes that can characterise an ecosystem. Indeed, the identification of such properties can have considerable practical importance, including, for example: understanding how different plant root traits can contribute to protecting natural and engineered slopes against landslides (Stokes, 2009); or, how specific functions of forest ecosystems can help identify strategies for socio-economic and environmental sustainability (Rusch et al. 2017). We suggest, that the idea of ecosystem function rather than of intermediate services is a less ambiguous way of exposing the factors that determine the capacity of ecosystems to generate ecosystem services (cf. Villamagna et al., 2013).

The science of ecosystem services is clearly more than an argument about definitions and terms. Labels are, however, important insofar as they help us distinguish things in ways that provide insights into the mechanisms that underpin ecosystem services. They are also important to consider in situations where different disciplines come together – because they might denote quite different ideas. In the case of ecosystem accounting, for example, ‘intermediate ecosystem services’ specifically denote the flows *between ecosystem assets*, that is when the outputs of one ecosystem accounting unit is an input to another (UNSD, 2017). The analogy here is with the intermediate production of goods and services as part of a supply chain in the economy as opposed to those consumed or enjoyed by people or households. The ecological equivalent might be the example of migratory species which breeds in one ecosystem but provides a cultural service elsewhere (cf. Semmens et al., 2011); in accounting terms pollinators could also be seen as providing ‘intermediate ecosystem services’ if they move between ecosystems, as in the case of the habitat provided by semi-natural grasslands to insects that pollinate crops. However, in the accounting context, the term does not include the underpinning elements *within* an ecosystem, which is related to the ideas of ecosystem ‘capacity’ or ‘condition’, and which refer to the various structures processes that determine the ability of an ecosystem to generate services (European Commission, 2016).

Although the concept of ecosystem condition and how to measure it is still an active area of debate, the focus of thinking is sufficiently well aligned with ideas about the functional characteristics that underpin ecosystem services to suggest that they are largely congruent. The term ‘condition’ could be used to refer to general descriptors of the status of an ecosystem (e.g. vegetation cover and stratification, functional diversity), whereas ‘capacity’ measures are used more specifically to denote the functional characteristics of the system that underpins a particular ecosystem service using our notion of ecosystem function (e.g. organic matter mineralization and nutrient uptake, soil binding and sediment capture). The lesson we therefore draw from current general usage is intermediate ecosystem services tend to obscure rather than clarify issues about the capacities and preconditions necessary for service output. We suggest, therefore, that it is best avoided– or at least used in a more qualified and specific way as in the case of intermediate services in accounting. In a strict sense, all ecosystem services are final – otherwise they would not be a service – and the notions of an intermediate service is simply misnomer.

As the field of ecosystem services enters a mature phase where applications need to be rigorously grounded on evidence, it is important that we are precise about what we measure and how those metrics inform our understanding of the ways ecosystem services are generated and sustained. As we test and hone our concepts, the community moves to explaining what aspects of the ecosystem service paradigm "are novel and what aspects are well established in research and policy" (cf. Danley and Widmark, 2016, p. 132).

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