Title: **The problem of intermediate services and the case for abandoning the concept**

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The problem of intermediate services and the case for abandoning the concept

A comment on the paper by Saarikoski et al. (2015): Exploring operational ecosystem service definitions: The case of boreal forests. *Ecosystem Services 14:* 144-157.

By

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The terms 'intermediate' and 'supporting' services are widely used in the literature as ways of indicating specific ecological characteristics or behaviours that somehow 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 MA (2005), which conceptualizes supporting ecosystem services as underlying the generation of all other kinds of ecosystem services, and that of TEEB (De Groot et al. 2010), which regards them as the *direct* and *indirect* contributions that ecosystems make to human well-being. In these cases, the ideas of 'intermediate' and 'supporting' services represent indirect contributions. The distinction has been further emphasized in the context of ecosystem services accounting in which 'double-counting' has been an issue of concern, but also for ecosystem services analysis. Saarikoski et al. (2015) state that "*the MA categories of ecosystem services are not operable as such because they do not distinguish between intermediate ecosystem processes and the services that are directly consumed or enjoyed by people*".

We argue that this distinction is often difficult to make because that what constitutes a final service is context specific. For instance, Saarikoski et al. (2015) consider 'wild berries' as a final ecosystem service underlying recreational activities and generating various kinds of immaterial experiences with nature, and 'game' fulfils a similar function. However, wild berries are also consumed by game species. In this context, wild berries are both an intermediate and a final service. Boyd and Banzaf (2007) gave the example of the quality of a water body raising a similar argument. Water purification could be regarded as a direct, final service if the use is drinking water. However, from the perspective of the recreational angling, water purification is an intermediate component that affects, for instance, the recruitment of fish populations that more directly contribute to 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 concepts of intermediate and supporting services analytically. For example, although Saarikoski et al. (2015) do not explicitly refer to supporting services, they distinguish between 'processes' (photosynthesis, nutrient cycling) and 'intermediate services' (biomass production), without specifying what makes something a 'process' rather than an 'intermediate service', and since both make 'indirect' contributions it is difficult to make a distinction. Moreover, since all ecological structures associated with a particular ecosystem can probably be said to contribute to one or more services 'indirectly', there seems to be no more that catch-all terms for the characteristics and behaviours associated with a particular ecological situation. Thus, one may ask what characteristics and behaviours of ecosystems are not covered by the terms 'processes', 'supporting' and 'intermediate' services?

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In terms of defining 'intermediate' services more tightly, it could be argued that these are ecological features and functions that can either have a final or underpinning role, depending on the circumstances. However, the problem here is not simply one of labelling: it should be recognised that the specifics of the ecological phenomena that are apparently covered by the same term are in fact different, depending on whether they have an 'intermediate' or 'final' role. For example in the case of water quality, 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. Looking at the 'same thing' in different value contexts seems to obfuscate our understanding of the biophysical conditions necessary for different kinds of service.

To address the need of understanding the particular ecological capacities that give rise to a final service, and in order to understand how variations in these capacities affect the level of service output, the cascade model proposed (following others) the notion of 'ecological functions' (Potschin and Haines-Young, 2016). While this concept has itself been challenged because of the different meaning associated with the term 'function' (e.g., Jax, 2016; Wallace, 2007), it does at least have the merit of encouraging people to identify the pre-conditions required for one or more services to be generated. The concept is also a widely employed to refer to dynamic features that encapsulate various ecological processes at various levels. However, while Jax and Wallace both feel that the term is unnecessary, and that we simply need to understand the ecological structures and processes that characterise a given ecosystem, we argue that it has considerable merit. The concept can help communicate the collective outcome of many processes acting at multiple spatial and temporal scales, which may be either impossible or irrelevant to identify and quantify in a specific assessment context. Whatever set of labels is used we would argue that it is important to identify the sets of ecological components and processes that are associated with particular services because we are then better placed both to manage them and to understand how synergies and trade-offs arise within bundles of services.

In terms of the cascade model we therefore suggest that it is useful to distinguish more general ecological structures and processes from specific functional characteristics underpinning the generation of ecosystem services. We do so because it is evident that over space and time, ecological structures and processes can vary and change the capacity of ecosystems to generate services. Moreover, management interventions can manipulate these structures and processes and so can also change that capacity. Consider, for example, the case of forest. The ecological characteristics that determine the capacity of a forest stand that is 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. None of these characteristics 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 notion of 'processes' or 'supporting services'. The characteristics are specific and contingent on the service being considered.

We suggest that to understand how services arise, then it is useful to distinguish what determines these capacities as clearly as we can and that the notion of an 'ecological function' is helpful in this respect. In practical assessments it makes sense to map and assess these key functional characteristics that influence the supply of a high number of ecosystem services. Indeed the importance of understanding these characteristics is now recognised in work aimed at assessing 'ecosystem condition' in contemporary assessment guidance and practice (e.g. Maes et al., 2016).

The richness of the literature on functional traits and the insights it provides on the capacities of ecosystems to generate different services (e.g., de Bello et al., 2010; Lamarque et al., 2014; Lavorel et al., 2011) provides a good basis for operationalizing these 'underpinning' elements through this concept of ecosystem condition.

The science of ecosystem services is clearly more than an argument about definitions and terms. Labels are important only insofar as they help us distinguish things in ways that provide insights into the mechanisms that underpin ecosystem services. Terms such as 'intermediate' and 'supporting' services tend to obscure rather than clarify issues about the capacities and preconditions necessary for service output, and should, we suggest, be avoided. A clearer focus at final services and ecosystem condition instead can help to us better structure and operationalize our scientific understanding of ecosystem services for policies and decision support.

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