Link between Biodiversity and Ecosystem Services

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Introduction and 'State-of-the-art'

As was stated in the OpenNESS proposal, the quantitative relationship between biodiversity, ecosystem functioning and ecosystem services is still poorly understood. In recent years, many publications have appeared on this topic (e.g. Elmqvist et al., 2010, Mace et al., 2012) and EU-funded projects such as RUBICODE (www.rubicode.net) addressed this issue, but many questions remain. There is also an on-going discussion as to whether biodiversity is (or should be understood as) an ecosystem service itself (e.g. Mace et al., 2012)[1]. Especially the latter question hints at the important point that the link between biodiversity and ecosystem services is not just a matter of biophysical relations, but also one related to value dimensions and different emphasis of conservation strategies. It is still unclear under what circumstances an emphasis on ecosystem services in planning and decision making is (conceptually and practically) supportive of the protection of biodiversity, or when the two aims might be conflicting. Other conceptual issues are briefly highlighted under the paragraph on "problems" below. Regarding the operational, or practical, aspects, several studies and meta-analyses have furthered knowledge on the role of biodiversity in ecosystem functioning and the supply of ecosystem services (Balvanera et al., 2006; Luck et al., 2009; Bastian, 2013). However, the complexity of ecosystem functioning still poses uncertainties about the role of individual species and other components of biodiversity in the supply of ecosystem services, specifically when coupled with social-ecological systems. Two main areas of research have helped contribute to current knowledge on biodiversity – ES-linkages: (i) trait-based approaches, and (ii) the identification of ecosystem service providers or service providing units.

Trait-based approaches

Given their effects on underlying ecosystem services, several studies have used information on functional traits to quantify ecosystem service delivery (Kremen, 2005; De Bello et al. 2010; Díaz et al., 2011). These approaches may also aid in the understanding of mechanisms of multi-functionality and trade-offs. Although knowledge on associations and trade-offs between plant traits is well established, the study of the consequences of these on ecosystem functioning and the resulting services has only just begun (Lavorel and Grigulis, 2012). De Bello et al. (2010) suggested that the multiple associations between traits and services across different trophic levels result in what they call ***trait-service clusters***. Their review groups well-documented trait-service associations into clusters of ecologically-related services, such as clusters of traits of plants and soil organisms associated with nutrient cycling, herbivory, and fodder and fibre production. They propose that this approach will allow for the assessment of combined biotic effects on the simultaneous delivery of multiple services. Trait-service clusters would potentially serve to manage trade-offs of services associated with traits within a trophic level. For example, the same traits in plant communities that improve fodder production are likely to reduce soil carbon sequestration and might impede services associated with aesthetic and cultural values (De Bello et al., 2010). The approach can also be extended to multiple trophic levels (Lavorel and Grigulis, 2012), as well as facilitating the monitoring of clusters of services at different spatial scales. Until recently, most of the trait-based research has focused on plant trait effects on primary production (Lavorel, 2013). There is a need to extend it to a wider range of ecosystems, services and organisms. An initial endeavour to do so by Luck et al. (2012) sought to develop a framework for selecting response and effect traits which link environmental change with ecosystem services that can be applied to vertebrates.

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[1] See last page of this short paper for definitions of these two key-terms. Further terms as defined/used in OpenNESS are provided in the OpenNESS Glossary (http://www.openness-project.eu/library/glossary).

Ecosystem Service Providers and Service Providing Units

Luck et al. (2003) has highlighted that species populations are the fundamental unit in the provision of ecosystem services and stress the need to understand the links between population dynamics and service output. They offer the concept of a Service Providing Unit (SPU) to define a population in terms of the services it generates at a particular scale instead of geographic boundaries or genetic lines. For example, the entire population of a given tree species might provide the global service of carbon sequestration, whilst regional populations of the same tree species might provide a water filtration service that benefits local communities (Luck et al., 2003). Kremen (2005) extended the SPU concept and proposed identifying key Ecosystem Service Providers (ESP) and suggested defining ESPs in terms of their functional traits and how the dynamics of functional groups of species may impact service provision. This was extended by Kremen et al. (2007) into a framework for understanding the impact of broad scale interactions between the distribution of resources, traits and land-use change on service delivery. The SPU and ESP concepts were combined by Luck et al. (2009) into the *SPU-ESP continuum* to show how the service-provider concept can be applied at the population, functional group and community levels. This produced a more nested approach to the understanding of service functions and processes and offered a detailed categorisation of outputs and their relationship to human well-being. By using examples from existing literature, they provided a classification specifying the type of ecosystems concerned, the ecological unit providing the service or SPU, its attributes and a response measure to describe the relationship between the components of biodiversity and the level of service provision.

The EU-funded BESAFE project (www.besafe-project.net) has built on both the trait-based and ESP/SPU approaches to identify ecosystem service providers and evidence of their key attributes or traits for service delivery for 11 ecosystem services. The resulting interconnections between biodiversity and ecosystem services have then been analysed using network analysis to explore the possibility of reducing the complexity by revealing different typologies of relationships. Another EU project (BioScore, www.bioscore.eu), has highlighted the potential use of trait databases for future impact assessments on ecosystem services through species impacts.

Problems / Issues to be addressed during lifetime of OpenNESS

1. How do ecosystem services depend on ‘biodiversity’ (species/ecosystems/genes)? Is there a ‘typology’ of these relationships (Mace et al., 2012)? This is a question of biophysical relations but also, and importantly, of conceptual clarity of the broad concepts of biodiversity and ecosystem services. Do our definitions of biodiversity capture the essence of the strategies aiming at biodiversity protection? What is the role of ‘ecosystem functions’ and functional traits in ecosystem service provision? Is the distinction between ‘final and intermediate ES’ useful? Is ‘human capital’ (i.e. human inputs) always needed to provide a service?

2. How can the relationship between biodiversity/ecosystem characteristics and their associated functions and services be quantified? What criteria and indicators are needed? Is it possible/useful to distinguish stock (=state) <-> flow (=performance) indicators? What is the effect of scale?

3. What is the carrying capacity of an ecosystem to provide services? Are there benchmark-values for measuring maximum sustainable use levels? Are there possible critical thresholds? What is role of (bio) ‘diversity’ (in terms of quantity)? Is the concept of Service Providing Unit (Luck et al., 2009) or Ecosystem Service Providers (Kremen et al., 2007) useful?

4. How to deal with ‘bundles’ of ecosystem services and aggregation of their benefits and values? Is the notion of ‘Natural Capital’ useful to emphasise the need to look at entire (eco)systems, not single services? How can trade-offs in time and space be modelled and mapped? (de Groot et al., 2010).

Significance to OpenNESS and specific Work Packages:

WP1/WP2: (Regulatory Frameworks): As the scope of regulatory frameworks needs to be clear, the conceptual relation between ES and BD has to be clarified to allow the impacts of measures on either of them to be assessed. This includes being clear about how “biodiversity” and “ecosystem services” are defined and classified.

WP3: (Biophysical control): The issue addressed by this Synthesis Paper is very closely related to the topic of WP3 and close collaboration between WP1 and WP3 is important to identify the main topics to be investigated in more detail. The review on Natural Capital-ES relationships in WP3 could provide guidance on key relationships that could be explored/measured in the case studies and other WPs.

WP4: Valuation should be based on sustainable use levels so the issue of (carrying) capacity of ecosystems to provide services, and issues of resilience and thresholds (both of ecosystems and of society and its resource use) should be taken into account in WP4. Possible divergences between the valuation of biodiversity and that of ecosystem services should be considered and discussed.

WP5: As mentioned above, there is still a lack of empirical data on the link between biodiversity and ecosystem services, as well as testing of concepts (e.g. SPU) and methods (mapping & modelling) so concerted application in the case studies is essential to operationalise the concepts of ecosystem services and natural capital in practice.

Relationship to four challenges

Human well-being: The relation between biodiversity and ecosystem services provides an understanding of how biodiversity contributes to human well-being (see Cascade model).	**Sustainable Ecosystem Management:** Information on the relationship between biodiversity and ecosystem services can help to determine carrying capacity and sustainable use levels, which is essential information for sustainable ecosystem management.
Governance: Awareness about the importance of biodiversity for the provision of ecosystem services is crucial for good governance (and vice-versa), and for encouraging integration of biodiversity conservation in sectoral policies.	**Competiveness:** Collection of new, empirical data and data-storage on the relation between BD and ES, and development and testing of methods to clarify if BD and ES evaluation are complementary or overlapping, gives competitive advantage to the partners and EU in the rapidly developing field of ecosystem service assessment. This information can help to improve the use of ES to highlight dependency of markets, and businesses, on biodiversity and make them aware that protecting biodiversity (and its supporting ecosystems) can give a competitive edge for European SMEs and companies as well as regions.

Recommendations to the OpenNESS consortium:

Agree early in the project on a common understanding ('language') regarding the main concepts, definitions and methods to be used. Two key concepts are Biodiversity and Ecosystem Services which are briefly defined and discussed below (see the OpenNESS Glossary for more detail and definitions of other terms).

Biodiversity: Due to the very broad understanding of "biodiversity" by different researchers and other stakeholders, it is difficult to provide a definition that both is precise and at the same time encompasses all the different meanings attributed to it. For the sake of convenience we suggest to preliminary use in OpenNESS the definition given by the CBD which is: *"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*. It should be kept in mind, however, that this definition leaves room for many different interpretations as to the adequate measurement variables for biodiversity and its components. Are, e.g. specific species also "biodiversity" or only the diversity of different species, regardless of their species identity? Is "functional diversity" included? Also, especially in a conservation context, often cultural aspects underlie the uses of biodiversity, e.g. when biodiversity is perceived specifically only as "native" biodiversity or "typical biodiversity" to be important, while for other stakeholders specifically "high" biodiversity matters (regardless of being native or typical). Here issues of values and related conservation strategies have a major influence on assessing the relevant measures of biodiversity – and in consequence also on their specific relation to ecosystem services. No general definition will be able to capture all these different aspects related to the term "biodiversity". As they may be of importance to specific application fields, however, the scope of these various aspects should nevertheless be an object of conceptual and empirical research in the different WPs.

Ecosystem services: We propose to largely follow the definition given in the TEEB study and define Ecosystem Services as: *the contributions that ecosystems (whether natural or semi-natural) make to human well-being.* Their fundamental characteristic is that they provide the link to underlying ecosystem functions, processes and structures. As with "biodiversity" many different definitions and interpretations exist which are dealt with in more detail in the glossary and other synthesis papers.

Suggested Three 'Must read papers'

Elmqvist et al., TEEB (2010) Ch2: Biodiversity, Ecosystems and Ecosystem Services [NB: the entire TEEB Foundation report can be downloaded from www.teebweb.org]

Luck, G.W. et al. (2009). Quantifying the contribution of organisms to the provision of ecosystem services. Bioscience, 59(3): 223-235.

Mace, G.M., Norris, K. & Fitter, A.H. (2012): Biodiversity and ecosystem services: a multi-layered relationship. Trends in Ecology and Evolution 27(1): 19-26.

Further cites papers in this text

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.S., Nakashizuka, T., Raffaelli, D. & Schmid, B. (2006): Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters* **9**: 1146-1156.

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Díaz, S., Quétier, F; Cáceres, D., Trainor, S.F., Pérez-Harguindeguy, N., Bret-Harte, M.S., Finegan, B., Peña-Claros, M. & Poorter, L. (2011): Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. *Proc. Nat. Ac. Sciences* **108(3)**: 895-902.

Kremen, C. et al. (2007). Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change. *Ecology Letters* **10**: 299-314.

Kremen, C. (2005). Managing ecosystem services: What do we need to know about their ecology? *Ecological Letters* **8**: 468-479.

Lavorel, S. & Grigulis, K. (2012). How fundamental plant functional trait relationships scale-up to trade-offs and synergies in ecosystem services. *Journal of Ecology* **100(1)**: 128-140.

Lavorel, S. (2013). Plant functional effects on ecosystem services. *Journal of Ecology* **101(1)**: 4-8.

Luck, G.W., Daily, G.C. & Ehrlich, P.R. (2003). Population diversity and ecosystem services. *Trends in Ecology and Evolution* **18**: 331-336.

Luck, G.W. et al. (2012). Improving the application of vertebrate trait-based frameworks to the study of ecosystem services. *Journal of Animal Ecology* **81(5)**: 1065-1076.

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