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Biodiversity and ecosystem services: The Nature Index for Norway

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ABSTRACT

Valuation of ecosystem services has been advocated as a tool for communicating the importance of nature and biodiversity to policy makers. The complexity of the relationships between ecosystem functions and the biodiversity that supports them challenges conceptualization of ecosystem services and calls for comprehensive ecological frameworks as basis for valuation and policy. In this article, we discuss relationships between biodiversity and ecosystem services in the context of the Nature Index for Norway, recently developed as a biodiversity measurement framework. We suggest supplementing the Nature Index by complementary indicators for ecosystem services, in order to consider how the ecosystem services approach as a policy tool can be enhanced by taking into account an ecological framework for biodiversity measurement.

1. Introduction

Assessment and valuation of ecosystem services is a topic of large political and scientific interest, expressed by the approaches of *Millennium Ecosystem Assessments* (MEA, 2005) and *The Economics of Ecosystem Services and Biodiversity* (TEEB, 2010). Although biodiversity loss is well documented (Global Biodiversity Outlook, 2010), it has not reached the top of the political agenda (Braat and ten Brink et al., 2008). The difficulty of communicating nature values to policy makers – unless nature values carry a price-tag – has led many economists and ecologists to advocate monetary valuation of ecosystem services for pragmatic reasons, reflecting that “economists and policymakers speak the same language” (ten Brink, 2006). For example, the value of insect pollination of plants worldwide has been assessed to 150 billion euro (Gallai et al., 2009). Yet criticism is raised, as focus on monetary valuation of ecosystem services useful to humans may overshadow other values of biodiversity (Spash, 2008). The complexity of the relationship between ecosystem functions and the biodiversity that supports them challenges the conceptualization of ecosystem services and its usefulness for policy (Peterson et al., 2010; Mace et al., 2011). Continued exploration of different ways of building bridges between ecological and economic approaches is therefore important (Braat and de Groot, 2012; Farley, 2012).

In this article, we consider how the ecosystem services approach as a policy tool can be enhanced by taking into account an ecological framework for biodiversity measurement. Specifically, we discuss relationships between biodiversity and ecosystem services in the context of the Nature Index for Norway, recently developed as a framework for integrated biodiversity measurement (Nybø, 2010; Certain and Skarpaas et al., 2011; Nybø et al., 2012; Skarpaas et al., 2012). The article focuses on the use of biophysical indicators as both an alternative and a complementary approach to economic valuation, in order to express the importance of biodiversity for the provision of ecosystem services, arguing that other policy responses than monetary valuation and commodification of ecosystem services are required. We discuss how the Nature Index framework can be used to highlight trade-offs between the capacity of ecosystems to deliver economically valued ecosystem services and other ecosystem services. We suggest extensions of the Nature Index approach to enhance its representation of ecosystem services, for example to relate the provision of ecosystem services to attributes of biodiversity at different levels, such as species, functional groups and community scales (Harrison et al., 2014).

2. Ecosystem services, ecosystem functions and biodiversity

Ecosystem services are usually defined as direct and indirect contributions from ecosystems to human benefit (TEEB, 2010; de Groot et al., 2002). The term ecosystem services is widely interpreted as including goods and services, and in this extended

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meaning, the term nature goods may be used synonymously. Ecosystem functions are defined as interactions between ecosystem structures and processes. Examples of ecosystem functions include primary production, oxygen production, regulation of food web dynamics, water purification, flood control, carbon sequestration, decomposition of organic matter, soil formation, nutrients circulation, pollination, and biological pest control (Virginia and Wall, 2001). Ecosystem functions provide the capacity for ecosystems to deliver ecosystem services. The *Millennium Ecosystem Assessment* suggested the classification of supporting, regulating, provisioning, and cultural services (MEA, 2005). Supporting ecosystem services include e.g. primary production (basis for food webs) and formation of habitat for other species, such as coral reefs. Regulating ecosystem services include e.g. pollination, carbon sequestration, flood control, and biological pest control. Provisioning ecosystem services include e.g. fish, wood, and grazing resources. Cultural ecosystem services, also called experience and knowledge ecosystem services, include e.g. outdoor recreation, peace and quiet in nature, and nature knowledge. In contrast to MEA (2005), TEEB (2010) does not classify supporting ecosystem services as a service category, but as basis for the other types of ecosystem services. This is followed up in the recent report on ecosystem services in Norway, where supporting ecosystem services are described as basic life supporting processes (NOU, 2013:10).

Biodiversity is defined as the variability among living organisms from all sources including, 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 (Convention on Biological Diversity, 1993). Biodiversity is crucial in ecosystem structure and processes, with complex contributions to ecosystem functions. In contrast to variability-based measures of biodiversity, such as species richness of geographical units (Magurran, 2004), component-based measures, which include both individual biodiversity indicators and their combined state as a composite measure of ecosystem state, correspond more closely to the ecosystem services approach. An ecosystem can give rise to many different ecosystem services, with no one-to-one correspondence between components of an ecosystem and the ecosystem services. A component of biodiversity can contribute to several ecosystem services. For example, beetle larvae in dead wood contribute to food for woodpeckers (supporting ecosystem service) and to decomposition and nutrient circulation (regulating ecosystem services). Dead wood at different stages of decomposition is habitat for numerous organisms, contributes to carbon storage, and shapes the character of a natural forest into a large potential for nature experience (cultural ecosystem service). In many contexts, higher biodiversity is associated with increased ecosystem functions (Hooper et al., 2005). Living organisms are a precondition for all ecosystem functions, but not all ecosystem functions require a large diversity of organisms. Species richness has a key role for some ecosystem services (e.g. pollination) and a lesser one in others (e.g. carbon storage). Mace et al. (2011) discuss this complexity in terms of the two approaches of the 'ecosystem services perspective' and a 'conservation perspective'. Some ecosystem services may be increased by artificial means at the same time as biodiversity may be decreasing. Different ecosystem services, such as primary production, flood regulation, carbon sequestration or (the potential for) agricultural production, may not be achieved perfectly at the same time or may conflict with high biodiversity (Eigenbrod et al., 2009; Nelson et al., 2009). Biodiversity has key roles at all levels of ecosystem services: as regulator of ecosystem processes that underpin ecosystem services, as an ecosystem service in itself (e.g. biodiversity at the level of genes and species can contribute directly to goods and their values), and as a good in itself that is subject to valuation, economic or otherwise (Mace et al., 2011). Ecosystems produce multiple services that interact in complex ways, and different services are interlinked, both negatively and positively. If an ecosystem is managed principally for the delivery of one ecosystem service – say food or carbon sequestration – biodiversity and other ecosystem services may often be negatively affected. Braat and de Groot (2012) suggest how non-intensive use of an ecosystem often may give a higher value for a total "basket" or "bundle" of multiple ecosystem services. The challenges in conceptualizing multiple ecosystem services call for developing an interdisciplinary science of ecosystem services and management, bringing together ecologists, conservation biologists and economists (Mace et al., 2011).

3. Ecosystem capital, ecosystem capacity and ecosystem accounting

In economic terms, ecosystem functions can be described as ecosystem capital, a part of natural capital (MEA, 2005). Natural capital is an economic metaphor for the available stocks of physical and biological resources, defined as the present value (discounted value) of expected future flows of services from stocks of natural resources. Ecosystem capital is in principle defined as the present value of expected future flows of ecosystem services from biodiversity and the ecosystem functions it supports. Some ecosystem services, e.g. harvesting of fish or timber, or nature-based recreation may be valued by market prices and included in the natural capital. Supporting, regulating and cultural ecosystem services are generally not included in the natural capital, nor are ethical and intrinsic values of nature.

A system of ecosystem accounting, aiming to integrate ecological indicators to supplement economic accounting, is currently being developed (and thus referred to as "experimental") by the United Nations (2013). A core concept is ecosystem capacity – the capacity to sustain over time the delivery of a "basket" or "bundle" of multiple ecosystem services from a particular ecosystem at a given spatial level. While ecosystem capital as an economic concept is defined as the present value of expected ecosystem services, as envisioned today, ecosystem capacity represents a larger potential, taking into account that future trade-offs between baskets of multiple ecosystem services may require a larger capacity for ecosystem services than the current ecosystem capital, in which case a more sustainable management is needed. Different future priorities and trade-offs between ecosystem services may require different levels of ecosystem capacity. Hence, valuation of a basket of multiple ecosystem services cannot be based on current economic valuation. For example, if future decision-making will prioritize biodiversity, carbon storage and recreation in forests, in addition to forestry, the valuation of ecosystem capacity will be higher than what is reflected by ecosystem capital based on timber prices.

Ecosystem capacity is measured by ecosystem extent and condition (quality), see Fig. 1. The idea of ecosystem accounting is to integrate the use of ecosystem services and its impact on ecosystem condition, measured for example in terms of a biodiversity index, in order to indicate how the use of ecosystem services contributes to sustainable use of ecosystems (United Nations, 2013). The use and valuation of multiple ecosystem services need to be seen together, so that use of one ecosystem service (e.g. provisioning) will not undermine the potential to maintain other ecosystem services. This approach suggests a close connection between valuation of ecosystem services and assessment of ecosystem condition. In order to assess the ecosystem capacity, it must be taken into account that a reduction in biodiversity may reduce the capacity to deliver different