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The Gordian knot of mangrove conservation: Disentangling the role of scale, services and benefits

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ABSTRACT

Mangrove forests are among the most threatened tropical ecosystems. Their role as providers of important ecosystem services such as coastal protection, carbon storage and nursery habitats for economically important species is increasingly acknowledged. But mangrove destruction continues, and we might have to face the prospect of a world deprived of the services offered by mangrove ecosystems. Mangrove transformation and destruction is often caused by mismatches in mangrove system management. These root in interests that focus on selected ecosystem services only, but also result from a problem of fit between the spatial scales at which ecosystem services are provided, and those at which their benefits are realized. We argue that a combination of the ecosystem services concept with a careful approach to the issue of scales will help to overcome these problems and improve the management of mangrove systems. Drawing on two case studies from Indonesia and Brazil, we illustrate the relevance of our findings for different ecosystem services.

1. Introduction

In tropical and subtropical coastal regions all over the globe, mangrove ecosystems are in a state of transformation. Between 2 and 8% of the global mangrove cover is lost annually (Miththapala, 2008). The main drivers behind this loss are the conversion into fish and shrimp aquaculture ponds and unsustainable forest uses (Duke et al., 2007; Valiela et al., 2001). Until very recently, many governments considered mangroves to be relatively worthless (Walters et al., 2008), which is why these ecosystems have often been prime candidates for conversion to large development activities (Rönnbäck, 1999). While the causes for mangrove destruction have been discussed since the early 1970s (Canestri and Ruiz, 1973), it was not until the 1980s and early 1990s that significant research attention was dedicated to the analysis of interactions between humans and mangroves (Walters et al., 2008).

Since then, increasing awareness has evolved of the importance of mangroves for human activities and well-being. These include the habitat and nursery service for commercially important fish, crustaceans and mollusks', their role as natural coastal protection, nutrient and organic matter processing or sediment control, etc. (Polidoro et al., 2010; Rönnbäck, 1999; Walters et al., 2008). Mangroves are also considered "foundation species", primary producers that define the structure of the whole ecosystem and have direct links to the dynamics of dependent species and communities (Ellison et al., 2005; Polidoro et al., 2010). Furthermore, manifold resources are obtained from mangroves that are vital to subsistence economies and provide an important commercial base to local and national economies in coastal areas throughout the tropics (Glaser, 2003; Hamilton and Snedaker, 1984; Kaplowitz, 2001; Rönnbäck, 1999; Warren-Rhodes et al., 2011). Despite the intense scientific discussion on the value of mangrove ecosystems, their deforestation continues. Indeed, we have to face the prospect of a world deprived of the services offered by mangrove ecosystems, perhaps within the next 100 years (Duke et al., 2007). This would have serious negative ecological, economic and social consequences for many tropical coastal regions.

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The motivation for this paper roots in the observation that management has largely failed to ensure the conservation and sustainable use of mangrove forests. This is at least partly the result of the complexities associated with managing these systems. Being part land and part sea, mangroves are often subject to overlapping and competing interests of user groups and jurisdictional ambiguities between administrations (Glaser and Oliveira, 2004; Walters et al., 2008). Their management is further challenged by the interplay between ecological levels where important ecosystem services are generated with institutional levels where management decisions that influence these services are made (for example, a management body at provincial level which is only responsible for a part of the mangrove system). The issue of scales has to be addressed as an object of inquiry (Brown and Purcell, 2005). The unique position of mangroves as intermediate systems between the terrestrial and the marine realm amplifies the need to carefully analyze the various spatial and temporal scales at which their diverse resources and services are provided and utilized. From a management perspective, it has to be considered that decisions made at one institutional level can significantly influence the type, quality and quantity of resources and services and hence the benefits of stakeholders at other levels. Folke and colleagues (2007) introduced the term "functional mismatches" for developments driven by a strong interest of resource users in selected ecosystem benefits only. An analysis of the interests and perceptions of stakeholder groups at different governance levels will not only reveal such functional mismatches, but may provide insights on the questions of which institutions, both formal and informal, are necessary and appropriate to enable effective management (Hein et al., 2006). Both analysis and the implementation of management require a conceptual frame which integrates ecological and societal scales relevant for mangrove systems and their use.

Based on an anthropocentric perspective, the ecosystem service concept provides a framework to link natural capital to human uses of nature (Daily, 1997, 2000; de Groot et al., 2010b). By acknowledging the role of ecosystems as providers of essential goods and services; it links ecosystem functions with livelihoods and well-being (MA, 2005; Gahzoul, 2007). This provides a perfect "lens" to study the benefits which humans obtain from specific parts of an ecosystem. Such an analysis will indicate which management options they prefer, and how this might relate to the preferences of other stakeholders. Thus applied, the ecosystem service concept can make a substantial contribution towards more effective management of mangroves and other ecosystems. Policy makers have just started to include the ecosystem service concept into their guidelines and programmes, for example as part of the Convention on Biological Diversity targets for 2020 (CBD, 2010), and the EU Biodiversity Strategy to 2020 (European Commission, 2011). However, there is still a long way to go until ecosystem services are truly integrated into decision-making (Daily et al., 2009). Especially the importance of ecosystem services from coastal and marine systems is increasingly highlighted (TEEB, 2012), but these have hardly been subject to assessments which can actually be integrated into decision-making processes (Lopes and Videira, 2013).

Drawing on work by Boyd and Banzhaf (2007), Fisher and Turner (2008), Fisher et al. (2009), de Groot et al. (2010b), and Atkins et al. (2011), the aims of this article are to combine the concept of ecosystem services with a systematic investigation of ecological and societal scales, and to apply the relevant theoretical deliberations to two mangrove systems in Indonesia and Brazil. The article thus responds to the call for more attention to the issue of scale, and addresses the "problem of fit" between ecosystem processes and institutional arrangements of their management (Young, 2002). It adds to the application of the ecosystem service concept for management decisions, and contributes to the debate on mangroves and their protection.

The article is divided into two main sections. The following second section provides the conceptual background for the empirical analysis. Here, we clarify key terms of the ecosystem service concept before we discuss the issue of scales and its relations to the terms previously classified. This provides the basis for the third section of the paper, in which we draw on two case studies on mangrove systems: the Segara Anakan lagoon in Indonesia, and the Bragança region in Brazil. In these long-term case studies, we present examples ranging from a single ecosystem service namely habitat provision for shrimp and fish; to multiple services namely wood provision, sediment and carbon fixation. All ecosystem services observed have in common that their appearance and use connect various spatial and temporal levels in the ecological and the societal realm. In this respect, they provide excellent examples to illustrate the added-value of using the ecosystem service concept in a multi-scale system. Based on the case studies, we develop general recommendations for improved mangrove management.

2. Linking the ecosystem service concept to the issue of scales

2.1. Ecosystem services and ecosystem benefits

In the Millennium Ecosystem Assessment (MA), ecosystem services have been defined as "the benefits provided by ecosystems" (MA, 2003:39). This definition has been subject to some debate, because the mere existence of a certain good does not necessarily result in any benefits (Boyd and Banzhaf, 2007; Fisher and Turner, 2008). For example, the service of providing habitat and nursery areas (de Groot et al., 2010a) for fish exists independently of whether someone is catching the fish or not. But benefits – namely the fish caught or its monetary value – will only be created if potential beneficiaries are present and do actually catch fish. In most cases, the realization of benefits requires additional input, in our example at least fishing gear, knowledge, access to the area, and time for catching. In order to make the difference between ecosystem services and benefits explicit, Fisher and colleagues (2009) offer an alternative definition of ecosystem services as "aspects of ecosystems utilized to produce human well-being". It is important to mention that such utilization can either be active or passive (Fisher and Turner, 2008). Following this definition, ecosystem services include ecological processes and functions as well as the structure of ecosystems. Ecosystem services are ecological in nature, but their existence as "service" depends on the realization of benefits by humans (Fisher et al., 2009). It is human preferences which turn an ecological feature into an ecosystem service, which then (often in combination with other inputs) can create benefits to society or individuals. Additionally, an individual service can generate multiple benefits and interactions between individual ecosystem services may provide benefits that are actually "joint products" (Fisher et al., 2009). Protection from coastal erosion by mangrove systems is one example. It results from the ability of mangroves to stabilize shores with their roots and from forest function as a wind and wave breaker. The overall service supply of an ecosystem is strongly influenced by its use and management. Any change in the management of an individual ecosystem service will thus have an impact on the bundle of services provided by that system (de Groot et al., 2010b).

Since ecological processes and functions are dynamic, ecosystem services and the benefits they generate are characterized by spatial and temporal dynamics (Hein et al., 2006). They are neither evenly distributed, nor do they appear regularly. The realization of benefits may also diverge from the provision of ecosystem services