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Assessment of coastal protection as an ecosystem service in Europe

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ABSTRACT

Mapping and assessment of ecosystem services is essential to provide scientific support to global and EU biodiversity policy. Coastal protection has been mostly analysed in the frame of coastal vulnerability studies or in local, habitat-specific assessments. This paper provides a conceptual and methodological approach to assess coastal protection as an ecosystem service at different spatial–temporal scales, and applies it to the entire EU coastal zone. The assessment of coastal protection incorporates 14 biophysical and socio-economic variables from both terrestrial and marine datasets. Those variables define three indicators: coastal protection capacity, coastal exposure and human demand for protection. A questionnaire filled by coastal researchers helped assign ranks to categorical parameters and weights to the individual variables. The three indicators are then framed into the ecosystem services cascade model to estimate how coastal ecosystems provide protection, in particular describing the service function, flow and benefit. The results are comparative and aim to support integrated land and marine spatial planning. The main drivers of change for the provision of coastal protection come from the widespread anthropogenic pressures in the European coastal zone, for which a short quantitative analysis is provided.

1. Introduction

Coastal areas provide essential resources for wildlife (e.g. key nursery habitats), human well-being (e.g. recreation opportunities) and economy (e.g. fisheries). Coasts are the preferred space for human settlement with three times the average population density compared to the global average density (Small and Nicholls, 2003). Nearly half of the EU population (more than 200 million people) live at the coast, where the rate of population growth is larger than in other EU regions (Eurostat, 2011). The increasing pressure and demand for coastal resources causes habitat loss and degradation, pollution and overexploitation, thus leading to the degradation of coastal ecosystems (EEA, 2010). The first report by Member States on the conservation of wildlife pursuing the EU Habitats Directive showed that over two-thirds of coastal habitats and over half of coastal species have an ‘unfavourable’ status (European Commission, 2009). On top of the loss of ecological values, this degradation has large negative social and economic consequences.

The EU Biodiversity Strategy to 2020 (European Commission, 2011) aims to prevent further loss of biodiversity. The Strategy's approach includes assessing, mapping and valuing all ecosystem services in EU. Ecosystem services are the benefits supplied by natural ecosystems that contribute to the well-being of human populations. Last decade has seen a proliferation of studies on ecosystem services as a response to an increase in the demand of policies containing clear and objective messages able to raise awareness on environmental issues while considering also socio-economic aspects. In the EU, ecosystem services are an integral part of the biodiversity policy, which requires Member States to complete the first mapping and assessment by 2014 as one of its supporting actions.

This study provides a practical example to assess the ecosystem service coastal protection (CP) at EU scale. Coastal ecosystems may contribute between 36% (Costanza, 1999) and 77% (Martínez et al., 2007) of global ecosystem services value. However, given the complexity of coastal systems and the lack of precise economic valuations, both land and marine spatial planning usually neglect natural CP and other important ecosystem services. The consequences of natural hazards on the coastal zone and their impacts on humans (coastal vulnerability) have been subject of much research for many years (e.g. Capobianco et al., 1999; Pethick and Crooks, 2000; Bryan et al., 2001; Adger et al., 2005; Green and McFadden, 2007; Harvey and Woodroffe, 2008; Nicholls et al., 2008; McLaughlin and Cooper, 2010). The assessment of CP as an ecosystem service has been only recently addressed with a focus on the action of mangrove forests (Granek and Ruttenberg, 2007; Barbier et al., 2008; Das and Vincent, 2009), seagrass meadows (Bos et al., 2007), coastal wetlands (Costanza et al., 2008; Shepard et al., 2011), sand dunes (Everard et al., 2010), several of these habitats (Rönnbäck et al., 2007; Koch et al., 2009), the specific case of coastal managed realignment policy in England (Turner

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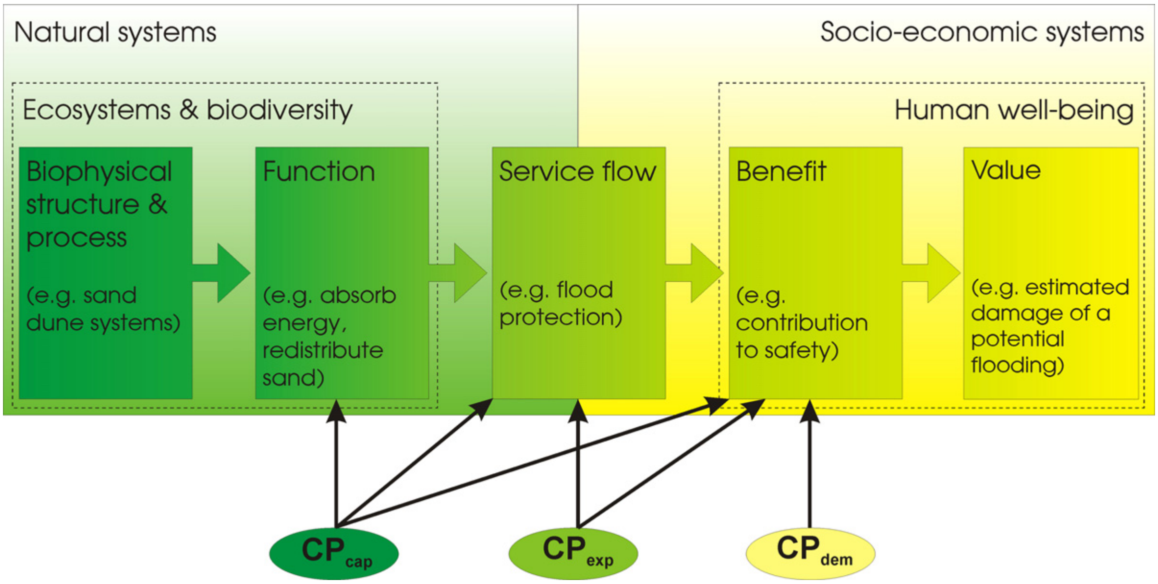

Fig. 1. Conceptual framework followed in this paper. The upper boxes show the basic structure of the cascade model framed within the natural and socio-economic context. The examples refer to the CP case study. The bottom shapes and arrows represent the indicators proposed in this paper that inform the different compartments of the cascade model.

et al., 2007; Luisetti et al., 2008), or even the attempt to quantify bioshield protection against tsunamis (Cochard et al., 2008; Sanford, 2009). Most studies focus on specific ecosystem types or local case studies, and provide useful examples of the application of the ecosystems service approach as a way to show the important role that particular natural environments play in coastal protection. However, none of these studies proposes a conceptual framework and specific metrics that can be replicated and compared across different areas or spatial–temporal scales. The only integrated and geographically explicit approach similar to the one proposed in this paper is the coastal vulnerability/protection model of InVEST (http://www.naturalcapitalproject.org/InVEST.html, Guerry et al., 2012), a decision support tool for mapping ecosystem services mostly at local scale.

This paper aims at assessing and mapping the CP ecosystem service at a continental (European) scale. The first part of the paper introduces the conceptual background and updates it with new, spatially explicit indicators that allow quantifying each step of the so called ecosystem services cascade model (Haines-Young and Potschin, 2010), namely protection capacity, coastal exposure and human demand for CP. Then we describe the study area, the main variables and the sources of information. The second part of the paper presents the distribution of the three novel CP indicators along European coastlines, and includes an analysis of the main anthropogenic pressures on the coastal zone. Finally, we map and assess the ecosystem service flow and the associated benefit, discuss the applicability of our approach, and propose future areas of improvement and lines of work.

2. Methods and data

2.1. Conceptual approach

For the purpose of this study, the CP ecosystem service is defined as the natural defence of the coastal zone against inundation and erosion from waves, storms or sea level rise. Protection here refers to the physical defence of any asset present in the coastal zone (e.g. property, people, or infrastructure). Therefore, this assessment includes several processes like attenuation of wave energy, flood regulation, erosion control or sediment retention.

Several approaches to map ecosystem services have been developed and their methodologies are reviewed in Burkhard et al. (2009) and Eigenbrod et al. (2010). In particular the ecosystem services cascade model, which links biodiversity and ecosystems to human wellbeing through the flow of ecosystem services (Haines-Young and Potschin, 2010; De Groot et al., 2010), proves to be useful for framing spatial indicators of ecosystem services at multiple scales (e.g. Kienast et al., 2009; Haines-Young et al., 2012; Liquete et al., 2011; Maes et al., 2012; van Oudenhoven et al., 2012).

The ecosystem services cascade model is adapted here for the particular case of CP (Fig. 1). In the cascade model, the biophysical structure and processes of an ecosystem determine its ecological functions, which define the capacity of an ecosystem to deliver a service. Those functions eventually provide a flow of ecosystem services that contribute to human well-being through specific benefits. Different methodologies, then, allow allocating monetary values to those benefits. While this model provides a valuable conceptual framework there is a need to include a set of quantitative indicators for each step of the cascade. This paper proposes such set of indicators and their metrics for the regulating service CP. The basic structure of those indicators is flexible to allow for replication at different scales or locations. The three novel indicators for CP are:

(a) *Capacity* (CP_{cap}): The natural potential that coastal ecosystems possess to protect the coast against inundation or erosion. This is based on geological and ecological characteristics. This indicator links to the second compartment of the cascade scheme (i.e. function or capacity).
(b) *Natural exposure* (CP_{exp}): The predicted need of CP based on the climatic and oceanographic conditions of each area. CP_{exp} together with CP_{cap} give an indication of the service flow (middle box in the cascade scheme) from a natural perspective, i.e. the use of the service will be higher where the coastal systems are exposed and do have protection capacity.
(c) *Human demand* (CP_{dem}): The estimated necessity of protection of the coastal populations based on the presence of residents and assets in the coastal zone. This indicator connects with one of the bottom compartments of the cascade scheme, benefit.