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Viewpoint

# Assessing estuarine quality under the ecosystem services scope: Ecological and socioeconomic aspects

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ABSTRACT

An increasing need for integrative assessments that measure the contributions of the environment to human welfare has recently been recognised. In the present study, a preliminary assessment of the services provided by the Mondego Basin in terms of system ecological quality was carried out. The ecological, economic, and societal relations of the Mondego estuarine services were analysed. An inventory of the main ecosystem services provided by the Mondego system was performed. The conditions and trends of the main services (food production, recreation and water quality maintenance) were determined, and the scale dependence of this assessment was interpolated on three different scales: Mondego Basin, Lower Mondego, and Mondego Estuary. The interdependence among services was quantified; an ecological assessment regarding water quality and ecological conditions was performed, and a preliminary valuation of the food production, recreation and tourism in the region was undertaken. In the study system, from 1992 to 2006, there was an increase in recreation activities and water uses and a simultaneous decrease in services such as food production (i.e., strong interdependence among services). Ecological quality improvement is reflected in both local communities' diversity and water quality. The market prices method was used to estimate the values for the three services considered; however, the Mondego catchment's full value cannot be calculated without estimating the real wetlands value because these are prone to underestimation. Uncertainties and shortcomings regarding the reliability of this kind of assessment for implementation on estuarine ecosystems are discussed.



## 1. Introduction

Most of the ecosystem analysis approaches adopt an anthropogenic perspective where the stocks of natural assets found within the system are connected to the flow of services that provide benefits to human society (Costanza et al., 1997; Turner et al., 2000; de Groot et al., 2002; Farber et al., 2002; MA, 2005). By definition, ecosystem goods (e.g., food) and services (e.g., water purification), hereafter ecosystem services, represent the benefits human populations derive directly or indirectly from ecosystem functions (Costanza et al., 1997). As such, ecosystem services are generated by ecosystem functions, which in turn are underpinned by biophysical structures and processes inherent to the system (de Groot et al., 2010). These concepts have been used by the Millennium Ecosystem Assessment framework (MA) (MA, 2005) to represent the flow of benefits to society generated by natural ecosystems and their consequences for human well-being. According to this framework, four categories of services were established (MA, 2005): provisioning (products obtained directly from the ecosystems); regulating (benefits obtained from the regulation of ecosystem processes); cultural (nonmaterial benefits people obtain from ecosystems through cognitive development and aesthetic experiences, for example); and supporting (those benefits that are necessary for the production of all other ecosystem services).

Through the integration of the ecosystem's inherent processes, the associated biodiversity and its sustainable use, the ecosystem approach focuses on conserving natural systems for their inherent value and for human well-being (Vitousek et al., 1997; Nunes and Bergh, 2001; de Groot et al., 2010). As so, it is necessary to identify all costs and benefits to the ecosystem of different human activities in order to protect the system's biodiversity and promote its sustainable use (Nunes and Bergh, 2001; Folke et al., 2004). This may be achieved through the identification of the impacts of human activities and through the quantification of their consequences for the supply of ecosystem services. When valuating a system, the intent is to provide a value for a specific asset, and to trace its condition and importance over time. This includes not

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only the ecosystem services that have a market price (e.g., agriculture products) but also services that currently have no market prices (e.g., disturbance regulation). According to Beaumont et al. (2006), there are two distinct approaches to working with the ecosystem services concept. Among economists, economic valuation methods prevail, which focus on the exchange values of ecosystem services (based on consumer preferences and cost-benefit analyses). On the other hand, there are ecological valuation methods that employ a more sustainability-oriented perspective, which are mainly advocated by natural scientists and ecologists, that derive ecological prices (measurement of biophysical units, rather than social or economic in nature) for ecosystem services via a cost-of-production approach (i.e., by modelling the interrelations between the biotic and abiotic components of a system). According to Costanza et al. (1997), both fields take into account concerns regarding the scale of the economy, distribution and efficient allocation of resources. Two scale-related problems are encountered when assessing ecosystem services (Heal & Kristrom, 2005): (i) the scale at which certain functions become important is not always the same and (ii) problems may arise when integrating and aggregating information at multiple scales where interrelations and feedback loops may operate at scales above the level being assessed. According to Limburg et al. (2002), scaling rules that try to describe the provision and delivery of ecosystem services have yet to be quantified and defined.

Using the Mondego estuary as a case study, we conduct a preliminary assessment of the services provided by the Mondego Basin under the constraint of the present limited data availability. Moreover, the aim of this work was to analyse the ecological/economic/societal costs and benefits of estuarine ecosystem services, giving special attention to their quality status, along the lines of the ecological sustainability trigon approach proposed by Marques et al. (2009). Specifically, we aimed to accomplish the following:

(i) provide a comprehensive inventory of the ecosystem services provided by the Mondego system;
(ii) determine the conditions and trends of the main ecosystem services;
(iii) interpolate the scale dependence of such assessments using three different spatial scales: the Mondego Basin, the Lower Mondego Valley, and the Mondego Estuary;
(iv) estimate the interdependence among services;
(v) perform an ecological assessment regarding water quality and ecological conditions; and
(vi) perform a preliminary valuation of the food production, recreation and tourism in the region.

## 2. Methodology

A generic framework has been implemented, assuming several steps in the ecosystem services valuation, together with the methodological tools necessary to provide a more comprehensive assessment. First, the characterisation of the system's condition and main uses was undertaken at different spatial scales. Second, an inventory of the main services provided by the Mondego Basin was carried out. It is important to note that biodiversity, despite not being considered an ecosystem service, was included in the assessment because it is assumed to play a necessary role in all of the considered services by promoting the correct performance of all ecosystem functions (Marques et al., 2009). Based on this inventory, the conditions and trends of the main considered ecosystem services were assessed and the interdependencies among them evaluated. The next step involved an ecological assessment of the main services and their relations with the biodiversity assets. Finally, the ecological valuation perspective was combined with a range of economic valuation methods (i.e., the economic perspective) in an attempt to provide a preliminary system valuation.

### 2.1. Spatial scales of the system and scale dependence

The Mondego Basin is located in the centre of Portugal and covers a 6670-km$^2$ catchment area with highly diverse characteristics in terms of hydrology, land use, and topography. It presents a peculiar and unique functional structure ranging from mountainous areas to a large alluvial plain discharging into the Atlantic Ocean (Marques et al., 2003) and supports a population currently estimated at 885,561 inhabitants (2006 data). The system can be divided into three main regions (PBH Mondego, 2001; Fig. 1):

(i) *Upper Mondego*: basin area located in the "Serra da Estrela" mountain range at the river headwaters, where it travels through glacial valleys.
(ii) *Middle Mondego*: basin area between the base of the "Serra da Estrela" and the city of Coimbra, where the river passes through deep valleys.
(iii) *Lower Mondego*: the final part of the river course, consisting of open valleys and plains, including the Mondego estuary ecosystem and a thick dune belt along the coastline.

Overall, the Mondego Basin has a high natural variability in environmental and social conditions (Table 1). In each of the three main regions, the secondary and tertiary sectors are well represented in the economic activities. However, in the Lower Mondego, a strong pressure is also evident from the abundant agriculture fields (primary sector), as well as from Figueira da Foz harbour. In summary, we may say that at the Basin level industrial activities related to wood extraction (due to the vast forest area), together with the glass, ornamental resources and beverage industries, dominate the economic activities taking place in the system. More specifically, in the Lower Mondego region (near the coastal area), the paper industry and aquaculture play the largest economic roles. The fibre and leather industries have the dominant position among the economic activities in the Upper Mondego area (PBH Mondego, 2001). These variations influence the system's management, water uses, and land occupation rates.

Under the Millennium Ecosystem Assessment (MA) scope, three main areas at different scales were considered for this study (Fig. 1): the Mondego Basin (basin scale), the Lower Mondego Valley (regional scale), and the Mondego Estuary (local scale). The scale dependency was mostly examined to infer the effects of upstream activities on local estuarine resources. To this end, several parameters were taken into account, including not only socioeconomic factors such as demographic pressures or activities around the basin but also ecological factors such as nutrient sources.

### 2.2. Comprehensive inventory of ecosystem services

The goal of the ecosystem services inventory was to provide a set of alternative ways to valuate estuarine services and thus provide insight into the economic perspective within the ecosystem approach. Several services provided by wetlands ecosystems have been identified (Costanza et al., 1997; Acharya, 2000; Atkins and Burdon, 2006). From this available set of services we considered two main factors that determine the Mondego Estuary services: the importance of its natural resources stock to local populations (i.e., estimation of their dependency upon the system) and the ecological importance of the system to the intrinsic biodiversity and human well-being (Fig. 2).

For the inventory assessment, several methods were considered, taking into account their specificities, to evaluate ecosys-