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Ecosystem services' mapping in data-poor coastal areas: Which are the monitoring priorities?

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ABSTRACT

A crucial goal of ecosystem-based management is to maintain the delivery of ecosystem services (ESS) over time. This requires ESS to be assessed repeatedly over time, a task that becomes extremely challenging in data-poor coastal areas, where the lack of data and resources sums up with the intrinsic difficulties of assessing marine and coastal ESS. This implies the need to develop simple ESS assessment methods and to optimize the monitoring effort required to implement them. The aim of this work is to identify which are the key monitoring priorities for ESS mapping in data-poor coastal areas, in the perspective of ecosystem-based management implementation. In order to do so, the ESS provided by *Posidonia oceanica* meadows in the northern African Mediterranean coastal area have been chosen as a case study, and assessed by mapping the service providing, benefiting and connecting areas. Different input data and methods have been tested to explore how the mapping approach can be kept as simple as possible to ensure a broad applicability, and which are the crucial data required, in order to optimize the monitoring effort. The spatial distribution of the habitat providing the ESS resulted to be the data to which the mapping outcomes are more sensitive, and should be thus considered a key monitoring priority. The other input data can be kept as simple as (1) an expert-driven estimate of the service connecting area, to be understood as an ecologically meaningful range of influence of the focal habitat, and (2) globally available datasets for mapping the service benefiting areas. Overall, this results in an aggregated mapping of the multiple ESS provided by a marine habitat, which, according to our results, seems to be an advisable strategy for a first ESS assessment suitable for application in a data-poor context.

1. Introduction

Ecosystem-based management (EBM) shifts the perspective from a sectoral to an integrated approach to management, in which humans are considered as integral parts of the ecosystem (Agardy et al., 2011; McLeod et al., 2005; UNEP/GPA, 2006). A core focus of EBM is the maintenance of ecosystem structures, processes and functioning, so that the long term delivery of ecosystem services (ESS) to humans is secured (Agardy et al., 2011; McLeod et al., 2005). ESS is thus a central concept in EBM implementation, as it explicitly connects the ecosystems, and their functioning, with human beneficiaries. This connection is underlined by the concepts of ESS supply and demand (Burkhard et al., 2012), which emphasize that the potential to supply ESS, based on the functioning of the ecosystem, is converted into ESS only if there is a demand for these services from society (Burkhard et al., 2014).

ESS mapping, and particularly mapping of ESS supply and demand, are increasingly used in ESS assessments (Burkhard et al., 2012; Kroll et al., 2012; Nedkov and Burkhard, 2012; Sturck et al., 2014; Wolff et al., 2015), because of their usefulness for an effective planning (Andrew et al., 2015). On these regards, the concepts of "service providing area" (SPA), i.e. the spatial units where the service is sourced, and "service benefiting area" (SBA), i.e. the spatial units where the service is needed or readily used or consumed, allow to frame ESS supply and demand in a spatial dimension (Fisher et al., 2009; Serna-Chavez et al., 2014; Syrbe and Walz, 2012). In general, ESS are provided where the supply meets the demand, however, SPA and SBA do not necessarily need to overlap in order to have the actual ESS provision, as the ESS provision is not restricted to the area of the SPA and ESS can reach beneficiaries located also outside of it. In operational terms, this has led to the conceptualization of the "service connecting area" (SCA) (Serna-Chavez et al., 2014; Syrbe and Walz, 2012), which spatially represents a sort of connecting area through which the ESS can flow from the SPA to the SBA if the two do not overlap (see Costanza, 2008; Fisher et al., 2009 for a classification of the possible spatial relationships between SPA and SBA).

If marine and coastal areas are considered, however, data and

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methods for ESS assessment are much more limited compared to terrestrial systems, and consequently, a gap in literature exists concerning marine and coastal ESS (Liquete et al., 2013). Reasons include, among others, the lack of knowledge about marine habitats' coverage, the complexity of assessing connectivity between habitats, and the difficulty in identifying clear boundaries and assessment units in maritime areas (Liquete et al., 2013). In the case of the seagrass *Posidonia oceanica*, for example, although being the most widespread and a rather well-studied seagrass species in the Mediterranean sea, the knowledge about the meadows' spatial distribution is patchy and characterized by mismatching assessment methods and spatial scales (Zucchetta et al., 2016). This makes the description of coverage and temporal trends at broad spatial scales quite challenging, and it is reflected in a knowledge about the ESS provided that mainly concerns specific case studies and a limited set of ESS (Campagne et al., 2014; Nordlund et al., 2016). On the other side, however, the recent directives (UNEP/MAP, 2012) engaged countries in the framework of the ecological status assessment and the consequent improvement of it, when needed. All these call for an increase of management capabilities and implies the decision on where to concentrate the effort and limited available resources. ESS mapping plays an important role in bringing ecosystems and their functioning to the attention of decision makers, highlighting their capacity to support human well-being and contributing to focus management efforts on the ecosystems whose ESS provision is critically decreasing. In data-poor coastal areas, where less research facilities and *in situ* data are available, the gap could become even larger, making the study of marine and coastal ESS even more challenging, in the perspective of an effective application of EBM and gaining of the Good Ecological Status.

In this context, the present study aims to identify the monitoring priorities for ESS mapping in the perspective of application of EBM in data-poor coastal areas. The ESS, indeed, represent good indicators being easily comprehensible also by policy makers and managers called to decide how to invest limited resources in environmental programs. In order to explore these aspects, the ESS provided by the *P. oceanica* meadows in the northern African Mediterranean coastal area have been chosen as a case study, being the seagrass meadows an example of submerged habitat for which ESS are still understudied, and the Southern Mediterranean coasts a data-poor area for which, to our knowledge, no scientific literature on ESS is available as yet. The mapping procedure has been repeated using different data and methods, in order to (1) check how the area of ESS provision vary in response to different inputs, and (2) compare the case in which ESS are resolved in an aggregated way (presence/absence of one or more ESS) with the case in which ESS are resolved one by one, including, in the latter case, the effect of applying different weights to different ESS within a simple benefit transfer exercise. The results have been used to explore which is the simplest mapping methodology capable to provide a reliable first ESS assessment suitable for application in a data-poor context, and which are the crucial information needed to perform the assessment.

2. Materials and methods

2.1. Study area and data availability

The study area covers the North African coastal area located within the Western Mediterranean Sea UNEP-MAP sub region (Garmendia et al., 2015; UNEP/MAP, 2012) (Fig. 1). The area has been subdivided into 6 subzones, using a zonation adapted from Garmendia et al. (2015). Along the coast-to-open-sea direction, coastal areas (CAs) and offshore water bodies (OWBs) are distinguished, the first ones including the land-sea interface from 1 km landward to 1 nm seaward respect to the coastline, and the second ones including the offshore area. CA and OWB are then further divided along a longitudinal gradient, based on the exclusive economic zones and terrestrial borders of Morocco (CA1 and OWB1), Algeria (CA2 and OWB2) and Tunisia (CA3 and OWB3).

The availability of data concerning the extension of *P. oceanica* meadows and, more generally, the status of coastal ecosystems as well as the main pressures which are affecting it, is a key issue for EBM in the study area. To this regard, a comprehensive region-wide monitoring program will be established in the framework of the implementation of the UNEP-MAP ECosystem APproach. Valuable information about national monitoring programs were collected during the EU FP7 project MEDINA. This survey highlighted that monitoring programs are being carried out in Algeria, Egypt, Morocco and Tunisia but, in most cases, they are not comprehensive, not regular in time and, with the exception of Egypt, they are managed by different agencies. More specifically, in Algeria biodiversity data are gathered by different institutions and collected and periodically published by the Centre National de Développement des Resources Biologique (CNDRB). In Morocco, several institutions and agencies collect data concerning biodiversity, the main ones being the Ministère de l'Energie, des Mines de l'Eau et de l'Environnement (MEMEE) and the Haut Commissariat aux Eaux, Forêts et à la lutte contre la Désertification (HCEFD). Reports concerning biodiversity are produced also by the regional centers of the Institut National de Recherche Halieutique (INRH). In Tunisia, national reports on biodiversity are produced by the Ministère de l’Environnement et du Development Durable (MEDD) in the framework of the CBD Convention. Clearing House Mechanisms website has been developed to exchange information, including a list of experts. Overall, data are sparse, scattered and difficult to access and this heavily hinders their use for research and effective management at regional scale. Concerning *P. oceanica*, we decided to estimate the extension of seagrass meadows in the region using a Species Distribution Model (Zucchetta et al., 2016), rather than trying to aggregate this sparse information.

2.2. Mapping approach

In this work, the mapping approach based on SPA, SBA and SCA (Serna-Chavez et al., 2014; Syrbe and Walz, 2012) has been used for mapping the ESS potentially provided by *P. oceanica*.

The SPA (service providing area) maps the presence/absence of the species or habitat providing the ESS. As data about the spatial distribution of *P. oceanica* meadows in the region are rather scarce, the outcomes of a species distribution model developed for this species (Zucchetta et al., 2016) have been used to map the SPA, providing an estimation of the potential distribution of *P. oceanica* along the North African coast. It is thus important to underline that the ESS assessment here performed reflects the potential ESS provision that would be realized if the meadows had the extension predicted by the above-mentioned distribution model. In case of the availability of a homogenous dataset of *P. oceanica* distribution across the whole region, it would have been possible to apply the same ESS estimation approach proposed in this work to actual seagrass distribution data, rather than to the potential ones.

The SBA (service benefiting area) reflects the areas where the demand for the ESS is located, that is, in the case of this work, where some type of interactions between human society and the *P. oceanica* meadows occur (or are likely to).

A simple “screening method” was used as baseline for SBA mapping, characterized by (1) having data requirements as low as possible, (2) being entirely based on publicly available datasets and (3) requiring the simplest possible processing, in order to ensure a broad applicability of the method to data-poor areas. It thus consists in the definition of a single SBA, which attempts to capture all possible ESS provided by meadows, and which is composed by three elements of demand:

- Urban areas, mapped using the Global Rural-Urban Mapping Project (GRUMP) (Balk et al., 2006; Center for International Earth Science Information Network - CIESIN - Columbia University et al., 2011).