Ecological Indicators 95 (2018) 41–52

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Review

Use and usefulness of open source spatial databases for the assessment and management of European coastal and marine ecosystem services

Claudia Caro[a,b,*], Rute Pinto[a,c], João Carlos Marques[a]

[a] MARE – Marine and Environmental Sciences Centre, Faculty of Sciences and Technology, University of Coimbra, Portugal
[b] Biology Department, Faculty of Sciences, La Molina National Agrarian University, Peru
[c] Ecohydrology Research Group, Department of Earth and Environmental Sciences, University of Waterloo, Canada

ARTICLE INFO

Keywords:
Spatial databases
Data accessibility
Coastal and marine ecosystem services
Marine Strategy Framework Directive

ABSTRACT

Assessing the stocks and flows of ecosystem services valued by society is crucial to ensure the sustainable management of marine ecosystems, as required by the European Marine Strategy Framework Directive (MSFD; EC, 2008). The mapping of these ecosystem services enhances the flow of information from researchers to practitioners, contributing to a better management of ecosystem services. The objective of this paper is twofold. First, a screening and evaluation of available open source spatial databases was conducted to assess their usefulness to map European coastal and marine ecosystem services. Second, these spatial databases were classified according to the DPSIR (Drivers, Pressures, Status, Impacts, Responses) framework and the MSFD descriptors to assess how this information can inform decision-makers. The supply of explicit spatial information was used as main screening criteria and allowed to identify 581 existing databases. These databases were then categorised according to a set of criteria (including data collection methods and updating frequency) related with their usefulness to be applied to map ecosystem services. The databases that did not meet the selected criteria (e.g. no explicit spatial information) were discarded. This process allowed to identify 329 spatial databases useful for coastal and marine ecosystem services mapping in Europe. The databases were then distinguished based on the ability to work the data on a GIS software, identifying 193 databases that allowed further analysis (hereafter applicable), and 136 databases that do not allow the extraction of data (hereafter non-applicable). The applicable spatial databases were further linked to the i) CICES framework for ecosystem services classification, ii) DPSIR framework and iii) descriptors considered in the MSFD. The obtained results showed that 42% of the spatial databases can be useful to map regulation services, followed by provision (33%) and cultural (21%) services. Considering the DPSIR framework, more than half can be used as proxies to evaluate coastal and marine ecosystems status (66%), followed by proxies of pressures (18%), drivers (8%), responses (4%), and finally impacts (4%). The available databases represent in a better way MSFD descriptors related to Hydrogeological conditions (D7), Eutrophication (D5), and Biodiversity (D1), being the non-indigenous species (D2) and contaminants in seafood (D9) descriptors somehow underrepresented. The obtained findings highlight the spatial open data limitations and challenges when mapping coastal and marine ecosystem services and contribute to the identification of spatial data gaps and opportunities when aiming for the sustainable management of marine ecosystems.

1. Introduction

Since the introduction of the ecosystem services concept in the 80ś (Ehrlich and Mooney, 1983) several studies have been conducted aiming to assess and value the services provided by ecosystems, taking into account physical, ecological, economic, social and cultural aspects (MEA, 2005; Wallace, 2007; TEEB, 2008; Martinez-Harms et al., 2015; Costanza et al., 2017). Most of the studies conducted have been, however, focused mainly on terrestrial ecosystems. Knowing that 70.9% of the Earth is covered by oceans (Halpern et al., 2012) and that around 43% of ecosystem services are provided by coastal and marine systems (Levrel et al., 2014), there is still a lack of studies focusing on the assessment and valuation of these natural resources. Marine ecosystem services can be defined as the final outcome of the internal structure,

* Corresponding author at: Marine and Environmental Sciences Centre, Faculty of Sciences and Technology, University of Coimbra, Calçada Martim de Freitas, 3000-456 Coimbra, Portugal.
E-mail address: ccaro@lamolina.edu.pe (C. Caro).

https://doi.org/10.1016/j.ecolind.2018.06.070
Received 23 March 2018; Received in revised form 28 June 2018; Accepted 30 June 2018
1470-160X/

processes and functioning derived from marine systems that contribute to the satisfaction of society demands, sustaining and enhancing human well-being (Müller et al., 2000; Pendleton et al., 2015). Yet, to guarantee the sustainable management of coastal and marine ecosystem services is essential to rely on reliable spatial information (Maes et al., 2013).

Good spatial data is crucial to ensure effective decision-making processes concerning, for example, the protection of a particular area, the assessment of spatial trade-offs between ecosystem services, to inform about species distribution, or even to communicate about policies implementation and targets (Martinez-Harms and Balvanera, 2012; Townsend et al., 2014). In this sense, Europe has conducted some mapping exercises for marine ecosystems to monitor, in a spatially explicit manner, not only the progresses in achieving important objectives related to the Marine Strategy Framework Directive (MSFD; EC, 2008), but also the advances in the Habitats and Species Directive (HSD; EC, 1992) and Biodiversity Strategy (BD; EC, 2011). All these European polices target the maintenance and protection of coastal and marine ecosystem services in Europe (Fraschetti et al., 2011; Albert et al., 2016; Bonamano et al., 2016). Likewise, mapping exercises can be useful to recognize the effects of pressures and impacts of human activities on ecosystem services delivery. This analysis requires the integration of both qualitative and quantitative information about the relationships between a systems' biophysical components and the socio-economic activities taking place in a specific area. One approach to structure this information is through the Drivers-Pressures-Status-Impacts-Responses Framework (DPSIR; OECD, 1993). This approach has been used to support decision-making regarding ecosystems' management actions, monitor strategies and determine ecosystem services trade-offs (e.g. Atkins et al., 2011; de Jonge et al., 2012; Pinto et al., 2013).

European marine ecosystem services mapping exercises have been mainly focused on the description of ecosystem's status as result of human pressures (Parravicini et al., 2012). From these, regulation services are the most described, especially carbon sequestration and storage (e.g. Liquete et al., 2013; Levrel et al., 2014) and coastal protection (e.g. Rioja-Nieto et al., 2017). These are closely followed by provision services, particularly food provision, fisheries and aquaculture activities (e.g. Deutsch et al., 2007; Pauly, 2007; Thiault et al., 2017). Finally, cultural services, like stakeholders' preferences related to marine protected areas (Halpern et al., 2012) and education or recreational opportunities (Davis and Darling, 2017) are amongst the least mapped services in coastal and marine ecosystems.

From these mapping exercises four main challenges have been identified. The first challenge is related with the gathering of enough qualitative and quantitative information to describe all the dimensions of marine ecosystems (Hauck et al., 2013). This process might be particularly complex due to i) the vertical component of oceans (depth), that makes harder to represent the benthic and pelagic dynamics across time (Lavorel et al., 2017); ii) the ambiguous boundaries within marine ecosystems; iii) the difficulties to associate species with their marine habitats with enough spatial resolution (Tempera et al., 2016); and finally iv) the social dynamics related with the ocean and the incorporation of associated economic values to these systems (Bergström et al., 2015; Moore et al., 2017).

The second challenge concerns the scale of the mapping exercises. Most studies are performed at the regional or national scale (Martinez-Harms and Balvanera, 2012), while there is the need to improve our knowledge regarding marine ecosystem services using global datasets that have higher resolution (Tyberghein et al., 2012).

The third challenge is linked to the existence of uncertainty sources in the existing maps that could hinder their use. Among them are, for example, the lack of consistency in the definition of the indicators to be used for mapping coastal and marine ecosystem services. The Common International Classification of Ecosystem Services (CICES) framework has been developed to try to fill this gap by creating a standardized framework to describe and categorize ecosystem services (Potschin-Young et al., 2016). Other operational challenges are found such as the i) lack of clear information about the methodology used in the data gathering; ii) scarcity of quantitative information in spatial databases (Levrel et al., 2014; Lavorel et al., 2017); and iii) defined methodology to map marine ecosystem services, resulting in different outputs depending on the methodology used (Schulp et al., 2014).

Finally, the fourth challenge regards the limitations that current technology offer, making difficult the full recognition of all marine habitats (Rao et al., 2015). For example, benthic habitats frequently are not visible with remote-sensing technology (Lavorel et al., 2017), making the mapping of marine ecosystems significantly more costly (Fraschetti et al., 2008) and reducing their elaboration for just those services that have a more direct economic interest (e.g. food production; Liquete et al., 2013).

The main objective of this paper is to conduct a review of existing spatial databases that can be used to map coastal and marine ecosystem services in Europe. More specifically, we aim to 1) make an inventory of existing georeferenced open source information for European seas; 2) assess how the available information can be used to map coastal and marine ecosystem services, using the CICES classification as benchmark, and finally 3) infer how the different variables available in those databases can be linked to existing frameworks and policies, such as DPSIR and MSFD descriptors, contributing to the management of coastal and marine ecosystem services.

2. Methodology

A comprehensive review of available spatial databases for European seas was undertaken, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009). The first step involved the listing of open source databases available in institutional websites, such as European Environmental Agency (EEA; https://www.eea.europa.eu/) or NASA (https://www.nasa.gov/), specific project websites (e.g. Copernicus project; http://www.copernicus.eu/), or even data repositories, such as Web of Science (https://apps.webofknowledge.com/), Scopus (https://www.scopus.com/), or ScienceDirect (http://www.sciencedirect.com/). Additionally, already existing European guides on how to map marine ecosystem services were reviewed (e.g. Tempera et al., 2016). This search only considered databases available in English and using the following keywords, either alone or in combination, 'ecosystem services', 'map', 'spatial data', 'coast', 'marine', 'sea', 'ocean', 'Europe', 'Marine Strategy Framework Directive'.

A total of 443 papers were retained for review, including review (e.g. Liquete et al., 2013) and local mapping (e.g. Hattam et al., 2015) papers, or databases created by research projects (e.g. Harris et al., 2014). A first screening was done to assess the originality of the data sources, to eliminate duplicated information, and to prioritize those with mapping exercises. From this, 205 papers that contained information on marine spatial databases were identified and considered for further analysis. The gathered information resulted in a list of links that helped to build an inventory of available coastal and marine spatial databases.

Based on the initial inventory, a further screening process was conducted considering three main selection criteria: i) access to spatial data, ii) spatial coverage, and iii) ability to work the data in a GIS software. Regarding the first selection criterion (access to spatial data), an effort was done to ensure that only open access databases were included in this review, either by direct download from database repositories (e.g. http://data.unep-wcmc.org/) or downloadable after a form completion (e.g. http://www.marineregions.org/downloads.php). The second selection criterion was related with the spatial coverage of the databases, where the listed links were classified into geographical ranges: local (e.g. http://www.mareano.no), national (e.g. http://atlas.marine.ie), regional (e.g. http://metadata.helcom.fi/geonetwork),