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Ecosystem-based management planning across aquatic realms at the Ria de Aveiro Natura 2000 territory

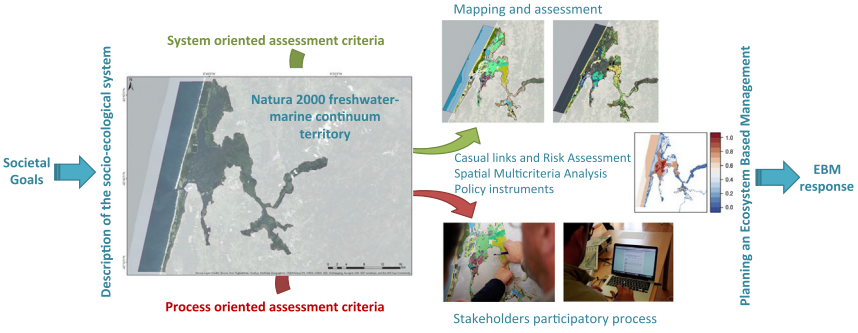
Ana I. Lillebø [a,*], Heliana Teixeira [a,*], Mariana Morgado [a], Javier Martínez-López [b], Asya Marhubi [c], Gonzalo Delacámara [c], Pierre Strosser [d], António J.A. Nogueira [a]

[a] Department of Biology & CESAM, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal
[b] BC3 - Basque Centre for Climate Change, Scientific Campus of the University of the Basque Country, 48940 Leioa, Spain
[c] IMDEA Water Institute, Av/Punto Com, 2, Parque Científico Tecnológico, Universidad de Alcalá, 28805, Alcalá de Henares, Madrid, Spain
[d] AcTeon, 5 Place Sainte-Catherine, 68000 Colmar, France

HIGHLIGHTS

- A Natura 2000 freshwater-marine continuum territory was used as showcase for EBM
- EBM planning process combining Science, Policy and Stakeholders' perspectives
- The latter matched the calculated causality links and risk assessment
- Ecosystem services were valued by stakeholders through spatial multi-criteria analysis
- EMB planning approach followed a stepwise procedure in line with resilience thinking and its principles

GRAPHICAL ABSTRACT



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ABSTRACT

Ria de Aveiro represents a coastal territory, in which its natural capital, mostly classified under a Natura 2000 network of protected areas, is of paramount importance for the regional and national economy, supporting harbour activities and maritime traffic, agriculture, commercial fisheries, aquaculture, manufacturing, tourism, sports and recreational activities. Current and foreseen changes connected to human activities, namely land and water uses and potential conflicts, in frame of environmental policies, sustainable economic development and human well-being require the implementation of ecosystem-based management (EBM) planning processes considering the connectivity across marine, transitional, freshwater, and terrestrial domains. The main objective is to elaborate on the co-development of the EBM planning process across the three water domains, all characterized by high biodiversity and by the wide range of services provided by ecosystems and their abiotic components, for the mitigation of impacts from the management plan under implementation. The approach used follows a stepwise procedure in frame of resilience principles, considering the analysis of the relationship between the social and ecological components and on how these can be connected through risk assessment and a spatial multi-criteria analysis based on the delivery of ecosystem services. Stakeholders' perception matched the ecosystem services provisioning risk assessment and supported the planning EBM response that consist in saltmarshes and seagrasses meadows restoration programs. Compliance of the proposed measures is achievable regarding policies (policy targets and policy instruments) and feasibility (scientific and technological knowledge and financial resources). The EBM response can support the Vouga estuary management plan and regional smart specialization (RIS3 Centro).

* Corresponding authors.
E-mail addresses: lillebo@ua.pt (A.I. Lillebø), heliana.teixeira@ua.pt (H. Teixeira).

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1. Introduction

Natura 2000 represents a European coordinated network of protected areas, both on land and at sea, to ensure the existence and conservation of the most valuable and threatened habitats and species. It is also the basis of European Union (EU) Biodiversity Strategy and EU international commitment to the international Convention on Biological Diversity and its Aichi Targets (*e.g.,* Marino et al., 2014b; Beresford et al., 2016; Rouillard et al., 2018). The management of Natura 2000 sites across aquatic realms entails the coordination of EU nature directives, that is Habitats Directive (92/43/EEC) and Birds Directive (79/409/EEC), with water related directives, namely Water Framework Directive (2000/60/EC), Marine Strategy Framework Directive (2008/58/EC) and Floods Directive (2007/60/EC) (European Union, 2016). The designation of Natura 2000 implies that the sites are managed in an active and sustainable manner, considering ecological and socio-economic features, therefore, when involving coastal and marine habitats marine spatial planning should also be considered (Domínguez-Tejo et al., 2016) following the Maritime Spatial Planning Directive (89/2014/EC). At the operational level, challenges interconnected to environmental integrated management relates to: i) coordination of measures due to the multiplicity of sectors involved; ii) communication, between academics, policymakers and practitioners, and the general public; iii) compliance with relevant policies and regulations; iv) knowledge gaps and scarcity of resources, namely in the context of climate change; and v) assessment of the effects of management actions on human well-being (*e.g.,* Cavanagh et al., 2016; Lillebø et al., 2016; Breslow et al., 2016; Drakou et al., 2017; Elwell et al., 2018; Fernandino et al., 2018; Rouillard et al., 2018).

Human well-being has gain increasing relevance since the consequences of ecosystem change for human well-being were assessed in the scope of the Millennium Ecosystem Assessment that was carried between 2001 and 2005 under the auspices of the United Nations (Millennium Ecosystem Assessment, 2005). One of the key questions identified was – "*what options exist to enhance the conservation of ecosystems and their contribution to human well-being*?" In this context, ecosystem-based management (EBM) planning process represents a holistic approach that aims to balance the multiple interrelated dimensions of ecological integrity (*e.g.,* natural capital and biodiversity through ecosystem processes, functions and services) and human well-being; considering different spatial and temporal scales and involving people holding stakes and the general public interested in the present and future health of the selected territory (*e.g.,* Leslie and McLeod, 2007; Long et al., 2015; Breslow et al., 2016; Barbosa et al., this issue). EBM planning process, including Natura 2000 sites, involve the coordination of policies, institutions, and practices in order to reduce negative trade-offs and/or provide positive synergies with other ecosystem services (ES) (Cavanagh et al., 2016). Some relevant examples of different approaches to operationalize EBM are: i) through the precautionary principle along with adaptive management (Curtin and Prellezo, 2010), ii) through a set of key principles (Long et al., 2015); iii) through a conceptual framework of human well-being (Breslow et al., 2016); iv) through collaborative networks considering actors with different capabilities, interests, and intentions (Bodin et al., 2016); v) through a set of detailed pre-screening of measures (Piet et al., 2017); vi) considering Policy-relevant principles (Rouillard et al., 2018); vii) through resilience thinking and principles (Curtin and Parker, 2014). The last one is a multidisciplinary approach to environmental problem solving that links social and ecological perspectives in a holistic approach. The concept emerged from resilience science, adaptive management and ecological policy design, and bridges the gap between social and ecological systems by considering ecology, management of natural capital and systems analysis (Curtin and Parker, 2014).

The area under study, *i.e.*, the Ria de Aveiro Natura 2000 territory, was selected following official reports by the Portuguese Nature Conservation and Forests, which is responsible for the Sectoral Plan for Natura 2000 Network (available at http://www2.icnf.pt/portal). The selected Natura 2000 area comprises the classified section of the Vouga River (2769 ha); the Vouga River estuary, which is part of Ria de Aveiro coastal lagoon (20,737 ha) and the adjacent coastal area (30,642 ha), and the freshwater wetland Pateira de Fermentelos (262.5 ha), also designated as Ramsar site. The location of the selected Natura 2000 territory, the identified aquatic and terrestrial realms within the area and its land use context are shown in Fig. 1. The locations of the above-mentioned sections, considered in the selected area, are presented as supplementary material (Fig. SM1). Within the selected Natura 2000 area, its natural capital, including the variety of ecosystem services and abiotic outputs, and biodiversity, are essential for socio-economic development, and has enabled the development of a wide variety of economic, cultural and recreational activities (*e.g.,* Lillebø et al., 2015; Dolbeth et al., 2016; Sousa et al., 2016; Bueno-Pardo et al., 2018). As a result, the area is subject to a complex range of land and water uses and potential conflicts, including anthropogenic pressures that impact the hydro-morphological conditions of the lagoon and the adjacent freshwater section of the Vouga River (Lillebø et al., 2015; Lillebø et al., 2016; Sousa, 2017). Stakeholders, including general public, have identified these changes as a major concern and a priority for management (Lillebø et al., 2015). The governance of the area involves a multiplicity of institutions, organizations and people holding stakes, as well as the articulation of programs and plans of local, regional and national levels (Lillebø et al., 2015; Sousa et al., 2016; Sousa, 2017).

The main objective is to contribute to the improvement of the integrated management of aquatic Natura 2000 sites, from catchment to marine waters, involving the concepts of science, policy and stakeholder interface. To do so the Natura 2000 area at Ria de Aveiro region, a coastal territory, will be presented as showcase for an EBM planning process. The management options foreseen at local/regional level that will be considered in the prospective scenarios are the dredging programme, named "Sediment Transposition for Optimization of Hydrodynamic Equilibrium in the Ria de Aveiro", that takes place in 2018/2019 (RECAPE, 2017); and the extension of a floodbank to prevent surface saltwater intrusion into agricultural areas, at the confluence of the Vouga River and the Ria de Aveiro coastal lagoon, that also takes place in 2018/2019 (DGADR, 2017). Results are discussed considering the planning process of an EBM in response to the foreseen associated unintended pressures, considering the articulation of the system-oriented assessment criteria attained from natural sciences (*e.g.,* habitats, ecosystem services provisioning, human activities), the process-oriented assessment criteria attained from social sciences (*e.g.,* stakeholders' perception, compliance with rules and regulations) and the combination of both (*e.g.,* spatial multi-criteria analysis by stakeholders), and on how this approach supports human well-being.

2. Methods

2.1. Characterization of the study area

The selected Natura 2000 area is located in the border between the Mediterranean and the north-western European bio-geographical regions (European Environment Agency, 2017). It is under the influence of a temperate maritime climate characterized by long, warm summers (June–September) and mild rainy winters (December–February), with an average temperature of 14 °C and an average precipitation of 1000 mm $year^{-1}$ (Stefanova et al., 2015). The Vouga River is characterized by episodic flood events that inundate the low-lying adjacent lands at the confluence with Ria de Aveiro coastal lagoon, the Baixo Vouga Lagunar (BVL) (for a detailed description of BVL see Martínez-López et al., this issue). The eight aquatic realms that were identified (Fig. 1) were combined into three water domains: freshwater, transitional and coastal/marine. A short description of each domain is presented in Table 1. Due to the complexity of the selected territory regarding its