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Towards adaptive management of the natural capital: Disentangling trade-offs among marine activities and seagrass meadows

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ABSTRACT

This paper investigates the ecological, social and institutional dimensions of the synergies and trade-offs between seagrasses and human activities operating in the Natura 2000 protected site of San Simón Bay (Galicia, NW Spain). By means of a multidisciplinary approach that brings together the development of a biological inventory combined with participatory mapping processes we get key spatial and contextual understanding regarding how, where and why marine users interact with seagrasses and how seagrasses are considered in policy making. The results highlight the fisheries' reliance on seagrass meadows and the controversial links with shellfisheries. The study also reveals unresolved conflicts among those management plans that promote the protection of natural values and those responsible for the exploitation of marine resources. We conclude that the adoption of pre-planning bottom-up participatory processes is crucial for the design of realistic strategies where both seagrasses and human activities were considered as a couple system.

1. Introduction

The report of the Millennium Ecosystem Assessment recognized that coastal ecosystems generate substantially higher ecosystem services (thereafter, ES) for human wellbeing than other systems (MEA, 2005). Several research studies highlight the key ecological role of seagrasses in the maintenance of marine biodiversity (Currás and Mora, 1996; Attrill et al., 2000; Nagelkerken et al., 2000; Fredriksen et al., 2010; Boström et al., 2011; McCloskey and Unsworth, 2015). In addition, seagrass has the potential role of protecting the coast against erosion (Ondiviela et al., 2014) and contributing to carbon sequestration (Fourqurean et al., 2012; Mazarrasa et al., 2015).

The links between seagrasses and the welfare of local populations are also demonstrated by studies carried out in the Caribbean (Baker et al., 2015), East Africa (de la Torre-Castro and Rönnbäck, 2004) and Indonesia (Unsworth et al., 2010). Interactions between coastal populations and seagrass involve both anthropogenic pressures and also ecological and social benefits. On the one hand, seagrasses are highly vulnerable. Their locations in the intertidal and nearshore areas, which generally favour human access and the occurrence of multiple marine uses, expose them to both terrestrial and marine based threats (Valiela, 2006; Cullen-Unsworth et al., 2014). On the other hand, seagrasses have an important role as feeding grounds for the marine food webs, and supporting coastal fisheries (Filgueira and Castro, 2011; Cullen-Unsworth et al., 2014; Baker et al., 2015).

Addressing the analysis of synergies and trade-offs between seagrass meadows and human marine uses, through a combination of biophysical and social evidences, enables a better understanding of the relationship between the environment and societies (Guerry et al., 2015). Involving stakeholders through participatory processes facilitates the gathering of local knowledge, which includes the local context of the seagrass trends. Participation and social involvement can increase the success of marine planning fostering a sense of being a part of the research and the decision-making process (Anuchiracheeva et al., 2003; Cudney-Bueno and Basurto, 2009; Song et al., 2013). In addition, the management of marine and coastal ecosystems is currently based on spatial information in which the role of data about the location of resources, users and problems is central for policy makers (Vajjhala, 2006; de la Torre-Castro et al., 2014). Accordingly, participatory mapping provides the ability to involve users of the marine space in the production of data, and provides useful information for the management of natural resources (Mahboubi et al., 2015).

The recognized importance of seagrass in the provision of goods and services and the recent reports of their global decline provide a strong impetus to develop a global seagrass conservation effort (Orth et al., 2006). However, seagrasses are often left out of the global conservation agenda for governments and international organizations (Kenworthy et al., 2006; Hendriks and Duarte, 2008; Unsworth et al., 2010). This aforementioned situation happens in the European region of Galicia (NW of Spain). Seagrasses are not part of the policy decision-making,

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even though their ecological role has been recognized by the European Water Framework Directive (WFD, 2000/60/EC) as one of the five biological quality elements to be included in the ecological quality assessment of estuarine waters. Moreover, the habitats in which seagrasses grow are included in the European Habitats Directive's (92/43/ECC) of Red Natura 2000; the Oslo–Paris Convention (OSPAR) also recognized the need to protect seagrasses.

In addition, many efforts have been made in recent years to consider natural resources in planning processes and some instruments determining to protect natural heritage have been approved in Galicia. However, the lack of knowledge about the interaction between marine ecosystems and social processes, together with the limited information about the status of seagrasses, makes it difficult to realistically integrate valuable phanerogams in decision-making processes.

Out of this context, the aim of this paper is to investigate the ecological, social and institutional dimensions of the synergies and trade-offs between seagrasses and the human activities operating in the marine–coastal area of the San Simón Bay (Galicia, NW of Spain). To address this range of issues, it has adopted a multidisciplinary approach not yet implemented in Spain, which brings together the development of a biological inventory to characterize the spatial distribution of the seagrass combined with an in-depth participatory process with the users of marine ES and policy makers/managers. Through the lens of marine uses as the way in which people interact with seagrass resources, spatial and contextual information is obtained to explore a) the local ecological knowledge on seagrass meadows, b) how local people use seagrass resources, and c) how public administration addresses the management of the seagrass-human relationships.

2. Material and methods

The multidisciplinary approach includes the gathering of primary data through the development of a biological inventory as well as the performance of participatory processes. Moreover, secondary data were collected from the review of public planning, regulations and scientific studies. Following the data collection a spatial analysis was performed to produce maps where the way in which seascape users interact with seagrass resources was visualized (Fig. 1).

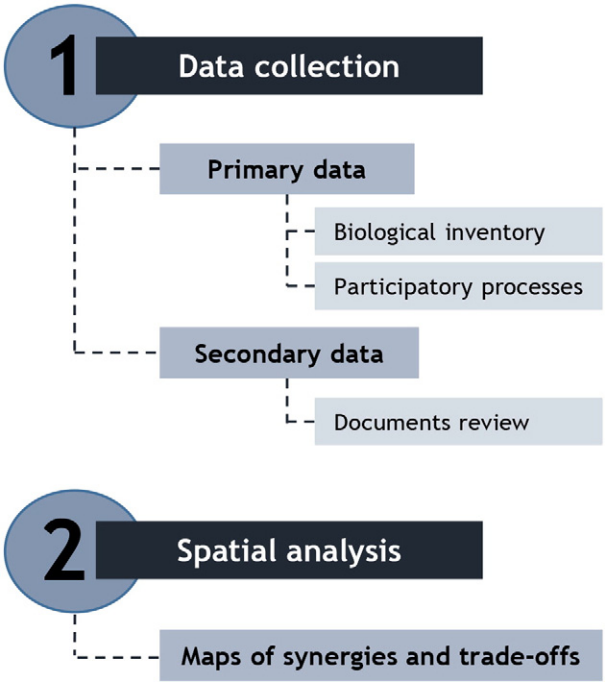

Fig. 1. Methodological diagram.
Source: own elaboration.

2.1. Study area

The San Simón Bay is a coastal area of 22.52 km^2 belonging to the European Natura 2000 Network located in the inner part of the Ría de Vigo (Galicia, NW Spain) (Fig. 2). Approximately 96% of the space under this Special Area of Conservation (SAC) belongs to a marine environment and hosts a variety of habitats including mud–sandy flats, sandy bottoms and marshes (Xunta de Galicia, 2014). The San Simón Bay also includes a remarkable presence of two species of seagrass meadows: *Zostera marina* and *Zostera noltii*.

The hydrodynamic conditions of the area are of low energy due to the morphology of the Strait of Rande and the shallowness of the bay, with depths mostly under 8 m (Nombela et al., 1992). Fluvial sediment input contributes to the gradual infilling of the bay, which acts as a sediment trap where silt and clay sediments deposit on the intertidal flats and the coarser ones deposit in the riverheads (Nombela et al., 1995).

The municipalities surrounding the San Simón Bay include a total population of 145,548 inhabitants (2014) with a mix of urban, agricultural, industrial and forestry uses. The marine activities include small-scale fisheries (e.g., cuttlefish, eel and sardines) and shellfisheries (e.g., clams and cockles) developed mainly by members of the fishing guilds (*cofradías*) of Arcade, Redondela and Vilaboa. The recreational and spiritual importance of the marine space might be explained by the presence of recreational activities such as windsurfing, kite surfing, bathing, canoeing and recreational fishing.

Conservation and management of seagrasses in the area is affected by multiple regulations and management actions operating simultaneously. We can find restrictions due to its status as a Special Area of Conservation, the allowed shares of catches regarding fisheries exploitation planning or the limits of pollutant discharge for the water bodies to achieve a healthy status.

2.2. Primary data collection

2.2.1. Sampling method for the biological inventory

The biological inventory allows the collection of detailed spatial data about the species of seagrass and their environmental context by using representative patches across the San Simón Bay. The fieldwork consisted of recording geotagged photographs of the intertidal area where seagrass beds are visible and accessible at low tide. We visited the bay frequently from May 2013 to September 2014 (10–12 times/year).

In addition, seagrass cover estimation was conducted in a monospecific patch of *Z. noltii* located near Matilde beach (Soutomaior) at the northeast of the bay. The cover values of the patches were determined by visual estimation of the quadrats located along transects by using the percentage cover photo guide provided by the Seagrass-Watch program (http://www.seagrasswatch.org/home.html). Combined with the coverture sampling, the perimeter of the patch was also measured with the mobile application Motion X-GPS. Both tasks were developed by a group of volunteers formed by youngsters from the European Voluntary Service and people interested in the marine environment. All of them were previously trained in an information session about seagrass's role in human wellbeing and were provided a detailed explanation about the purpose for gathering samples and the methodology used for sampling.

2.2.2. A bottom-up participatory approach

The interactions between marine ecosystems and coastal communities can be highly complex and interconnected (Folke et al., 2011; Villasante et al., 2013), and qualitative methods are useful tools for identifying the spatial dynamics and relationships between a wide range of variables, users and marine resources (Outeiro et al., 2015). Our qualitative approach, which included interviews and participatory mapping in-person, was based on narrative dialogues to find significant key topics related to how, where and why there are interactions between marine