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Integrating natural capital assessment and marine spatial planning: A case study in the Mediterranean sea

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ABSTRACT

Marine and coastal ecosystems are among the most productive environments in the world and their stocks of natural capital offer a bundle of vital ecosystem services. Anthropogenic pressure seriously threatens health and long-term sustainability of marine environments. For these reasons, integrated approaches capable of combining ecological and socio-economic aspects are needed to achieve nature conservation and sustainability targets. In this study, the value of natural capital of the Egadi Islands Marine Protected Area (EI-MPA) was assessed through a biophysical and trophodynamic environmental accounting model. The emergy value of both autotrophic and heterotrophic natural capital stocks was calculated for the main habitats of the EI-MPA. Eventually, the emergy value of natural capital was converted into monetary units to better communicate its importance to local managers and policy-makers. The total value of natural capital in the EI-MPA resulted in $1.12 \cdot 10^{21}$ sej, equivalent to about 1.17 billion of euros. In addition, using Marxan software, the results of the environmental accounting were integrated with spatial data on main human uses. This integration took into account the trade-offs between conservation measures and human exploitation by means of two different scenarios, with and without considering human uses in the EI-MPA. The comparison between the scenarios highlighted the importance of taking into account human activities in marine spatial planning (MSP), allowing the identification of key areas for natural capital conservation. In conclusion, this study showed the importance of integrating environmental accounting with conservation planning to support effective strategies for ecological protection and sustainable management of human activities. The results of this study represent a first benchmark useful to explore alternative nature conservation strategies in the EI-MPA, and, more in general, in Mediterranean MPAs.

1. Introduction

In the last years, scientific research on natural capital assessment has grown considerably driven by major international initiatives, such as the Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystems and Biodiversity – TEEB (www.teebweb.org).

From an anthropocentric perspective, the general concept of capital is that it has to be productive, generating goods and services that are useful to people (Dickie et al., 2014). Therefore, the notion of value is linked to the use of resources by humans.

Under a more ecological perspective, natural capital can be defined as the stocks of natural assets generating functions and flows of ecosystem services (Costanza et al., 1997, 2014; Daily, 1997; Folke et al., 2010, 2011; Jones et al., 2016; MA, 2005). The "ecological value" of natural resources is not necessarily linked to their use by humans, but it is related to the role that they play in the functioning of the biosphere at different scales and in support of different species (Odum, 1996).

At global level, natural capital stocks are exploited at an unsustainable rate to supply human economy, following the "growth ethic" paradigm based on the misconception that natural assets are unlimitedly available. This paradigm disregards the biophys-

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ical limits of the Earth system and the consequences generated by human activities on the biosphere and its stability (Brown and Ulgiati, 2011; Rockström et al., 2009a,b). The erosion of natural capital stocks over time leads to a severe decline of the services provided by ecosystems worldwide with broad consequences encompassing the ecological, economic, and social spheres (de Groot et al., 2012).

Marine and coastal ecosystems are among the most productive environments in the world (Martínez et al., 2007; UNEP, 2006). According to Costanza et al. (1997), they contribute for more than 60% of the total economic value generated by the biosphere while offering a wide variety of services (e.g., seafood provision, natural shoreline protection against storms and floods, water quality maintenance, cultural and spiritual benefits, among others).

Despite their importance, the health and long-term sustainability of marine ecosystems are seriously threatened by the overexploitation of their services (Doyen et al., 2007) and the increasing effects of anthropogenic disturbances, such as land use change, habitat loss, overfishing, invasive species, pollution, eutrophication, and climate change (Airoldi and Beck, 2007; Halpern et al., 2012; Milazzo et al., 2014). The highly threatened status of marine and coastal ecosystems requires effective and integrated approaches capable of combining ecological, economic, and social aspects to achieve their sustainable exploitation (Franzese et al., 2008, 2015).

In this regard, Marine Protected Areas (MPAs) are largely acknowledged worldwide as useful tools for both marine conservation and sustainable resources management (Fenberg et al., 2012; Guidetti et al., 2008; Halpern and Warner, 2002). The enforcement of protection measures in MPAs supports an increase of natural capital stocks and related ecosystem services such as fish populations, fishery yields, and tourism activity (Angulo-Valdés and Hatcher, 2010; Guidetti et al., 2008).

Environmental accounting can be used as a tool to assess both the biophysical and economic value of natural capital and ecosystem services in nature reserves and MPAs (Berrios et al., 2017; Franzese et al., 2017; Häyhä and Franzese, 2014; Häyhä et al., 2015; Lu et al., 2007; Nikodinoska et al., 2015; Vassallo et al., 2017). The scientific literature recognizes the existence of two main approaches, namely the biophysical and the preference-based approaches, for the estimation of nature's value (TEEB, 2010). The cluster of the biophysical methods focusing on the measure of the physical cost supported to generate products and services includes the emergy accounting method used in this paper.

The EU Biodiversity Strategy to 2020 committed Member States to boost the policy on nature conservation, biodiversity protection, and natural capital assessment. Following this trend, in 2014, the Italian Ministry of the Environment and Protection of Land and Sea financed a 4-years research programme entitled "Environmental Accounting in Italian Marine Proteceted Areas" (EAMPA) and based on the implementation of an environmental accounting system for all the twenty-nine Italian MPAs. The purpose of the project is to carry out a biophysical and economic assessment of natural capital stocks and ecosystem services flows, while also considering the impacts generated by human activities taking place within the MPAs (Franzese et al., 2015). The project also entails the spatial representation of both the ecological and economic value of natural capital within the investigated MPAs to support marine spatial planning (MSP). MSP refers to a comprehensive planning approach considering natural resources, processes, and human uses of a marine system to identify areas appropriate for specific uses, resolve conflicts between existing and future uses, and achieve a range of ecological, economic, and social objectives (Smythe, 2017).

Biodiversity and ecological features have traditionally been the main driving factors for the design and establishment of new marine reserves, while socio-economic factors have usually been disregarded or considered *a posteriori* (Stewart and Possingham, 2005). If only ecological aspects are considered, conflicts with stakeholders can arise, undermining the success of protection measures. Hence, successful managements need to strike a balance between conservation measures and socio-economic viability, considering the possible trade-offs in marine reserve design (Klein et al., 2008, 2013).

The achievement of consevation goals requires spatial planning strategies and tools needed to identify areas devoted to socio-economic development and conservation while supporting their management (Margules and Pressey, 2000). Marxan software is one of the most widely used conservation planning tool to design both terrestrial and marine reserves worldwide (Ball et al., 2009; www.marxan.org). The rezoning of the Great Barrier Reef Marine Park in Australia (Fernandes et al., 2005) and the support in the design of marine protected areas for the Channel Islands in California (Airamé et al., 2003) are among its most important applications in marine environments. In the Mediterranean Sea, Marxan applications were addressed to evaluate the possible set up of a system of MPAs along the Apulia coasts of Italy (Fraschetti et al., 2009), and to apply a systematic planning approach on the main key habitats: seagrass meadows, coralligenous, and marine caves (Giakoumi et al., 2013).

In this study, in the framework of the EAMPA project, the biophysical and non-market monetary value of natural capital of the Egadi Islands MPA (South Italy) was assessed through the emergy accounting method. In addition, by using Marxan software, the results of the environmental accounting were integrated with spatial data on main human uses to identify key areas for natural capital conservation, taking into consideration the trade-offs between protection measures and human exploitation.

2. Materials and methods

2.1. Study area

Established in 1991 by the Italian Ministry of the Environment, the Egadi Islands MPA (hereafter EI-MPA) is located off the western coast of Sicily (37°57′09″N 12°13′23.88″E) and surrounds three islands named Favignana, Levanzo, and Marettimo, and two islets named Maraone and Formica (Fig. 1). The extension of the MPA is 53,992 ha, and with a coastline of 74 km it is one of the largest marine reserves in Europe (D'Anna et al., 2015).

The economy of the archipelago is mainly based on fishing and tourism. Professional fishing and the seasonal sea-based tourism are indeed the main economic driving forces. In particular, beach tourism, boat tripping, restaurants and hotels benefit from the summer flow of tourists as well as the many diving centers authorized by the MPA.

The MPA has a high naturalistic value as it hosts important habitats such as coralligenous and vermetid reefs, and includes the largest *Posidonia oceanica* meadow in the Mediterranean, all listed in the European Red List of Habitats (Gubbay et al., 2016). The rich biodiversity associated to its habitats also comprises rare and threatened species, e.g. the Mediterranean monk seal *Monachus monachus*, the sea turtle *Caretta caretta*, the dusky grouper *Epinephelus marginatus*, and the noble pen shell *Pinna nobilis*.

The EI-MPA is managed by the Municipality of Favignana and protection is enforced by the Coast Guard and by other institutional bodies or voluntary associations (D'Anna et al., 2015).

Like all Italian MPAs, the EI-MPA is divided into three subareas characterized by different levels of protection and accessibility, but, in addition, it is the only one having a fourth buffer zone allowing a higher degree of human exploitation (Fig. 2). All human uses and activities (e.g., fishing, scuba diving, and tourism) are regu-