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Identification and prioritization of areas with high environmental risk in Mediterranean coastal areas: A flexible approach

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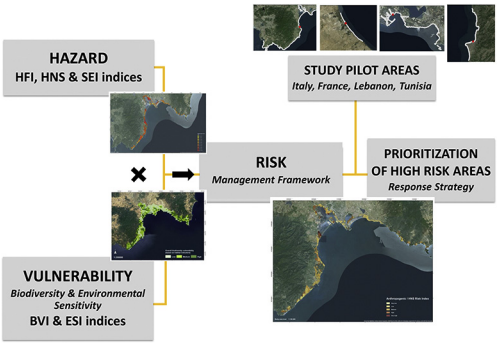
HIGHLIGHTS

- Respond to the need of an interdisciplinary management of coastal ecosystems
- Biosphere, lithosphere and anthroposphere data were considered, combined in a prioritization procedure
- A set of criteria for prioritizing sites mainly based on plant diversity in response to oil spill, fragmentation and HNS
- Different areas were prioritized for each hazard, the response of habitat and habitat and species were highly correlated
- This approach can provide public administrations and local communities an easy-to-use instrument towards ICZM

GRAPHICAL ABSTRACT



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ABSTRACT

Interdisciplinarity and transdisciplinarity are the cornerstone for the future management of coastal ecosystems with many vulnerability and hazard indexes developed for this purpose, especially in the engineering literature, but with limited studies that considered ecological implications within a risk assessment. Similarly, the concept of prioritization of sites has been widely examined in biodiversity conservation studies, but only recently as an instrument for territory management. Considering coastal plant diversity at the species and community levels, and their vulnerability to three main potential hazards threatening coastal areas (oil spills, Hazardous and Noxious Substances pollution, fragmentation of natural habitats), the objective of this paper is to define an easy-to-

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use approach to locate and prioritize the areas more susceptible to those stressors, in order to have a practical instrument for risk management in the ordinary and extra-ordinary management of the coastline. The procedure has been applied at pilot areas in four Mediterranean countries (Italy, France, Lebanon and Tunisia). This approach can provide policy planners, decision makers and local communities an easy-to-use instrument able to facilitate the implementation of the ICZM (Integrated Coastal Zone Management) process in their territory.

1. Introduction

The Mediterranean Basin constitutes one of 200 ecological regions with the highest level of biodiversity in the world (Olson and Dinerstein, 1998). Although covering only 0.8% of the world's sea surface and 0.3% of its seawater volume, the Mediterranean Sea is home to 10,000 to 17,000 marine species, 20% of which are endemic (Bazairi et al., 2010; Coll et al., 2010). The terrestrial plant diversity of the Basin is similarly rich, with about 25,000 species native to the region (60% of them are Mediterranean endemics, half of which corresponds to narrow endemics; Thompson, 2005), and around 10% of the world's higher plants concentrated in an area covering <2% of the land mass (Medail and Quezel, 1999). Therefore, the Mediterranean Basin is also recognized as one of 34 Global Biodiversity Hotspots (Mittermeier et al., 2005; Myers et al., 2000).

According to the IUCN (IUCN, 2016), the major causes of threat to Mediterranean species include, by order of importance, habitat loss and degradation, pollution and over exploitation of natural resources (Cuttelod et al., 2008). Moreover, urbanization, tourism and industrial development are the main drivers of land cover change (Benoit and Comeau, 2005; European Environment Agency, 2013). It is estimated that the number of people living permanently in the Mediterranean coastal regions will increase by 1.4% per annum along the Southern and Eastern shorelines, reaching 108 million by 2025; while the Northern shorelines are expected to stabilize at about 68 million (Coudert and Larid, 2006). These increases are predicted to cause the loss of 200 km per year of coastline to urban areas between the present and 2025. The Mediterranean Basin is also one of the world's busiest areas for maritime traffic with 200,000 commercial ships crossing annually the sea and approximately 30% of international sea-borne volume originating from its ports or directed towards them (Abdulla and Linden, 2008). Tourism and freight transport, offshore platforms and waste discharges from boats or affluent rivers are an additional important pollution source for the semi-enclosed sea (Lejeusne et al., 2010; Cózar et al., 2015). The request for an easy and efficient application of ICZM to the Mediterranean Basin remains very relevant (Buono et al., 2015; Prem, 2010). This is especially true when considering also that the overall response capability of many Mediterranean countries (Italy, Greece, Malta, Spain) to deal with Hazardous and Noxious Substances (HNS) incidents was still rather limited few years ago (EMSA, 2013).

Historically, engineers were the main party in charge of the management of coasts, because management was essentially focused on coastal projects that consisted of infrastructure design and construction to enhance the exploitation, or the physical protection of the coastal area (Kamphuis, 2011). As such, several instruments for the assessment of vulnerability and hazard have been developed, especially in the engineering literature (Appelquist and Balstrøm, 2015; Komendantova et al., 2014) with limited studies focusing on the assessment of the concept of risk and hazard considering the ecological implications (see for a review De Lange et al., 2010). More recently, the definitions of coastal management and engineering have been extended with interdisciplinarity and transdisciplinarity evolving to become the cornerstone for the future management of coastal ecosystems (Kamphuis, 2011; Stock and Burton, 2011). In fact, decision makers have started to feel that "simple solutions to complex problems" is not the key towards the successful management of a territory (Jackson, 2006; Reyers et al., 2010). As a consequence, both the scientific communities and funding agencies are refocusing their efforts towards integrating the research outcomes from multidisciplinary research, trying to break down barriers that often prevent our shared understandings of complex issues (Jackson, 2006; Stock and Burton, 2011). Similarly, the concept of prioritization of sites has been widely examined for biodiversity conservation (e.g. Pressey et al., 1993; Wilson et al., 2006), for public health implications in case of pollution (Harold et al., 2014) but only recently as an instrument for the routine management of the territory (e.g. for harbors in Valdor et al., 2016).

Within this context, the GREAT Med project (Generating a Risk and Ecological Analysis Toolkit for the Mediterranean), funded by the ENPI CBC Med program of the European Union, aims to contribute to the development of an interdisciplinary strategy for assessing plant diversity and the main human pressures in critical areas of the Mediterranean coasts, with a view towards conservation and monitoring of natural heritage. The specific objectives of the project include the development of an accessible and understandable procedure for assessing coastal plant diversity and its vulnerability to potential stressors (such as oil spills, fragmentation of natural habitats), and the definition of an easy-to-use approach to locate and prioritize the more susceptible areas. This would provide a practical instrument for risk management in the ordinary and extra-ordinary management of the coastline. The project involves several pilot areas in four Mediterranean countries from different sides of the Mediterranean Basin (Italy, France, Lebanon and Tunisia), an engagement deemed crucial for setting up effective and standardized descriptors, criteria and indicators that take into account different ecological and socio-economic contexts. The objective of our planning was to create a methodological framework that can be used and adapted to diverse situations, i.e. different knowledge of the biodiversity of the local area, different types of threats/pressure, different socio-economic situation, different objectives of prioritization (for instance for biodiversity conservation, tourism development, oil spill emergencies).

We present a flexible and adaptable methodological approach to i) assess environmental risk in coastal areas and, accordingly, ii) prioritize the areas more prone to suffer from one (or more) selected risks.

2. Material and methods

2.1. Pilot areas

The project implemented its activities in four pilot areas in the Mediterranean basin, which are characterized by high levels of biodiversity and economic development. Each pilot area comprises at least 60 km of coastline that is meant to cover the broad scale extension of the assessment in which 11 sites were selected to address the local scale (small extension, Fig. 1). The selection process encompassed the main types of land use/cover, environmental characteristics, and main types of human pressures present in the whole Mediterranean basin. In particular, we focused on the presence of oil refineries, commercial port, Hazardous and Noxious Substances (HNS), and urban pressure.

Pilot Area 1 – The Provence-Alpes-Côte d'Azur (PACA) region is at the southeastern coast of France. This region includes two National Parks, *Calanques* and *Port Cros* with terrestrial and marine protected areas and is limited to the west by the Camargue Regional Park. Tourism activities play a central role in the regional economy, with the PACA Region being the second most important touristic region in France. The

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