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Integrated management in coastal lagoons of highly complexity environments: Resilience comparative analysis for three case-studies

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ABSTRACT

Enclosed coastal seas are usually high environmental value territories that are located, in many cases, in developed countries often subjected to a large catalog of anthropic activities such as tourism, agriculture or industry. These more difficult to manage cases are precisely those that require more complex mechanisms to both diagnose their needs as well as to implement measures that allow the cohabitation between existing activities and the preservation of the natural values of these territories.

This article analyzes the link between the lagoon and such activities from a multidisciplinary approach. This new perspective is raised toward implementing integrated analysis methodologies using indicators that determine global diagnostics capable of being compared from one lagoon to another in different parts of the world. To this end, a comparative study has been developed of three highly complex cases located in three different continents: the Salton Sea in America, the Mar Menor in Europe and the Mar Chica in Africa. Through the implementation of GIS-LiDAR analysis tools, an integrated assessment of the situation and the challenges facing these three lagoons will be set out in order to help solve their current issues. The results will enable to highlight the ability of the lagoons to absorb the impacts of the activities that surround them and guide us to where their future management should be routed.

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1. Introduction

1.1. Current issues in coastal management of enclosed lagoons

Coastal lagoon management is a field highly subscribed to research because of the important natural and ecological values that are usually present in these territories. In this context, there are numerous individual studies worldwide (O'Neill et al., 2015; McFadden and Schernewski, 2014; Bellio and Kingsford, 2013) and some theoretical approaches with a certain vocation to address common problems such as water salinity, turbidity or impacts in protected fauna and flora derived from land transformation due to human industrial activities, coastal urbanization or nitrates contributions from agriculture (Tavares et al., 2015; Casini et al., 2015; Conde et al., 2015 or Newton et al., 2014). However, it is difficult to establish general rules regarding such issues since the specific boundary conditions from each context do not make it possible to implement common diagnoses on different case studies.

Within this field, cases focused on lagoons under the effect of

different anthropic activities with significant impacts that have to cohabit with the correct preservation of environmental values are particularly interesting (Rivera-Guzmán et al., 2014). In this sense, very interesting examples of complex cohabitation with activities such as tourism (Suman et al., 2005; Armaitiené et al., 2007), agriculture (Green-Ruiz and Pérez-Osuna, 2003; Santos et al., 2008) or industry (Loureiro et al., 2009; García and Muñoz-Vera, 2015) can easily be found. In this sense, questions like “What is the level of impact of these activities on the lagoon?” and “Is the lagoon able to withstand the current situation?” are normally difficult to answer in these contexts of high economic activity. In most cases it is possible to determine some patterns of behavior, with environmental regulations and the degree of consolidation of these activities often being a differentiating factor of the environments located in developing countries (Kumar et al., 2016) in comparison to the developed countries of Europe or the USA (Acquavita et al., 2015; Dorsey et al., 2013). In order to illustrate this situation, three examples encompassing a wide range of geographic, socioeconomic and environmental settings, resulting in different degrees of severity in the respective lagoons, have been selected. The complex management and difficult cohabitation between human activities and the natural environment in coastal lagoons located on three

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different continents: Africa (Mar Chica), Europe (Mar Menor) and North America (Salton Sea), will be exposed for a further integrated diagnosis.

1.2. Case study locations

The Mar Chica, also called Nador lagoon, Sebkhia Bou Areg or Rbhar Amzian, is a salty coastal lagoon of 115 km² located in northern Morocco, at the feet of the city of Nador. It has a maximum depth of 8 m and is located a few kilometers south of the Spanish colony of Melilla. Semicircular in shape, it is separated from the Mediterranean Sea by two sandy strips: Boukana (10 km long) to the north, and Aljazeera (12.5) south, separated by a 120-m-wide mouth, where the Mar Chica connects to the Mediterranean (Fig. 1).

The cities of Nador (inside edge), Beni Ansar (border with the Spanish colony of Melilla) are on its shores to the north and Kariat lies to the south, generating the pressure of 200,000 people living near the coast of the lagoon. Because of its importance for water-birds, the Mar Chica has been declared a RAMSAR site and has been the subject of several research works (Ruiz et al., 2006; Bocci et al., 2016).

This lagoon has been subjected to various human activities such as agriculture for decades, mainly located to the south on the plain of Bou Areg, there is an agricultural area of 92 km² reaching the coastal strip of the lagoon. Likewise, since the early twentieth century different urban settlements have existed from the Spanish colonial presence in Morocco, several of them linked to the defunct mining activity in the area. Both impacts are directly connected with the lagoon from the south, the first through the Selouane River and the second through the riverbed of Boussardouri. More recently, development has begun on some tourism activity, mainly focused on the peninsula of the Atalayoun, where some residential complexes, marinas and golf courses have been built (although others have been paralyzed as a result of the international financial crisis). Despite not having traditionally been a territory threatened in environmental values, the major transformations undertaken in the vicinity of the lagoon in recent years have generated various criticisms, which have been reflected in studies on the risks from heavy metals (Maanan et al., 2015) or the bloom of harmful algae (Daoudi et al., 2012).

A second example of a coastal lagoon with some differences and similarities regarding the Mar Chica of Morocco is the Mar Menor in Spain. This salt lake of about 135 km² located on the southeast of the Spanish Mediterranean coast is a paradigmatic example of environmental resilience, and possibly has one of the most varied catalogs of anthropic effects on a salt lagoon (urban settlements, intensive agriculture, mass tourism, industry, mining, fishing, ports, etc. see Fig. 2). This complex management environment has been inhabited by humans for centuries on its continental coastal strip and in summer suffers the effects of the presence of more than 450,000 people.

The lagoon is separated from the Mediterranean Sea by a 20-km former dune ridge (heavily urbanized since the 1960s; see García-Ayllón, 2015), which is connected to its waters through 5 channels called “golas”. This configuration gives the environment a unique ecosystem of great natural value, currently protected by numerous European and international regulations (Pérez-Ruzafa et al., 2005; Miralles and García-Ayllón, 2013). This context of complex management to sustain its fragile equilibrium is fundamentally threatened by the contributions of the sediments from the wadis that flow into the lagoon. Within these contributions fed by large basins on the mainland special mention must be made to those coming from intensive farming in the west area of the lagoon, and which have been studied extensively in the literature from the biological perspective (Pérez-Ruzafa et al., 1991, 2000 and 2002; Velasco et al., 2006). The worrisome drift that has occurred since last year, 2015, in the situation of the lagoon waters has caused alarm both in environmental circles and in the tourism sector. This situation has forced authorities to launch an ambitious recovery plan of the lagoon that commits all administrations and private agents. The lagoon has been designated by the European Union for the period 2014–2020 as one of the three objectives of Integrated Territorial Investment authorized in Spain.

A third case with some similarities but larger and farther from the coast is the Salton Sea in North America. It is a salted and endorheic lake in California, southwest United States. The lake is physically in a depression between the mountains of San Jacinto to the East and the Chocolate Mountains to the West. It is located in an arid desert environment, to the north of Imperial Valley and just 10 km south of the first urban areas linked to the well-known

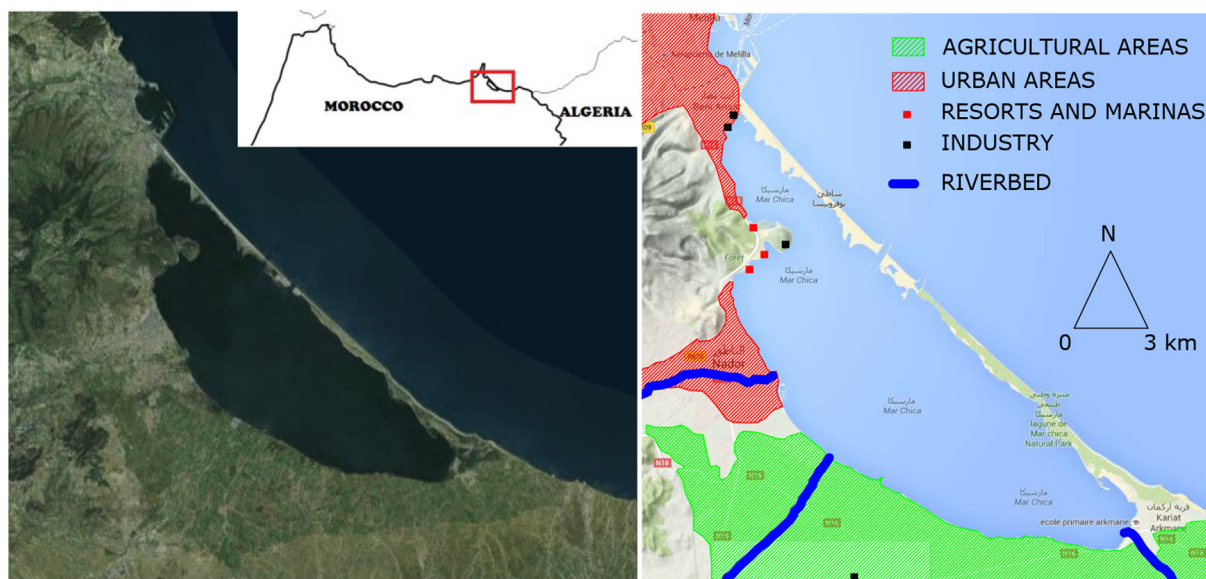


Fig. 1. Mar Chica configuration (left). Activities and uses (right).

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