



Relationships between coastal urbanization and ecosystems in Spain



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ABSTRACT

Coastal regions have long demonstrated growing demographic concentration. This process is of great importance in Spanish coastal zones, where cities develop the majority of economic activities. Moreover, the coastal zone is the region where vulnerable coastal ecosystems are located. This research aims to assess the influence of coastal urban areas on the coastal zone of Spain, which is defined as a social-ecological system. The main goals are focused on defining the Spanish coastal social-ecological system (CSES), analyzing coastal urban areas and their economic activities, and identifying coastal ecosystems linked to coastal urban areas.

The results demonstrate that more than 11 million inhabitants are concentrated on the Spanish urban coast, and they develop economic activities related to the coast. Additionally, the results of the research establish the importance of coastal ecosystem services provided to the population. Eighty per cent of coastal urban areas and 90% of population are associated with coastal ecosystems of interest for Integrated Coastal Zone Management (ICZM).

This paper describes the main coastal urban areas in Spain where economic activities and coastal ecosystems converge. Coastal areas with more ecosystem diversity are preferred by the urban society, and therefore, they should have priority for Integrated Coastal Zone Management (ICZM) programs.

1. Introduction

Almost everywhere in the world, coastal areas record a clear process of demographic concentration, in which coastal cities play a role of great importance (Barbier, et al., 2008; Barragán & de Andrés, 2015). This phenomenon is the cause of the loss of the services that coastal ecosystems provide to human well-being (UNEP, 2006). In Spain, the coastal zone is configured as one of the most important areas for population and economy. The process, in which people, activities, infrastructures and facilities are concentrated close to the coast, is known as “littoralisation” (Barragán, 1994a).

Coastal areas have suffered a significant degradation during last five decades. This process is well studied by various experts (Bertolo, et al., 2012; Serra, et al., 2008). The Spanish National Ecosystem Assessment highlights that coastal ecosystems have degraded faster and more intensively than others (Spanish National Ecosystem Assessment, 2013). Additionally, they identify the main direct drivers of change as: A) Transformation of land use; it is evident in the extensive development of coastal areas, in the construction of large infrastructures or facilities, and in an increasingly artificial coastline. B) External inputs; which are identified through diffused pollution by urban and industrial discharges. C) Intensive exploitation of aquatic ecosystem services, through catchment of large freshwater sources

(Barragán & Borja, 2012).

The impact that drivers of change produce on coastal ecosystems is particularly pronounced in urban areas (Agardy et al., 2005; Lee, et al., 2015). Human activities that occur in these geographical regions allow for the addressing of coastal zone management from a single social-ecological system. The theory of considering the coastal zone as a social-ecological system is based on the interaction of ecological and social processes where adaptive management is needed to ensure human well-being (Cumming, 2011; Norberg & Cumming, 2008). Consequently, the study of social-ecological systems requires the analysis of multiple variables (natural, social, economic) that also takes into account the governance system (Ostrom, 2009). The analysis model for the coastal zone as a social-ecological system has been implemented in previous research in different case studies around the world (Montes & Tapia, 2008; Palomo & Montes, 2011). Thus, a complex reality is analyzed to obtain answers based on governance and management.

The overall objective of the research is to analyze the relationship and importance of urban coastal areas in Spain from a social-ecological perspective, defining the coastal social-ecological system (CSES). If the relationship and importance between the social and ecological approach are high, this result will be interpreted as one of the keys for a higher consideration of Ecosystem Based Management in the context of

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a public policy for coastal zone management.

The four specific objectives of this research are: a) Delimiting the Spanish coastal zone as a social-ecological system and defining its geographical units; b) Analyzing the urban areas of the coastal social-ecological system and studying the main urban activities associated with them; c) Studying the relationship between coastal ecosystems and urban areas over recent decades (1951–2014); d) Identifying the most vulnerable coastal urban areas by interactions between economic development and ecosystem diversity.

Pressures on coastal ecosystems and their services are recognized worldwide (Agardy et al., 2005). They are determined in those countries where the Millennium Ecosystem Assessment was implemented. (Pereira, Domingos, & Vicente, 2004; UK National Ecosystem Assessment, 2014), and specifically in the Spanish coastal zone (Spanish National Ecosystem Assessment, 2013). Consequently, a deficient model of management in coastal areas was observed (Barragán & de Andres, 2016). This reality underlies the urgency in improving processes of Integrated Coastal Zone Management (ICZM) in Spain.

2. Conceptual framework

The conceptual framework in which urban areas are framed is defined from a social-ecological perspective, specified according to geographical, ecological and administrative criteria. The CSES comprises three different geographical units: a) coast, b) coastal zone, c) coastal-influence zone (Barragán & de Andres, 2016). *Coast* is defined as the area on either side of the contact line between the land and the marine water, where physical-natural events occur with greater intensity and speed. The coast is divided into three units: *coastal waters*, *intertidal area*, and *shoreland*. The *coastal zone* is defined as the geographical area, marine and land, where the existence or influence of the sea affects human activities (Barragán, 2004). Finally, the *coastal-influence zone* is identified as the area, also marine and land, far from the coast, whose boundaries are related to the impact of human activities on the coast. The study of urban areas analyses only terrestrial units: *shoreland*, *coastal uplands* and *coastal-influence lands*.

Urban areas are the main areas of interest of this study. An urban area being defined as one or more municipalities situated around a city with a population greater than 20,000 inhabitants, established according to the AUDES method (Ruiz, 2011). This method is based on the Canadian model (Mendelson and Lefebvre, 2003), adapted to the Spanish reality. Cities are defined as urban entities that consist of an urban continuity, and totaling at least 10,000 inhabitants. Urban entities are identified in the Spanish National Statistic Institute when they have more than 1,000 inhabitants. Additionally, conurbation is defined as a group of two or more urban areas physically connected. The importance of this method is due to the combination of geographic criteria, such as the continuity of population centers or land use; and functional criteria, such as commuting (Gisbert, 2013).

Human activities associated with coastal urban areas are the uses and economic activities that depend on the coastal territory or their ecosystem services. The Spanish National Ecosystem Assessment underlines the main human activities developed on the coast as: population settlement, fishing, shell fishing, aquaculture, greenhouse agriculture, industrial enterprise, tourism and port activity (Barragán & Borja, 2012). Four of which are also associated with urban areas: human settlement (McGranahan and Marcotullio, 2004), industrial enterprise (Loures, 2015), maritime commerce (OECD, 2010) and tourism (Roca, 2014).

Regarding coastal ecosystems, those that are most altered by urban activities are considered (UNEP, 2011; UNEP-WCMC, 2011). In addition to urban growth, the development of activities on the coast, cause impacts resulting in their degradation and fragmentation (McGranahan & Marcotullio, 2004). The Spanish Ecosystem Assessment highlights the coastal ecosystems most damaged by urban development:

Table 1
Geographic information sources for delimiting the coastal zone as a social-ecological system.

Delimitation	Geographic information sources
Ecological delimitation	Coastline shapefiles (Spanish Navy Hydrographic Service) River basins shapefiles (Spanish Navy Hydrographic Service)
Socio-economic delimitation	Spanish reservoirs shapefiles (Spanish Navy Hydrographic Service) Urban centers shapefiles (Corine Land Cover)
Administrative delimitation	Municipalities shapefiles (Spanish National Statistics Institute) Maritime-Terrestrial Public Domain shapefiles (Ministry of Agriculture, Food and Environment)

estuaries, beaches and dunes, coastal wetlands, sea grasses and bays (Spanish National Ecosystem Assessment, 2013). Many of which are considered ecosystems of interest in the Protocol on Integrated Coastal Zone Management in the Mediterranean (UNEP/MAP/PAP, 2008).

3. Information sources and method

3.1. Data collection

The geographic demarcation of the CSES was executed using QGIS 2.16 software. The Spanish National Statistic Institute provided geographic information for the delimitation. The urban characteristics of every unit in the CSES were obtained from different shape-files and statistical information: data of urban areas and conurbations (Ruiz, 2011); the line of demarcation of the Maritime-Terrestrial Public Domain (Ministry of Agriculture, Food and Environment); the coastline (Spanish Navy Hydrographic Service); the polygon of the reservoirs and river basins of Spain (Centre for Hydrographical Studies); the boundaries of Spanish municipalities (National Statistics Institute), and the polygon of urban centers (Corine Land Cover) (Table 1).

Additionally, it was necessary to analyze several sources of information for the study of human activities. From the Spanish National Statistics Institute, the population census of Spanish municipalities (1951–2014), the values of production in every Autonomous Community, and the number of touristic vacancies in each province were obtained. The Spanish government agency Puertos del Estado provided the information of maritime traffic in ports. Information and mapping of the physiographic units and the coastal ecosystems of interest for ICZM were obtained from Corine Land Cover (2006): coastal wetlands; coastal lagoons and estuaries; beaches, dunes and sands. Seagrasses were collected from the atlas of UNEP-WCMC. The bays of Spain were geo-referenced from Google Earth.

3.2. Method

The method of study consisted of the analysis of the urban areas in every unit of the coastal social-ecological system: *shore-land*, *coastal uplands*, and *coastal-influence lands*. The interrelation between the terrestrial region of the coast, and marine and intertidal areas was one of the bases for the ICZM (Barragan, 2004; Barragán, 2014; Clark, 1996; UNEP, 1995). The first step of the research involved defining geographically the three units (Fig. 1). For this purpose;

- *Shore-land* was interpreted as the area between the coastline and the line connecting the inner boundary of coastal urban entities or protected coastal areas. Thus, cities, protected areas and coastal ecosystems within the limits were encompassed.
- *Coastal uplands* were demarcated from the end of the *shore-land*, to the inner boundary of the coastal municipalities. Furthermore, municipalities that did not satisfy this condition but belonged to

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