ARTICLE IN PRESS

Coastal Engineering xxx (2017) 1–11

Contents lists available at ScienceDirect

Coastal Engineering

journal homepage: www.elsevier.com/locate/coastaleng

The Tordera Delta, a hotspot to storm impacts in the coast northwards of Barcelona (NW Mediterranean)

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ABSTRACT

The Catalan coast, as most of the developed Mediterranean coastal zone, can be characterized as a high-risk area to the impact of storms due to the large concentration of values together with the dominance of eroding shorelines. In consequence, any long-term coastal management scheme must include a risk analysis to permit decision makers to better allocate resources. This can be done in a nested approach in which hotspots are first identified along the coast at a regional scale and secondly, they are further analysed to produce dedicated risk reduction strategies. In this work, we apply the methodology developed within the RISC-KIT project for identifying and analysing coastal hotspots in the Catalan coast as a test for applying it to Mediterranean conditions. Obtained results show that this methodology is very efficient in identifying hotspots of storm-induced flooding and erosion at a regional scale. The adoption of the response approach resulted in the direct assessment of the hazards' probability distributions, which allowed for the selection of the severity of the hotspots to be identified. When a given coastal stretch behaves as a hotspot for both hazards, it is identified as a very highly-sensitive area to storm impacts. In the study area, the Tordera Delta possesses this condition of very high "hotspotness." This has been demonstrated by the large and frequent damages suffered by the site during the past decades. The paper analyses different aspects related to the risk management of this area, including stakeholder actions.

1. Introduction

Two of the most important natural hazards causing significant damages in costal systems worldwide are storm-induced erosion and flooding (Kron, 2013). The progressive concentration of urban settlements in coastal zones has increased the exposed values and this, together with the nearly worldwide erosive trend of our coastlines (Bird, 2000; European Commission, 2004), has led to an increase in the associated risks, even under a steady-storm climate e.g., (Zhang et al., 2000; Jiménez et al., 2012a). Moreover, it is expected that under a climate change scenario, these risks will increase in the near future (Hallegatte et al., 2013; Wong et al., 2014). This current situation and the plausible perspective of worsening conditions stress the need for including risk management as a regular chapter in any exercise of long-term coastal planning. In this sense, the Protocol for Integrated Coastal Zone Management in the Mediterranean (PAP/RAC, 2007) dedicates a specific chapter to natural hazards where parties (countries) are advised to undertake vulnerability and hazard assessments to address the effects of natural disasters in coastal zones. To this end, there is an increasing number of existing practical approaches ranging from vulnerability to risk assessments e.g., (Ferreira, 2004; Bosom and Jiménez, 2011; Villatoro et al., 2014; Cirella et al., 2014; Rangel-Buitrago and Anfuso, 2015). In this line, recently in the framework of the RISC-KIT research project, a set of tools and approaches have been developed to support storm-induced risk management in coastal areas (van Dongeren et al., 2017).

When this risk management process is going to be implemented for very large spatial scales, one of the first steps to be done is the identification of hotspots. In simple terms, a *coastal hotspot* can be defined as a coastal stretch that is more sensitive to a given hazard (and within the context of this work, an associated risk) than surrounding areas. This is a screening process that allows for the delimitation of sensitive stretches along the coast to storm impacts, where a further and -more refined risk assessment analysis will be implemented at a later time.

Within this context, the main aim of this paper is twofold: (i) to identify hotspots to the impact of storms along the coast northwards of Barcelona (NW Mediterranean) by applying the methodology developed within the RISC-KIT project (Viavattene et al., 2017); and (ii) to analyze the importance of storm-induced risks in the most highly-sensitive hotspot of the area, namely, the Tordera Delta.

The structure of the remainder of this paper is as follows: (i) the second section describes the study area and the data used; (ii) the third section presents the identification of hotspots at the regional scale along the Maresme coast; (iii) the fourth section analyses in detail risk assessment and management at the hotspot scale in the Tordera Delta; and

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http://dx.doi.org/10.1016/j.coastaleng.2017.08.012
Received 2 February 2017; Received in revised form 18 June 2017; Accepted 9 August 2017
Available online xxxx

finally, (iv) the summary and general conclusions of this work are presented in the last (fifth) section.

2. Study area and data

2.1. Study area

Maresme is the coastal region of Catalonia (Spain, NW Mediterranean), extending from the city of Barcelona to the south to the Tordera river to the north (Fig. 1). It is composed by about 45 km of straight, coarse, sandy beaches that, originally was an uninterrupted coast. Today it is segmented into five coastal cells due to the presence of five marinas. The combination of relatively high net longshore sediment transport rates directed toward the SW, and the presence of these barriers has induced a typical alternating shoreline evolution pattern, with upcoast accreting beaches and downcoast eroding ones.

From an administrative standpoint, the coastal fringe extends along 16 municipalities, which are the most densely-populated areas of the region (IDESCAT, 2014). The region can be divided into two different areas in terms of socio-economic and territorial dynamics. Southern municipalities are strongly influenced by the presence of the city of Barcelona, which has a large, residential development, while the northern ones have largely based their economies on tourism. This area supports an important transport link composed of a coastal railway and a national road. The coastal railway is located very close to the shoreline, and in many sections is only separated from the sea by a revetment protecting the infrastructure against direct wave impact. The large urban and infrastructure development in the coastal fringe makes this region particularly vulnerable to extreme marine events, having experienced significant damage during the past decades (Jiménez et al., 2012a).

The northern end of the study area is formed by the Tordera Delta coast (Fig. 1). This is a highly dynamic zone, currently in retreat due to the net result of the littoral drift and the decrease of the Tordera River sediment supplies. As a result of this, beaches surrounding the river mouth, traditionally stable or accreting ones, are being significantly eroded during the last 20 years, with a measured shoreline retreat of about 120 m at the point of maximum erosion (Jiménez et al., 2011, 2016). The hinterland of this area is composed by the deltaic plain, which is occupied in its outer part by different campsites which are solely protected from wave action by existing beaches, with the exception of a few spots where small revetments exist.

2.2. Data

The topography of the study area has been characterized by using a 2 m × 2 m Digital Elevation Model obtained from Lidar flights performed between 2008 and 2011 by the Cartographic and Geologic Institute of Catalonia. Sediment sizes along the coast have been obtained from data supplied by (CIIRC, 2010).

Wave and water level data have been obtained from the extended SIMAR dataset obtained by Puertos del Estado (Spanish Ministry of Public Works) for the Spanish coast. This dataset originally consisted of a 44-year (1958–2001) time series of wave and water level data obtained within the Hipocas project (Guedes-Soares et al., 2002; Ratsimandresy et al., 2008), which has been extended until 2016. Waves were generated by using the third-generation wave model WAM forced by wind fields, whereas sea level data were obtained by means of the baroclinic HAMSOM model. This database has been widely used (Bosom and Jiménez, 2011; Gomis et al., 2008; Alvarez-Ellacuria et al., 2009; Casas-Prat and Sierra, 2010) and has been extensively validated in the Mediterranean (Ratsimandresy et al., 2008; Sotillo et al., 2005; Musić and Nicković, 2008). Although some extreme events are underestimated, we have used the time series without further calibration. A similar approach was also used by (Casas-Prat and Sierra, 2010) in analysing storminess along the Catalan coast.

To characterize existing land uses in the coastal zone we have used the last version of the land-use map of Catalonia developed by CREAF for the Government of Catalonia (Ibàñez and Burriel, 2010). Socio-economic

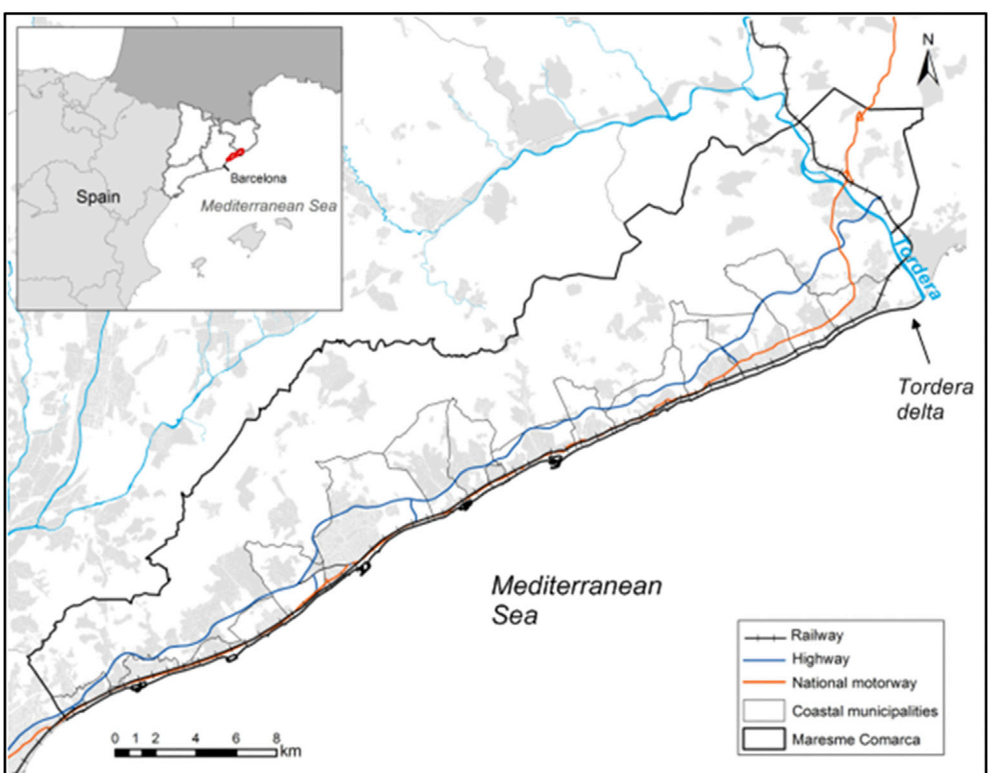

Fig. 1. Study area.