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The effect of coastal defense structures (mounds) on southeast coast of Buenos Aires province, Argentine

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ABSTRACT

The rapid increase of tourism and urbanization in the coastline of Buenos Aires province resulted in the need of infrastructure and services development along the entire coast. However, the lack of environmental criteria of human activities altered the aero and hydrodynamic conditions and is causing important cliffs regression and beach erosion.

In this scenario and to minimize such problems, since 1980's, installing coastal defense structures became a very used method. The main types used in the study area are mounds built with blocks of quartzite and set up as longitudinal defenses on the cliff base. It was seen that these structures reduced coastline retreat but caused several environmental alterations changing natural dynamic conditions. These alterations caused serious consequences in coastal configuration, local and regional hydrodynamic, morphometry of beaches, environment and ecology of the coast and obviously, in the human activities and recreation areas.

This paper analyses the coastal system evolution after mounds settlement, their functions and consequences to nature (comparing altered environments with those which still preserves natural conditions) and discuses its advantages and disadvantages with the objective of establish precedent for future integrated and conscious coastal management projects.

1. Introduction

During the last decades, the increase of urbanization and tourism activities have brought serious changes in the natural environments of this area, affecting direct and indirectly, the input rates of sediment supply to the coast (López and Marcomini, 2011). The lack of sustainability between human activities and the geomorphological setting of the coastal system has increased the erosion on those well-developed urban centers (Marcomini and López, 2008). The main effects are cliffs regression and beach erosion. According to Bértola (2006), the anthropogenic processes of beach alteration (with direct or indirect effects) exceed the morphodynamics variations originated by natural process.

The main causes of disturbance in the natural balance of coasts and its environmental conditions are originally related to the building and management of Mar del Plata harbor and other coastal protection structures. The construction of Mar del Plata breakwaters in 1920 induced an important longshore drift undersaturation downdrift. By 1970, the shoreline had been compartmentalized by adding a large number of different groins (Marcomini and López, 2006). Despite of they increase the accumulation rate of sand in beaches, they didn't solved the problem and the erosion extended northward affecting the most important beaches of the resort (Isla, 2006). According to Bruun (1990), man's intervention in coastal processes began with the installation of breakwaters to protect ports against waves and sets of groins in the seafront for coastal protection and beach rebuilt. This type of construction began in the 19th century in the Mediterranean and on the British Isles shores (Bruun, 1990). The effects of this type of human intervention are described later by Bruun (1995). He shows the long and short term disturbances effects during the 20th century in different coasts of the world, from Florida, France and Egypt to Japan.

The rapid erosion along Buenos Aires coast is caused by several processes that act in concert; these are natural processes that occur frequently (storm surges and waves) and anthropogenic activities such as human settlement and harbor and coastal defenses.

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Consequently, between 1920 and 1970, more than 60 groins were built to mitigate the continuous displacement of the erosive wave to Mar de Cobo and Mar Chiquita (30 km northwards). The coastline retreat rates obtained were about 5 and 6 m/year (Schnack et al., 1983; Merlotto and Bértola, 2009; San Martín, 2012), being a regional erosion process (López and Marcomini, 2011). In Santa Clara del Mar, Schnack et al. (1983) registered regression rates slightly higher to 1 m/year. In 2001, a report of the State Print Direction and Official Newsletter of Argentina (DIEBO, 2001) mentions a territory loss of about 9470 m^2 along 2260 m of coast (including the locations of Playa Dorada, Santa Helena, Frente Mar and part of Atlántida) between 1982 and 2001. It also reveals a coastline retreat of about 4.19 m and an erosive rate of 0.21 m/year during that period. A similar coastline retreat rate was calculated by Bunicontro (2012), getting values among 0.49 and 0.20 m/year, between 1975 and 2009.

Numerous protection techniques have been applied to prevent coastline retreat in General Pueyrredón and Mar Chiquita resorts. One of the most frequent has been the setting up of rocky mounds. These structures, built with blocks of quartzite, are set up on the cliff foot over rocky wave cut platform. These types of structures began to be built in 1980's decade to reduce cliff retreat and protect the Nº 11 road. The main use of mounds is to protect cliffs from wave attack. The dissipation of wave energy through absorption rather than reflection distinguishes rubble mound breakwaters from other types of fixed breakwaters (Palmer and Christian, 1998). However, the excessive sea cliffs armoring can be an erosive practice in those places were the source of sand to the beaches and to the littoral drift depends exclusively on the cliff erosion (Runyan and Griggs, 2003).

The present study aims to analyze the general characteristics of mounds as coastal protection structures in this area and its evolution during the last years. This will allow us to determine its effectiveness and to identify the main changes on some natural environment aspects, as the coastal hydrodynamics, coastal ecology, beaches morphodynamics and the recreational use of this tourist resource.

1.1. Study area

The studied area extends southeast of Buenos Aires province, Argentine (Fig. 1), from Mar del Plata toward Mar de Cobo, with a length of about 4 km along Buenos Aires coast. It includes Playa Dorada, Santa Helena, Frente Mar and Atlántida localities, southern Santa Clara del Mar resort.

1.2. Background

Types and designs of coastal defense structures, as rubble mounds, were described by the Coastal Engineering Research Center of United States (1984). An overall review of physical processes involved with rubble mound structures (hydraulic and structural parameters) and its classification was done by Van der Meer (1995). Other techniques use compact armor units interlocked each other but despite more than six decades of applied research, design continues to be based largely on experience and physical modeling of the proposed structure (Palmer and Christian, 1998). Later, Sigurdarson et al. (2001) describes the Icelandic type berm breakwater used since 1980 as a successful solution for navigational safety in harbor entrances with heavy breaking waves. For these authors, the goal of the design of a berm breakwater is to achieve the highest wave energy absorption to minimize wave reflection and overtopping. Other contributions about designs and general set up of these structures were done by Losada (2005) followed by Sigurdarson and Viggosson (2005). Also, Mani (2007) discusses the construction of an S-type rubble mound sea wall and its effectiveness as an alternative method to protect the beach in the east coast of India.

Locally, Tassara and García (2005) analyzed the positive and negative effects of setting up these mounds on the studied area, focusing on the integrated management to diminish vulnerability. On the other hand, as the amount of sediment delivered to the Argentine continental shelf by cliff erosion is higher than the fluvial transport, it should be also considered in the balance of beaches fed by longshore transport (Isla and Cortizo, 2014). According to these authors, Buenos Aires is a populated province where cliff erosion is a critical problem at tourist areas and the north cost of Mar del Plata is the most affected by man-made constructions, blocking beach drift. Considering this, riprap walls and revetments are assumed to be the most economic solution to maintain the stability of these cliffs.

2. Material and methods

The construction and characteristics of the coastal defense structures currently located in Playa Dorada, Santa Helena and Frente Mar were studied through a historical survey and the analysis of aerial photographs of 1975 and 1985 (scale 1:20.000, Geodesy Department of Buenos Aires) and satellite images Google Earth 2003, 2009 and 2011. Structures descriptions were supported by field observations and technical specifications of the work "Defense of N°11 Road by cliff protection" (DIEBO, 2001). A morphometric analysis of the beach was done by performing topographic profiles transverse to the coastline, using a Total Station. The profile, named "Type Profile" (37° 52′ 56.1″ S–57° 31′ 4.3″ W), was referenced to a setpoint in the urban area with Global Positioning System (GPS) in case of future monitoring.

The annual volume of sediment eroded from cliffs was calculated first in m^3/m/year and then considering the entire coast (4 km) in m^3/year. Annual erosion rates (m/year) were multiplied by the height of the cliffs in order to obtain the volume eroded per meter of coastline. The rate were estimated considering a mean coastal retreat for the studied area (0.47 m/year) proposed by Isla and Cortizo (2014) and by Bunicontro (2012); and the average height of the cliffs was estimated in 7 m.

Sediment samples were collected at the foreshore (low tide, mid tide and high tide) and backshore (stormline), and on the ancient beach at the continental side of the mound. Grain size analysis was conducted to determine the beach hydrodynamics. Sediments were dried divided up to obtain a weight between 80 and 100 g. They were sieved using a Ro-Tap during 15 min with sieves between −2 and 4 phi (from coarse to fine sand). Statistical parameters as mean, median, mode, sorting, skewness and kurtosis were estimated.

Mineralogical composition of sediments were determined using petrographic microscope and were compared with the sediments of the same environments of another profile (Beach Profile A) near Santa Clara del Mar Beach (37° 50′ 16.4″ S–57° 29′ 52″ W). It is important to notice that the main mode of the sample between the mound and the cliff was very fine sand almost silt, so the secondary mode (medium sand) was analyzed. The classification of the sediments was determined using the ternary diagram proposed by Folk et al. (1970).

3. Geological settings

3.1. Geology

The studied coastal zone is represented by cohesive cliffs carved on Santa Clara Formation (middle to late Pleistocene, Schnack et al., 1982). It is composed by yellowish to dark brown clayey silt to