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БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ

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EFFECTS OF COASTAL ARMOURING IN THE BOLIVAR DEPARTMENT (CARIBBEAN SEA OF COLOMBIA)

Nelson Rangel-Buitrago[1], Giorgio Anfuso[2], Margarita Stancheva[3]

Progressive erosion had started to affect the 1760 km long Caribbean coastline of Colombia over the past century. In response to this ongoing eroding process since 1970s large number of various hard defence structures have been emplaced in the coastal zone. In this regard, the present paper is devoted to inventory the main types and distribution of installed coastal structures around the municipalities of Cartagena and Santa Catalina in the Bolivar Department, Caribbean Sea of Colombia. A total number of 289 different structures with a length of 44 km were observed at the 366 km long studied coastal area, including jetties, groins, breakwaters, dune fences, promenades, seawalls/historical fortifications, ports, harbours etc.

To assess the extent of technogenous impact on the coastline caused by armouring structures, a specific coefficient *K* was used as an indicator. Despite this coefficient shows averaged extent of impact for study area, there are sites with very high concentration of coastal structures: the tourist zone of Cartagena, which presents a *K* value of 0.60 indicating maximal extent; and some harbour areas within the Bay of Cartagena show *K* values equal and/or higher than 1, because the coastline here has been completely armoured. Based on the study outcomes some of adverse visual effects of structures and consequences of reducing sediment supply to the littoral, accelerating downdrift erosion and irreversible coastline modifications were also outlined and analysed.

INTRODUCTION

Historical human occupation of coastal areas, the need to protect the coast against erosion and increased demand of using beaches for recreations have been leading to numerous developments and buildings. Placement of “hard’ coast-protection structures, such as seawalls, solid groins, breakwaters or embankments and revetments or even harbours, are commonly known as coastline armouring. With rising developing of infrastructures and progressive eroding of the coasts there is also additional request for installing structures both to retain the coast and to preserve private/public properties. As a result, the potential impacts of armouring the coastline could involve negative visual effects, beach access restriction, reduction of sediment supply and also active and passive erosion (G r i g g s , 2005).

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In Colombia, coastal occupation has started since Spanish colonisation, i.e. during 16th century (in detail Cartagena was founded in 1533), with the construction of human settlements and sea towns intended to various commercial activities and particularly related to maritime transport. In fact, the exportation of goods, such as spices, coffee, sugar, etc., took essentially place through maritime transport, this way forcing many harbours and ports constructions, as well as a number of defence structures to prevent the attack of Caribbean pirates. In regard to Spanish colonisation of Colombia, most practices and methods for coastal protection had been inherited from Europe. In particular Spain has a long history of coastal occupation and associated constructions by human settlements. Earlier developments had mostly been installed as ports and harbours, but also as defence structures to protect coastal towns from enemy attacks. As an example, along the coasts of Mediterranean Sea, many ports were constructed during the Phoenician and Roman ages, and their emplacement had retained over the centuries, providing today useful evidences of coastline evolution and sea level changes during the past 2,500 years (Morhange et al., 2007).

Over the last decades there has been a great increase of human occupation along coastal areas mostly due to recreational purposes and presently coastal tourism is one of the world's largest industries (Klein et al., 2007). As example, in the Mediterranean region, tourism is the most important activity with 298 million international arrivals in 2008, followed by approximately 400 million domestic arrivals. In many Spanish coastal areas the built up zone exceeds 45 % (EEA, 2006), with tourism receipts accounting for some 5 % of the gross domestic product (http://www.world-tourism.org...). Spain plus Italy, France, Greece and Turkey account for *'the most significant flow of tourists…. a sun, sea and sand (3S) market'* (Dodds, Kelman, 2008) and "Travel & Tourism" worldwide, is expected to grow at a level of 4 % per year over the next ten years.

Promenades, summer houses, hotels, restaurants, etc. have been built many times in areas that are susceptible to coastal hazards, including surges, storm waves, tsunamis and sea level rise. As a result, a number of developments are nowadays threatened by coastal retreat. A great variety of protective works have been placed to protect human constructions and activities. Initially, hard *vs.* soft solution was preferred and groins, breakwaters, seawalls and revetments were emplaced (Ranasinghe, Turner, 2006). Different materials have been used according to their availability, as the most common are concrete units with a big variety of types and shapes, as well as blocks of natural suitable rocks and wood (for groins mostly in northern Europe). In resent decades soft beach solutions, in particular sand nourishment, have been employed with different purposes and mostly to enlarge the beach and make it more attractive to coastal tourism (Hanson et al., 2002).

The study coastal area around the Bolivar department has also experienced an accelerated urbanisation and development over the last decades. This is in particular due to migration of population from southern undeveloped and conflict areas to the coastal zone. For example, the number of coastal inhabitants has increased from 904 603 (in 2005) to 968 848 (in 2010) (DANE, 2005) and ports and harbours have been progressively enlarged to attend the development for commercial and tourist activities (i.e. Mamonal and Bosque harbours and Manga tourist port).

In addition, pleasant weather conditions and attractive sandy beaches in Colombia make coastal environment popular destination for many national and international tourists during much of the year and mostly over the periods June–July and November–January. Just in the town of Cartagena data referred to the period between November 2009–January 2010 show an increase of coastal tourists of about 10 % by contrast to the previous year which recorded 291 000 visitors.

Due to the high recreational value of the study area and large number of tourists arriving, numerous hotels, residences, restaurants, etc. have been constructed since 1950s and mostly in Cartagena, at Bocagrande area (fig. 1). Progressive erosion processes had started to affect the coastline over the past century and since 1970s a number of various hard protective structures have been emplaced in the coastal zone. All these activities along the study area have caused coastline occupation, which presently results in many adverse impacts on coastal zone sustainability.

The aim of this paper is to analyze the main characteristics, distribution and potential effects of installed coastal structures around the municipalities of Cartagena and Santa Catalina in the Bolivar Department, Caribbean Sea of Colombia. In addition, an assessment of extent of technogenous impact on the shoreline caused by armouring was performed.

STUDY AREA

The investigated coastal area is about 370 km long and includes the municipalities of Cartagena and Santa Catalina within the Bolivar Department, Colombia (fig. 1). The supply of terrigenous sediments (generally from the Magdalena River), which represent the major component of local beaches, is determined by seasonal migration of the Intertropical Convergence Zone (ITCZ) that controls precipitations in the area of Caribbean Sea. The ITCZ is the area encircling the earth near the equator where winds originating in the northern and southern hemispheres converge together. Concerning seasonal distribution of precipitations, it includes: 1) dry season (November–March); 2) transition season (April–August); 3) rainy season (August–November). During the dry season the Caribbean Current, the NE winds and associated waves, result in a SW alongshore current and related sediment drifting. During the rainy season, when the NE Darien Counter-Current is stronger, drifting of sediments is reduced (Pujos et al., 1984). In this season, hurricanes, which are originated as tropical depressions, could occasionally hit the study area thus producing NE directed sediment transport (fig. 1).

The interaction among tectonic, climatic and oceanographic processes has resulted in coastal settings characterised by different geomorphological units: 1) dissipative beaches and barrier islands composed by sandy sediments of terrigenous and carbonate origin; 2) marine terraces and cliffed sectors, formed by Tertiary sandstones; 3) coastal plains associated with fluvial-marine sedimentary processes, and iv) costal lagoons with mangrove swamps.

Tidal range is 30 cm (micro tidal environment) and lapse-time between successive high tides varies from 10 to 14 hours. Waves approach the coast from third and fourth quadrants with average wave height of 1.5 and 2 m and 6–9 seconds associated periods. Most significant erosive events are mostly related to storm waves (locally named “mar de leva”) which approach the coast from NE and occur during January – March period.

DATA AND METHODS

In this work Geographic Information System (GIS) tools were used for processing and mapping natural landforms/structures and for the assessment of technogenous impact on the coastline. Human structures were mapped within the littoral zone extending from the shoreline to a landward distance of 100 m. Satellite images from DigitalGlobe map (2009) and Base Map cartography from Agustín Codazzi Geographic Institute (IGAC) – Colombia, in scale 1:25 000, were used in the present research. The information obtained was then complemented by accurate field observations regarding the main characteristics, composition, etc. of port and coast-protection structures.

Following the methods described (Jimenez et al., 1997; Leatherman, 1983; Pajak, Leatherman, 2002), all satellite images were geo-referenced and computer rectified to remove scale and distortion problems (Moore, 2000). The Ground Control Points (GCPs) for document registration have been obtained from the geo-referenced 2010 satellite image and all the information was presented in Projected Coordinate System: Universal Transverse Mercator (UTM)_ Zone18. Taking into account the smooth topography of the studied area, a polynomial transformation was applied in the registration process (Chuvieco, 2000).

At a second phase, all human structures and adjacent coastline were digitalised and mapped generating different ArcGIS shape files corresponding to points, lines and polygons. The collected spatial information was incorporated into a GIS which allowed establishment of an initial open-ended database for the entire coastline of Bolivar department.

RESULTS AND DISCUSSIONS

Mapping human modifications of the coastline is an important issue due to many reasons. It is a key part for the assessment of tourist sustainability, coastal scenery evaluation, as well as for identification of areas recording bathers' safety problems and/or coastal hazards (Ergin, 2004; Hartmann, 2006). Hence, such results from inventorying coastal structures and evaluating their impacts on the coast could help to highlight the state of the coastline and to form the primary base useful in any coastal decision-making (Anfuso, Martinez Del Pozo, 2005; Sharples, 2006).

A large number of different human constructions were identified along the coast of Bolivar department, including maritime structures, i.e. cross- and long-shore ones, detached or not, etc., which were divided into: jetties, groins, breakwaters, dune fences, promenades, seawalls and historical fortifications, ports, harbours and salt pools.

A total number of 289 structures with a length of 44 km were observed at the 366 km long study coastal area (tables 1–2). Around Cartagena Municipality, most common human structures are harbours and ports, which have a total length of 19,5 km or they constitute 44 % of the total length of all structures. Within the Cartagena Bay, human constructions include also industrial developments (oil refineries at Mamonal), commercial activities (Bosque), military uses (Manzanillo) and tourist activities (Manga, Pegasos, Bocagrande and El Laguito).

One hundred groins, with total length of about 4 km have been observed between Castillogrande and Crespo (fig. 2). They were emplaced in 1970s to control coastal erosion along most important sandy beaches, such as El Laguito, Bocagrande, Las Tenazas and Marbella. As major reasons for rising beach erosion could be considered the decrease of sediment input from rivers solid discharge and sediments impounding in the northern area due to natural processes (C o r r e a , 1990). In fact, construction of the first few groins had not mitigated the negative effects of severe erosion at this section. Conversely, over the time they have produced downdrift erosion along the coastline and new structures have been then continuously constructed. These groins were designed as impermeable and were made of blocks of calcareous rocks obtained from Tertiary rocks extracted in near quarries, with an average cost of 20 €/m^3. At this point groins have locally stopped erosion creating a swash aligned coastline with typical "zig-zag" shape.

T a b l e 1

General statistics of human structures in the Bolivar department

Structures	Cartagena	Santa Catalina
Length (m)	348980	17320
Total (m)	366300	
Number of Structures	276	13
Total Structures	289	
Structure Length (m)	39793.76	4270.94
Total	44064.70	
% (Municipality)	11.40	24.66
% (Department)	12.03	
K Index (Municipality)	0.11	0.25
Type	Averaged	Averaged
K Index (Department)	0.12	
Type	Averaged	

A number of twenty-two breakwaters with total length of 1.7 km were observed in the study area. They have been constructed with blocks of calcareous rocks and have been used to protect and enlarge urban beaches between Crespo and Bocagrande. By contrast with ineffective groins structures, these breakwaters have properly functioned and have enlarged the adjacent beach by creating well formed "tombolos" and with occurrence of a slight erosion downdrit. Only one jetty is observed at the mouth of a coastal lagoon (Cienaga de la Virgen) which was artificially connected to the sea fifteen years ago to solve euthrophization processes. A few promenades, three historical fortifications, with total length of 0.9 km, and thirty-nine seawalls, with total length of 9.5 km, were constructed along the coast of Manga Island and the historical town of Cartagena. More recent developments, i.e. promenades, have been built in Manga and Bocagrande during the last two decades. Modern seawalls have been constructed to protect urban areas from severe storms and floods coinciding with unusual high tide conditions annually recorded in September and October. A long fence was built at Crespo to stop landward sand migration which affects vehicle circulation in a backing avenue. Last, two shrimp pools were observed in the southern part of the area.

The coastal area of Santa Catarina Municipality is distinguished with large natural beaches along which a total number of thirteen various structures have been installed, such as: ten groins with a length of 470 m; a salt pool (salina de Galerazamba) which is connected to the open sea with a channel stabilised by one jetty and partially protected from erosion processes with a seawall. Materials and costs of the constructions are similar to the ones recorded at Cartagena area. The total length of all structures is over 4 km.

For evaluating impact of all indicated maritime structures around the Bolivar coastal zone, the so called coefficient of technogenous impact K was used as an indicator. This coefficient is a relation between the total length (l) of all man-made structures (i.e. jetties, groins, breakwaters, etc.) at certain coastal section and the length (L) of the investigated sector (A y b u l a t o v, A r t y u k h i n, 1993):

$$K = l/L$$

According to this methodology, different categories of technogenous impact can be obtained ranging from minimal at K = 0.0001–0.1; averaged when K = 0.11–0.5; maximal at K = 0.51–1.0 and extreme if $K > 1.0$.

For the Bolivar department K value of 0.12 was obtained for 44 064 m total length of 289 observed structures and coastline length of 36 6300 m (table 1). The coefficient K was also estimated for each municipality: at Cartagena and Santa Catarina K was obtained as values of 0.11 and 0.25, respectively (table 1). After applied classification the extent of technogenous impact for both areas belongs to the "averaged" class ($0.11 \leq K < 0.5$).

However, the obtained K values for the Bolívar department coastline and the two investigated municipalities are not very realistic due to the irregular distribution of man-made structures along the shoreline. Example of this is the tourist zone of Cartagena between Castillogrande and Crespo, where a number of 80 coast-protection structures have been built: this sector presents a high K value (0.60) which characterizes the sector with maximal extent of armouring impact. Moreover, some harbour areas within the Bay of Cartagena show K values equal and/or higher than 1, because the coastline here has been completely armoured.

The governance of coastal hazards, such as erosion and flooding along the investigated area is currently administrated only on a reactive basis. In most cases the protective measures have been introduced under remedial rather than preventative conditions. Many defence structures have been installed in response to local stockholders' pressure when their properties would be exposed to destruction, however without required environmental impact assessment or preliminary evaluations of potential risks and visual effects. This way, hard stabilisation structures have caused a technogenous occupation of the coastline, which has altered the natural environment. Structures cause coastal armouring, preserve some areas to be eroded, but reduce sediment supplies to the downdrift areas (G r i g g s, 2005; R u n y a n, G r i g g s, 2003) and in many cases erosion processes could be exacerbated or even new erosion spots in adjacent coastal areas could be generated (R o d r i g u e z, D e a n, 2009) and new struc-

Table 2

Types and characteristics of human structures in the study area

Structures		Cartagena	Santa Catalina	Structures (%)	Coastline (%)
Ports	Number	35	0	34.08	4.10
	Total	35			
	Length (m)	15015.39	0.00		
	Total	15015.39			
Harbours	Number	69	0	10.20	1.23
	Total	69			
	Length (m)	4495.64	0.00		
	Total	4495.64			
Groins	Number	102	10	9.88	1.19
	Total	112			
	Length (m)	3887.02	468.68		
	Total	4355.70			
Breakwaters	Number	22	0	3.93	0.47
	Total	22			
	Length (m)	1733.49	0.00		
	Total	1733.49			
Jetties	Number	1	1	1.73	0.21
	Total	2			
	Length (m)	661.40	101.83		
	Total	763.23			
Promenades	Number	2	0	1.58	0.19
	Total	2			
	Length (m)	698.15	0.00		
	Total	698.15			
Historical Fortifications	Number	3	0	2.15	0.26
	Total	3			
	Length (m)	948.25	0.00		
	Total	948.25			
Salt Polls	Number	0	1	8.24	0.99
	Total	1			
	Length (m)	0.00	3632.30		
	Total	3632.30			
Shrimp Polls	Number	2	0	4.12	0.50
	Total	2			
	Length (m)	1814.45	0.00		
	Total	1814.45			

tures are needed to be placed according to the "domino" effect (Cooper et al., 2009). These were the cases of Bocagrande, El Laguito and Castillogrande (fig. 2).

Other important aspects are related to the interaction between incident waves and structures which often produces strong rip currents, a high drowning risk for bathers (Hartmann, 2006) especially in many areas of Cartagena. These are the cases of Las Tenazas and Marbella beaches where strong currents are observed in particular during the stormy period and produce scores of deaths (about 10 per year).

In conclusion, man-made structures generate a great negative impact on coastal scenery, which evaluation is essentially based on human and natural parameters (Ergin, 2004). Native parameters are not susceptible to be modified so that coastal managers and planners should assess ways of upgrading scenic human parameter scores.

Results presented in this study can be used as primary information for coastal managers in order to be provided with sound scientific basis available for any envisaged management plans. In this sense, for further developments, in order to increase values of physical *vs.* human parameters, beach nourishment and restoration works can be preferred *vs.* construction of hard protective structures. For one, a well vegetated dune ridges constitute a buffer between beach and built environment, this way producing the diminution of noise disturbance, visual impact of buildings, etc. also protecting backshore from erosion processes. Such kind of measures could be carried out at Crespo; groins should be removed and beach nourishment implemented and vegetation implanted on the dunes to stop sand migration and to create a natural barrier between the beach and the backing avenue. Sometimes coastal structures have been placed to protect not only very high capital land use zones but also low density or very specific areas as spread summer houses at Santa Catalina municipality. It is therefore evident that these costs, especially those associated with the construction of numerous groins, are at places much greater than the value of eroded areas.

CONCLUSIONS

Large number of various human structures were identified along the coast of Bolivar department, including cross- and long-shore ones, detached or not, etc., which were divided into: jetties, groins, breakwaters, dune fences, promenades, seawalls and historical fortifications, ports, harbours and salt pools. Around the coast of Cartagena Municipality, most common structures are harbours and ports, which have a total length of 19.5 km or they constitute 44% of the total length of all structures.

The coastal area of Santa Catalina Municipality is distinguished with large natural beaches along which a total number of thirteen various type structures have been installed with total length over 4 km. The estimated coefficient of technogenous impact ***K*** for both areas – 0.11 and 0.25 respectively, presents an averaged extent of coastline armouring. However there are sites with very high concentration of coastal defence constructions: the tourist zone of Cartagena between Castillogrande and Crespo, where a number of 80 structures have been built. This sector presents a high ***K*** value (0.60) indicating maximal extent of armouring impact. Moreover, some harbour areas within the Bay of Cartagena show ***K*** values equal and/or higher than 1, because the coastline here has been completely armoured. Therefore, for adequate management of the study area the effects of built human structures and the effectiveness of applied coastal defence methods should be thoroughly evaluated and preferably soft options for prevention should be employed in the future.

REFERENCES

Anfuso G., J. A. Martinez Del Pozo. 2005. Towards management of coastal erosion problems and human structure impacts using GIS tools: case study in Ragusa Province, Southern Sicily, Italy. Environmental Geology, (48), 646–659.

Aybulatov N.A., Y.V. Artyukhin. 1993. Geoecology of the World Ocean`s Shelf and Coasts. Hydrometeo Publishing, Leningrad, ISBN 5-286-00763-5, 304 p. (In Russian)

Chuvieco E. 2000. Fundaments in Spatial Teledection. Rialp Ed., 567 p. (In Spanish)

Cooper, A., G. Anfuso, L. Del Rio. 2009. Bad beach management: European perspectives The Geological Society of America, Special Paper 460, 167–179.

Correa, I.D. 1990. Environmental Geology and Natural Hazards of the Andean Region. 13, 1990, 117–128.

Dodds R., I. Kelman. 2008. How Climate Change is Considered in Sustainable Tourism Policies: A Case of the Mediterranean Islands of Malta and Mallorca. Tourism Review International, 12, 57–70.

EEA (European Environment Agency) Staff. 2006. The changing faces of Europe`s coastal areas (Report 6), Copenhagen, 107 p.

Ergin A., E. Karaesmen, A. Micallef, Williams, A.T. 2004. Coastal Scenery: Appreciation and Evaluation. Area. 36 (4), 367 – 386.

Griggs, G. 2005. The impacts of coastal armouring. Shore and Beach, vol. 73, № 1, Winter, 13–22.

Hanson H., A. Brampton, M. Capobianco, H.H. Dette, L. Hamm, C. Laustrurr, A. Leechuga, R. Spanhoff. 2002. Beach nourishment projects, practices, and objectives – a European overview. Coastal Engineering, 47, 81–111.

Hartmann, D. 2006. Beach management and drowning along the Israeli Mediterranean Beaches. Journal of Coastal research. 22 (6), 1505–1514.

Jimenez J., A. Sanches-Arcilla A, J. Bou, M. Ortiz. 1997. Analysing short-term shoreline changes along the Ebro delta (Spain) using aerial photographs. Journal of Coastal Research, 13 (4), 1256–1266.

Klein, Y.L., J.P. Osleeb, M.R. Viola. 2004. Tourism-Generated Earnings in the Coastal Zone: A Regional Analysis. Journal of Coastal Research, 20 (4), 1080–1088.

Leathermen, S. 1983. Shoreline mapping: a comparison of techniques. Shore and Beach, 51, 28–33.

Moore L. 2000. Shoreline mapping techniques. Journal of Coastal Research. 16 (1), 11–124.

Morhange C., N. Marriner, N. Sabatier, C. Vella. 2007. Revue Géographique des Pays Méditerranéens. Geographical Journal of Mediterranean Countries, 108 p. (in French)

Pajak M.J., S. Leatherman. 2002. The high water line as shoreline indicator. Journal of Coastal Research, 18 (2), 329–337.

Pujos M., J.L. Pagliardini, R. Steer, G. Vernette, O. Weber. 1984. Bulletin of Geologic Institute Bassin d'Aquitaine, 35, 77–85. (In French)

Ranasinghe R., I. Turner. 2006. Shoreline Response to Submerged Structures: A Review. Coastal Engineering, 53, 65–79.

R o d r i g u e z E., R. D e a n. 2009. A Sediment Budget Analysis and Management Strategy for Fort Pierce Inlet, Florida. Journal of Coastal Research. 25 (4), 870–883.
R u n y a n, K., G r i g g s, G. 2003. The effects of armoring seacliffs on the natural sand supply to the beaches of California. Journal of Coastal Research. 19 (2), 336–347.
S h a r p l e s C. 2006. Consultant report to department of primary industries and water, Tasmania (2nd edition), 2006, 173 p.
x x x DANE (National Department of Statistics). 2005. General Census of the Colombian Republic (Report 1), Santa Fe de Bogota, 501 p. (In Spanish)
x x x URL: http://www.dpiw.tas.gov.au/inter.nsf/WebPages/PMAS-6B56BV?open.
x x x URL: http://www.world-tourism.org/newsroom/Releases/2006/June/baro,eter.html (last seen on 20.02.2010)

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ПОСЛЕДСТВИЯ ОТ АРМИРАНЕТО НА БРЕГОВАТА ЛИНИЯ В ОБЛАСТТА БОЛИВАР (КОЛУМБИЯ, КАРИБСКО МОРЕ)

Н. Ранхел-Буитраго, Дж. Анфузо, М. Станчева

(Р е з ю м е)

През изминалия век прогресивно нарастващата абразия започва да засяга 1760 km от Карибското крайбрежие на Колумбия. Това е наложило стартирането на мащабно брегозащитно строителство от 70-те години на миналия век, осъществявано предимно с традиционните брегозащитни методи и съоръжения. В този контекст настоящото изследване има за цел да се инвентаризират основните типове брегови съоръжения и тяхното разпространение в общините Картахена и Санта Каталина, област Боливар, Карибското крайбрежие на Колумбия.

По протежение на изучавания брегови участък с дължина 366 km са идентифицирани 289 на брой различни типове съоръжения с обща дължина 44 km, включващи пристанищни молове, буни, вълноломи, дюнни заграждения, морски стени/исторически укрепления, пристанища и др.

За оценка на степента на техногенно въздействие върху изследвания участък, причинено от пристанищни и брегозащитни съоръжения, като индикатор е използван специфичен коефициент (***K***). Въпреки че полученият коефициент ***K*** индикира средна степен на техногенно въздействие за целия участък, налице са някои участъци с много висока концентрация на брегови съоръжения. Такива например са туристическата зона на Картахена със стойности за коефициента ***K*** = 0.60 и съответно максимална степен на въздействие, а също и някои пристанищни участъци в залива на Картахена със стойности на ***K***, равни или по-големи от 1, поради факта, че тук бреговата линия е напълно армирана със съоръжения. На основата на получените резултати са анализирани и негативните визуални ефекти от изградените съоръжения и последствията от тяхното въздействие, като редуцирано постъпление на седиментен материал, ускорена абразия откъм подветрената страна на съоръженията и необратими модификации на бреговата линия.

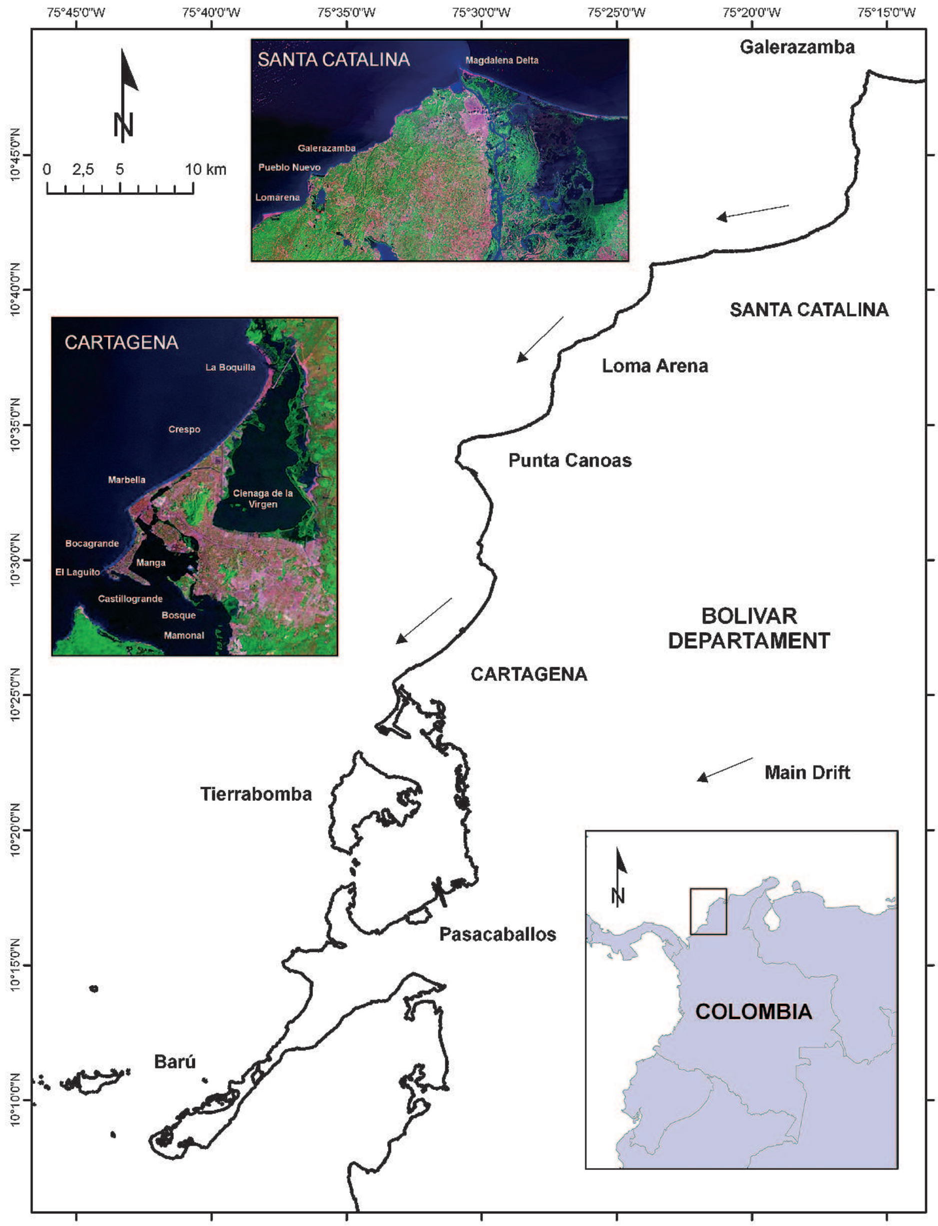

Fig.1. Map of the Bolivar department with most important localities of each municipality

Fig. 2. Aerial view of coastal occupation and groin fields (“domino effect”) at Bocagrande, El Laguito and Castillogrande sectors (Cartagena City). The images on the left side correspond to 1950s, the ones on the right correspond to 2005 (courtesy of Historic Archive of Cartagena de Indias)