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Editorial

Towards a stronger collaboration among Latin American countries to enhance Coastal Zone Management

The traditional definition of Latin America covers all countries of the American continent, from México to Argentina, that were colonized by Portugal and Spain from 16th to the 19th century. Over the past few decades, emigration and commercial relations have spread the cultural values of Latin America all over the world. Despite the existing differences, which arise from the dimension of the geographical area populated by Latin Americans share common traits that are easily recognized among and beyond them, being a powerful integrating factor. In that sense, sharing of concepts and experiences in delineating and implementing the Integrated Coastal Zone Management (ICZM) is certainly an important cultural and scientific challenge transcending the national borders in South and Central America and frequently involving Portugal and Spain.

Integrated Coastal Zone Management (ICZM) is understood as a process of participative governance based on cooperation between institutional and individual stakeholders. The overarching aim of this approach is to promote a sustainable development through the integration of, scientific knowledge, policies, strategies and sectorial plans in space and time. According to Perez-Cayero (2014), the "integration" in the coastal management process must be comprehended in a multi-system space i.e. administrative, geographical, ecological (ecosystem services) and social.

In the current context of global change, improving of coastal governance is a priority of paramount importance for billions of people around the world. Integrated Coastal Management is increasingly relevant in eradication of poverty and social inequalities in our region, and to promote efficient adaptation measures to the local forcings of global change. It is understood and accepted that only by protecting and restoring the natural base on which we depend, we may create a socially inclusive and truly sustainable economic growth. The articles presented in this thematic issue seek to contribute to regional dialogue both among scientists and decision makers and between the countries of the region facing common challenges.

The thematic scope of the presented papers is broad. It covers the topics on physical forcings on the coastal fringe (*e.g.,* erosion and climate change), coastal infrastructures, and Coastal Management policies, with the equal share in terms of importance for developing coastal management initiatives.

For instance, the work of Mendoza *et al.* demonstrates the importance of having a practical tool to measure the volume of solid waste in beaches in order to develop protocols on beach monitoring.

Marine litter issue is also addressed in the work of Eastman *et al.,* which analyses the importance of a hands-on approach in school education. The authors developed a seven steps procedure for designing a successful citizen science project that involves schoolchildren in monitoring of the coasts. The experience shows the usefulness of the gathered data for coastal managers and proves to be a meaningful support in decision-making processes.

Amaral *et al.* work, also deals with evaluation of schoolchildren's change in awareness and perception of reef conservation, which was produced by environmental education targeting that issue. In their survey they applied questionnaires to 10-12 years old children,

before and after environmental educational activities. The survey proved that after the educational activities children had shown an improved perception of the need for reef conservation, rather than just seeing the reef as an asset for tourism. This demonstrates the importance of environmental education in changing attitudes of the future adults towards a more participative citizenship, involved in territorial management process.

The article by Isla & Cortizo addresses fluvial sediment inputs and cliff erosion in the Atlantic continental shelf of Argentina, from Buenos Aires down to Tierra del Fuego. The averaged rate of cliff retreat estimated in this study approaches 0.6 meters per year. The authors conclude that the sediment supply from the cliff erosion exceeds the sediment brought to the shelf by fluvial transport. The practical implications of these findings for coastal management are huge and the research recommends seriously taking into account both processes when addressing sand balance accreted to or eroded from the beaches and transported by the longshore current.

The article by Nagy *et al.* deals with the present and future, climate related risks in the Rio de la Plata coast and the estuarine front in Uruguay. The analyses and forecast are based on the outcomes of a project that analysed adaptation measures in several pilot sites and built a climate scenario for the coastal area of Uruguay. The study highlights lessons learned from ICZM experiences and the need for working with stakeholders in participatory problem-solving as well as the benefits of developing alternative futures to prioritize actions.

Moreira *et al.* analyses the spatial and temporal phytoplankton distribution and the occurrence of harmful algal blooms (HABS) in the Cienfuegos Bay in Cuba, with the aim of developing indicators of coastal eutrophication. Phytoplankton biomass, harmful/toxic algal blooms occurrence and bottom dissolved oxygen concentrations are used as proxies of overall trophic rank. The main findings of this study point to the necessity of addressing the water quality issue in the areas of reduced water dynamics along Cienfuegos Bay. Efforts for coping with sewage discharge and improving environmental quality due to eutrophication and the presence of harmful algal blooms are suggested as part of a major coastal management plan for Cienfuegos Bay. This plan also would have to consider the implementation of control on molluscs' harvesting during bloom periods. Green mussel Perna viridis, is proposed for monitoring and a special attention is recommended for observation of fish mortality due to the red tide forming dinoflagellate Cochlodinium polykrikoides.

The article by Romero *et al.* proposes an evaluation of the environmental management systems in Brazilian ports. Several methods of analyses – such as SWOT, Gap and SDM were combined and allowed to conclude that this procedure allows managers to better delineate the challenges and strategies in order to improve the environmental management of the ports. From the analyses of questionnaires responded by port managers, the authors concluded that the environmental problems did not receive an adequate attention from the managers who tended to minimize their importance. A better understanding of environmental management systems and better communication tools are cited as solutions to improve theses systems in the Brazilian Ports.

In their study dedicated to the coral reefs Loiola *et al.* propose the definition of priority areas for conservation, creating No-Take Zones (NTK). The study was carried on in a coastal reef complex off the eastern Brazilian coast. The authors recommend a creation of two NTK areas, each of 12 km^2, over two different reefs classified as high priority for conservation.

The work of Morais & Abessa addresses the coastal problems of the Complexo Estuarino-Lagunar Iguape-Cananéia (CELIC), using the pressure-state-response method (PSR), a simplified version of the DPSIR methodology. The authors argue that, although pressure in urban development is lower compared to other coastal areas, status indicators show that there are structural deficiencies in terms of basic needs, such as health and sanitation, and that the problem is increasing due to the lack of proper government response to this issue.

Last, but not least, the investigation of Caviedes *et al.* synthesizes the findings of the diagnosis of integrated coastal areas of Honduras, as well as a critical and proactive analysis of the current management methods applied in this Central American country. The article is based on the collective work of IBERMAR Group Honduras, which has been leading, from academia to government and non-governmental organizations, the current process of discussion, design, formulation and approval of the State Policy-oriented for Integrated Coastal and Marine Management. The main value of the approach used in this work, besides being a valuable scientific contribution, consists in supporting the process potentially leading to a better governance of the coastal and marine areas in strategic locations.

The analysis of 11 Latin-American countries, plus Portugal and Spain, done by Barragán (2010), stressed the need of a regional initiative to deal with coastal problems and management. The author proposes a Latin American platform for experiences interchange, which could be a propeller for new ideas on ocean and coast governance, as well a place to build capacity on human resources to deal with this great challenge. This thematic number of Journal of Integrated Coastal Zone Management contributes to this communication congregating some Latin American experiences on ICZM.

We would like to acknowledge all those who have contributed towards this thematic issue of JICZM - Journal of Integrated Coastal Zone Management, including authors, reviewers, invited editorial board and collaborators. Among the collaborators we would like to especially acknowledge Carmen Gonçalez, Fernando Peña, Filomena Pedrosa Martins, Monica Gomez, Daniel Conde and Pedro Arenas for their contribution on this issue.

References

Barragan, J.M.M. (coord.) (2010) - *Manejo Costero Integrado y Política Pública en Iberoamérica: Un diagnóstico. Necesidad de Cambio*. 380p., Red IBERMAR (CYTED), Cádiz, Spain. Available on-line at http://hum117.uca.es/ibermar/Resultados y descargas/librodiagnosticoibermar

Perez-Cayero, M. L. (2014) - Gestión Integrada de Áreas Litorales. Análisis de los Fundamentos de la Disciplina. 404p., Editorial Taber, Madrid, Spain, ISBN: 978-8473604895

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Sediment input from fluvial sources and cliff erosion to the continental shelf of Argentina *

Federico I. Isla[@, a, b]; Luis C. Cortizo[c]

ABSTRACT

The coasts of southern Buenos Aires, Patagonia and Tierra del Fuego are dominated by cliff erosion. Mean rates of cliff retreat are estimated to be about 0.5-0.6 m/year by comparing old photographs with modern satellite images. Considering the height of the Patagonian and Fueguian cliffs (70 to 120 m), the volume of sediment eroded from these cliffs exceeded the volumes provided by the erosion of the cliffs of Buenos Aires (10 to 20 m height). These erosion rates support an estimated delivery of 217 million tons of sediment per year to the continental shelf, exceeding significantly the 22 millions of tons/year transported by the larger Patagonian rivers Negro and Colorado. However, the contribution of these rivers has decreased since the Late Pleistocene changes in the direction of transport of some watersheds. The Chubut and Chico de Santa Cruz rivers suffered reductions of 21-24% in their watershed areas, resulting in reductions of about 33-34% in the volume of water transported to the Atlantic Ocean per year. 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.

Keywords: cliff erosion, sediment supply, drainage reversal, Patagonia, Buenos Aires

RESUMO

Fornecimento sedimentar de origem fluvial e da erosão costeira à plataforma continental Argentina

O litoral de Buenos Aires, Patagónia e Terra del Fuego é dominado pela erosão de falésias marinhas. As taxas de medias de recuo foram estimados em 0,5-0,6 m/ano, com base na comparação de fotografias aéreas antigas com imagens satelitárias modernas. Considerando a altura das falésias patagónicas e fueguinas (70 a 120 m), o volume de sedimento erodido supera os volumes que provêm das falésias de Buenos Aires (10 a 20 m). Estas taxas de erosão permitiram estimar um aporte de 217 milhões de toneladas por ano de sedimento à plataforma continental, superando os 22 milhões de toneladas/ano transportados pelos rios da Patagónia, Negro e Colorado. Além disso, a contribuição fluvial diminuiu devido às alterações na drenagem que afetaram algumas bacias desde o Pleistoceno Superior. Os rios Chubut e Chico de Santa Cruz sofreram reduções de 21-24% nas áreas de drenagem, o que significou diminuições de 33-44% nas contribuições de água para o Oceano Atlântico. Como o volume de sedimentos proveniente da erosão de falésias e fornecido à plataforma continental argentina supera o do fornecimento fluvial, tal deve ser também considerado na análise do balanço sedimentar das praias alimentadas pela deriva litorânea.

Palavras-chave: *erosão de falésias, aporte sedimentar, inversão da drenagem, Patagonia, Buenos Aires*

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1. Introduction

During the 20th century, the study of cliff-erosion rates required use of detailed topographic maps or aerial photographs. These methods were expensive and needed much care to handle projections, scales, resolutions, relationships between vertical and horizontal datums, and the precision to represent intertidal areas (Barrier & Sloan, 2007). The use of aerial photographs applied to coastal areas was initiated during World War II with the objective of forecasting landing conditions at the Pacific Islands (Lundahl, 1948). These techniques evolved later to monitor cliff erosion rates (Hapke 2004, Maiti & Bhattacharya, 2009). The first satellite planned for land resources (Landsat 1) had no spatial resolution useful for measuring cliff recession rates (79 m). To the end of the 20th century, improvements in spatial resolution (Ikonos, Quickbird and OrbView satellites) permitted monitoring programs with a minimum resolution. The GPS (Global Position System) constellation was another improvement to reference fixed points for the change analysis.

Some empirical models have been proposed to forecast cliff-recession rates:

$$dX = Cs * f * dt \qquad (1)$$

where dX is the rate of erosion, t is time, f the erosive force, and Cs is considered as the rock erodability (Horikawa & Sunamura, 1967); f is considered a function of a constant and the wave altitude. Significant differences in Cs were explained by the different behavior of igneous and sedimentary rocks (Emery & Kuhn, 1982; French 2001). Specifically, the lithology, structure and slope of the cliffs should be considered (Del Río & Gracia, 2004). Modern studies incorporated the effects of variations of the water table (Leatherman, 1986), heavy rainfalls (Duperret *et al.,* 2004) and the episodic effects of earthquakes or El Niño effects (Hapke & Richmond, 2002; Hampton *et al*., 2004). Groundwater and rainfall effects are particularly important to forecast the retreat rates of the cliffs of Buenos Aires. In recent years, anthropogenic effects are considered to be of increasing concern (Wilkinson & McElroy, 2007). In urbanized areas south of Mar del Plata, the seasonal variations of the water table depend on the touristic demand for water and the local recharge induced by the operation of multiple cesspools. Rock revetments recently constructed along the coastline of Mar del Plata have caused significant effects on the coastal sediment budget due to a decrease in the sand availability. In Patagonia, monthly variations in the tidal ranges can have significant effects on the erodability of clayey cliffs. In order to discern anomalous places or episodic recession rates (storm effects), it is useful to consider statistical approximations averaged either along distance or time (Galgano *et al.,* 1998; Zuzek *et al.,* 2003). Combinations of techniques are recommended, taking advantage of photographs from old satellites (as the Corona program) compared to new images of better spatial resolution (Bayram *et al.,* 2004).

The first evaluation of the sediment input to the Argentine Basin was estimated assuming that the main sources were provided by the continent, and neglecting the quantity of sediment provided from Antarctica (Siegel, 1973). Considering only the inputs of the Colorado (6.9-7.7 x 10^6 metric tons) and Negro rivers (15.2-13.6 x 10^6 metric tons, Depetris, 1968; Depetris & Griffin, 1968), Siegel summed a fluvial input of 22 x 10^6 tons transported by these two major Patagonian rivers; the input supply by coastal erosion was disregarded. It should be stressed that the watershed of the Colorado River can increase its discharge during ENSO events, when the Curacó-Desaguadero system can become operable (Spalletti & Isla, 2003).

Dealing with coastal erosion, cliff recession rates between 1 and 4 m/yr were estimated for the coastal cliffs north and south of Mar del Plata (Cionchi *et al.,* 1998). The processes that were controlling coastal erosion at the cliffs of the provinces of Rio Negro and Chubut were assumed to be different (Schillizzi *et al.,* 2003). At the northern coast of Rio Negro, cliff recession rates varied between 0.2 and 2 m/year (Del Río *et al.,* 2007).

In the present study, cliff erosion rates of the whole coast of Argentina, comprising Buenos Aires, Patagonia and Tierra del Fuego, were estimated for the first time, combining information extracted from aerial and satellite photographs, and the modern referenced satellite images. Taking advantage of some GIS procedures to enhance definition, this cliff contribution of sediment to the continental shelf was compared in relation to the sediment transport provided by the more important rivers. In this sense, the Holocene decay in the contribution of these rivers was also evaluated.

2. Regional Setting

The coast of Argentina extends from 33º S to 50º S. Climate varies from temperate and humid in Buenos Aires, to very cold and dry in northern Tierra del Fuego (Schäbitz, 1994). There are significant variations in the precipitation in Patagonia, spanning from 200 mm/yr at the north to 2500 mm/year at the southwestern extreme (Coronato *et al.,* 2008). In Tierra del Fuego, differences of 2000 mm/ year occur to both flanks (north and south) of the Darwin Cordillera (Tuhkanen, 1992; Coronato *et al*., 2008).

The Buenos Aires coast is dominated by storm effects in a microtidal regime with diurnal inequalities (spring

tidal range is lower than 1 m). On the other hand, semi-diurnal tides over a 4 m tidal range are dominant in Patagonia (Figure 1). Tidal ranges increase within gulfs: in the Bahía Blanca embayment it increases from micro to a mesotidal regime (Isla & Bértola, 2003); in the San Jorge Gulf it increases from meso to a macrotidal regime (Isla *et al.,* 2002).

Along the Tierra del Fuego coastline, mean tidal range diminishes from 6.6 m in San Sebastián Bay (Isla *et al.,* 1991) to 5.7 m in Caleta La Misión, 4.16 m in Río Grande and 4.63 m in Caleta San Pablo. Due to the westerly winds, in San Sebastián Bay, maximum tidal currents are over 2 knots at the inlet and of 5 knots within the bay. Spring tides can increase to 10.4 m (Figure 1).

In regard to wave climate at high latitudes of the South Atlantic coast, it can be stated that:

(a) the frequency of wave heights higher than 3.5 m is very low; 20% of the waves were less than 1 m in height throughout the year;

(b) long-period waves are relatively uncommon; wave periods greater than 10 s come from the E and NE,

(c) gales of 41–47 knots from any direction between N and ESE (with a return period of 50 years) are estimated to generate extreme wave heights of 12 m (period of 11.5 sec) in a depth of 50 m (Isla & Bujalesky, 2004).

A regional longshore drift has been reported from north to south in regard to coastal features and sediment transport experiments (Codignotto & Malumián, 1981; Codignotto & Kokot, 1988; Isla *et al.,* 1991). However, beach heavy minerals suggest longshore transport from south to north (Gomez Peral & Martínez, 1997). The recurving spit of Río Grande inlet also evolves in response to a local drift from south to north (Isla & Bujalesky, 2004).

The Buenos Aires coastal plain is composed of sandy silts, with caliche levels that fortunately resist the persistent erosion induced by waves. Waves dominate from SE and NE in Mar del Plata, and from the S in

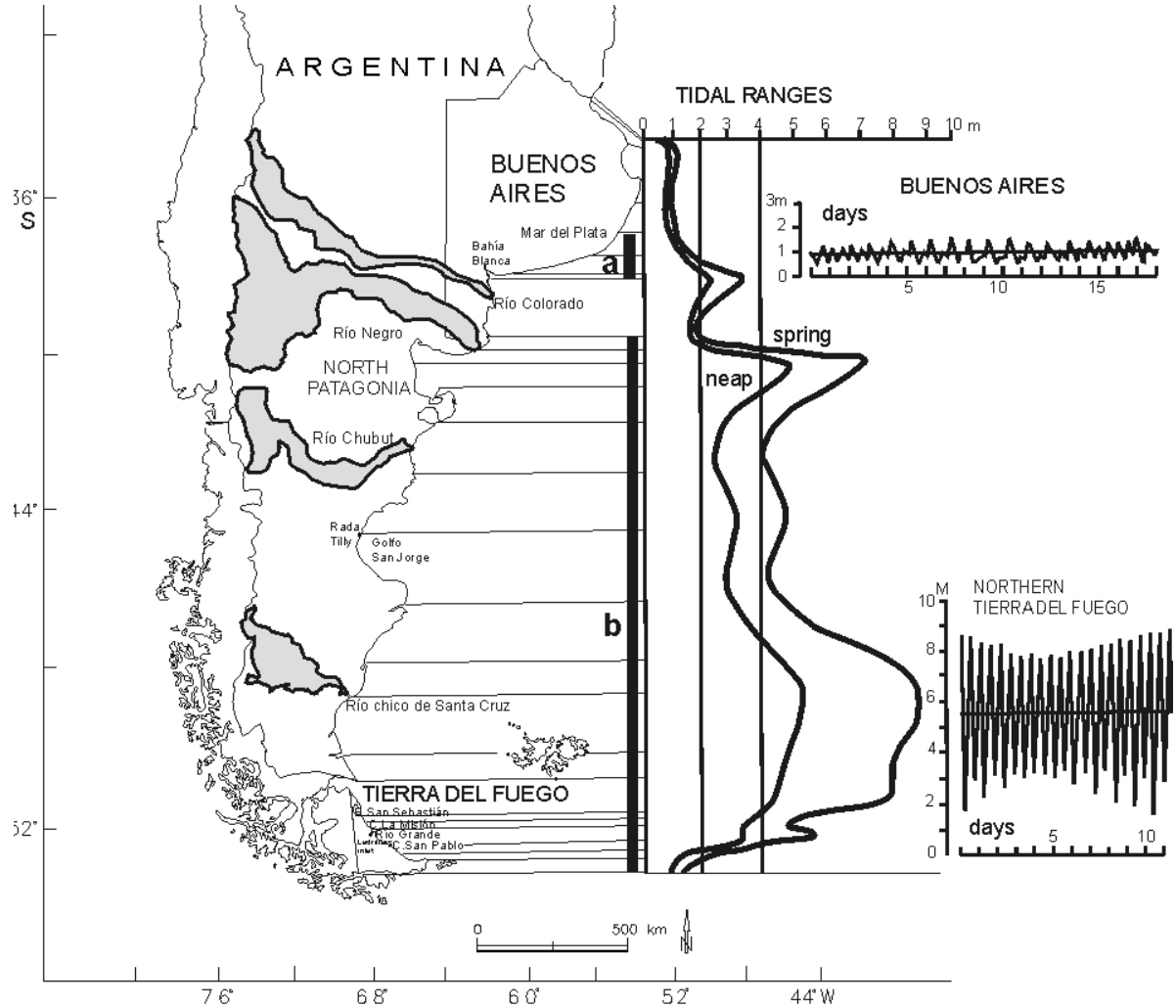

Figure 1 - Location of studied cliffs and the watersheds analysed. Bar "a" comprises the cliffs reported from Buenos Aires Province; bar "b", the cliffs studied from Patagonia.

Figura 1 - Localização das falésias estudadas e das bacias hidrográficas analisadas. "a" compreende as falésias da Província de Buenos Aires; "b", as falésias estudadas da Patagónia.

Necochea; higher waves are more frequent (seasonal) in Mar del Plata than in Necochea. The Patagonian coast consists of different systems of plateaus of tectonic origin and marine terraces originated by Quaternary sea-level fluctuations (Rutter *et al.,* 1989; Schellmann, 1998; Isla & Bujalesky, 2008). The cliffs are of 40-50 m height at the Rio Negro Province, and increase to more than 120 m towards the Magellan Strait. An uplift of the southern extreme of the South American Plate was estimated at about 8 cm/1000 years (Guilderson *et al.,* 2000). At the coast of Tierra del Fuego, glacial moraines and marine terraces are reminders of the climatic fluctuations that occurred during the last 120,000 years (Isla & Bujalesky, 2008).

3. Materials and methods

Old aerial photographs, from 1964 and 1971, were compared to modern Landsat ETM images (spatial resolution 15 m) registered into the Gauss-Krugger coordinate system (National reference system of Argentina). Edge-enhacement techniques were applied to distinguish coastal cliffs (Figure 2).

For the Buenos Aires cliffs, Landsat 5 images were applied (from 1998 and 1999), while in Patagonia, Landsat 7 images (from 2003) were also used. In all cases fixed points, mostly lighthouses of known geographic position, and altitudes (at their bases) referred to mean sea level, were recognized and measured in their distances to the top of the cliffs, with the help of charts and publications of the National Hydrographical Survey (Servicio de Hidrografía Naval, 1978, scales 1/50,000 or 1/100,000). These comparisons generated variations in the precision of the distance measurements (Hapke & Richmond, 2002; Zuzek *et al.,* 2003; Hapke, 2004). It is assumed that shoreline variations are subjects to errors of ± 50-150 m using aerial photographs,

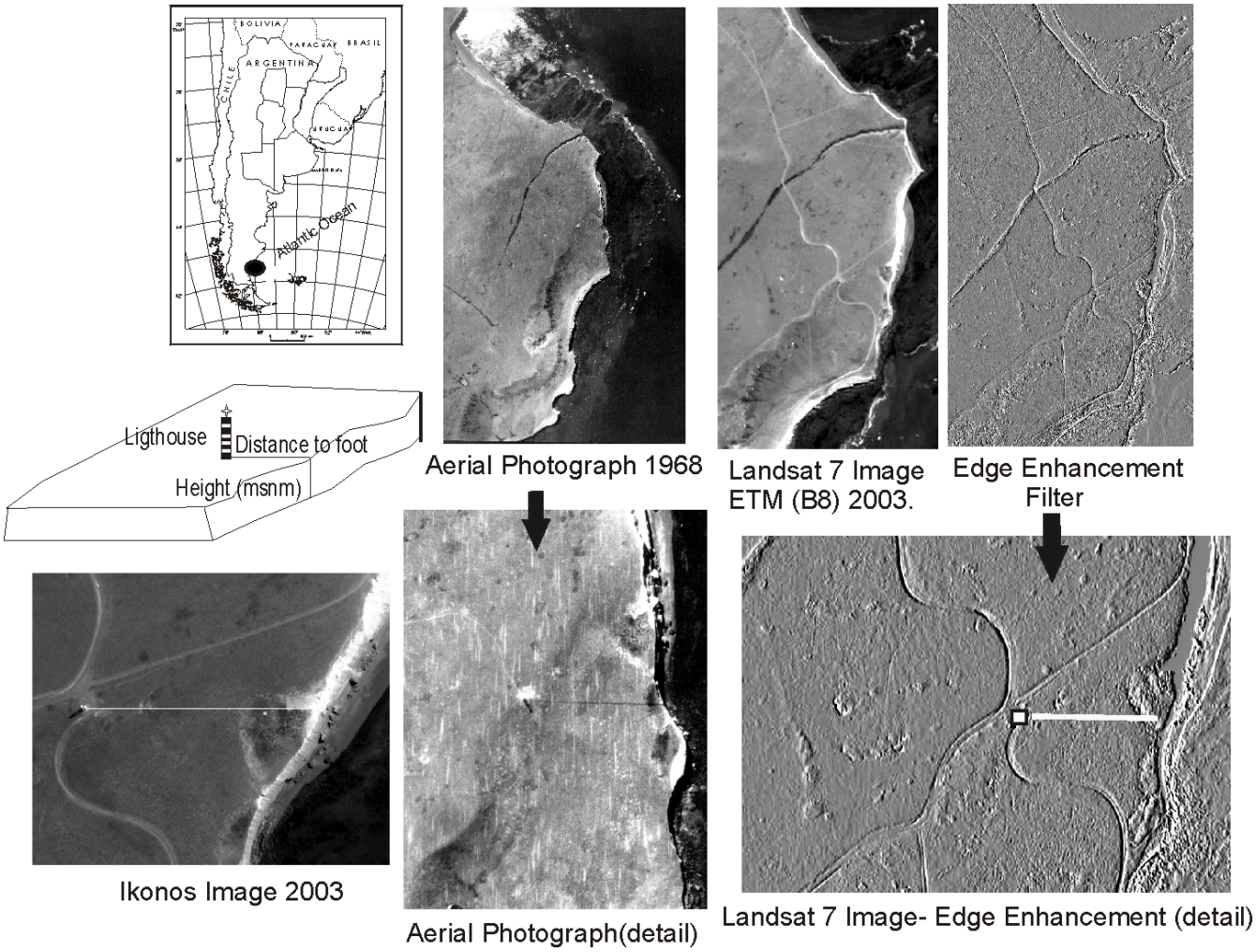

Figure 2 - Remote sensing methods applied to Curioso cape (Santa Cruz Province). Aerial photographs of 1968 are compared to a Landsat TM images of 2003. The position of the lighthouse is related to the cliff foot applying edge enhacement procedures.

Figura 2 - Métodos de sensoriamento remoto aplicados ao Cabo Curioso (Província de Santa Cruz). Fotografias aéreas de 1968 são comparados com imagens Landsat TM de 2003. A posição do farol está relacionado com a base da falésia através da aplicação de procedimentos de realce.

reduced to ± 15 m dealing with topographic surveys (Ruggiero *et al.,* 2003). Different statistical methods to analyze the cliff retreat can be useful for different purposes (Fletcher *et al.,* 2003). For the identification of the coastal retreat, the foot of the cliffs (or foredunes) was considered as the most sensitive feature. However, where the shadows of the tall cliffs prevented the recognition of their feet, the top of the cliffs were selected for monitoring. The sources of error increased for the TM images where the spectral reflectance of the cliffs is similar to the spectral reflectance of the beach (sand or gravel beaches). In macrotidal coasts, the area washed by the last high tide helped to distinguish the foot of the foredune.

Annual erosion rates (m/year) were multiplied by the height of the cliffs in order to obtain the volume eroded per meter of coastline (French 2001). Considering the distances assigned for each lighthouse, the annual volume of sediment eroded was calculated (m^3/year). The volumes eroded from the retreat of abrasion platforms were disregarded because their sediment contribution is negligible if there is not a significant change in sea level. As sea level is thought to be dropping during the Holocene (Isla, 1989), no long-term sea-level rise factor was considered in these estimates.

In order to evaluate the changes in the watersheds that reversed during the Last Deglaciation, two watersheds, Chubut and Chico of Santa Cruz, were compared in their areas and volumes of discharge during Late Pleistocene ("ice divide") and Holocene ("water divide").

A Digital Elevation Model (DEM) was downloaded from the SRTM web site (Shuttle Radar Terrain Model; http://srtm.csi.cgiar.org). This model has a ground spatial resolution of 90 m. The information was handled with the Global Mapper v.7.04 (http://www.globalmapper.com). Modern watersheds were drawn in a Geographic Information System (GIS) and compared to drainage areas provided by the web (http://www.hidricosargentina.gov.ar). As the differences between both watersheds showed significant decrease in the water discharge, this evaluation not only considered variations in the basin area but also in the amount of water discharge per year (assuming that the distribution of rain within the basins has not changed significantly).

Both watersheds were digitized into an Arc View 3.0 environment (Environmental Systems Research Institute 1996). Isohyets were also plotted into this GIS environment in order to calculate the annual recharge in each watershed (km^3/yr).

4. Results

4.1. Buenos Aires cliff retreat

Comparing photographs of 1970 and images of 2004, a recession cliff retreat of 0.4 to 0.7 m/year is common. To the north of Mar del Plata, from Camet Norte to Mar Chiquita, the coast is composed of foredunes under erosion, where the retreat increases from 1.5 to 3.9 m/year (Figure 3a). Volumes eroded increase to the south as the cliffs have higher altitudes (Figure 3b).

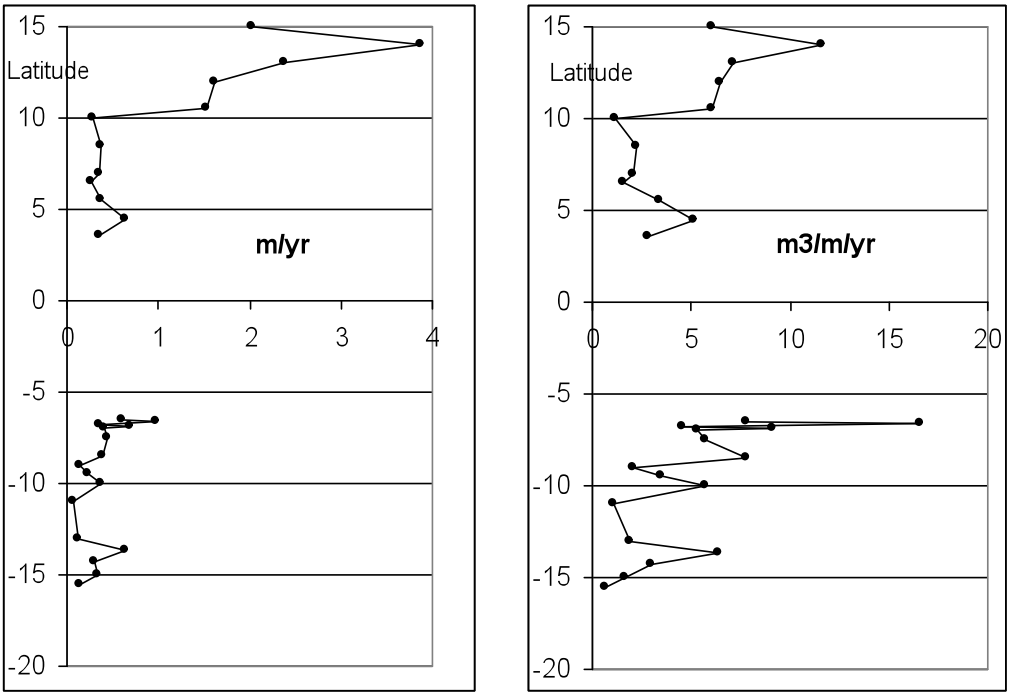

Figure 3 - a) Coastal erosion rates (X=m/yr) close to Mar del Plata city (y axes in minutes to the north and south of the parallel 38º S). b) Volumes eroded (m^3/m/year) to the north and south of Mar del Plata.

Figure 3 - Taxas de erosão costeira nas proximidades da cidade de Mar del Plata (eixos x em m/ano; eixos y em minutos ao norte e ao sul do paralelo 38º S). b) Volumes erodidos (m^3/m/ano) ao norte e ao sul de Mar del Plata.

Similar results from these cliffs of Mar del Plata were estimated between 1970 and 1992 conducting periodic topographic surveys (Cionchi *et al.,* 1998). It was confirmed that erosion rates can have significant variations during different periods, without any regional trend. In a simple interpretation of cliff erosion rates, the anthropogenic activity has been stated as the main cause, considering storms as a secondary cause, and neglecting any significant effect of sea-level rise (Cionchi *et al.,* 1998). However, in discriminating between the northern and southern coast, it can be concluded:

1. The coast north of Mar del Plata is more affected by man-made constructions blocking beach drift. Although groyne fields have diminished cliff erosion, they increased it where the drift is more severely blocked. Some groin fields have caused significant changes in the grain-size composition of some beaches (Isla *et al.,* 2001).
2. The coast south of Mardel Platais less affected by groin fields, but more subject to the direct attack of storms coming from the south. The coast has increased its erosion rate due to these episodic effects (Table 1).

Considering the volume of sediment eroded annually, and due to the higher altitude of the cliffs, the critical area is located south of Mar del Plata where the average volume eroded is greater than 5 m^3/m/year (Figure 3b).

Buenos Aires is a populated province where cliff erosion is a critical problem at touristic areas. Percolation of water causes fracture cracks, and groundwater fluctuations also impacts cliff stability (Figure 4a). Joints or plant roots also increase this instability (Bird, 1994). Touristic facilities are difficult to maintain due to the recurrence of episodic storms from the South (Figure 4b). Riprap walls and revetments are assumed to be the most economic solution to maintain the stability of these cliffs (Figures 4c and d).

4.2. Patagonia cliff retreat

From the measurements calculated, the cliffs from Patagonia to Tierra del Fuego (Río Negro inlet to Beagle-Channel) are receding at a mean rate of 0.47 m/year, and delivering 25 m^3/m/year average (Figure 5). Considering the altitude of the retreating cliffs and the distance assigned between lighthouses, maximum inputs of sediment caused by this mechanism are located at Rio Negro (Río Negro), Punta Lobos (Chubut), Punta Campana (Santa Cruz) and Cabo San Pablo (Tierra del Fuego) lighthouses (Figure 5a). In terms of volumes eroded per year, Punta Lobos is delivering a maximum of 140 m^3/m/year (Figure 5b). These estimates imply that cliff retreat yields an annual input of sediment to the continental shelf of 82 x 10^6 m^3/year. Considering the density of the sediments similar to quartz (2.65 g/cm^3), the total annual sediment input amounts to 217 million tons per year.

The Patagonian cliffs are composed of Pliocene sands at the north (Figure 6a), and bioclastic sediments corresponding to the Miocene transgression (Scasso *et al.* 2012) from 42 to 50º S (Figure 6b). The retreat of some cliffs is reduced by the natural setting of armored bedforms at their feet (Figure 6c). In the Atlantic Tierra del Fuego, soft cliffs are composed of silt at the north (Tudisca *et al.,* 2012), and very hard siltstones at the southern

Table 1 - Erosion rates estimated for the 1970-88 and 1988/92 intervals, to the north and south of Mar del Plata city (from Cionchi et al. 1998). Erosion rates estimated in this paper spanned between 1970 and 2004. Values are given in meters/year.

Tabela 1 - Taxas de erosão estimadas para os intervalos de 1970-1988 e 1988-1992, para as partes norte e sul da cidade de Mar del Plata (de Cionchi et al., 1998). As taxas de erosão estimadas neste trabalho referem-se ao período entre 1970 e 2004. Os valores são dados em metros / ano.

Location	70/88 Cionchi *et al* 1998	88/92 Cionchi *et al* 1998	cause	70/04 This study
GADA-FUCamet	1.10	1.33	Anthropic increase	0.31
Parque Camet Norte	2.83	1.75	Anthropic decrease	0.64
Parque Camet Sur	0.69	-		0.64
Arroyo La Tapera	0.55	0.80	Anthropic increase	0.35
MAR DEL PLATA				
Playa San Jacinto	4.44	2.50	Natural decrease	2.3
Playa San Carlos	3.56	-		1.6
Estafeta Chapadmalal	0.16	1.87	Natural increase	0.10
Colonia Chapadmalal	0.20	0.55	Natural increase	0.13
Arroyo Las Brusquitas	0.61	1.00	Natural increase	0.30

Figure 4 - Cliffs from Mar del Plata (38º S, see figure 1 for location). a) Fracture cracks on the top of the cliffs. b) Sea-side constructions are usually located attached to the cliffs composed of indurated siltstones. c) Rock revetments under construction. d) Armored structures are today protecting some cliffs.

Figura 4 - Falésias de Mar del Plata (38º S, ver figura 1 para localização). a) Fissuras de fratura no topo das falésias. b) As construções à beira-mar estão geralmente localizadas junto às falésias constituídas por siltitos endurecidos. c) Enrocamento em construção. d) Estruturas enrocadas protegem atualmente algumas falésias.

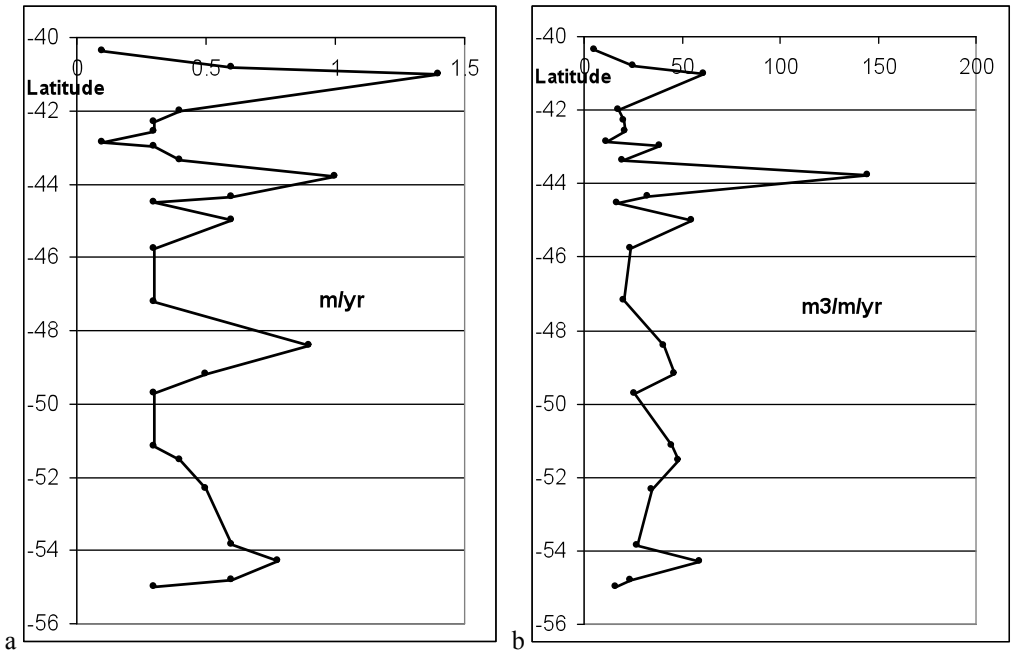

Figure 5 - a) Coastal erosion rates (in m/yr) vs. Latitude South (y=degrees South) from Northern Patagonia to Tierra del Fuego. b) Volumes eroded (in m^3/m/yr) from the cliffs of Patagonia and Tierra del Fuego.

Figura 5 - a) Taxas de erosão costeira (em m/ano) vs Latitude Sul (y = graus sul) do Norte da Patagônia à Tierra del Fuego. b) Volumes erodidos (em m^3/m/ano) das falésias da Patagônia e Tierra del Fuego.

Figure 6 - a) The very tall cliffs close to the Rio Negro estuary are composed of Pliocene aeolian sandstones. . b) Rada Tilly (Chubut Province) is a pocket beach composed of sand and gravel between very tall cliffs. c) Along the northern coast of Santa Cruz Province, some cliffs remain stable due to the natural armor of resistant blocks. d). Gravel-dominated spits are protecting the cliffs at the inlet of the Ladrillero River (Northern Tierra del Fuego Province). See Figure 1 for locations.

Figura 6 - a) As falésias de grande altura próximo do estuário do Rio Negro são compostas por arenitos eólicos pliocénico. b) Rada Tilly (província de Chubut) é uma praia de bolso composto por areia e cascalho entre falésias muito altas. c) Ao longo da costa norte da Província de Santa Cruz, algumas falésias permanecem estáveis devido à proteção natural contituída por blocos resistentes. d) As falésias à entrada do rio Ladrillero (norte da província de Tierra del Fuego) estão protegidas por restingas cascalhentas. Ver localização na Figura 1.

extreme of the island. During the last mid- Holocene fluctuation spits and barriers formed, blocking estuaries, and protecting cliffs from wave attack (Isla & Bujalesky, 2008) (Figure 6d).

4.3. The quiz about Patagonian fluvial loads

Patagonian rivers are misfit in the sense of Thornbury (1954). They transported more water and sediment during the Pleistocene than they do today. The moraines left by the Last Glaciation (Oxygen Isotopic Stage 2, or Wisconsin in North America) dammed the original pathways to the Atlantic Ocean, reversing their drainage direction towards the Pacific Ocean (Quensel, 1910). Some of the piedmont lakes reversed in their direction of flow during Late Pleistocene; others reversed during the Early Holocene (Del Valle *et al.,* 2007). Today, most of the rivers discharging to the Atlantic Ocean are not transporting much sediment. The Deseado River diminished significantly since the last Glaciation, and today it is not discharging a significant amount of water (Iantanos *et al.,* 2002). The calving of the ice lobe of the Lago Buenos Aires valley occurred at the end of the Pleistocene. The division of the unique ice cover into two ice fields (North Patagonia and South Patagonia) was dated about 11,500 years BP (13,500 calibrated years, *sensu* McCulloch *et al*., 2000).

Some watersheds, as the Chubut and Chico de Santa Cruz rivers, diminished significantly during that Pleistocene-Holocene transition. Moraines left during the last Glaciation enclosed piedmont lakes. Their snow recharge areas at the Andes are today flowing towards the Pacific Ocean (Martínez & Coronato, 2008). These reductions in the drainage areas were about 21-24 % in relation to the Late Pleistocene watersheds (Figure 7), and signified reductions between 32 and 34 % in terms of volume discharged per year (Table 2).

5. Discussion

No relationship was found between tidal range and cliff erosion. At the microtidal coast of Buenos Aires, storms were the significant factor controlling cliff retreat (Fiore *et al.,* 2009). On the other hand, the indurated abrasion platforms of Buenos Aires are more resistant to erosion than the bases of the Patagonian cliffs, where wave action distributes its impact on different levels of the cliffs. Geology is largely known as a significant factor to explain long-term spatial differences in cliff recession rates (Honeycutt & Krantz, 2003).

Present scenarios of sea level rise lead to modeling the response of different rocky cliffs using Bruun's Rule (French, 2001). However, the modeling of the soft cliffs of Southern England induced errors that can fluctuate

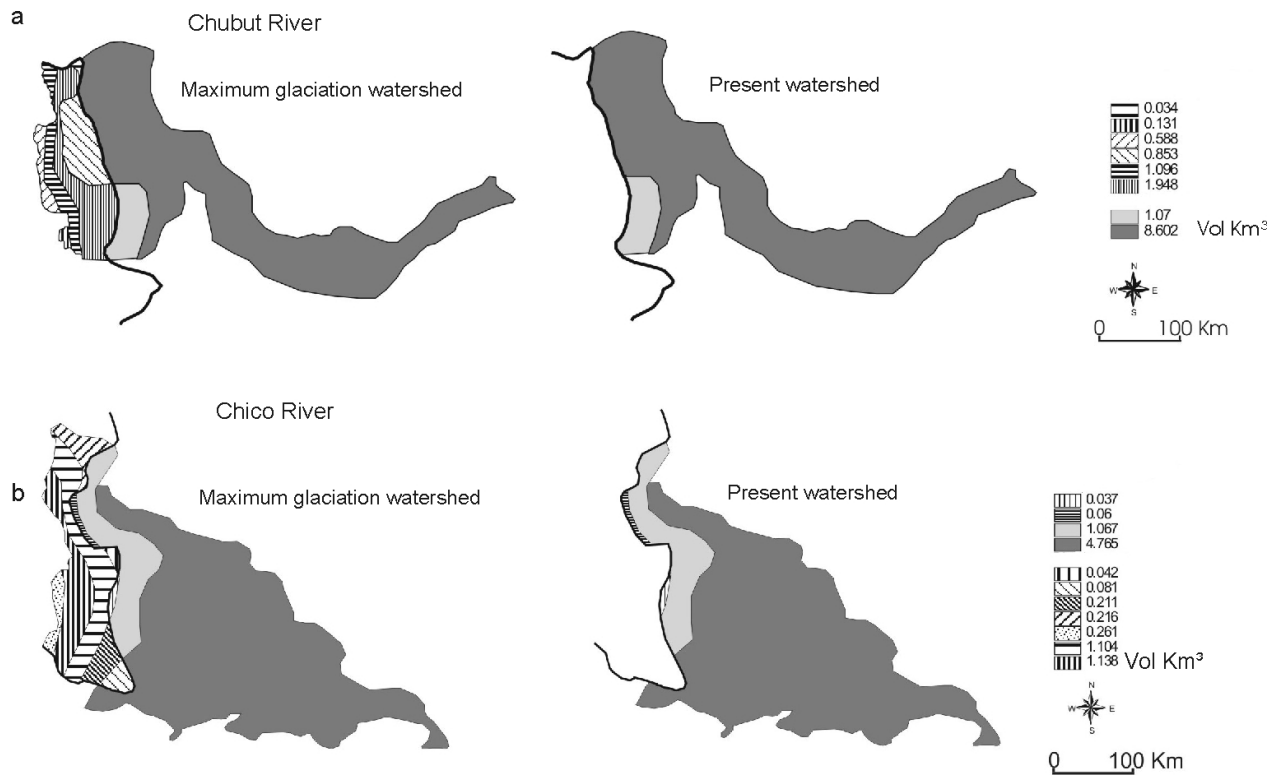

Figure 7. Reductions of Patagonian watersheds from Maximum Glaciation to Present considering similar amounts of precipitations. a) Comparison of the area of the Chubut watershed since Maximum Glaciation to Present. b) Comparison of the area of recharge of the Chico de Santa Cruz river watershed since Maximum Glaciation to Present. Significant changes were estimated (See Table 2).

Figura 7 - Reduções das bacias hidrográficas da Patagônia desde o Máximo Glaciário até ao Presente, considerando quantidades semelhantes de precipitação. a) Comparação da área da bacia hidrográfica de Chubut desde o Máximo Glaciário até ao Presente. b) Comparação entre as áreas de recarga da bacia do rio Chico de Santa Cruz desde o Máximo Glaciário até ao Presente. Foram estimadas as alterações significativas (ver Tabela 2)

Table 2 - Differences in the areas of the watersheds of the Chubut and Chico de Santa Cruz rivers (km^2), and their volumes precipitated per year (assuming similar P rates) in km^3/yr.

Tabela 2 - Diferenças nas áreas das bacias hidrográficas dos rios Chubut e Chico de Santa Cruz (km^2), e volumes de precipitação por ano (assumindo taxas semelhantes de P) em km^3/ano.

watershed	Upper Pleistocene Only Atlantic	Present Atlantic	Present Pacific	% of change Atlantic
Chubut (km^2)	61,640	46,577	15,063	-24.40
Chubut (km^3/yr)	14.3	9.67	4.62	-32.30
Chico (km^2)	35,144	27,700	7,444	-21.18
Chico (km^3/yr)	9.05	6	3.05	-33.70

between 22 and 133 % (Bray & Hooke, 2007). Cliff recession from the coast of Oregon, USA, is related to major storms that become more frequent during El Niño years (Allan *et al.,* 2003). For Patagonian cliffs, this sea-level-rise effect was not considered as sea level has been dropping in the last 6,000 years (Isla, 1989; Schellmann, 1998).

When comparing the erosion rates between Patagonia and Buenos Aires (disregarding the effects of different tidal ranges), the armoring accumulations of shingle at the base of the Patagonian cliffs are considered to be of significant importance, reducing the potential effect of waves and storms.

On the other hand, it should be also considered that some depressions on the Argentine continental shelf (San Matías, Nuevo and San Jorge gulfs) are perfect traps for sediment delivered by cliff erosion (Isla, 2013). Experiments performed along the coast of the

English Channel demonstrated that the main effect of shingle is to reduce the water depth at the toe of the cliff (Bossard & Duperret, 2004). In Oahu (Hawaii), rigid armored structures have induced an increase in beach erosion in sectors without coastal protection (Fletcher *et al.,* 1997). The excessive armoring of cliffs can induce erosion problems at areas downdrift from the protected coast, mainly where the sand supply depends on cliff retreat (Runyan & Griggs, 2003).

Dramatic geomorphological variations occurred in Patagonia in the past, reducing the frequency of floods, but also changing the cliff-recession rates. It is assumed that coastal erosion rates were at their maxima during the early millennia of the Holocene when the sea level was rising at maximum rates (Guilderson *et al.,* 2000; Isla, 2013), and diminished when the sea level stabilized 6000 years ago (Isla, 1989; 2013). In a more extended perspective, Kokot (2004) proposed a climatic explanation for the diminution of sediment input to the Patagonian coast during the Pleistocene. He paid attention to the gravel deposits composing the glaciofluvial terraces (Schellmann, 1998), and estimated the maximum discharges necessary to transport those gravels. He concluded that Patagonian rivers reduced their discharges during Late Quaternary, and that the maximum discharge of present Santa Cruz river (2520 m^3/s) is one tenth of the discharge estimated for the Pleistocene fluvial terraces. In this sense, he concluded that these maximum discharges would have been similar to those occurring today at the Paraná River (Kokot, 2004). In the same line of reasoning, climatic reconstructions derived from pollen and glacier studies indicate more humid conditions during the Holocene than today (Rabassa & Clapperton, 1990; Schäbitz, 1994; Mancini *et al*., 2008).

Similar drainage reversals have been repeatedly recorded in association with Quaternary morphological changes induced by glaciations and deglaciations. In the cases described for Patagonia the amount of water delivered can be estimated. At the upper Tuttle Creek reservoir, Kansas, USA, there is evidence that the creek reversed its flow direction due to the deposition of an ice lobe during the Upper Pleistocene (Chelikowsky, 1976). Tectonics may also cause significant changes in the watersheds. During Upper Tertiary, Lake Russell changed in its flow direction within the Mono Basin, central Sierra Nevada (Reheis *et al.*, 2002).

6. Conclusions

1. Present cliff erosion is annually contributing about 82 x 10^6 m^3 of sediment to the Patagonian continental shelf, i.e., about 217 x 10^6 tons/yr. This amount of sediment is exceeding the present contribution of major Patagonian Rivers.
2. Although an increase in precipitation probably occurred in the transition from the Maximum Glaciation to Present Interglacial, there were dramatic geomorphological changes that explain a discharge reduction of some Patagonian watersheds.
3. These reversals in the direction of the flow of some Patagonian rivers, as the Chubut, and Chico de Santa Cruz rivers, caused a reduction of about 21-24% in the extension of the Holocene watersheds, and a reduction of about 32-34% in their annual water discharges.
4. Defense structures have decreased the erosion rates in some intervals of Buenos Aires coastline, although they have also increased the erosion and beach loss where they block beach drift.

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References

Allan, J.C.; Komar, P.D.; Priest, G.R. (2003) - Shoreline variability on the high-energy Oregon coast and its usefulness in erosion-hazards assessments. *Journal of Coastal Research* (ISSN: 0749-0208), SI38:83-105, West Palm Beach, FL, U.S.A.

Barrier, P.M.; Sloan, N.A. (2007) - Reconciling maps with charts towards harmonizing coastal zone base mapping: a case study from British Columbia. *Journal of Coastal Research,* 23(1):75-86. DOI: 10.2112/05-0526.1.

Bayram, B.; Bayraktar, H.; Helvaci, C.; Acar, U. (2004) - Coastline change detection using Corona, Spot and IRS 1D images. *20th ISPRS Congress, International Society for Photogrammetry and Remote Sensing*, 5p. Istambul, Turkey. Available on-line at http://www. isprs.org/proceedings/xxxv/congress/comm7/comm7.aspx.

Bird, E.C.F. (1994) - Cliff hazards and coastal management. *Journal of Coastal Research* (ISSN: 0749-0208), SI12:299-309, West Palm Beach, FL, U.S.A.

Bossard, J.; Duperret, A. (2004) - Coastal chalk cliff erosion: experimental investigation on the role of marine factors. *Engineering Geology Special Publications,* 20:109-120, Geological Society of London, London, U.K. DOI: 10.1144/GSL.ENG. 2004.020.01.08.

Bray, M.J.; Hooke, J.M. (1997) - Prediction of soft-cliff retreat with accelerating sea-level rise. *Journal of Coastal Research* (ISSN: 0749-0208), 13(2):453-467, For Lauderdale, FL, U.S.A.

Chelikowsky, J.R. (1976) - Pleistocene Drainage Reversal in the upper Tuttle Creek Reservoir area of Kansas. *Kansas Geological Survey Bulletin* (ISSN 0097.4471) 211, Part 1, 10p., Lawrence, KS, U.S.A. Available on-line at http://www.kgs.ku.edu/ Publications/Bulletins/211_1/

Cionchi, J.L.; Alvarez, J.R.; Del Río, J.L.; Ferrante, A. (1998) - El efecto antrópico en el retroceso de la línea de costa del Partido de General Pueyrredón (Provincia de Buenos Aires). *XII Con-*

greso Geológico Argentino y II Congreso de Exploración de Hidrocarburos, Actas, VI, 318-322.

Codignotto, J.O. and Kokot, R.R. (1988) - Evolución geomorfológica holocena en Caleta Valdés, Chubut. *Revista Asociación Geológica Argentina* (ISSN: 0004-4822), 43(4):474-481, Buenos Aires, Argentina.

Codignotto, J.O.; Malumián, N. (1981) - Geología de la región al norte del paralelo 54° Sur de la Isla Grande de la Tierra del Fuego. *Revista de la Asociación Geológica Argentina* (ISSN: 0004-4822), 36(1):44-88, Buenos Aires, Argentina.

Coronato, A.M.J.; Coronato, F.; Mazzoni, E.; Vazquez, M. (2008) - The Physical Geography of Patagonia and Tierra del Fuego. *In:* J. Rabassa (ed.), *The Late Cenozoic of Patagonia and Tierra del Fuego*, pp.13-55, *Developments in Quaternary Sciences* (ISSN: 1571-0866), no.11. ISBN: 978-0-444-52954-1

Del Río, L.; Gracia, F. J. (2004) - Erosion risk assessment of active coastal cliffs in temperate environments. *Geomorphology,* 112(1-2):82-95. DOI: 10.1016/j.geomorph.2009.05.009.

Del Río, J.L.; López de Armentia, A.M.; Alvarez, J.R.; Ferro, G.; Bo, M.J.; Martínez Arca, J.; Camino, M.A. (2007) - Shoreline retreat at the Gulf of San Matías. *Thalassas* (ISSN: 0212-5919), 23(2):43-51, Universidade de Vigo, España. Available on-line at http://webs.uvigo.es/thalassas/20Thalassas%2023(2)/T23(2)_05_del%20R%C3 ADo%20et%20al.pdf

Del Valle, R.A.; Tatur, A.; Rinaldi, C.A. (2007) - Cambios en lagos y circulación fluvial vinculados al calentamiento climático del Pleistoceno Tardío-Holoceno temprano en Patagonia e Isla 25 de mayo, Islas Shetland del Sur, Antártica. *Revista de la Asociación Geológica Argentina*, (ISSN: 0004-4822) 62(4):618-626, Buenos Aires, Argentina.

Depetris, P.J. (1968) - Algunas consideraciones sobre la velocidad de erosión en la República Argentina. *Revista de la Asociación Geológica Argentina,* (ISSN; 0004-4822) XXIII: 237-245, Buenos Aires, Argentina.

Depetris, P.J.; Griffin, J.J. (1968) - Suspended load in the Río de la Plata drainage basin. *Sedimentology,* 11(1-2):53-60. DOI: 10.1111/j.1365-3091.1968.tb00840.x

Duperret, A.; Genter, A.; Martínez, A.; Mortimore, R.N. (2004) - Coastal chalk cliff instability in NW France: role of lithology, fracture pattern and rainfall. *In:* R. N. Mortimore & A. Duperret (eds.), *Coastal Chalk Cliff stability*, pp.33-55, Engineering Geology Special Publications 20, Geological Society, London, U.K. ISBN: 9781862391505.

Emery, K.O.; Kuhn, G.G. (1982) - Sea-cliffs: their processes, profiles and classification. *Geological Society of America Bulletin,* 93(7):644-654. DOI: 10.1130/0016-7606(1982)93<644:SCTPPA>2.0.CO;2

ESRI (1996) - *Arc View GIS. The Geographic information system for everyone.* 350p., ESRI – Environmental Systems Research Institute, Redlands, California, U.S.A.

Fiore, M.; D'Onofrio, E.E.; Pousa, J.L.; Schnack, E.J.; Bértola, G.R. (2009) - Storm surge and coastal impacts at Mar del Plata, Argentina. *Continental Shelf Research*, 29(14):1643-1649. DOI: 10.1016/j.csr.2009.05.004

Fletcher, Ch.H.; Mullane, R.A.; Richmond, B.M. (1997) - Beach loss along armoured shorelines on Oahu, Hawaiian Islands. *Journal of Coastal Research* (ISSN: 0749-0208), 13(1):209-215, West Palm Beach, FL, U.S.A. Available at http://www.soest.hawaii.edu/coasts/publications/JCRBeachLoss.pdf

Fletcher, Ch.H.; Rooney, J.; Barbee, M.; Lim, S.Ch.; Richmond, B. (2003) - Mapping shoreline change using digital orthophotogrammetry on Maui, Hawaii. *Journal of Coastal Research* (ISSN: 0749-0208), SI38:106-124, West Palm Beach, FL, U.S.A.

French, P.W. (2001) - *Coastal Defences. Processes, problems and solutions*. 366p., Taylor & Francis, Routledge, London, U.K. ISBN; 97804115198448.

Galgano, F. A.; Douglas, B. C.; Leatherman, S. P. (1998) - Trends and variability of shoreline position. *Journal of Coastal Research* (ISSN: 0749-0208), SI26:282-291, Royal Palm Beach, FL, U.S.A.

Gómez Peral, M.A.; Martínez, D.E. (1997) - Distribución de minerales pesados en playas del litoral atlántico de la Tierra del Fuego, entre Cabo San Sebastián y Cabo Domingo. *Revista de la Asociación Geológica Argentina,* (ISSN: 0004-4822), 52(4):504–514, Buenos Aires, Argentina.

Guilderson T.P.; Burckle, L.; Hemming, S.; Peltier, W.R. (2000) - Late Pleistocene sea level variations derived from the Argentine Shelf. *Geochemistry, Geophysics, Geosystems*, 1(12). DOI: 10.1029/2000GC000098

Hampton, M.A.; Griggs, G.B.; Edil, T.B.; Guy, D.E.; Kelley, J.T.; Komar, P.D.; Mickelson, D.M.; Shipman, M. (2004) - Processes that govern the formation and evolution of coastal cliffs. *In:* M.A. Hampton & G.B. Griggs (eds.) *Formation, evolution, and stability of coastal cliffs. Status and trends,* pp.7-38, USGS professional paper (ISSN: 1044-9612) no 1693, US Geological Survey, Reston, VA, U.S.A. Available on-line at http://www.geology. wisc.edu/~davem/abstracts/04-2,3,4.pdf

Hapke, Ch. (2004) - The measurement and interpretation of coastal cliff and bluff retreat. *In:* M.A. Hampton & G.B. Griggs (eds.) *Formation, evolution, and stability of coastal cliffs. Status and trends*, pp.39-50 USGS professional paper (ISSN: 1044-9612) no 1693:39-50, US Geological Survey, Reston, VA, U.S.A. Available on-line at http://www.geology.wisc.edu/~davem/abstracts/04-2,3,4.pdf

Hapke, C..; Richmond, B. (2002) - The impact of climatic and seismic events on the short-term evolution of sea cliffs based on 3-D mapping: Northern Monterey Bay, California. *Marine Geology,* 187(3-4):259-278. DOI: 10.1016/S0025-3227(02)00315-8.

Honeycutt, M. G.; Krantz, D. E. (2003) - Influence of the geologic framework on spatial variability in long-term shoreline change, Cape Henlopen to Rehoboth beach, Delaware. *Journal of Coastal Research* (ISSN: 0749-0208), SI38:147-167, West Palm Beach, FL, U.S.A.

Horikawa, K.; Sunamura, T. (1967) - A study on erosion of coastal cliffs by using aerial photographs. *Coastal Engineering Japan,* 10:67-83.

Iantanos, N.; Estrada., E.; Isla, F. (2002) - Formas mareales de la Ría del Deseado, Santa Cruz. *Revista AAS* (ISSN: 0328-1159), 9(1):43-52, Asociación Argentina de Sedimentología, Buenos Aires, Argentina. Available on-line at http://www.scielo.org.ar/pdf/raas/v9n1/v9n1a03.pdf.

Isla, F.I. (1989) - The Southern Hemisphere sea-level fluctuation. *Quaternary Science Reviews,* 8(4):359-368. DOI: 10.1016/0277-3791(89)90036-X

Isla, F.I. (2013) - The flooding of San Matías Gulf: the Northern Patagonia sea-level curve. *Geomorphology*, *in press*. DOI: 10.1016/j.geomorph.2013.02.013

Isla, F.I.; Bértola, G.R. (2003) - Morfodinámica de las playas meso y micromareales entre Bahía Blanca y Rio Negro. *Revista AAS* (ISSN: 0328-1159), 10(1): 65-74, Asociación Argentina de Sedimentología, Buenos Aires, Argentina. Available on-line at http://www.scielo.org.ar/pdf/raas/v10n1/v10n1a06.pdf

Isla, F.I.; Bértola, G.R.; Farenga, M.O.; Cortizo, L.C. (2001) - Variaciones antropogénicas de las playas del sudeste de Buenos Aires, Argentina. *Revista Pesquisas en Geociências* (ISSN: 1518-2398), 28(1):27-35, Universidade Federal do Rio Grande de Sul, Porto Alegre, Brasil.

Isla, F.I.; Bujalesky, G.G. (2004) - Morphodynamics of a gravel-dominated macrotidal estuary: Rio Grande, Tierra del Fuego. *Revista de la Asociación Geológica Argentina,* (ISSN: 0004-4822) 59(2):220-228. Available on-line at http://www.scielo.org.ar/pdf/raga/v59n2/v59n2a06.pdf

Isla, F.I.; Bujalesky, G.G. (2008) - Coastal Geology and morphology of Patagonia and Fueguian Archipelago. *Developments in Quaternary Sciences,* 11: 227-239. DOI: 10.1016/S1571-0866(07)10010-5

Isla, F.I.; Iantanos, N.; Estrada, E. (2002) - Playas reflectivas y disipativas macromareales del Golfo San Jorge. *Revista AAS* (ISSN: 0328-1159), 9(2):155-164, Asociación Argentina de Sedimentología, Buenos Aires. Argentina. Available on-line at http://www.scielo.org.ar/pdf/raas/v9n2/v9n2a04.pdf

Isla, F.I.; Vilas, F.E.; Bujalesky, G.; Ferrero, M.; González Bonorino, G.; Arche Miralles, A. (1991) - Gravel drift and wind effects over the macrotidal San Sebastián Bay, Tierra del Fuego. *Marine Geology,* 97(1-2):211-224. DOI: 10.1016/0025-3227(91)90027-2

Kokot, R.R. (2004) - Erosión en la costa patagónica por cambio climático. *Revista de la Asociación Geológica Argentina,* (ISSN: 0004-4822), 59(4):715-726, Buenos Aires, Argentina. Available on-line at http://www.scielo.org.ar/pdf/raga/v59n4/v59n4a18.pdf

Revista de la Asociación Geológica Argentina (ISSN: 0004- 4822), 69(1):43–60, Available on-line at http://www.scielo.org.ar/pdf/raas/v10 n1/v10n1a06.pdf

Leatherman, S.P. (1986) - Cliff stability along Western Chesapeake Bay, Maryland. *Marine Technology Society Journal* (ISSN: 0025-3324), 20(3):28-36, Washington, DC, U.S.A.

Lundahl, A.C. (1948) - Underwater depth determination by aerial photographs. *Photogrammetric Engineering,* 14(4):454-462.

Maiti, S.; Bhattacharya, A.K. (2009) - Shoreline change analysis and its application to prediction: A remote sensing and statistics based approach. *Marine Geology,* 257(1-4):11-23. DOI: 10.1016/j.margeo.2008.10.006

Manzini, M.V.; Prieto, A.R.; Páez, M.M.; Schäbitz, F. (2008) - Late Quaternary Vegetation and Climate of Patagonia. *In:* J. Rabassa (ed.), *The Late Cenozoic of Patagonia and Tierra del Fuego*, pp.351-367, Elsevier, Amsterdam, The Netherlands. ISBN: 978-0444529541

Martínez, O.A.; Coronato, A.M. J. (2008) - The Late Cenozoic fluvial deposits of Argentine Patagonia. *In:* J. Rabassa (ed.), *The Late Cenozoic of Patagonia and Tierra del Fuego*, pp.205-226, Elsevier, Amsterdam, The Netherlands. ISBN: 978-0444529541

McCulloch, R.D.; Bentley, M.J.; Purves, R.S.; Hulton, N.R.J.; Sugden, D.E.; Clapperton, C.M. (2000) - Climatic inferences from glacial and palaeoecological evidence at the Last Glacial termination, southern South America. *Journal of Quaternary Science,* 15(4):409-417. DOI: 10.1002/1099-1417(200005)15:4<409::AID-JQS539>3.0.CO;2-%23

Quensel,P.D.(1910)-Ontheinfluenceoftheiceageonthe continental watershed of Patagonia. *Bulletin Geological Institute of the University of Upsala,* IX:60-92, Upsala, Sweden.

Rabassa, J.; Clapperton, Ch.M. (1990) - Quaternary glaciations of the Southern Andes. *Quaternary Science Reviews*, 9(2-3):153-174. DOI: 10.1016/0277-3791(90)90016-4

Reheis, M.C.; Stine, S.; Sarna-Wojcicki, A.M. (2002) - Drainage reversals in Mono Basin during the Late Pliocene and Pleistocene. *The Geological Society of America Bulletin* (ISSN: 0016-7606), 114(8):991-1006, Boulder, Co, U.S.A.

Ruggiero, P.; Kaminsky, G.M.; Gelfenbaum, G. (2003) – Linking proxy-based and datum-based shorelines on a high-energy coastline: Implications for shoreline change analyses. *Journal of Coastal Research* (ISSN: 0749-0208), SI38:57-82, West Palm Beach, FL, U.S.A.

Runyan, K.; Griggs, G.B. (2003) - The effects of armoring sea cliffs on the natural sand supply to the beaches of California. *Journal of Coastal Research* (ISSN: 0749- 0208), 19(2):336-347, West Palm Beach, FL, U.S.A.

Rutter, N.; Schnack, E.J.; Fasano, J.L.; Isla, F.I.; Del Rio, L.; Radke, U. (1989) - Correlation and dating of Quaternary littoral zones along the Patagonian coast, Argentina. *Quaternary Science Reviews,* 8(3):213-234. DOI: 10.1016/0277-3791(89)90038-3

Scasso, R.A.; Dozo, M. T.; Cuitiño, J.I.; Bouza, P. (2012) – Meandering tidal-fluvial channels and lag concentration of an ancient estuary in Patagonia. *Latin American Journal of Sedimentology and Basin Analysis* (ISSN: 0328-1159), 19(1):27-45, La Plata, Argentina. Available on-line at http://www.scielo.org.ar/pdf/lajsba/v19n1/v19n1a03.pdf

Schäbitz, F. (1994) - Holocene climatic variations in northern Patagonia, Argentina. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 109(2-4):287-294. DOI: 10.1016/0031-0182(94)90180-5

Schellmann, G. (1998) - Jungkanozoische landschaftgeschichte Patagoniens (Argentinien): Andine Vorlandvergletscherungen, Talentwicklung und marine Terrasen. *Essener Geographische Arbeiten,* 29, 216p. Essen, Germany.

Schillizzi, R.; Gelós, E.M.; Spagnuolo, J. (2003) - Procesos de retracción de los acantilados patagónicos entre la desembocadura de los ríos Negro y Chubut, Argentina. *Revista AAS,* (ISSN: 0328-1159) 11(1):17-26, Asociación Argentina de Sedimentología, Buenos Aires, Argentina.

Servicio de Hidrografía Naval (1978) - Faros y señales marítimas. Parte II - Costa del Atlántico. Desde Cabo San Antonio hasta Cabo Vírgenes. 250p., Publicaciones Náuticas no H-212, Buenos Aires, Argentina.

Siegel, F.R. (1973) - Possible important contributors to Argentina Basin lutites: Argentine rivers. *Modern Geology* (ISSN: 0026-7775), 4:201-207, Taylor & Francis Ltd, Oxford, U.K.

Spalletti, L.A.; Isla, F.I. (2003) - Evolución del delta del Río Colorado ("Colú Leuvú"), Provincia de Buenos Aires, República Argentina. *Revista AAS* (ISSN: 0328-1159), 10:23-27, Asociación Argentina de Sedimentología, Buenos Aires, Argentina.

Thornbury, W.D. (1954) - Principles of Geomorphology. 2nd edition, 594p., Wiley, New York, U.S.A.

Tudisca, E.P.; Pazos, P.J.; Ghiglione, M. C.; Cianfagna, F. A. (2012) – Estudio de "las capas del Cabo Ladrillero Superior" en el canal homónimo, Mioceno inferior de la Cuenca Austral, Tierra del Fuego. *Revista de la Asociación Geológica Argentina* (ISSN: 0004-4822), 69(1):43–60, Buenos Aires, Argentina. Available on-line at http://www.scielo.org.ar/pdf/raas/v10n1/v10n1a06.pdf

Tuhkanen, S. (1992) - The climate of Tierra del Fuego from a vegetation Geographical point of view and its ecoclimatic counterparts elsewhere. *Acta Botanica Fennica* (ISSN: 0001-5369), 145:1–64. Finnish Zoological and Botanical Publishing Board, Helsinki, Finland

Wilkinson, B.H.; McElroy, B.J. (2007) - The impact of humans on continental erosion and sedimentation. *Geological Society of America Bulletin,* 119(1-2):140-156. DOI: 10.1130/B25899.1

Zuzek, P.J.; Nairn, R.B.; Thieme, S.J. (2003) - Spatial and temporal considerations for calculating shoreline change rates in the Great Lakes Basin. *Journal of Coastal Research* (ISSN: 0749-0208), SI38: 125-146, West Palm Beach, FL, U.S.A.

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):553-568 (2014)

http://www.aprh.pt/rgci/pdf/rgci-472_Nagy.pdf | DOI:10.5894/rgci472

Adjusting to current climate threats and building alternative future scenarios for the Rio de la Plata coast and estuarine front, Uruguay*

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ABSTRACT

In this paper we present a climate adjustment and scenario building experience in the coastal areas of Uruguay within the framework of GEF-Project ”Implementing pilot sites adaptation measures in coastal Uruguay”. The Project goals are to increase resilience, promote interactions between relevant institutions and stakeholders, and to incorporate climate threats in the political agenda. Assuming that many readers are more familiar with Integrated Coastal Zone Management (ICZM) than with climate adaptation a summary of concepts is presented based on both the international literature and local experience. Emphasis is put on the knowledge of coastal climate-driven threats, the implications of adaptive and risk-based management approaches to current climate, adaptation planning, and future scenarios. Then, a review of our recent publications on the subject is made in order to give a picture of the lessons learned during the Project experience. Here we focus on the Rio de la Plata’s estuarine front “Adaptation Pilot Site” and the interaction between scientists and stakeholders from 2009-2013. Emphasis is put on recent climatic time-series (1997-2012) since during this period most of them reverted as compared to the Project’s climate baselines (1961-2008). This short-term variability is fundamental to cope with current climate threats (adjustment) and introduces additional uncertainties to future scenarios. The continuous interaction with stakeholders and experts allows building alternative futures from the current perspective and climate models. The process itself - planning and implementing actions - creates capacity to move forward. Natural and social scientists continuously inform stakeholders, to promote adjustment, interactive adaptive management, and planning. Thinking of “futures” together with experts and stakeholders can be thought as a “what if” learning exercise and a way to develop alternative scenarios.

Keywords: Adaptation Concepts; Climate Drivers; Monitoring.

RESUMO

Enfrentando as ameaças climáticas atuais e construindo cenários futuros alternativos para a costa e frente estuarina do Rio de La Plata, Uruguai

Neste artigo apresentamos uma adaptação climática e uma construção de cenários baseados na experiência nas áreas costeiras do Uruguai, no âmbito do Projeto GEF- "Implementacao de medidas de adaptação em locais pilotos na costa do Uruguai". As metas do projeto são aumentar a resiliência, promover as interações entre instituições e as partes interessadas, no senso de incorporar as ameaças climáticas na agenda política. Partindo do princípio que muitos leitores estão mais familiarizados com a ICZM do que com a adaptação climática é apresentado um resumo de conceitos com base a literatura internacional e experiência local. A ênfase é colocada sobre o conhecimento das ameaças provocadas pelo clima do litoral, as

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implicações de adaptação e gestão baseada em risco se aproximam ao clima atual, o planejamento de adaptação, e cenários futuros. Então, nossas recentes publicações sobre o assunto são revisadas, a fim de dar uma imagem das lições aprendidas durante a experiência do Projeto. Aqui nos concentramos em na frente estuarina do Rio de la Plata "Local piloto de adaptação" e da interação entre os cientistas e os interessados entre 2009 e 2013. Ressaltamos sobre a evolução da recente série temporal climática (1997-2012), quando a maioria deles com uma tendência revertida em comparação com as linhas de base do clima do projeto (1961-2008). Esta variabilidade de curto prazo é fundamental para lidar com as ameaças climáticas atuais (de ajuste) e introduzem incertezas adicionais as típicas dos cenários futuros. A interação contínua com as partes interessadas e especialistas permite construir futuros alternativos a partir da perspectiva atual e os modelos climáticos. O processo em si - o planejamento e implementação de ações - cria capacidade para avançar. Os cientistas naturais e sociais informam continuamente as partes interessadas para apoiar o ajustamento atual, a gestão adaptativa interativa e o planejamento. Pensando em "futuros", juntamente com peritos e partes interessadas pode ser pensado como um exercício "what if" e uma maneira de desenvolver cenários alternativos de aprendizagem.

Palavras-chave: *adaptação, forçantes climáticos, monitoramento, cenários.*

1. Introduction

This paper is one of four written for the GEF project "*Implementing Pilot Adaptation Measures to Climate Change in Coastal Areas of Uruguay",* from now on "the Project" (UCC, 2011, http://www.adaptationlearning.net). The three other papers, which will be summarized in section 4 and Table 1, discuss the methodological evolution to cope with observed and current variability and to adapt to future climate change at the pilot sites "Laguna de Rocha", an estuarine coastal lagoon at the Atlantic coast (10 km to the west of La Paloma, Figure 1), and the "Estuarine Front", where fresh and seawater mix within the Rio de la Plata river estuary (Figure 2).

The development and approaches of the Project were both supported and inspired by EcoPlata Program, a successful Integrated Coastal Zone Management (ICZM) Program (Gómez-Erache *et al*., 2010; Nagy *et al*., 2014a).

According to Christie *et al*. (2005) "Integrated Coastal Zone Management" (ICZM) assumes interdependence of coastal human communities and associated resources,

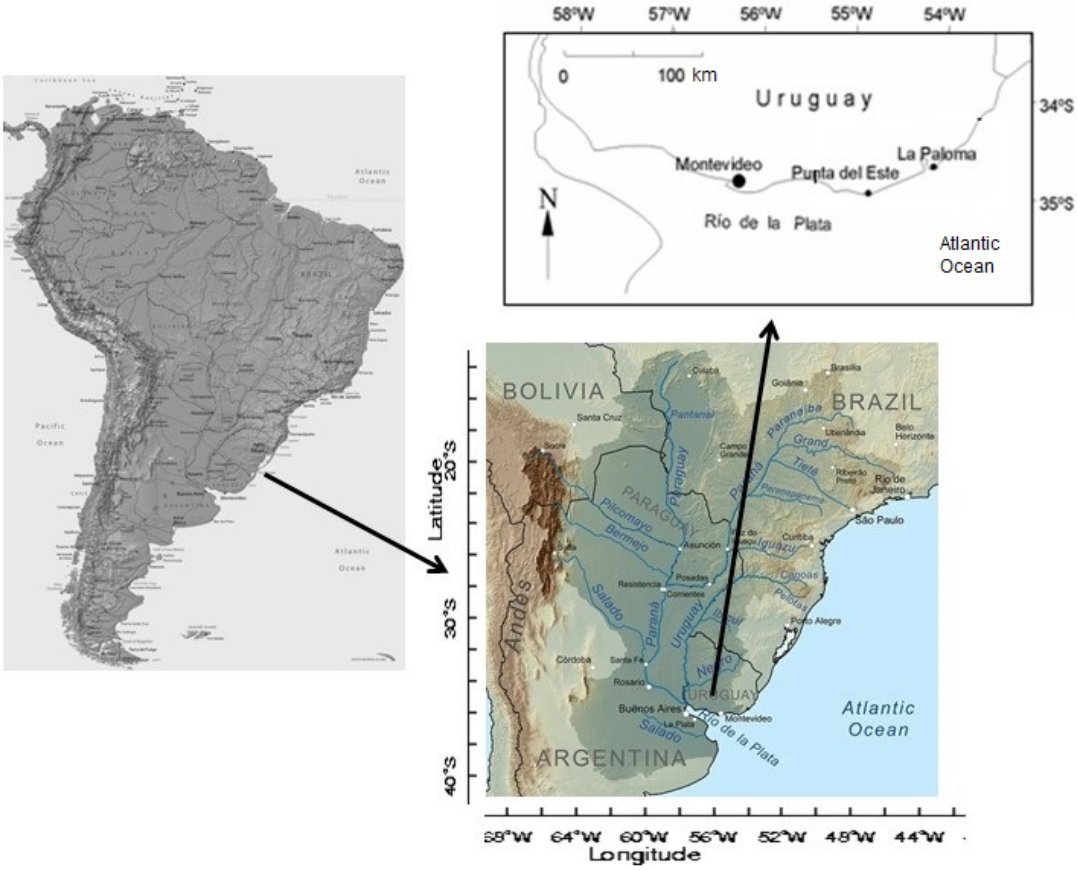

Figure 1 - Rio de la Plata basin and river estuary, Southeastern South America. Source: Nagy *et al*. (2014a).

Figura 1 - Bacia e estuario de Rio de la Plata, Sudeste da América do Sul. Fonte: Nagy et al. (2014a).

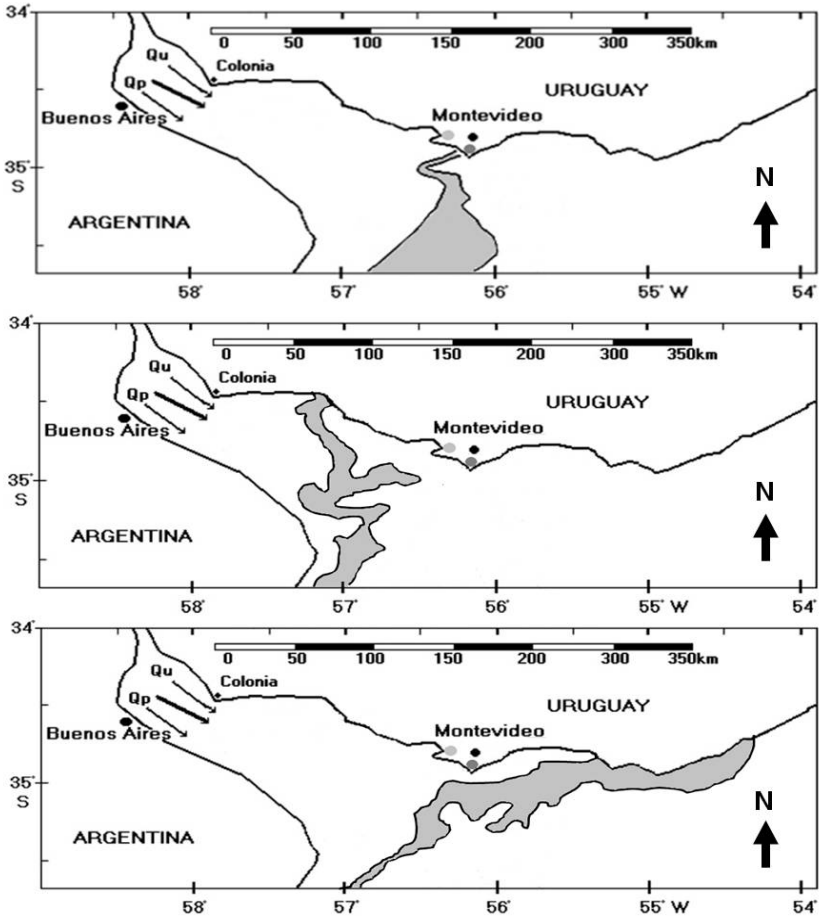

Figure 2 - Schematic estuarine frontal system-EFS (shadowed area). The gray color represents the area of frontal mixing of fresh- and sea-water with typical salinities about 1-12. The three shown locations and dates represent: i) average flow (upper, 11/27/03,) close to Montevideo, ii) up-river (middle, 02/09/09) due to an extreme La Niña-related low flow, and seaward (below 09/20/09) due to an extreme El Niño-related high flow. Modified from Lappo *et al*., 2005 and Nagy *et al*. (2008a, 2013, 2014a).

Figura 2 - Esquema do sistema frontal estuarino EFS (área sombreada). A cor cinza representa a área de mistura frontal de água doce e água do mar com salinidades típicas cerca de 1-12. Os três locais e datas indicados representam: i) vazão média (superior, 11/27/03), próximo a Montevidéu, ii) rio superior (médio, 02/09/09) devido a um baixo fluxo relacionado com o evento La Niña extremo, e ao largo (abaixo de 09/20/09), devido a um alto fluxo extremo relacionado com o evento El Niño. Modificado de Lappo et al., 2005 and Nagy et al. (2008a, 2013, 2014a).

calls for user conflict resolution and the reduction of cumulative impacts, and considers local participation as a critical management component". According to Conde *et al*., (2012) "In an ICZM context, the contributions from academic studies are critical for making management decisions based on the best scientific information available".

In agreement with these statements, the Project understood ICZM approach was a framework in order to resolve conflicts of climatic origin with stakeholders' participation. The EcoPlata Program (http://www.ecoplata.org) has focused since 1994 on the strengthening of institutional capacity, the scientific community, managers and public in general, in all issues relative to ICZM strategy, including climate indicators and vulnerability assessments. Both the Project and EcoPlata Program aim to develop strategies to effectively manage future climate change impacts by promoting a participatory and adaptable management model, developed over many years by EcoPlata. This model is based on technical and scientific research and capacity building of institutions and local stakeholders, so that knowledge can be integrated into the design and application of policies and collective action (Gómez-Erache *et al*., 2010; Nagy *et al*. 2014a). Analysis of the combined experience of both initiatives has revealed some significant lessons learned. Firstly, coastal adaptation efforts need to build on, and support, existing frameworks for ICZM efforts to strengthen coastal zone management. Secondly, the enhanced coordination in assessment of extreme event-related impacts was the main driver to increased awareness. Thirdly, providing a strong scientific basis and understanding around coastal processes and climate change has proved to be very effective in moving the adaptation agenda forward in coun-

try. Usually ICZM in Uruguay deals with current issues, including climatic variability and extremes, and vulnerability (Nagy *et al*. 2014a).

The goals of this article are to:

- Revisit and synthesize recent literature on climate change and variability adaptation experiences and lessons in coastal Uruguay.
- Update current climatic data useful to coastal management and climate adaptation, over the past few years (1997-2012).
- Present participatory alternative climate scenarios for 2030-50.
- Focus on the Rio de la Plata Estuarine Front pilot site.

2. The Uruguayan Coast and the Rio de la Plata Estuary: a Climate Perspective

The Republic of Uruguay (177,000 km^2) is located in the La Plata River Basin (which spreads over a 3,1 million km^2, Figure 1). The Uruguayan coast is 670 kilometers in length with 450 km lying along the Rio de la Plata estuary (38,000 km^2, average depth <10 m) and the remaining 220 km along the Atlantic Ocean. The complex geophysical environment of the Uruguayan coast within the Rio de la Plata is under stress from existing pressures such as changing hydro-climatic and wind regimes, sea-level rise, extreme events, growing population and associated increases in development over the last few decades (Nagy *et al*., 2008a, 2013a, 2014a).

The rivers Parana and Uruguay are major tributaries of the Rio de la Plata. Total yearly river inflow (Q_{RP}) varies between 22,000 and 28,000 m^3/s during normal years and <20,000 m^3/s and >30,000 m^3/s during dry and wet years, often associated with La Niña and El Niño events, respectively (Nagy *et al*. 2008a). The flows of both rivers mix with the Atlantic Ocean within the Rio de la Plata microtidal river estuary system. The mixing zone or estuarine frontal system (EFS) may be defined by discontinuities of turbidity where fresh turbid water and marine green water prevail up and down-river the estuarine frontal system respectively. The cyclic variability of river flows displaces the EFS up-river with low flow and down-river with high flow (Figure 2) and changes salinity and turbidity on seasonal and interannual time-scales, which impact its environment and resources. Most observed interannual variability over the last two decades is ENSO-related, e.g., El Niño events of 1997-98, 2002-03, 2009-10 and La Niña events of 1999-00, 2008-09, 2011-12. These flows and their seasonal and interannual variability have significantly increased over the last five decades, especially from 1971-1997 (Garcia & Vargas, 1994; Nagy *et al*., 2008a; Nagy *et al*., 2013a).

Climatic time-series of temperature, rainfall, river flows, and sea-level have shown positive trends from 1961-2008 (Bidegain *et al*., 2005, 2009), whereas wind regime has slightly changed, with an increase in south-eastern winds. All of these changes are expected to continue until 2030-50 (Bidegain *et al*., 2011a,b). The increase in the occurrence of extreme events such as wind storm surges over the last few years is the greatest coastal concern if this trend is to be continued (Verocai *et al*., 2013). Only the increase in storm-surges is already directly affecting the coast, whereas both the observed moderate sea-level rise (SLR: 11-12 cm) and the increase in freshwater inflow to the Rio de la Plata river estuary trigger the effects of wind-storms (Bidegain *et al*., 2005, 2009; Nagy *et al*., 2007, 2013b; Verocai *et al*., 2013; Gutiérrez *et al*., 2013).

3. Clarifying concepts on climate adaptation

Assuming that many readers are more familiar with Integrated Coastal Zone Management (ICZM) than with Climate Change impacts, adaptation and vulnerability (IAV) and because some terms have different meanings, we present the definitions and concepts used in this paper based on recent literature and our experience.

According to Weber (2006), evidence-based perceptions of long-term risk show that global warming does not scare us yet. Here we understand "*Climate threat*" as any "climate-driven, continuous (climate change) or discrete (extreme weather or climate-related events) stressor on the environment and humans", and the ambient stressors, risk domain, and impacting processes associated with (Adapted from Reser & Swim, 2011).

The perceptions of climate threats are usually incorporated into participatory decision-making and action processes (Tompkins, 2005; Few *et al*., 2007; Eisenack *et al*., 2007; Nagy *et al*., 2014b). Public participation encompasses a range of procedures and methods designed to consult, involve, and inform the public to allow those that would be potentially affected by a decision or policy to have input into the process. The latter are also known as Stakeholders (IFC, 2007). The IPCC (2007) defined Climate Vulnerability, Adaptation and Scenarios as follows:

- Vulnerability: "the degree to which a human or natural system is susceptible to, or unable to cope with, adverse effects of climate change".
- Adaptation: "the adjustment in natural or human systems in response to actual or expected climatic

stimuli or their effects, which moderates harm or exploits beneficial opportunities" respectively.

- Scenarios: "plausible futures that allow you to envision and evaluate the outcomes of potential decisions in the context of different sets of background conditions".

Several authors have argued that there are societal limits to climate adaptation (Adger *et al*., 2009), or that it will likely fail (Dessai & Van der Sluijs, 2007), whereas Johnston *et al*. (2013) stated' Failure of climate change adaptation and rising greenhouse gas emissions as among those global risks considered to be the most likely to materialize within a decade'.

According to Dessai & Van der Sluijs (2007) some relevant concepts of *uncertainty and climate change adaptation* are as follows:

- "Statistical uncertainty concerns the uncertainties which can adequately be expressed in statistical terms, e.g., as a range with associated probability".
- "The top-down-prediction-oriented-approaches are strong in statistical uncertainty and the resilience and robustness type of bottom-up approaches are strong in coping with recognized ignorance and surprises".
- Scenario uncertainty concerns uncertainties which cannot be adequately depicted in terms of probabilities, but which can only be specified in terms of (a range of) "possible outcomes" Thus, *s*cenario uncertainties are often constructed in terms of "what-if" statements.

To simplify the sometimes confusing concepts of vulnerability and risk, Nagy *et al*. (2013a, 2014b) used an operational understanding for both of them as follows:

- "Impact-oriented vulnerability", where threats and vulnerability are perceived as "any possible harm or loss and potential impacts" respectively.
- "Climatic risk" could be "any possible threat from observed and possible change, variability, and extremes, which probability distribution is not always well characterized".

Climate change may mean more frequent extreme events, or more severe extreme events, in the future. Adaptation planning for these events will strongly rely on lessons learnt in past events (Kiem *et al*., 2010). A lack of adaptation to current climate variability and observed change is a failure to keep pace with development called by Burton (2004) "adaptation deficit". This concept captures the notion that countries are underprepared for current climate conditions, much less for future climate change. The shortfall is not the result of low levels of development but of less than optimal allocations of limited resources (World Bank, 2010).

Scenarios in the area of climate and global change assessment are dominated by exploratory, top-down scenarios in forecasting mode. However, the research community is making a serious effort to develop *participatory scenarios* that cross the boundaries between knowledge and action and are salient, credible and legitimate (after Cash *et al*., 2003, in Jones 2010a). Scenarios do not tell us what will happen but they can be used as a tool to identify future actions. Scenarios are used widely in vulnerability and risk assessment exercises to inform impact models from which scientists, managers and/or resource-users identify adaptation strategies to minimize risk. Rarely do these processes go on to appraise, evaluate, or implement the adaptation strategies identified (Wilby & Dessai, 2010).

Scenario planning allows managers to envision a range of possible futures. These futures may be near-term and simple (what if?), or they may be long-term and complex, addressing the interactions of highly uncertain drivers. All scenarios should take into account relatively well-known trends. Scenario planning is not merely a prediction, but is a systematic way of bracketing uncertainty. Scenario planning or "participatory scenario analysis" supports the interaction of diverse participants (*e.g*., community stakeholders, political decision-makers, resource managers, scientists) to develop a shared understanding of risks, trade-offs, and possible management actions" (Cobb & Thompson, 2012; Moore *et al*., 2013). The use of "what if" or "what future do you envision" seems useful to communicate uncertainty and risks to the stakeholders (Nagy *et al*., 2014b).

A closer scrutiny of the risks reveals that many coastal adaptation actions appropriate for long-term planning are identical to those employed to manage or mitigate severe and more immediate impacts of other coastal hazards (Bender 2011; Dholakia-Lehenbauer & Elliott, 2012). Climate change and sea-level rise will usually be on the list of justifications to present adaptation options but are often less compelling threats than other appropriately presented coastal hazards (Rogers & Tanski, 2012).

Risk-management encompasses the implementation of strategies for reducing vulnerabilities to risk, increasing resiliency to problematic conditions, and positioning resources to exploit opportunities (Mahmoud *et al*., 2009). In this regard Preston *et al.,* (2013) said "Climate adaptation has emerged as a mainstream risk-management strategy for assisting in maintaining social-ecological systems within the boundaries of a safe operating sp*ac*e". Often, there are not accepted metrics to assessing threats and risks. Scientists provide historical records of extremes, recurrences, projections, and future scenarios to stakeholders who

rank impacts and threats based on this information, their perception, and priorities. Certainly, a great degree of uncertainty remains and that is why climate adaptation is basically a risk-management approach. In other words, what happens if the assumptions, scenarios and/or actions are wrong? (Jones, 2010b). "Adaptive co-management can be thought as a making-decision and learning by-doing process in which stakeholders operate under uncertainty" (Tompkins, 2005). According to Butler & Coughlan (2011) this requires continued reevaluation of locally and temporally relevant management strategies so that they evolve along with the climate. They suggest to adapting the concept of variability as a proxy of change.

4. Revisiting recent contributions and methodological approaches

This paper explores previous experiences of the Project during the period 2008-13 aiming to link climate and coastal science, effective communication with stake-holders, and management. For doing so, a brief synthesis of the main goals, methodological approaches, results and learned lessons are presented based on recent literature.

4.1. Recent Contributions

Three recent peer reviewed contributions of the Project's series "Approaches to Implementing Coastal Adaptation in Uruguay" (www.adaptationlearning.net) are revisited. These articles, summarized in Table 1, are:

1. A risk-based and participatory approach to assessing climate vulnerability in coastal Uruguay (Nagy *et al*., 2014a).
2. Stakeholders' climate perception and adaptation in coastal Uruguay (Nagy *et al*., 2014b).
3. Integrating climate science, monitoring, and management in the Rio de la Plata estuarine front, Uruguay (Nagy *et al.*, 2014c).

4.2. Methodological Approaches

The methodology followed in this article to plan and implement measures in coastal pilot adaptation sites builds upon the three above mentioned ones (Table 1). All of them share:

- The classical IPCC-type science-driven, prescriptive top-down General Circulation Models (GCMs) in forecasting mode.
- Expert judgment matrices included to support decision-making.
- A diagnostic bottom-up participatory approach based on the UNDP Vulnerability Reduction Assessment Approach-VRA (Droesch *et al.,* 2010) was followed to inquire stakeholders' perceptions about climatic threats and adaptations constraints and options.
- A participatory process, e.g., several meetings, semi-structured and in depth interviews, and workshops with identified stakeholders, scientists, practitioners were held to select, prioritize, and define adaptation options to be planned or implemented.
- Adaptive and risk-based management type approaches were discussed with stakeholders.

This article shares with the third one (Nagy *et al*., 2014c) the use of a system dynamics (SD) approach. System dynamics is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system (Sterman, 2001). An original SD stock and flow model diagram is presented. Stock and flow model helps in studying and analyzing the system in a quantitative way. A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change or accumulation of the stock (Meadows, 2008).

Finally, an original participatory scenario planning is explored in this article. According to the U.S. National Climate Assessment (NCA, 2013) the primary purpose of this approach in climate assessment has been the application of information about the range of potential future conditions to identify robust options for development, resource and management. Some benefits of a participatory approach are communication and understanding of uncertainties, consideration of local knowledge and perspectives, co-creation of scenarios that stretch thinking of scientists and decision makers about adaptation options, and development of motivation to act on the information gained. In contrast to prognoses, the scenario analysis is not using extrapolation of the past. It does not rely on historical data and does not expect past observations to be still valid in the future.

The approach followed in this article is the development of alternative contrasted scenarios or "futures" with two opposed climatic trends which must be plausible and logic (Cobb & Thompson, 2012; Moore *et al*., 2013).

5. Updating current climatic scenario and impacts for adjustment

According to Moss et al., (2010) because of the extensive uncertainties that exist in the future drivers of and responses to climate change, future scenarios are necessary to explore the potential consequences of different management response options.

5.1. Climate scenarios

The Project developed time-series for the period 1961-2008 (current baselines), e.g. sea-level rise (Fi-ure 3) and future GCM-based climate scenarios (HADCM4 and ECHAM5) downscaled with Hadley PRECIS tool to regional scales of 50 x 50km (Bidegain *et al*., 2009; Nagy *et al*., 2014a), as well as the high resolution (60 x 60 km)MRI-JMA CGCM2.3 (Bidegain *et al*., 2011a).

In order to plan, select and prioritize the adaptation measures to be implemented this knowledge was communicated and discussed with the stakeholders. It was outlined that several variables such as the total river inflow to the Rio de la Plata (Q_{RP}) and sea-level were below the long-term trend since ca. 2004. River flow fluctuations, wind regime, and SLR are sensitive to ENSO variability (Gutierrez *et al*., 2013; Nagy *et al*., 2013a,b). This influence on SLR is explained by the local effect of a close mouth of a great river (Nicholls *et al*., influence sea-level all along the Uruguayan coast (Bidegain *et al*., 2009; Nagy *et al*., 2014b). This influence reaches +/- (up/down) 5-20 cm/year (Nagy *et al*., 2005; Bidegain *et al*., 2009),

Table 1 - Summary of aims and methodological approaches, results, and lessons of the Project's recent peer reviewed contributions.

Tabela 1 *- Resumo dos objectivos e abordagens metodológicas, resultados e lições de contribuições recentes do Projeto.*

Article	Aims and Methodological Approach	Results	Learned lessons
1 Nagy *et al*., 2014a	**Aim**: To Increase resilience and capacity to link ICZM and participatory climate adaptation at two Pilot Sites (Laguna de Rocha - a coastal lagoon - and the Frontal Zone of Rio de la Plata river estuary). **Approach**: In order to assess the potential risks of climate change on the pilot sites, four "cascading" supporting streams of activity were undertaken, namely: 1. Vulnerability mapping to consider key system drivers. 2. Baseline Vulnerability Reduction Assessment (VRA). 3. Development of a customized risk management conceptual model (MESA). 4. Multi-criteria approaches for selecting adaptation options.	The Uruguayan coast was identified as one of the most exposed in Latin America to sea-level rise and wind-induced flooding.	Adaptation efforts need to build on existing frameworks for ICZM. Providing a scientific understanding of coastal processes and climate change has proved to be very effective in moving the adaptation agenda forward in country.
2 Nagy *et al*., 2014b	**Aim**: To review stakeholders' involvement in adaptation planning focused on the Laguna de Rocha (coastal lagoon) site. **Approach**: A combination of top-down climate analysis and modelling, and expert judgment with a participatory process including consultations, workshops, and a VRA intended to inquire stakeholders' perception of coastal climate threats and adaptation was followed to prioritize actions.	The project incorporated stakeholder analysis, climate scenarios, and the necessary trade-offs in order to manage climate change. This process empowered stakeholders.	Stakeholders understand future scenarios with difficulty. Thus, vulnerability was assessed with stakeholders following an impact-oriented perspective. The success of integrating scientists and stakeholders into the management policy is a learning-by-doing lesson. Stakeholders prefer no-regret adaptation measures which facilitate conflict resolution.
3 Nagy *et al*., 2014c	**Aim**: To focus on institutional arrangement for managing climate variability risks within the Rio de la Plata Estuarine Front Pilot site. **Approach**: The use of a system dynamics stock and flow diagram was explored as a tool to analyze the complexity of multi-causal problems and the implementation of a monitoring-modelling-early warning system to support the implementation and timing of management options.	Periodic hydro-climatic fluctuations, often in coincidence with ENSO induced variability, allows the development of an early warning system to support management.	The institutional agreements and the consultation process imply stakeholders' ownership and facilitate the implementation. Monitoring of ENSO related variables allows forecasting the future behavior of the estuarine front displacement and salinity close to Montevideo.

which is far greater than the observed 0.11 cm/year SLR from 1902-2002 (+ 11cm), reaching 0.3 cm/year from 1971-2003 (Magrin *et al*., 2007; Bidegain *et al*., 2005, 2009), or only 0,1 cm/year from 1961-2012 (Verocai *et al*., 2013).

These cycles and short-term trends are discussed during participatory adaptation meetings because stakeholders expressed to be more concerned by recent trends (5 to 20 years), and extreme events, than by long-term series and GCMs' outputs (Nagy *et al*. 2014b).

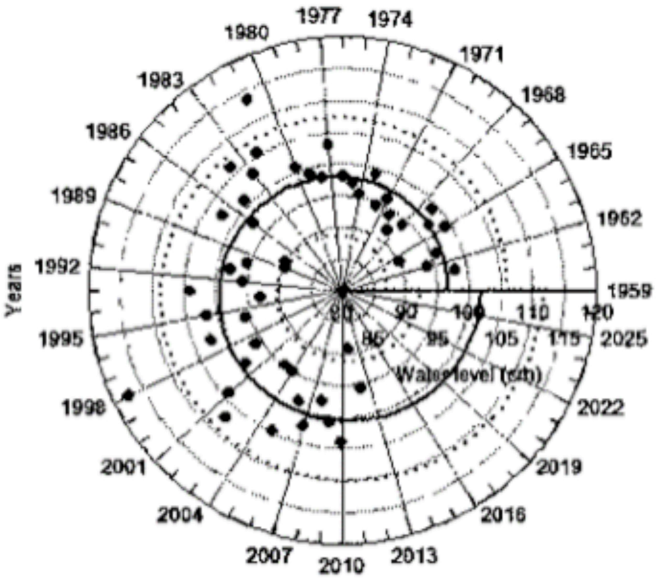

Figure 3 - Sea-level rise in Montevideo (1961-2012). The circular mode shows the years (points), the increasing trend (line) from 96 to 101 cm, and 95% confidence interval (dotted line). The regressive projected value for 2025 is 102 cm (range: 92-112 cm).

Figura 3 - Elevação do nível do mar, em Montevidéu (1961-2012). O modo circular mostra os anos (pontos), a tendência crescente (linha) 96-101 cm, e intervalo de confiança de 95% (linha pontilhada). O valor projetado regressivo para 2025 é 102 cm (intervalo: 92-112 cm).

The update of the series up to 2012 show that all positive climatic trends during the period 1961-2008 reverted to negative ones from 1997-2012 - except for temperature - (Nagy *et al*., 2013b), *e.g.*, the ENSO Equatorial Pacific Index Sea Surface Temperature (SST 3.4), the regional river inflow, and the local SLR (Figure 4). Even if communication and participatory processes have increased stakeholders' understanding of the need of analysing 30 years and plus climatic data, they are concerned by short-term trends and cycles. In this regard, Nagy *et al*. (2014b) argue that long-term robust trends over the last few decades created a "perceived continuity of changing" among stakeholders that may overcome the uncertainty about future climate change.

A common pattern shown in figure 4 is the decrease since 2003-04. Are really these trends that robust or just a cycle? Kosaka & Shang-Ping (2013) have shown that the recent observed decrease in the pace of global warming (from late 90s) - when compared to that of atmospheric carbon - or the "g*lobal-warming hiatus",* might be tied to a decadal variability (Pacific Decadal Variability - PDO) of Equatorial Pacific surface cooling *or* "La Niña-like decadal cooling*"*. A question that remains to be answered is if the recent short-term climatic trends observed in coastal Uruguay could be linked with PDO.

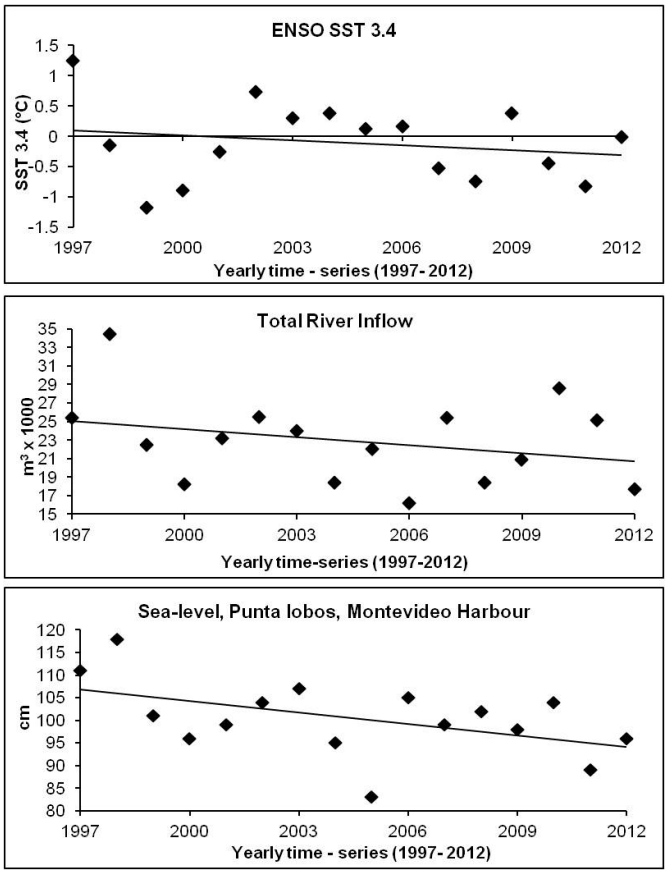

Figure 4 - Yearly means time-series from 1997-2012 for ENSO SST 3.4 index (above), river inflow to the Rio de la Plata (middle), and seal-level rise in Montevideo (below). Accordingly to Nagy *et al*., (2013b).

Figura 4 - Serie temporal anual do indice ENSO SST 3,4 do período 1997-2012 (acima), fluxo de entrada no Rio de la Plata (meio) e elevação do nível do mar em Montevidéu (abaixo). Segundo Nagy et al, (2013b).

5.2. Climate threats, impacts and stakeholders' adjustment

The overall observed impacts on coastal communities and sectors associated with climate threats and SLR remains low to moderate, *e.g.*, low physical capital losses and low human risk. However, locally, the experience of impacts may be sometimes greater (Nagy *et al*. 2007; 2014b; Gomez-Erache *et al*., 2013). The main climate threats and impacts, and some stakeholders' responses are synthesized (Table 2).

The participation of local citizens and other stakeholders in the adjustment to climate change processes in Uruguay usually occurs within the national and local level institutional and legal framework which promotes public consultation.

These participatory processes empower stakeholders without a perceived loss of power from the institutions (Nagy *et al*., 2014b). Autonomous community-level responses are not frequent, with the exception of artisanal fishermen who migrate as a response to climate variability within the estuarine front (Nagy *et al*., 2008b; 2014c).

One of the goals of the Project is to link science with management and to communicate it to stakeholders in an effective way. In order to do so, a system dynamics approach was used. A stock and flow diagram of the climatic and oceanographic variables (Figure 5) was developed to explain the behaviour of the Rio de la Plata estuarine front (Nagy *et al*., 2013b,c). This approach simplifies the complexity by focusing on the key variables.

In our example, there are three key variables: Global Warming, El Niño (represented by SST 3.4), and Pacific Decadal Oscillation (PDO). There are two stocks: Salinity and Turbidity, associated with freshwater and suspended matter inputs to the system respectively. There are three flows: River Inflow (m^3/s), basin and local rainfall (mm), and frontal (EFS) displacement (km) all of which are scaled to monthly time-scale. Time delays (months) represent the typical cause-effect lag of time, e.g., an increase in SST 3.4 (El Niño) is followed by an increase in river inflow 3-6 months after.

The diagram shows both the plausible influence of PDO and the well-known ENSO-related variability on climatic drivers and relationships relevant to explain the observed trends and the possible near future. The diagram is centered on the displacement of the estuarine front (see figure 2) because it is - together with sea-level - associated with the main regional climate drivers, river inflow and wind. Running "what if" simulations to test certain auxiliary variables or flows on such a model can greatly aid in understanding how the system changes over time.

This diagram will be useful not only to make simulations but as a tool to illustrate complexity and for developing creative scenarios based on how the system changes with climate drivers or policy measures. Unfortunately, there is not much to be done to control and manage the drivers of change and variability shown in the diagram (due to the huge dimensions and geopolitical complexity of the basin), but enhancing modeling, monitoring, communication to users, and rapid response.

Table 2 - Participatory climate scenario for adaptation planning. Expected changes are represented by symbols:not significant (=), increase (+), and decrease (-). Based on Escobar et al. (2004); Bidegain et al. (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy et al. (2008 b, 2014a); Alves & Marengo (2010).

Tabela 2 - Cenário climático participativo para o planejamento da adaptação. As mudanças esperadas são representadas por símbolos: não significativo (=), aumento (+) e diminuição (-). Baseado em Escobar et al. (2004); Bidegain et al., (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy et al. (2008 b, 2014a); Alves & Marengo (2010).

Climate threats, magnitude, effects and impacts		**Stakeholders' response**	**Sources**
Threat and Magnitude	**Effect and Impact**		Nagy et al. 2014 a,b,c. for all of the threats
Sea-level rise: Weak (≤ 12 cm)	Weak to moderate Beach and Wetland loss	Diagnostic reports	Bidegain *et al*. (2005, 2009); Gómez-Erache *et al*. (2013); Nagy *et al*. (2014b); this article
Increase in River inflow: Strong (> 25% since 1971) and variability	Moderate to Strong Estuarine front sea-ward displacement	Fishermen migration	García & Vargas (1994); Nagy *et al*. (2008b, 2013a,b); this article
ENSO-related Wind regime variability: Moderate to Strong	Weak to Moderate Beach erosion (up to 32% erosive coast)	Beach, dune, and lagoon-bar management and "soft" protection	Nagy *et al*. (2007, 2008b); Bidegain *et al*. (2009, 2011b); SNRCC (2010); Gutiérrez *et al*. (2013); Gómez-Erache *et al*. (2013); Conde *et al*. (2013); Verocai *et al*. (2013)
Increase in storm-surges	Overall coastal erosion; increase of physical, economic and natural capital at risk.	Diagnostic reports and emergency response plans	
Increase in local rainfall: (≥ 23 %) and regime change	Moderate to strong Beach and Cliffs erosion; (episodic) decrease in beach microbial quality	Beach and dune soft protection. Municipal beach monitoring and bath restrictions	Bidegain *et al*. (2005, 2009); Nagy *et al*. (2014c)

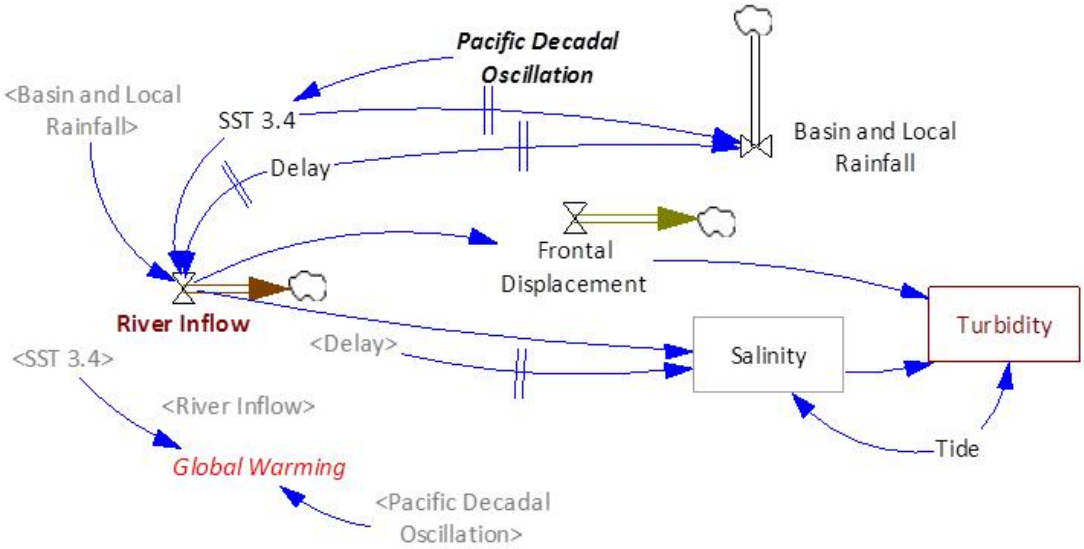

Figure 5 - Stock and flow diagram (VENSIM System Dynamics software) of the Rio de la Plata Estuarine Frontal System. Boxes: stocks (accumulations), e.g., freshwater (salinity) and suspended matter (turbidity). Narrow arrows: direct relationship between auxiliary variables, e.g., El Niño (SST 3,4) increases rainfall. Delay is a time lag of a cause-effect relationship. Wide arrows: flows, e.g. river inflow, frontal displacement, and rainfall. Accordingly to Nagy *et al*. (2013b,c).

Figura 5 - Diagrama de estoque e fluxo (software System Dynamics VENSIM) do sistema frontal estuarino do Rio de la Plata. Caixas: estoques (acumulações), por exemplo água doce (salinidade) e material em suspensão (turbidez). Setas estreitas: relação direta entre variáveis auxiliares, por exemplo, El Niño (SST 3,4) aumenta a pluviosidade. O atraso (Delay) é um intervalo de tempo de uma relação causa-efeito. Setas largas: fluxos, por exemplo, fluxo do rio, o deslocamento frontal, e precipitação. Segundo Nagy et al. (2013b, c).

From a management perspective, any soon change in the pace and trends of climate drivers will increase stakeholders' trust on scholars, and probably on the new generation of future scenarios. In this regard, the role of social scientists and communicators is central, together and in narrow coordination with natural scientists, to increase public awareness.

Even if some institutional stakeholders and elected officials do not believe in climate change or prefer to ignore it because of the priority of economic development, they cannot completely ignore people's concerns and must pay careful attention to climate trends and threats. The project is continuously updating data and generating plausible future scenarios based on models and projections within an adaptive- and risk-based co-management approach.

6. A simple scenario for adaptation planning

The Project followed a mixed approach to construct participatory scenarios based on the prescriptive GCM models future outputs, e.g., 2030 to 2050, the projection of robust trends, e.g., 1961-2008, and discussions with experts and stakeholders. The participatory phases involved in depth interviews, impact-ranking with analysis of obstacles, opportunities, time-horizons, and accepted thresholds of impact. The last one usually failed. The approach, explained in some detail in Nagy *et al*., (2014b), shared many concepts, procedures, and goals with other approaches explained in section 3 such as the risk-based management and the scenario planning for climate change.

According to Moore *et al*., (2013) "The process of developing scenarios gives scientists an opportunity to clearly articulate the potential consequences of uncertain drivers in a manner that empowers decision makers, rather than leaving them paralyzed with no clear path of action. Scenario planning is only as useful as the scenarios are plausible to the exercise participants. Without buy-in to the scenarios, scenario planning becomes a mere exercise in imagination". The questions usually discussed during scenario planning are focused on:

- The direction of change (increase or decrease?).
- The magnitude and threshold (How much? Is the impact affordable or not?).
- The rate of change/timing of impacts (How soon/ At what time of year will the change or event likely happen?).
- The interaction of climatic and non-climatic socio-economic, environmental, and technological drivers.

All available information was shared with experts from the academia (University of the Republic) and institutional stakeholders (Directorate of the Environment, Directorate of Aquatic Resources, and Municipal Governments) in a workshop held in March, 2012 (Nagy *et al*., 2014c). Before the workshop was held, the Project

communicated some results to institutional managers and scientist in order for them to make some inputs to the draft of adaptation management, scientific and/or monitoring measures. Thus, besides increasing confidence and awareness, it was possible to adjust the expectative to the institutional needs and implementation possibilities. During the workshop the Project's climate science and management experts analyzed climate threats and scenarios, identified vulnerabilities, participants. Without buy-in to the scenarios, scenario planning becomes a mere exercise in imagination". The questions usually discussed during scenario planning are focused on:

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During the workshop the Project's climate science and management experts analyzed climate threats and scenarios, identified vulnerabilities, and a list of best adaptation measures based on the international literature and local experience. The goals of the workshop were to:

1. Communicate scientific results and potential future management options.
2. Receive feedbacks from the attendants.
3. Increase awareness with regard to climate change and variability.
4. Involve those who wished to participate in the implementation of the process.

The results of GCMs' outputs, impact-ranking according to expert judgment (N= 8), and institutional practitioners (N=5), as well as the discussions during the meetings and the workshop were synthesized (Table 3).

Table 3 - Participatory climate scenario for adaptation planning. Expected changes are represented by symbols:not significant (=), increase (+), and decrease (-). Based on Escobar *et al.* (2004); Bidegain *et al.* (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy *et al.* (2008 b, 2014a); Alves & Marengo (2010).

Tabela 3 - Cenário climático participativo para o planejamento da adaptação. As mudanças esperadas são representadas por símbolos: não significativo (=), aumento (+) e diminuição (-). Baseado em Escobar et al. (2004); Bidegain et al., (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy et al. (2008 b, 2014a); Alves & Marengo (2010).

Climate variable	General change expected for 2030-50 / Relative size compared to already observed changes	Confidence level
River flow (total river inflow).	(= or +) in total annual river flow, but not uniform on both seasonal and interannual time-scales. Different patterns should be expected for both tributaries separately.	Low to Moderate
Temperature	(+) in annual mean, but not uniform on both seasonal and interannual time-scales. Likely (+) by 2030 and (++) by 2050 plus.	High to Very High
Rainfall (basin and local level)	(= or +) in total annual rainfall, but not uniform on time and geographic scales. Very likely lower than during 1971-2002 and likely reverting the slight (-) tendency since ca. 2004.	Low to Moderate
Sea-level	(+) in total annual SLR, but not uniform on both seasonal and interannual time-scales. Probably similar or greater than during 1971-2003 and greater than during 1997-2012 since probably 2015-20. Likely (++) by 2050 plus.	High to Very High
Winds	Unclear. (=or +) in average. Likely increase in South-Eastern (on-shore) wind and likely relatively (+) East-ward for 2030-50. Likely (= or +) than during 1961-90.	Moderate to High
Extreme events: River Flow	Unclear. (=or +) likely during spring-summer time for 2050, thus more impacts on most environmental issues. Likely (= or -) than during 1961-2012. Perhaps less than during 1997-2012, if not severe impacts are likely to occur.	Low to Moderate
Extreme events: Rainfall	Unclear. (= or +) likely during spring-summer time. Likely summer extreme rainfalls will impact beach water quality at Montevideo capital city without new "hard-engineering" adaptation measures.	Moderate
Extreme events: Storms	Likely (=or +) which will increasingly impact resources and infrastructure for 2030.	High to Very High

Alternative Scenarios

Some alternative scenarios with opposed drivers were developed for the Rio de la Plata and the Uruguayan coast, e.g. more or less river inflow, or more or less South-Easterly (on-shore) / North-Westerly (offshore) winds (Figure 6).

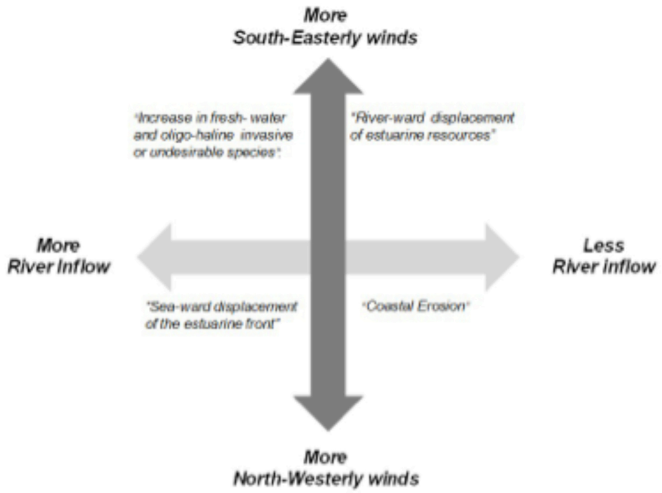

Figure 6 - The four climatic scenarios from the alternative futures of the Rio de la Plata estuarine waters and Uruguayan coast. Potential environmental impacts were chosen for each combination.

Figura 6 - Os quatro cenários climáticos para as alternativas futuras das águas estuarinas e da costa uruguaia de Rio de la Plata. Foram escolhidos, para cada combinação, os potenciais impactos ambientais.

According to Evans *et al*., (2013), this kind of approach becomes a risk-management research tool. Emphasis can be put on "what if" instead on a future uncertain time-frame. If a future was to be specified, it could be 2025, thus the outputs of GCMs for 2020-29 could be intercepted with long-term trend projections. In our experience stakeholders do not need "plausible" or "catastrophic" futures to be aware of the need of adaptation, but "realistic ones which can impact on them". Thus, (alternative) scenarios are tools to learn to adapt more than to foresee. An effective adaptation to an uncertain - but likely worse future - is better than a good forecast (if possible) without adaptation (adaptation deficit).

The use of "more and less" in figure 6 is based on the participatory scenarios (see Table 2) implying some degree of change which is both "perceived by stakeholders" and produce measurable significant effects in climatic and environmental records and processes, *e.g.*, coastal erosion, sandy-barriers opening, displacement of the estuarine front, changes in fishing season and catch, cyanobacterial blooms, and coliforms' survival.

7. Final Reflections

During this stage of building capacity to analyze and implement adaptation measures in coastal Uruguay many authors and local experiences have been consulted. Here, we emphasize on two - among several useful concepts - that describe the "essence of our feeling" on coastal climate adjustment and adaptation discussed along this article.

Firstly, the need of "adapting to variability before change" and "the analysis of preexisting adaptation strategies for climate variability is a proxy for future adaptation planning" (Butler & Coughaln, 2011).

Secondly, "persistent vulnerability to climate variability is a symptom of an adaptation deficit in socio-ecological systems" (Preston *et al*., 2013).

Living with increased climate variability in South-Eastern South America since the early 70s (the "ENSO era"), implies that both the expert and local knowledge are expressed through adjustment actions. All over the world and in Uruguay, the increase in extreme events has fostered climate awareness. Many of these events occurred during ENSO years. Going from reactive actions to negotiation and anticipatory planning which combines existing knowledge, information, and capacities with capacity building is still the overarching goal.

Adaptation efforts often cannot follow the increase in climate threats. The fact of not been able to (successfully) cope with current climate stressors is not a lesson to adapt to an uncertain future. However, we can learn from this failure.

Scientists (especially from physical domains) usually prefer top-down predictions with statistical uncertainty, whereas managers prefer some certainty, narrow range of values, and near-future time-horizons. The issue is that adaptation is a socio-political process and in order to reduce the adaptation deficit the best practitioners can do is to contribute to "grounded" science to fill the gap with management.

Robust trends are preferred by most stakeholders. They facilitate adaptation "buy in" (by stakeholders), especially if they are associated with long-standing socio-environmental problems related to climate drivers. The reverted trend prevailing since 1997, especially since 2003-04, is not strongly perceived among coastal scientists and managers yet. If it is to continue, it could affect the perception of future climate change, not of the need of a better understanding of the present and the near-future.

The incorporation of climate threats into policy and plans through the mix of top-down and bottom-up approaches allowed increasing stakeholders and decision-makers' capacities to implementing adaptation. This is due to the fact that the process focuses on the identifica-

tion of specific, feasible, and flexible actions through negotiation, prioritization, and search of agreements and synergies among the institutional and local stakeholders in charge of the implementation phase.

The exchange between natural and social scientists with stakeholders and decision-makers increase mutual understanding, thus a "common language" can be used to planning adaptation. Thus, it is a learning by-doing experience intended to increase the feasibility and capacities for adaptation.

Thinking "alternative futures" is a task the academia and practitioners must incorporate, together with stakeholders, into the political agenda. A simple comprehensive near-future scenario was developed as a communication and research tool for adaptation planning based on science, expert-judgment, and expectations. It is not intended as an end product but as a way to explore "what if" in the future. This scenario can be transformed into axes of opposed drivers to explore, together with stakeholders, potential impacts under changing climate drivers. This type of participatory exercise should be a key component to building adaptation capacities at the national level.

Finally, the importance of the subject and of the obtained results in this article - as well as of the three previous ones - to integrated coastal zone management may be synthesized as follows:

- The mix of current coastal climatic threats and future climate change and sea-level rise (SLR) scenarios, because the latter are not usually considered in ICZM in Uruguay.
- The Project learned from ICZM experience the importance and the need of working with a multi-stakeholders and problem-solving.
- The development of participatory alternative futures where both scientific knowledge and stake-holders' perceptions and needs can be explored to prioritize actions.

References

Adger, W.N.; Dessai, S.; Goulden, M.; Hulme, M.; Lorenzoni, I.; Nelson, D.R.; Naess, L.O.; Wolf J.; Wreford, A. (2009) - Are there social limits to adaptation to climate change? *Climatic Change*, 93(3-4):335–354. DOI: 10.1007/s10584-008-9520-z

Alves, L.; Marengo, J. (2010) - Assessment of regional seasonal predictability using the PRECIS Regional climate modeling system over South America. *Theoretical and Applied Clima-tology*, 100(3-4):337-350. DOI: 10.1007/s00704-009-0165-2

Bender, S. (2011) - Global Lessons on Development Planning and Climate Hazards Reduction. *The Public Manager*, *40*(1):27-31. Available on-line at http://www.astd.org/Publications/Magazines/The-Public-Manager/Archives/2011/Spring/Global-Lessons-on-Development-Planning-and-Climate-Hazards-Reduction

Bidegain, M.; Coronel, G.; Ríos, N.; de los Santos, B. (2012) - Escenarios climáticos futuros para Paraguay. *Meteorológica* (ISSN 1850-468X), 37(2):4-34, Centro Argentino de Meteorólogos, Buenos Aires, Argentina. Available on-line at http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1850-468X2012000200001

Bidegain, M.; de los Santos, M.; de los Santos, B.; de los Santos, T.; Goso, C.; Verocai, J.E. (2009) - *Escenarios Climaticos, del Nivel del Mar y Vulnerabilidad Geológica en Áreas Costeras del Uruguay*, Working paper, GEF-Project Implementing pilot adaptation measures in coastal areas of Uruguay, UCC-DINAMA-UNDP, Facultad de Ciencias, Montevideo,Uruguay, 106 pp. Available on-line at www.adaptationlearning.net/.pdf

Bidegain, M.; de los Santos, B.; Skusunosky, S.; Kitoh, A. (2011a) - Escenarios Climáticos futuros con el modelo japonés MRI-CGCM2.3. *Anais do 7° Simpósio de Meteorología e Geofísica da APMG y XIV Congreso Latinoamericano e Ibérico de Meteorologia*, Portugal.

Bidegain, M.; de los Santos, M.; Rodriguez, C.; Verocai, J.E. (2011b) - *Escenarios Climáticos, eventos extremos y dinámica de la zona frontal del Rio de la Plata*. 91p, working paper, GEF-Project Implementing pilot adaptation measures in coastal areas of Uruguay, UCC-DINAMA-UNDP, Facultad de Ciencias, Montevideo, Uruguay.

Bidegain, M.; Caffera, R.M.; Pshennikov, V.; Lagomarsino, J. J.; Nagy, G.J.; Forbes, E.A. (2005) - Tendencias climáticas, hidrológicas y oceanográficas en el Río de la Plata y costa Uruguaya. *In:* V. Barros, A. Menéndez & G.J. Nagy (eds.), *El Cambio Climático en el Río de la Plata*, pp. 137–143, Centro de Investigaciones del Mar y la Atmósfera, Universidad de Buenos Aires (UBA), Buenos Aires, Argentina. Available on-line at http://www.cima.fcen.uba.ar/~lcr/libros/Cambio_Climatico-Texto.pdf

Burton, I, (2004) - Climate change and the adaptation deficit. *In:* Adam Fenech, Don MacIver Heather Auld, Robin Bing Rong and Yongyuan Yin (*eds.*), *Climate Change: Building the Adaptive Capacity*, pp.25-33, Meteorological Service of Canada / Environment Canada, Toronto / Ontario, Canada. ISBN: 0662384954. Available on-line at http://projects.upei.ca/ climate /files/2012/10/Book-5_Paper-3.pdf

Butler, K.; Coughlan, E. (2011) - Adapting to Variability before Change. An analysis of preexisting adaptation strategies for climate variability through a socioecological resilience framework: The Case of the Republic of the Marshall Islands. *ICARUS II Conference*, University of Michigan, Ann Arbor, Michigan, USA. Available on-line at http://www.icarus.info/wp-content/uploads/2011/624-Butler_and_Coughlan_Adapting_to_ Variability_Before_Change.pdf

Cash, D.W.; Clark, W.C.; Alcock, F.; Dickson, N.M.; Eckley, N.; Guston, D.H.; Jaeger, J.; Mitchell, R.B. (2003) - Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14):8086-8091. DOI: 10.1073/pnas.1231332100

Camilloni, I.; Bidegain, M. (2005) - Escenarios Climáticos para el Siglo XXI. *In:* V. Barros, A. Menéndez & Nagy, G. J. (eds.), *El Cambio Climático en el Río de la Plata*, pp.33-39, Centro de Investigaciones del Mar y la Atmósfera, Universidad de Buenos Aires (UBA), Buenos Aires, Argentina. Available on-line at http://www.ina.gov.ar/pdf/Libro-Cambio-ClimaticoRDP.pdf

Christie, P.; Lowry, K.; White, A.T.; Oracion, E.G.; Sievanen, L.; Pomeroy, R.S.; Eisma, R.L.V. (2005) - Key findings from a multidisciplinary examination of integrated coastal management process sustainability. *Ocean & Coastal Management*, 48(3-6):468-483. DOI: 10.1016/j.ocecoaman. 2005.04.006

Cobb, A.N.; Thompson, J.L. (2012) -. Climate change scenario planning: a model for the integration of science and manage-

ment in environmental decision-making. *Environmental Modelling & Software*, 38:296–305. DOI: 10.1016/j.envsoft.2012.06.012

Conde D.; de Álava, D.; Gorfinkiel, D.; Menafra, R.; Roche, I. (2012) - Sustainable coastal management at the public university in Uruguay: a Southern Cone perspective. *In:* W. Leal (ed.) *Sustainable Development at Universities*: *New Horizons,* pp 873-885, Peter Lang Scientific Publishers, Frankfurt, Germany. ISBN: 978-3631625606. ,

Conde, D.; Rodriguez-Gallego, L.; De Alava, D.; Solari, S.; Verrastro, N.; Chreties, C.; Lagos, X.; Piñeiro, G.; Teixeira, L.; Seijo, L.; Panario, D.; Caymaris, H.; Vitancurt, J. (2013) - Soluciones para el manejo sustentable de una laguna costera: del conflicto hacia un sistema multi-criterio de decisión consensuado, *XV COLACMAR*, Punta del Este, Uruguay.

Dessai, S.; van der Sluijs, J. (2007) - *Uncertainty and Climate Change Adaptation - a Scoping Study.* 95p., Copernicus Institute for Sustainable Development and Innovation Department of Science Technology and Society (STS), Utrecht, The Netherlands, ISBN: 978-9086720255. Available on-line at http://www.nusap.net/downloads/reports/ucca_scoping_study.pdf

Dholakia-Lehenbauer, K.; Elliott, E.W. (2012) – Decisionmaking, Risk, and Uncertainty: An Analysis of Climate Change Policy, Cato Journal (ISSN: 1943-3468), 32(3)539-556, Washington, DC, USA. Available on-line at http://object.cato.org/sites/cato.org/files/serials/files/cato-journal/2012/12/v32n3-5.pdf

Droesch, A.C.; Gaseb, N.; Kurukulasuriya, P.; Mershon, A.; Moussa, K.; Rankine, M.; Santos, A. (2008) - *A guide to the vulnerability reduction assessment*. 13p., UNDP Working Paper, United Nations Development Programme, New York, NY, USA. Available on-line at http://www.seachangecop.org/files/documents/2008_12_CBA_Vulnerability_Reducation_Assessment_Guide.pdf

Eisenack, K.; Tekken, V.; Kropp, J. (2007) - Stakeholder Perceptions of Climate Change in the Baltic Sea Region. *In:* G. Schernewski, B. Glaeser, R. Scheibe, A. Sekścińska & R. Thamm (eds.), *Coastal development: The Oder estuary and beyond,* pp 245-251, Coastline Report N° 8 (ISSN: 0928-2734), EUCC-Germany, Warnemünde, Germany. Available on-line at http://databases.eucc-d.de/files/documents/00000272_Artikel24_Eisenack_Tekken_Kropp.pdf

Escobar, G.; Vargas, W.; Bischoff, S. (2004) - Wind tides in the Rio de la Plata estuary: meteorological conditions. *International Journal of Climatology*, 24(9):1159–1169. DOI: 10.1002/joc.1026

Evans, L.S.; Hicks, C.C., Fidelman, P.; Tobin, R.C.; Perry, A.L. (2013) - Future Scenarios as a Research Tool: Investigating Climate Change Impacts, Adaptation Options and Outcomes for the Great Barrier Reef, Australia. *Human Ecology*, 41(6):841-857. DOI: 10.1007/s10745-013-9601-0

Few, R.; Brown, K.; Tompkins, E.L. (2007) - Public participation and climate change adaptation: avoiding the illusion of inclusion, *Climate Policy*, 7(1):46-59. DOI: 10.1080/14693062.2007.9685637.

García, N.O.; Vargas, W. (1998) - The temporal climatic variability in the Rio de la Plata Basin displayed by the river discharges. *Climatic Change*, 38(3),359-379. DOI: 10.1023/A:1005386530866

Gómez-Erache, M.; Fernández, V.; Guigou, B. (2013) - Análisis de la vulnerabilidad de la costa uruguaya ante el aumento del nivel medio del mar. *XV COLACMAR*, Punta del Este, Uruguay.

Gómez-Erache, M.; Conde, D.; Villarmarzo, R. (2010) - *The sustainability of integrated management in the coastal zone of Uruguay: Connecting knowledge to action*, EcoPlata, Program, Montevideo, Uruguay. ISBN: 978-9974764682.

Gutiérrez, O.; Panario, D.; Bidegain, M.; Montes, C. (2013) - Teleconexiones El Niño – La Niña con retrocesos-avances de playas del estuario medio del Rio de la Plata, *XV COLACMAR*, Punta del Este, Uruguay,

IFC. (2007) - *Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets.* 72p., International Finance Corporation (IFC), World Bank Group, Washington D.C., USA. Available on-line at http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/learning+and+adapting/knowledge+products/publications/publications_handbook_stakeholderengagement__wci__1319577185063

IPCC (2007) - *Climate Change 2007: Impacts, Adaptation and Vulnerability*. 976p., Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson (eds.), Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland / Cambridge University Press, Cambridge, UK. ISBN: 978 0521 88010-7. Available on-line at http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf

Johnston, G.S.; Burton, D.L.; Baker-Jones, M (2013) - *Climate change adaptation in the boardroom.* 68p., NCCARF - National Climate Change Adaptation Research Facility, Gold Coast, QLD, Australia. ISBN: 978-1921609961. Available on-line at http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Johnston_2013_Climate_adaptation_boardroom.pdf

Jones, R.N. (2010a) - *The use of scenarios in adaptation planning: managing risks in simple to complex settings*. 17p., Victorian Centre for Climate Change Adaptation Research (VCCCAR), Melbourne, VIC, Australia. Available on-line at http://www.vcccar.org.au/sites/default/files/vcccar/Jones%20scenarios%20presentation%2011-11-10.pdf

Jones, R. N. (2010b) - A risk management approach to climate change adaptation, *In:* R.A.C. Nottage, D.S. Wratt, J.F. Bornman, K. Jones (eds), *Climate change adaptation in New Zealand: Future scenarios and some sectoral perspectives*, pp.10-25, New Zealand Climate Change Centre, Wellington, New Zealand. ISBN: 978-0473163679. Available on-line at http://www.nzclimatechangecentre.org/sites/nzclimatechangecentre.org/files/images/research/Climate%20Change%20Adaptation%20in%20New%20Zealand%20%28NZCCC%29%20high%201.pdf

Kiem, A.S.; Verdon-Kidd, D.C.; Boulter, S.L.; Palutikof, J.P. (2010) - Learning from experience: Historical case studies and climate change adaptation. 33p., National Climate Change Adaptation Research Facility, Gold Coast, QLD, Australia. ISBN: 978-1921609268. Available on-line at http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Kiem_2010_Learning_from_experience_historical_case_studies.pdf

Kosaka, Y.; Shang-Ping, X. (2013) - Recent global-warming hiatus tied to Pacific surface cooling. *Nature*, 501(7467):403-407. DOI: 10.1038/nature12534

Lappo ,S.S.; Morozov, E.G.; Severov, D.N.; Sokov, A.B.; Klyuvitkin, A.A.; Nagy, G. (2005) - Frontal mixing of river and sea waters in Rio de La Plata. *Doklady Earth Sciences* (ISBN: 1028-334X), 401(2):226-228, Moscow, Russia.

Magrin, G.; Gay-Garcia, C.; Cruz-Choque, D., Giménez, J.C., Moreno, A.R., Nagy, G.J., Nobre, C.; Villamizar, A. (2007) - Latin America, *In:* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson (eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 581-615, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland / Cambridge University Press, Cambridge, UK. ISBN: 978 0521 88010-7. Available on-line at http://www. ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf

Mahmoud, M.: Liu, Y.Q.; Hartmann, H.; Stewart, S.; Wagener, T.; Semmens, D.; Stewart, R.; Gupta, H.; Dominguez, D.; Dominguez, F.; Hulse, D.; Letcher, R.; Rashleigh, B.; Smith, C.; Street, R.; Ticehurst, J.; Twery, M.; van Delden, H.; Waldick, R.; White, D.; Winter, L. (2009) - A formal framework for scenario development in support of environmental decision-making. *Environmental Modelling and Software,* 24(7):798-808. DOI: 10.1016/j.envsoft.2008.11.010

Meadows, D. (2008) - *Thinking in Systems: A Primer*. 240p., Chelsea Green Publishing, London, UK. ISBN: 978-1603580557.

Moore, S.S.; Seavy, N.E.; Gerhart, M. (2013) - *Scenario planning for climate change adaptation: A guidance for resource managers*. 61p., Point Blue Conservation Science and California Coastal Conservancy, Petaluma, CA, USA. Available on-line at http://scc.ca.gov/files/2013/07/Scen-planning_17july2013_FINAL-3.pdf

Moss, R.H.; Edmonds, J.A.; Hibbard, K.A.; Manning, M.R.; Rose, S.K.; van Vuuren, D.P.; Carter, T.R.; Emori, S.; Kainuma, M.; Kram, T.; Meehl, G.A.; Mitchell, J.F.B.; Nakicenovic, N.; Riahi, K.; Smith, S.J.; Stouffer, R.J.; Thomson, A.M.; Weyant, J.P.; Wilbanks, T.J. (2010) - The next generation of scenarios for climate change research and assessment. *Nature*, 463(7282):747-756. DOI: 10.1038/nature08823.

Nagy, G.J.; Gomez-Erache, M.; Kay, R. (2014a) - A risk-based and participatory approach to assessing climate vulnerability and improving governance in coastal Uruguay, Ch. 15. *In:* B. Glavovic, R. Kay, M. Kelly & A. Travers (eds.), *Climate Change and the Coast: Building Resilient Communities,* CRC Press, Boca Raton, FL, USA. ISBN: 9780415464871

Nagy, G.J.; Seijo, L.; Bidegain, M.; Verocai, J.E. (2014b) - Stakeholders' climate perception and adaptation in coastal Uruguay. *Journal of Climate Change and Strategies Management*, Lay Rationalities of Climate Change, 6(1):63-84. DOI: 10.1108/IJCCSM-03-2013-0035

Nagy, G.J.; Muñoz, N.; Verocai, J.E.; Bidegain, M.; de los Santos, B.; Seijo, L.; Feola, G.; Brena, B.; Risso, J.; Martín, J. (2014c) - Integrating Climate Science, Monitoring, and Management in the Rio de la Plata Estuarine Front (Uruguay). *In:* W. Leal Filho, F. Alves, U. Azeiteiro, & S. Caeiro (eds.), *International perspectives on climate change: Latin America and Beyond*, pp.79-91, Springer, Heidelberg, Germany. ISBN:978-3319044880. DOI: 10.1007/978-3-319-04489-7.

Nagy G.J.; Seijo, L.; Verocai, J.E.; Brugnoli, E.; Bidegain, M. (2013a) - Enfoque, Conocimiento y Medidas Para enfrentar las Amenazas del clima Presente en la Zona frontal del Río de la Plata, Uruguay. *Costas*, *Revista Iberoamericana de Manejo Costero Integrado* (ISSN: 2304-0963), 2(2):69-87, Oficina Regional de Ciencia para América Latina y el Caribe de la Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura (UNESCO), Montevideo, Uruguay.

Nagy, G.J.; Muñoz, N.; Bidegain, M.; de los Santos, B.; Verocai, J.E. (2013**b**) - Variabilidad temporal y espacial de variables hidroclimáticas y oceanográficas en el Río de la Plata y costa Uruguaya: 1997-2012. *XV COLACMAR*, Punta del Este, Uruguay.

Nagy, G.J.; Muñoz, N.; Verocai, J.E.; Bidegain, M. (2013c) - Simulación del comportamiento del sistema frontal del Rio de la Plata bajo escenarios hidroclimáticos. *Boletín de Dinámica de Sistemas* (ISSN 1988 7205), Septiembre 2013, 21p., Available on-line at http://www.dinamica-de-sistemas.com/revista/1213b-dina mica-de-sistemas.pdf

Nagy G.J.; Severov, D.N.; Pshennikov, V.A.; de los Santos, M.; Lagomarsino, J.J.; Sans, K.; Morozov. E.G. (2008a) - Rio de la Plata estuarine system: Relationship between river flow and frontal variability. *Advances in Space Research*, 41(11):1876-81. DOI: 10.1016/J.asr.2007.11.027

Nagy, G.J.; Bidegain, M.; Caffera, R.M.; Norbis, W.; Ponce, A.; Pshennikov, V.; Severov, D.N. (2008b) - Fishing strategies for managing climate variability and change in the Estuarine Front of the Rio de la Plata. *In:* Leary, N., Adejuwon, J., Barros, V. Burton, I., Kulkarni, J. and Lasco,R. (Eds), *Climate Change and Adaptation*, pp:353-370, Earthscan, London, UK. ISBN: 978-1844074709.

Nagy, G.J.; Gomez- Erache, Fernandez, V. (2007) - El aumento del nivel del mar en la costa uruguaya del Río de la Plata: Tendencias, Vulnerabilidades y medidas para la adaptación. *Medio Ambiente y Urbanizacion* (ISSN: 0328-0306), 67(1):77-93, Instituto Internacional de Medio Ambiente y Desarrollo, América Latina (IIED-AL), Buenos Aires, Argentina..

Nagy, G.J.; Ponce, A.; Pshennikov, V.; Silva, R.; Forbes, E.A.; Kokot, R. (2005) - Desarrollo de la Capacidad de Evaluación de la Vulnerabilidad Costera al Cambio Climático: Zona Oeste de Montevideo como Caso de Estudio. *In:* V. Barros; A. Menéndez & G.J. Nagy (orgs.), *El Cambio Climático en el Río de la Plata, project assessments of impacts and adaptation to climate change (AIACC)*, pp.173-187, CIMA-CONYCET-UBA, Buenos Aires, Argentina.

NCA (2013) - Scenarios for Climate Assessment and Adaptation: Participatory Scenario Planning. NCA - National Climate Assessments- United States Global Change Research Program. Available on-line at: http://scenarios.globalchange.gov/accouncement /17.pdf

Nicholls, R.J.; Hanson, S.E.; Lowe, J.A.; Warrick, R.A.; Lu, X.; Long, A.J.; Carter, T.R. (2011) - Constructing Sea-Level Scenarios for Impact and Adaptation Assessment of Coastal Area: A Guidance Document. 47p., Supporting Material, Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA), Available on-line at http://www.ipcc-data.org/docs/Sea _Level_Scenario_Guidance_Oct2011.pdf

Preston, B.L; Dow, K.; Berkhout, F. (2013) - The Climate Adaptation Frontier, *Sustainability*, 5(3):1011-1035. DOI: 10.3390/su5031011.

Reser, J.P.; Swim, J. K. (2011) - Adapting to and coping with the threat and impacts of climate change. *American Psychologist*, 66(4) :277–289. DOI: http://www.ncbi.nlm.nih.gov/pubmed/ 21553953

Rogers, S.; Tanski, J. (2012) - "Win-Win" Climate Change Adaptation Strategies: Lessons Learned From Sea Grant Coastal Processes and Hazards Programming. 14p., North Carolina Sea Grant Wendy Carey, Delaware Sea Grant UNC-SG-12-06,14 pp. Available on-line at http://seagrant.noaa.gov/Portals/0/ Documents/what_we_do/focus_areas/hazard_resilient_coastal_communi ties/resources/White Paper - Coastal Processes and Hazards.pdf

Sistema Nacional de Respuesta al Cambio Climático-SNRCC (2010) - Plan Nacional de Respuesta al cambio Climático: Diagnóstico y lineamientos estratégicos. Sistema nacional de Respuesta al Cambio Climático y la Variabilidad (SNRCC), Ministério de Vivienda, Ordenamiento Territorial y Médio Ambiente (MVOTMA). Montevideo, Uruguay. Available on-line at: http://www.preventionweb.net/files/21530_15250pnralcclimuruguay 20101.pdf

Sterman, J. D. (2001) - System dynamics modeling: Tools for learning in a complex world. *California Management Review,* 43(4):8-25. DOI: 10.2307/41166098

Tompkins, E.l. (2005) - "Planning for climate change in small islands: Insights from national hurricane preparedness in the Cayman Islands". *Global Environmental Change,* 15(2):139-149. DOI: 10.1016/j.gloenvcha.2004.11.002

UCC (2011) - Implementing pilot adaptation measures in coastal areas of Uruguay. 6p., UCC - Unidad de Cambio Climático,

working paper 1, GEF-Project URU/07/G32 "Implementing pilot adaptation measures in coastal areas of Uruguay", UCC-DINAMA-UNDP, 2011, Montevideo, Uruguay, 6 pp. Available on-line at https://www.google.com.br/search?client=safari&rls=en&q=www.adaptationlearning.net.pdf&ie=UTF-8&oe=UTF-8&gfe_rd=cr&ei=JNxaVNrrKNGJhASdm4CwAw

Verocai, J.E.; Caballero, J.; Nagy, G.J.; Bidegain, M.; Gomez-Erache, M. (2013) - Eventos extremos que impactaron la costa uruguaya: Causas y Consecuencias. *XV COLACMAR*, Punta del Este, Uruguay.

Weber, E.U. (2006) - Evidence-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). Climatic Change, 77(1-2):103-120. DOI: 10.1007/s10584-006-9060-3

Wilby, R,; Dessai, S. (2010) - Robust Adaptation to Climate Change. *Weather*, 65(7):180–185. DOI: 10.1002/wea.543

World Bank (2010) - *The Costs to Developing Countries of Adapting to Climate Change New Methods and Estimates. Consultation Draft.* 84p., EACC - Economics of Adaptation to Climate Change Team, The World Bank, Washington, DC, USA. Available on-line at http://siteresources.worldbank.org/EXTCC/Resources/EACC-june2010.pdf

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):569-579 (2014)

http://www.aprh.pt/rgci/pdf/rgci-507_Eastman.pdf | DOI: 10.5894/rgci507

The potential for young citizen scientist projects: a case study of Chilean schoolchildren collecting data on marine litter*

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ABSTRACT

A wealth of environmental and ecological questions are answered with the help of citizen scientists of all ages, but schoolchildren (<18 years) rarely participate in these projects. This is surprising considering that many citizen science projects would ideally complement modern school curricula, ranging from science, to math, reading and arts. Here we present a citizen science project supported by schoolchildren who investigate the problem of marine litter along the Chilean coast. Schoolchildren received specially designed education materials, carefully tested instructions and sampling kits. Wherever possible they were accompanied by recent university graduates, who supported the teacher in supervising the sampling process. After the samplings, schoolchildren were enthusiastic and expressed interest in participating in future environmental projects. Based on our experience, we present seven steps for designing a successful citizen science project with schoolchildren. We suggest that involving schoolchildren in citizen science projects will not only enhance the spatial and temporal scale of data collection, but also support school curricula, public understanding of the scientific process, and environmental management decisions.

Keywords: citizen science, schoolchildren, data collection, education materials, marine litter

RESUMO

O potencial para projetos de jovens cientistas cidadãos: um estudo de caso de alunos chilenos na recolha de dados sobre lixo marinho

Uma grande variedade de questões ambientais e ecológicas são respondidas com a ajuda de cidadão cientistas de todas as idades, mas os alunos (<18 anos) raramente participam nestes projetos. Isto é surpreendente, considerando que muitos projetos científicos de cidadania idealmente complementam os modernos currículos escolares, que vão desde ciência, matemática, leitura e artes. Aqui apresentamos um projeto de ciência e cidadania apoiada por alunos que investigam o problema do lixo marinho ao longo da costa chilena. Os alunos receberam materiais de educação especialmente concebidos, instruções cuidadosamente testadas e kits de amostragem. Sempre que possível, os alunos foram acompanhados por jovens diplomados, que apoiaram o professor na supervisão do processo de amostragem. Após as recolhas, os alunos estavam entusiasmados e manifestaram interesse em participar em futuros projetos ambientais. Com base na nossa experiência, apresentamos sete passos para a conceção de um projeto de ciência e cidadania bem sucedido com alunos. Sugerimos que envolver alunos em projetos de ciência e cidadania irá não só aumentar a escala espacial e temporal da recolha de dados, mas também apoiar currículos escolares, a compreensão pública do processo científico, e as decisões de gestão ambiental.

Palavras-chave: *Ciência cidadã; alunos; recolha de dados; materiais de educação; lixo marinho*

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1. Introduction

The study of many environmental and ecological questions requires the collection of data over dense spatial and temporal scales (Devictor *et al.*, 2010; Hochachka *et al.*, 2012). Where these data cannot be obtained remotely (e.g. by automatic stations or satellites), extensive networks of sampling stations on the ground are needed. Taking frequent samples at many different sites poses enormous challenges for small research teams. Therefore, when data collection can be done by untrained collaborators, scientists often work together with interested citizens, who can come from a wide range of educational backgrounds (Silvertown, 2009). Citizen scientists support a wealth of scientific studies, gathering biological records (from plants to insects, snails, fish and birds), assessing ecological risks (invasive species), and measuring water quality, soil parameters, noise pollution or climate data (*e.g.,* Beaubien & Hamman, 2011; Kolok *et al.*, 2011; Worthington *et al.*, 2011; Bonney *et al.*, 2014).

In the marine management field, challenges like counting whale sightings require vigilance over long periods of time (Davies *et al.*, 2012): an ideal task for a rotating group of young students for a science project. Also, when trying to accurately identify the range of invasive marine species, volunteers can successfully cover the extensive spatial scales needed (Thiel *et al.*, 2014). Instead of using limited university resources to send laboratory members into the field for weeks at a time, trained teachers and their schoolchildren could cover many times more territory due to sheer numbers. National studies that would otherwise be impractical suddenly become possible when one considers using networks of citizen scientists from localities spread along extensive coastlines (Eastman *et al.*, 2013; Hidalgo-Ruz & Thiel, 2013).

Most of these citizen science projects involve adult collaborators, including university students (Dickinson *et al.*, 2010, and references therein). Younger citizens, e.g. schoolchildren, rarely participate in the collection of scientific data (for exceptions see Osborn *et al.*, 2005; Delaney *et al.*, 2008; Braschler *et al.*, 2010; Weckel *et al.*, 2010; Galloway *et al.*, 2006, 2011). This is surprising since many of the aims of citizen science projects nicely complement the objectives of modern school curricula (e.g. Villegas *et al.*, 2010). For example, distinguishing the color morphs in snails and using those data to calculate percentages is something that schoolchildren all over the world can do to support the learning objectives of math classes. Measuring the pH of water samples fits perfectly in the chemistry curriculum. Reading and interpreting instructions complements the objectives of language curricula. The annual schedule of most courses is ideally suited for long-term monitoring programs that require an annual sampling frequency. Engaging schools throughout the state or country would guarantee a high spatial resolution of sampling. Most importantly, though, schoolchildren would gather their data under the supervision of a university-trained teacher (e.g. Galloway *et al.*, 2011), who is knowledgeable in his or her field and also the ideal connection to the research scientists. All these considerations underline the enormous potential for schoolchildren as contributors to citizen science projects.

Our objectives in this contribution are (i) to present the design and some results of a citizen science program, initiated in 2007, in which schoolchildren supported several scientific studies that examined the problem of marine litter along the coasts of Chile, (ii) to provide a guide, based on our experience, of the seven main steps required for successful research projects supported by schoolchildren, (iii) to promote this approach in linking scientists and schoolchildren in the quest to find answers to urgent environmental questions, and (iv) to demonstrate the relevance of data produced by young citizen science studies in coastal management.

A case study: marine litter – a worldwide problem that requires local knowledge

Throughout the world large quantities of anthropogenic litter reach the oceans, causing significant ecological impacts (Gregory, 2009). Litter comes from ships, rivers and shoreline users (Pruter, 1987). Most anthropogenic litter in the sea are plastics (Thompson *et al.*, 2009), which persist for many years in the environment and are distributed throughout all ocean environments (Barnes *et al.*, 2009). Some litter may immediately sink to the seafloor and litter has been found at all depths of the oceans (Barnes *et al.*, 2009). A large proportion of plastic litter floats at the sea surface, smothering coastal environments (Williams & Simmons, 1997), or accumulating in the center of the oceanic gyres (Maximenko *et al.*, 2012). Over time, most of these plastics fragment into ever smaller pieces (Moore, 2008). Plastics of all sizes cause harm to wildlife, fish and marine invertebrates by entanglement or by ingestion (Gregory, 2009; Teuten *et al.*, 2009).

The accumulation of marine litter, and specifically of plastic debris, has caused concern in many countries throughout the world. Most research on the distribution, sources and impacts of marine litter have been conducted in the northern hemisphere. While the problem is widespread in other parts of the world, e.g. in Asia, Africa or South America, knowledge about the distribution and sources of marine litter is limited (Ivar do Sul & Costa, 2007). In particular, in the SE Pacific little information was available about the amounts of marine litter in coastal environments. A quantitative survey in coastal waters had suggested that floating litter was more abundant near coastal cities (Thiel *et al.*, 2003),

but the lack of information about litter distribution hinders identification of sources. During a scientific outreach project (http://www.cientificosdelabasura.cl/), schoolchildren recorded large amounts of litter on beaches in northern-central Chile (30° S) and initial observations indicated that most of this litter had local sources because litter had spent little time at sea due to onshore winds and coastal currents (Bravo *et al*., 2009; Thiel *et al*., 2011). Since the coasts of Chile extend over most of the SE Pacific, a program was established to examine the problem of marine litter across 4000 km of shoreline (from 18° S to 53° S). Over the past 7 years this research program was supported by more than 5,000 schoolchildren from all over Chile.

Schoolchildren investigating marine litter in Chile

Scientists in Chile have a long tradition of collaborating with schoolchildren. During the late 1960s the "*Juventudes Científicas de Chile*" (Scientific Youth of Chile) were founded, replicating similar initiatives in Europe. Since the early 1970s the *Juventudes Científicas* were active throughout the country with many local chapters that were directed by university-trained scientists. They conducted summer camps (*Campamento Científico*) and also science fairs for young explorers (*Feria Científica Juvenil*) at the National Museum of Natural History. Supported by individual efforts and despite political turmoil, the *Juventudes Científicas* continued these activities during the 1970s and 80s. Finally, in 1995 the Chilean Science Foundation CONICYT established a program (EXPLORA) that encouraged scientists to return to the classroom and work with schoolchildren. In most cases, scientists let the schoolchildren participate in particular aspects of their current research. Some of these initiatives have gone on to collaborations with school-children to gather new data that otherwise would not be available.

Marine litter is a ubiquitous problem along the entire coast of Chile, but it had remained mostly ignored by the small marine science community, which was mainly occupied with other urgent problems such as shoreline construction, pollution from industry and mining, overfishing, species invasions and others (for overview see Fernández *et al.*, 2000). Given its ubiquity and the fact that counting marine litter does not necessarily require sophisticated equipment, this was considered an ideal topic to be investigated by schoolchildren.

2. Research program and collaborative approach

This program is being conducted along the entire Chilean coast, from Arica in the north (18° S) to Punta Arenas in the south (53° S). Every year a specific research topic is tackled by participating schools, ranging from 30 to 48 schools. Within the program of the *Científicos de la Basura* so far three national research studies have been conducted, on (i) the amounts and types of marine litter, (ii) the quantities and types of microplastics, and (iii) the perceptions of beach users. In the first study schoolchildren counted and classified anthropogenic litter in 9 m^2 plots that were replicated in several transects across the beach. In the second study, they carefully scraped and sieved the upper sand layer from 0.25 m^2 plots; they then sorted and counted all microplastic items retained in the sieve. The perceptions of beach users were obtained from a national survey where schoolchildren interviewed people in their local community, asking them about sources of litter, their littering behaviors and suggestions to mitigate the problem of marine litter.

Each study consists of at least one preparatory activity, the field sampling, and in the most recent study, also a concluding activity. Participating students come from grades 5 to 11. Contacts with the schools were established by phone, email or through local advisors. These scientific advisors, in most cases marine biologists graduated from Universidad Católica del Norte (UCN) who work in administrative positions (*e.g.,* fisheries services or environmental agencies) or at universities across the country, were contacted to support the schoolchildren during the sampling process. Schools were selected to cover the entire country. Most schools readily agreed to participate in the samplings, and for each school one teacher together with his/her course participated in the annual study. These teachers were accompanied by the scientific advisors and were in constant contact with our administrative office via email and telephone. During each study, some schools (< 20 %), which had originally agreed to participate and received all the materials, either did not conduct the sampling or did not send the data or samples. On the other hand, some teachers participated in several studies during successive years.

Learning about the problem and preparation

The participating courses received education materials, instructions and sampling kits. For each activity the research team and artists prepared story books (26 to 34 pages) that were specifically designed for the respective study and targeted to the age group of the participating schoolchildren but were not directly tied to any curriculum. Each story followed a thread that touched on all the environmental issues at stake. For example, the most recent story follows the journey of a little female fish (Jurella) and her friends into the open ocean where they ingest microplastics and become sick (figure 1A and 1B, download the story at http://www. Cientificos-delabasura.cl/docs/jurella.pdf)

The story is fictional, but it contains some factual issues, e.g. that the jurel (horse mackerel – *Trachurus murphyi*) is the most important pelagic fish in Chile,

and that larvae and early juvenile stages develop within the Humboldt Current System but then migrate towards open ocean waters (Thiel *et al.,* 2007). Microplastic ingestion by pelagic fishes has indeed been observed (Boerger et al., 2010; Davison & Asch, 2011), but whether *T. murphyi* ingests microplastic is not known at present. Thus, the story itself mingles factual and fictional elements. However, on each page there is a brief paragraph that reports biological and environ-mental facts that are based on the scientific literature (figure 1B).

Each schoolchild receives a personal copy of the story book. During the preparatory class, the schoolchildren read the story in class (figure 1C). Teachers may then discuss particular aspects of the story with their class. The schoolchildren take their copy home where they can continue to read the story and also might share it with family and friends. Adequate educational materials are important assets for citizen science projects (Bonney *et al.,* 2009).

The protocols for the marine litter studies are prepared for the age groups participating in the program (grades 5 – 11). They are initiated by a brief motivational dialogue of fictional characters. These dialogues and the protocols are read during the preparatory class (figure 1D). The sampling protocols are kept as simple as possible, being supported by schematic drawings, data tables and a list of sampling tools (for importance of supporting materials see also Hochachka *et al.,* 2012).

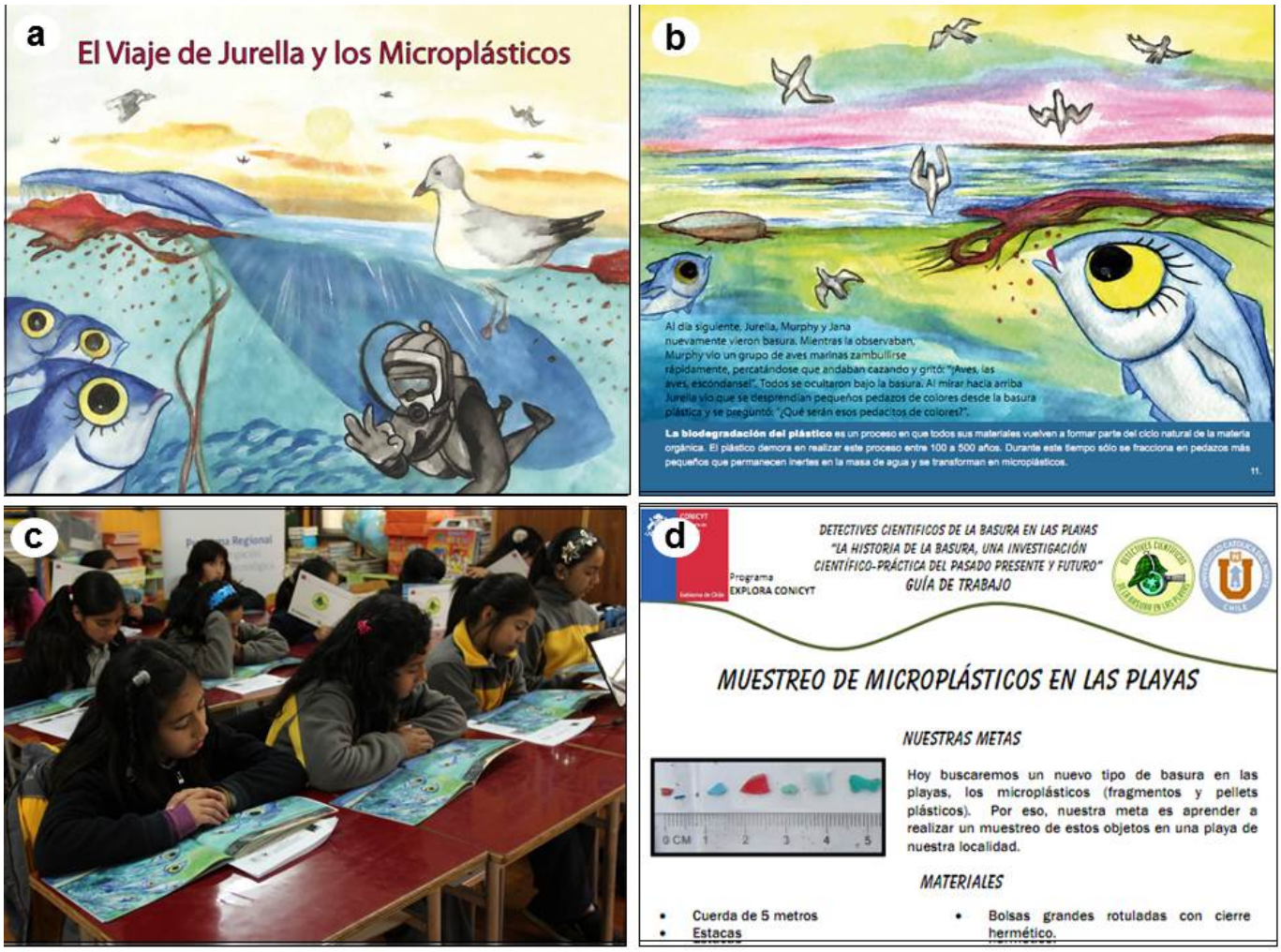

Figure 1 - (A) Cover of the story book reporting the travels of the main character (the young female fish Jurella) together with her friends into the open South Pacific ocean. Translated title: The Travels of Jurella and the Microplastics. (B) Example page from the book with the fictional story in the center and brief facts on the bottom. (C) Schoolchildren reading the story in class. (D) Manual for microplastics sampling. All stories created by the *Cientificos de la Basura* can be downloaded at http://www.cientificosdelabasura.cl/cuentos.php where other materials for schoolteachers are also available (in Spanish).

Figura 1 - (A) Capa do livro que conta a história das viagens do personagem principal (o peixe jovem do sexo feminino chamado Jurella) com os seus amigos no sul Oceano Pacífico. Titulo traduzido: As Viagens de Jurella e os Microplásticos. (B) Uma das páginas do livro com a história ficcional na parte central e com alguns fatos na parte inferior. (C) Alunos lendo a história na sala de aula. (D) Manual para amostragem de microplásticos. Todas as histórias foram criadas por Cientificos de la Basura (Cientistas do Lixo) e podem ser baixadas em http://www.cientificosdelabasura.cl/cuentos.php onde também estão disponíveis (em espanhol) outros materiais para os professores.

Sampling marine litter and collecting data

Sampling strategies for marine litter are highly variable (*e.g.*, Ryan *et al.,* 2009; Hidalgo-Ruz *et al.,* 2012). Scientific sampling schemes for marine litter can be complex and might require expensive laboratory equipment. For example, sampling of very small microplastics (<1 mm) requires an infrared spectrometer in order to confirm the identity of the plastic particles. Clearly these kinds of sophisticated samplings and laboratory analyses are prohibitive for most citizen science projects. Straightforward sampling techniques and instantaneous data collection are desirable attributes for projects with schoolchildren (Braschler *et al.,* 2010), and compromises might have to be made between scientific goals and feasibility.

Herein, the basic tools were simple, consisting of marked ropes and sticks to delimit the sampling areas on the beach, and additionally sieves, trays and plastic bags for the microplastic study (figure 2). For all studies, there was a datasheet on which the data or the answers of interviewees were recorded (figure 2). Sampling was always done in groups of 2-6 schoolchildren, and teamwork was encouraged in the groups. For example, in the case of the interview survey, one kid read the questions while the other one wrote down the answers of the person that was interviewed (figure 2D).

Data evaluation, reflection, and communication of results

All data evaluation was done centrally at the home of the *Científicos de la Basura* at Universidad Católica del Norte in Coquimbo, Chile. Once all datasheets were received, these were carefully checked for incomplete or unreasonable data. In all cases the vast majority of the datasheets passed this quality control. In the case of the microplastics study, all samples were counted by the

Figure 2 - (A) Sampling for macroplastics. (B) Sieving of sand for microplastics. (C) Sorting of microplastics from material retained in the sieve. (D) Recording the answers of interviewees; one kid asked the questions, while the other wrote down the answers.

Figura 2 - (A) Amostragem de microplásticos. (B) Peneiração da areia para microplásticos. (C) Triagem de microplásticos no material retido na peneira. (D) Registrando as respostas dos entrevistados; um garoto fazia as perguntas, enquanto o outro escrevia as respostas.

schoolchildren, but they were asked to send the samples to our laboratory, where these were recounted. We found a good correlation between the numbers of microplastics reported by the schoolchildren and our recounts (Hidalgo-Ruz & Thiel, 2013).

Data evaluation was mainly descriptive, supported by graphs (figure 3). Graphics were kept as simple as possible, because the results were gathered in a study report that was shared with the teachers and also with the general public (figure 3). The results show that there is variation across the country, with highest amounts of litter and large proportions of samples with microplastics in the northern zone, where beach visitors are thought to be responsible for the majority of the litter on the beaches (figure 3).

Teachers were encouraged to reflect upon their results together with their class. While some teachers provided us with feedback, for the first two studies (marine litter and user perceptions) we did not know whether all teachers conducted this concluding activity. For the most recent study (microplastics), we therefore designed a brief activity that was done a few days after the microplastic sampling. Schoolchildren entered their data in an interactive website, and they could then generate simple bar graphs, which allowed them to compare their own results with those of the other participating schools.

Schoolchildren also responded to a brief survey about the activity and their perceptions of it. For example, after the microplastics study more than 70% of the schoolchildren admitted that before this activity they did not know about microplastics. Almost all of them (96%) expressed interest in participating in future environmental activities.

Participation in the projects also generated curiosity. Without explicitly soliciting it, we occasionally received questions that schoolchildren raised during the post-sampling reflection. Some teachers also asked the schoolchildren to write or draw about their experiences. Promoting independent inquiry is an important benefit of citizen science projects (Trumbull *et al.*, 2000), and this process should be encouraged during the class room reflections (Barab & Hay, 2001). Conferences where schoolchildren present their results are also considered highly valuable, because they allow the students to discuss their own data with others (Evans *et al.*, 2001).

Communication of results throughout educational establishments, local communities, and via scientific publications is the last part of the process and a crucial one. This provides a source of recognition that motivates young scientists to stay committed to the task over the years, which is necessary for long-term studies. For the research presented here, results were sent to the most prestigious and most widely read Chilean newspapers and were subsequently published with a high level of accuracy, becoming a point of pride and validation for all participants. The studies on marine litter (Bravo *et al.*, 2009), microplastics (Hidalgo-Ruz & Thiel, 2013), and beach user perception (Eastman *et al.*, 2013) were published in international journals, and publication of the other studies is presently in progress.

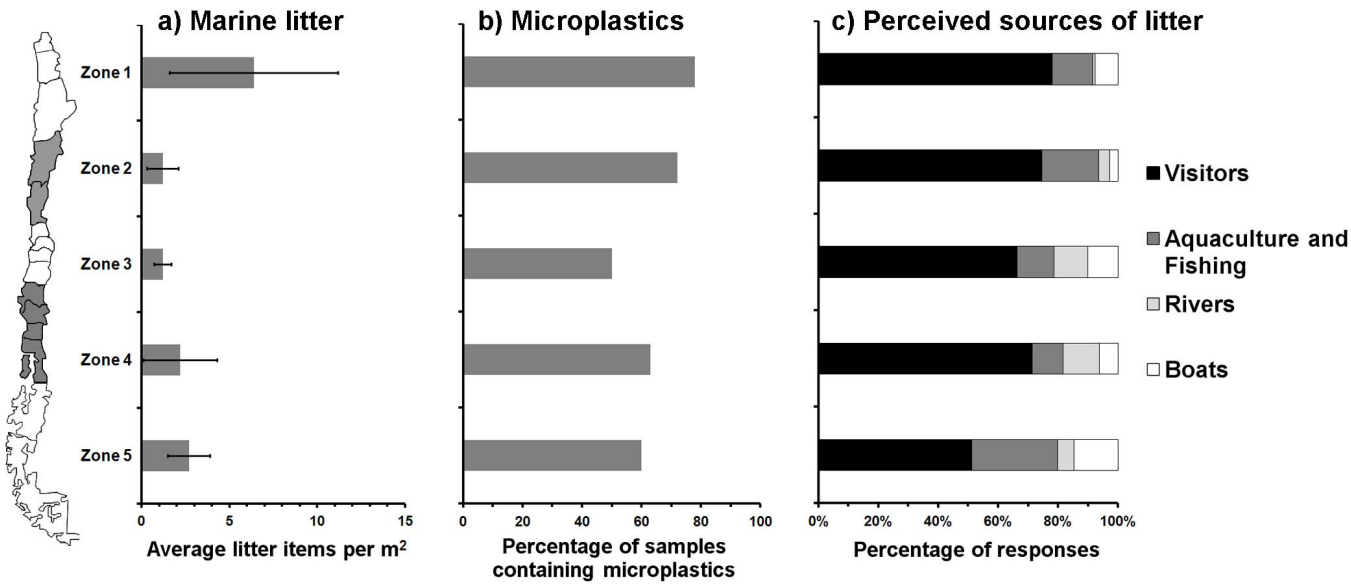

Figure 3 - (A) Amounts of macroplastics along the coast of Chile. (B) Proportion of samples with microplastics. (C) Participants' answers to the question: "where does the trash in your community come from?"

Figura 3 - (A) Quantidades de microplásticos ao longo da costa do Chile. (B) Proporção de amostras com microplásticos. (C) Respostas dos participantes à pergunta: "qual é a origem do lixo na comunidade?"

3. Discussion

Seven steps for a successful scientific study with schoolchildren

Our experience carrying out extensive research projects with young citizen scientists has led us to synthesize the process into a straightforward series of steps to follow to design a successful research project with school-children (Table 1), regardless of scientific field or habitat. To get started one must identify the research question, which should be expressed in plain words so as to be easily understood by the participating schoolchildren. After initial contact with interested teachers and scientific advisors, the project coordinators should frequently communicate with them – any scientific study supported by schoolchildren depends on the interest, knowledge and experience of the teacher! During an introductory class, schoolchildren are introduced to the study and they receive educational materials with background information. After reading the protocol with the question, the instructions, and data tables, the schoolchildren are familiarized with the sampling kit. On the sampling day, they are divided in groups, and each group carefully collects its samples and records them on the datasheet. At the end of the field sampling, the teacher gathers all completed datasheets, revises them for completeness, and then sends them to the research scientists together with eventual samples. Following the data evaluation, the research scientists share the principal results with the schoolchildren, which opens space for discussions and inquiry. This is also the opportunity to acknowledge each school with a certificate of participation and additional tokens. Teachers should also have the option to request the study data for their classes, e.g. science or math classes. The scientists leading the project should make an effort to publish the results in not only scientific publications but also local and national news media so as to recognize the citizen scientists' work. Any publications resulting from a study should be sent to the teachers and school direc

Table 1 - Seven steps required for the design of a successful research project supported by schoolchildren.

Tabela 1 - Sete etapas necessários para a elaboração de um projeto de pesquisa apoiado pelo sucesso escolar.

Seven steps	Description
(1) Identify question	Define a clear and simple question, expressing it in plain words. Answering this question should make a contribution to the advancement of scientific knowledge. Ensure that data sampling is inexpensive and can be conducted by schoolchildren.
(2) Recruit teacher and scientific advisor	Contact teacher and scientific advisor (a local professional with a relevant university degree), explain the objectives of the project, and describe the relevance of the study and the benefit for the schoolchildren. Generate specific instructions for the teacher, and make sure that (s)he prepares before the field sampling. Maintain frequent communication with the teacher, who is your most important ally.
(3) Motivate schoolchildren	Develop education materials and sampling protocols (with schemes and data tables) targeted to schoolchildren. Describe to them the importance of the project, making sure they understand that they will gather environmental data that will contribute to resolving a scientific question. Have tokens for each kid, e.g. storybooks, caps, calendars, notepads, pencils, and/or awards for groups or the entire course.
(4) Do the sampling	On the way to the sampling site or the day before the activity, schoolchildren re-read the protocol. At the site, schoolchildren are divided into teams, each receiving its own sampling tools. Within each team, some kids take samples or read interviews, while others record the data. The teacher and the scientific advisor are available to answer questions. At the end of the field sampling, the teacher gathers the completed data sheets.
(5) Reflect about sampling	Back in the class room the schoolchildren reflect about the event; the teacher raises questions that promote independent inquiry (Examples: Did you expect so much litter? Where did the litter come from? What ecological impact does the litter cause? Do you think that other schools will have different results? Why?).
(6) Gather and evaluate data	Request that all teachers collect the datasheets, check them for correct identification, and mail the originals to you immediately after the event. Remind teachers and use this opportunity to thank them for their participation. Generate descriptive statistics of your data that show the key results in straightforward terms.
(7) Communicate results to schoolchildren and public	Prepare simple graphics that can be easily understood by schoolchildren. Integrate these results in a news bulletin that is available on the website or printed. Send this to the school together with a certificate of participation and tokens of appreciation. Keep teachers and students informed if the study is publicized in the news media or in a scientific publication so as to recognize their hard work.

tors, who then may share them with the participating schoolchildren (depending on the time lag between the study and publication date).

Schoolchildren supporting environmental research

Our experiences showed that schoolchildren (grades 5 - 11) are able to follow simple sampling instructions and to collect environmentally relevant data. Results from another citizen science project that required correct identification of two invasive crab species showed that very young schoolchildren (grade 3) achieved 80% correct identification, while older schoolchildren (grade 7) correctly identified the crabs in more than 95% of the cases (Delaney *et al.*, 2008). In a project on intertidal rocky shorelines, schoolchildren from grades 7 to 12 counted emblematic organisms such as purple seastars with the same precision as well-trained university scientists (Osborn *et al.*, 2005). Estimates by school-children (grades 3 – 10) of white oak stands coincided with those of professionals (Galloway *et al.*, 2006). In another study, schoolchildren (grades 1 – 8) counted mule deer and elk reliably along their daily schoolbus routes (Galloway *et al.*, 2011). For water samples taken and analyzed by schoolchildren (grades 5 - 12), there was a good correlation with the values obtained by professionals (Peckenham *et al.*, 2012). These examples show that schoolchildren can collect useful environmental data when receiving well-designed instructions (see also Rock & Lauten, 1996). The schools participating in our program come from highly variable backgrounds (all economic levels; rural and urban schools) and also the family background of schoolchildren varied widely within each class. In order to overcome possible problems, we asked the teachers to assemble the working groups adequately, i.e. ensuring that each group had one academically strong student and one student with positive leadership abilities.

Working with schoolchildren on citizen science projects can have many advantages, including wide spatial coverage (if many schools are involved), regular sampling (annual schedules) and competent supervisors (university-trained teachers). However, several aspects need to be kept in mind. The motivational level of schoolchildren and teachers might initially not be as high as that of many other citizen science groups, such as bird watchers, flower friends, and others. Most citizen scientists are highly motivated volunteers, and while this initially might not be the case for schoolchildren they are curious to learn about their environment and can be easily motivated.

Any citizen science project should also give something back to the participating citizens (Silvertown, 2009). This is especially the case for projects with schoolchildren. Educational material and simple sampling tools (e.g. a magnifying glass, forceps, or a notepad), which each participating schoolchild obtains as a personal token can have a lasting impact, especially when it can be shared with others, e.g. a book or a tool (Galloway *et al.*, 2011). The most important reward for the schoolchildren is the contact with a scientific project and with the research scientists (Braschler *et al.*, 2010). Seeing that they contribute information and help solve a scientific question can be very motivating for the schoolchildren. It is thus instrumental that the scientists return the results from their study to the schoolchildren (Hochachka *et al.*, 2012). We recommend preparing a concise news bulletin (published in print or on a website) that describes the main result of the study in clear and plain language, supported by a figure and a photograph. This information can also be shared with local and national news media, thus making the students feel part of an important network of young scientists and reinforcing camaraderie.

It is important to note that the long-term success of citizen science projects with schoolchildren depends on the teachers and school directors (Weckel *et al.*, 2010). Frequent interactions with them are important (Osborn *et al.*, 2005) and having in-person interaction, whether with the research scientists or local scientific advisors, can help maintain their interest and technical expertise. Coordinators of citizen science projects should also listen to the teachers who best know their schoolchildren, what they can and like to contribute, and also what they – as educators – would expect from a program (Evans *et al.*, 2001; Brewer, 2002; Baumgartner *et al.*, 2006). While standardized data are important for scientific studies, instructions should be sufficiently flexible such that teachers can adjust them to their course curricula (Spencer *et al.*, 1998). Enthusiastic teachers might even incorporate aspects from the project into their course programs and further develop the project beyond questions initially designed by research scientists (see e.g. Osborn *et al.*, 2005). Because long-term scientific questions require repetition of procedures year after year, to keep teachers engaged in the process intermediate goals and rewards could be set for the teacher to ensure long-term commitment.

Schoolchildren doing environmental science – an opportunity for coastal managers

Many scientific studies require large-scale sampling of basic environmental data. This poses enormous challenges to small research teams. At the same time schoolchildren learn scientific methods in the classroom, receiving elemental training in recognizing species or measuring environmental parameters such as temperature or pH. Similar science curricula are covered in schools throughout the world, and identical topics are taught to new students every year. This offers a great opportunity because schoolchildren can collect

meaningful data that would not be available otherwise. Several citizen science projects (including those described and discussed here) have shown that with specific instructions schoolchildren are capable of gathering reliable data. Based on these considerations we encourage research scientists and school teachers to form alliances in the quest for gathering large-scale and long-term environmental data (see also Kolok & Schoenfuss, 2011).

These alliances have produced practical management results. A review of marine citizen science studies showed that a principal focus of this work has been to inform management decisions (Thiel *et al.*, 2014). A study using data gathered in a schoolkid survey project in Chile (Eastman *et al.*, 2013) regarding beach users was cited by the Chilean Senate as part of a law proposal to fine those who litter on beaches (Senado de Chile, 2012). Another citizen science survey of marine debris in central California directly influenced a ban on Styrofoam take-out containers from local municipalities (Rosevelt *et al.*, 2013).

In addition to generating scientific information, schoolchildren learn about their environment and the scientific process (Osborn *et al.*, 2005; Weckel *et al.*, 2010). Gathering ecological data and reflecting about the results also raises environmental awareness (Braschler, 2009) and can connect children to nature in a way that lasts a lifetime (Sagarin and Pauchard, 2012). This is especially relevant because this approach reaches broad demographic groups (as opposed to birders, for example), and schoolchildren can transmit their new knowledge and enthusiasm to their families who also may not have contact with the scientific or environmental fields, multiplying the societal benefit of these programs. Working with schoolchildren poses specific challenges to research scientists because instructions need to be targeted towards the training background of these young citizen scientists. However, the rewards are manyfold as enthusiastic schoolchildren are ideal ambassadors for the scientific cause.

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References

Barab, S.A.; Hay, K.E. (2001) – Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, 38(1):70–102. DOI: 10.1002/1098-2736(200101)38:1<70::AID-TEA5>3.3.CO;2-C

Barnes, D.K.A.; Galgani, F.; Thompson, R.C.; Barlaz, M. (2009) – Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B,* 364:1985–1998. DOI: 10.1098/rstb.2008.0205

Baumgartner, E.; Duncan, K.M.; Handler, A.T. (2006) – Student–scientist partnerships at work in Hawaii. *Journal of Natural Resources and Life Sciences Education,* 35:72–78. DOI: 10.2134/jnrlse2006.0072

Beaubien, E.G.; Hamann, A. (2011) – Spring flowering response to climate change between 1936 and 2006 in Alberta, Canada. *BioScience,* 61(7):514–524. DOI: 10.1525/bio.2011.61.7.6

Boerger, C.M.; Lattin, G.L.; Moore, S.L.; Moore, C.J. (2010) – Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Marine Pollution Bulletin,* 60(12):2275–2278. DOI: 10.1016/j.marpolbul.2010.08.007

Bonney, R.; Cooper, C.B.; Dickinson, J.; Kelling, S., Phillips, T.; Rosenberg, K.V.; Shirk, J. (2009) – Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience,* 59(11):977–984. DOI: 10.1525/bio.2009.59.11.9

Bonney, R.; Shirk, J.L.; Phillips, T.B.; Wiggins, A.; Ballard, H.L.; Miller-Rushing, A.J.; Parrish, J.K. (2014) – Next steps for citizen science. *Science,* 343(6178):1426–1437. DOI: 10.1126/science.1251554

Braschler, B. (2009) – Successfully implementing a citizen-scientist approach to insect monitoring in a resource-poor country. *BioScience,* 59(2):103–104. DOI: 10.1525/bio.2009.59.2.2

Braschler, B.; Mahood, K.; Karenyi, N.; Gaston, K.J.; Chown, S.L. (2010) – Realizing a synergy between research and education: how participation in ant monitoring helps raise biodiversity awareness in a resource-poor country. *Journal of Insect Conservation,* 14(1):19–30. DOI: 10.1007/s10841-009-9221-6

Bravo, M.; de los Ángeles Gallardo, M.; Luna-Jorquera, G.; Núñez, P.; Vásquez, N.; Thiel, M. (2009) − Anthropogenic debris on beaches in the SE Pacific (Chile): Results from a national survey supported by volunteers. *Marine Pollution Bulletin,* 58(11):1718−1726. DOI: 10.1016/j.marpolbul.2009.06.017

Brewer, C. (2002) – Conservation education partnerships in schoolyard laboratories: A call back to action. *Conservation Biology,* 16(3):577–579. DOI: 10.1046/j.1523-1739.2002. 01633.x

Davies, T.K.; Stevens, G.; Meekan, M.G.; Struve, J.; Rowcliffe, J.M. (2012) – Can citizen science monitor whale-shark aggregations? Investigating bias in mark–recapture modelling using identification photographs sourced from the public. *Wildlife Research,* 39(8):696–704. DOI: 10.1071/WR12092

Davison, P.; Asch, R.G. (2011) – Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. *Marine Ecology Progress Series,* 432:173–180. DOI: 10.3354/meps09142

Delaney, D.G.; Sperling, C.D.; Adams, C.S.; Leung, B. (2008) – Marine invasive species: Validation of citizen science and implications for national monitoring networks. *Biological Invasions,* 10(1):117–128. DOI: 10.1007/s10530-007-9114-0

Devictor, V.; Whittaker, R.J.; Beltrame, C. (2010) – Beyond scarcity: Citizen science programmes as useful tools for conservation biogeography. *Diversity and Distributions,* 16(3):354–362. DOI: 10.1111/j.1472-4642.2009.00615.x

Dickinson, J.; Zuckerberg, B.; Bonter, D.N. (2010) – Citizen science as an ecological research tool: Challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics,* 41:149–172. DOI: 10.1146/annurev-ecolsys-102209-144636

Eastman, L.B.; Núñez, P.; Crettier, B.; Thiel, M. (2013) – Identification of self-reported user behavior, education level,

and preferences to reduce littering on beaches – A survey from the SE Pacific. *Ocean & Coastal Management,* 78:18–24. DOI: 10.1016/j.ocecoaman.2013.02.014

Evans, C.A.; Abrams, E.D.; Rock, B.N.; Spencer, S.L. (2001) – Student/scientist partnerships: A teachers' guide to evaluating the critical components. *The American Biology Teacher,* 63(5):318–323. DOI: 10.1662/0002-7685(2001)063[0318:SSP]2.0.CO;2

Fernández, M.; Jaramillo, E.; Marquet, P.A.; Moreno, C.A.; Navarrete, S.A.; Ojeda, F.P.; Valdovino, C.R.; Vásquez, J.A. (2000) – Diversity, dynamics and biogeography of Chilean benthic nearshore ecosystems: an overview and guidelines for conservation. *Revista Chilena de Historia Natural,* 73(4):797–830. Available on-line at: http://www.scielo.cl/pdf/rchnat/v73n4/art21.pdf

Galloway, A.W.E.; Tudor, M.T.; Vander Haegen, W.M. (2006) – The reliability of citizen science: A case study of Oregon white oak stand surveys. *Wildlife Society Bulletin,* 34(5):1425–1429. DOI: 10.2193/0091-7648(2006)34[1425:TROCSA]2.0.CO;2

Galloway, A.W.E.; Hickey, R.J.; Koehler, G.M. (2011) – A survey of ungulates by students along rural school bus routes. *Society and Natural Resources: An International Journal,* 24(2):201–204. DOI: 10.1080/08941920903222572

Gregory, M.R. (2009) – Environmental implications of plastic debris in marine settings – Entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B,* 364:2013–2025. DOI: 10.1098/rstb.2008.0265

Hidalgo-Ruz, V.; Gutow, L.; Thompson, R.C.; Thiel, M. (2012) – Microplastics in the marine environment: A review of the methods used for identification and quantification. *Environmental Science and Technology,* 46(6):3060–3075. DOI: 10.1021/es2031505

Hidalgo-Ruz, V.; Thiel, M. (2013) – Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): A study supported by a citizen science project. *Marine Environmental Research,* 87-88:12–18. DOI: 10.1016/j.marenvres.2013.02.015

Hochachka, W.M.; Fink, D.; Hutchinson, R.A.; Sheldon, D.; Wong, W.K.; Kelling, S. (2012) – Data-intensive science applied to broad-scale citizen science. *Trends in Ecology and Evolution,* 27(2):130–137. DOI: 10.1016/j.tree.2011.11.006

Ivar do Sul, J.A.; Costa, M.F. (2007) – Marine debris review for Latin America and the wider Caribbean region: from the 1970s until now, and where do we go from here? *Marine Pollution Bulletin,* 54(8):1087–1104. DOI: 10.1016/j.marpolbul.2007.05.004

Kolok, A.S.; Schoenfuss, H.L. (2011) – Environmental scientists, biologically active compounds and sustainability: The vital role for small-scale science. *Environmental Science and Technology,* 45(1):39–44. DOI: 10.1021/es100455d

Kolok, A.S.; Schoenfuss, H.L.; Propper, C.R.; Vail, T.L. (2011) – Empowering citizen scientists: The strength of many in monitoring biologically active environmental contaminants. *BioScience,* 61(8):626–630. DOI: 10.1525/bio.2011.61.8.9

Maximenko, N., Hafner, J.; Niiler, P. (2012) – Pathways of marine debris derived from trajectories of Lagrangian drifters. *Marine Pollution Bulletin,* 65(1-3):51–62. DOI: 10.1016/j.marpolbul.2011.04.016

Moore, C.J. (2008) – Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research,* 108(2):131–139. DOI: 10.1016/j.envres.2008.07.025

Osborn, D.A.; Pearse, J.S.; Roe, C.A. (2005) – Monitoring rocky intertidal shorelines: A role for the public in resource management. *In:* O. T. Magoon, H. Converse, B. Baird, B. Jines & M. Miller-Henson (eds.), *California and the World Ocean '02, Conference Proceedings*, pp. 624-636, American Society of Civil Engineers, Reston, VA, USA. DOI: 10.1061/40761(175)57

Peckenham, J.M.; Thornton, T.; Peckenham, P. (2012) – Validation of student generated data for assessment of groundwater quality. *Journal of Science Education and Technology,* 21(2):287–294. DOI: 10.1007/s10956-011-9317-0

Pruter, A.T. (1987) – Sources, quantities and distribution of persistent plastics in the marine environment. *Marine Pollution Bulletin,* 18(6, suppl.B):305–310. DOI: 10.1016/S0025-326X(87)80016-4

Rock, B.N.; Lauten, G.N. (1996) – K-12 Grade students as active contributors to research investigations. *Journal of Science and Technology,* 5(4):255–266. DOI: 10.1007/BF01677123

Rosevelt, C.; Los Huertos, M.; Garza, C.; Nevins, H.M. (2013) – Marine debris in central California: Quantifying type and abundance of beach litter in Monterey Bay, CA. *Marine Pollution Bulletin,* 71(1-2):299–306. DOI: 10.1016/j.marpolbul.2013.01.015

Ryan, P.G.; Moore, C.J.; van Franeker, J.A.; Moloney, C.L. (2009) – Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B,* 364:1999–2012. DOI: 10.1098/rstb.2008.0207

Sagarin, R.; Pauchard, A. (2012) – *Observation and ecology: broadening the scope of science to understand a complex world*. Island Press. ISBN: 978-1597268264. DOI: 10.5822/978-1-61091-230-3.

Senado de Chile (2012) - Quienes ensucien o dañen playas, ríos y lagos deberán realizar un mínimo de 15 días de trabajos comunitarios (Proyecto de ley). Senado de Republica de Chile, Boletín 8179-07, Valparaíso, Chile. Available on-line at http://www.senado.cl/quienes-ensucien-o-danen-playas-rios-y-lagos-deberan-realizar-un-minimo-de-15-dias-de-trabajos-comunitarios/prontus_senado/2012-03-09/121332.html

Silvertown, J. (2009) – A new dawn for citizen science. *Trends in Ecology and Evolution,* 24(9):467–471. DOI: 10.1016/j.tree.2009.03.017

Spencer, S.; Huczek, G.; Muir, B. (1998) – Developing a student-scientist partnership: Boreal forest watch. *Journal of Science Education and Technology,* 7(1):31–43. DOI: 10.1023/A:1022532131864

Teuten, E.L.; Saquing, J.M.; Knappe, D.R.; Barlaz, M.A.; Jonsson, S.; Bjorn, A.; Rowland, S.J.; Thompson, R.C.; Galloway, T.S.; Ymashita, R.; Ochi, D.; Waanuki, Y.; Moore, C.; Viet, P.H.; Tana, T.S.; Prudente, M.; Boonyatumanond, R.; Zakaria, M.P.; Akkhavong, K.; Ogata, Y.; Hirai, H.; Iwasa, S.; Mizukawa, K.; Hagino, Y.; Imamura, A.; Saha, M.; Takada, H. (2009) – Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B,* 364:2027–2045. DOI: 10.1098/rstb.2008.0284

Thiel, M.; Hinojosa, I.; Vásquez, N.; Macaya, E. (2003) – Floating marine debris in coastal waters of the SE-Pacific (Chile). *Marine Pollution Bulletin,* 46(2):224–231. DOI: 10.1016/S0025-326X(02)00365-X

Thiel, M.; Macaya, E.C.; Acuña, E.; Arntz, W.E.; Bastías, H.; Brokordt, K.; Camus, P.; Castilla, J.C.; Castro, L.R.; Cortés, M.; Dumont, C.P.; Escribano, R.; Férnandez, M.; Gajardo, J.A.; Gaymer, C.F.; Gomez, I.; González, A.E.; González, H.E.; Haye, P.A.; Illanes, J.E.; Iriarte, J.L.; Lancellotti, D.A.; Luna-Jorquera, G.; Luxoro, C.; Manriquez, P.H.; Marín, V.; Muñoz, P.; Navarrete, S.A.; Peréz, E.; Poulin, E.; Sellanes, J.; Sepulveda, H.H.; Stotz, W.; Tala, F.; Thomas, A.; Vargas, C.A.; Vasquez, J.A.; Vega, J.M.A. (2007) – The Humboldt current system of northern and central Chile: Oceanographic processes, ecological interactions and socioeconomic feedback.

Oceanography and Marine Biology: An Annual Review (ISSN: 0078-3218), 45:195–344. Available on-line at http://figema.cl/online/pdf/OceanogrMarBiolAnnuRev_45_195_344.pdf

Thiel, M.; Bravo, M.; Hinojosa, I.A.; Luna, G.; Miranda, L.; Núñez, P.; Pacheco, A.S.; Vásquez, N. (2011) – Anthropogenic litter in the SE Pacific: an overview of the problem and possible solutions. *Journal of Integrated Coastal Zone Management,* 11(1):115-134. DOI: 10.5894/rgci207

Thiel, M.; Penna-Díaz, M.P.; Luna-Jorquera, G.; Salas, S.; Sellanes, J.; Stotz, W. (2014) – Citizen scientists and marine research: volunteer participants, their contributions, and projection for the future. *Oceanography and Marine Biology: An Annual Review,* 52:257–314.

Thompson, R.C.; Moore, C.J.; vomSaal, F.S.; Swan, S.H. (2009) – Plastics, the environment and human health: Current consensus and future trends. *Philosophical Transactions of the Royal Society B,* 364:2153–2166. DOI: 10.1098/rstb.2009.0053

Trumbull, D; Bonney, R.; Bascom, D.; Cabral, A. (2000) – Thinking scientifically during participation in a citizen-science project. *Science Education,* 84(2):265–275. DOI: 10.1002/(SICI)1098-237X(200003)84:2<265::AID-SCE7>3.0.CO;2-5

Villegas, J.C.; Morrison, C.T.; Gerst, K.L.; Beal, C.R.; Espeleta, J.E.; Adamson, M. (2010) – Impact of an ecohydrology classroom activity on middle school students' understanding of evapotranspiration. *Journal of Natural Resources and Life Sciences Education,* 39(1):150–156. DOI: 10.4195/jnrlse.2009.0044k

Weckel, M.E.; Mack, D.; Nagy, C.; Christie, R.; Wincorn, A. (2010) – Using citizen science to map human-coyote interaction in suburban New York, USA. *Journal of Wildlife Management,* 74(5):1163–1171. DOI: 10.2193/2008-512

Williams, A.T.; Simmons, S.L. (1997) – Estuarine litter at the river/beach interface in the Bristol Channel, United Kingdom. *Journal of Coastal Research,* 13(4):1159–1165. Article Stable URL: http://www.jstor.org/stable/4298724

Worthington, J.; Silvertown, J.; Cook, L.; Cameron, R.; Dodd, M.; Greenwood, R.; McConway, K.; Skelton, P. (2011) – Evolution MegaLab: A case study in citizen science methods. *Methods in Ecology and Evolution,* 3(2):303-309. DOI: 10.1111/j.2041-210X.2011.00164.x

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):581-590 (2014)

http://www.aprh.pt/rgci/pdf/rgci-513_Amaral.pdf | DOI: 10.5894/rgci513

The role of environmental education in changing school students' perceptions of and attitudes toward coral reefs in the Fernando de Noronha Archipelago, Brazil *

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ABSTRACT

The objective of this study was to investigate attitudes regarding the conservation of reef environments at the Fernando de Noronha Archipelago. The project was conducted with students aged 10-18, in 2005, and included several educational activities, as well as the creation of a Reef Environment Museum at the local public school; questionnaires were administered in order to compare students' knowledge before and after these activities by using reference concepts of reefs, corals, environmental education and citizenship. We also analyzed students' views on the importance of corals, possible benefits brought about by reefs, changes in the marine environment, and their interest in participating in projects related to the conservation of reef environments. Initially, corals and reefs were perceived by students as valuable resources only when they generated economic advantages through tourism. After the educational interventions the students acquired concepts that were more aligned with environmental conservation per se; among the main results approximately 25% more students said they would agree to participate in educational projects to promote the conservation of reef environments after the interventions. However, due to the lack of interest in the project by several of what should have been key actors in the process, this study also showed that support from indirect actors (teachers, parents, school personnel) is just as important as the participation of the targeted group itself.

Keywords: citizenship; environmental perception; environmental education; coral reefs

RESUMO

O papel da educação ambiental na mudança das percepções e atitudes dos estudantes quanto aos recifes de coral no Arquipélago de Fernando de Noronha, Brasil

O objetivo deste estudo foi investigar atitudes relacionadas à conservação dos ambientes recifais no Arquipélago de Fernando de Noronha. O projeto foi conduzido com estudantes com idades entre 10 e 18 anos, em 2005, e incluiu diversas atividades educacionais, bem como a criação de um Museu de Ambientes Recifais na escolar pública local; questionários foram aplicados a fim de comparar o conhecimento dos alunos antes e após estas atividades, através do uso dos conceitos de referência de recifes, corais, educação ambiental e cidadania. Também se analisou a visão dos estudantes sobre a importância dos corais, os possíveis benefícios trazidos pelos recifes, as mudanças no ambiente marinho e o interesse na participação de projetos relacionados à conservação dos ambientes recifais. Inicialmente, os corais e os recifes foram percebidos pelos estudantes como recursos valiosos apenas quando geravam vantagens econômicas por meio do turismo.

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Após as intervenções educativas, os estudantes adquiriram conceitos que estavam mais alinhados com a conservação ambiental por si só; entre os resultados principais, aproximadamente 25% mais estudantes disseram que aceitariam participar de projetos educacionais para promover a conservação dos ambientes recifais após as intervenções. Entretanto, devido à falta de interesse de alguns dos que deveriam ter sido atores chave no processo, este estudo também mostrou que o apoio de atores indiretos (professores, pais, funcionários da escolar) é tão importante quanto à participação do grupo enfocado.

Palavras-chave: *cidadania; percepção ambiental; educação ambiental; recifes de coral*

1. Introduction

The Fernando de Noronha Archipelago (FN) is a ditrict of the state of Pernambuco, Brazil, located 545 km from the capital, Recife. The archipelago is formed by 21 islands and islets of volcanic origin; the main island – the only one that is inhabited – occupies an area of approximately 17 km^2.

The first scientific expeditions to the archipelago were carried out by Charles Darwin in the 19th century on board of the H.M.S. Beagle (Amaral *et al*., 2009; Laborel, 1970), yet anthropogenic impacts on the archipelago date back to the 18th century. At that time, most of the plant cover was removed to prevent fugitives from the local prison from hiding, and such modifications in the environment are still visible today. In spite of this, the beautiful and unique scenery that remains has potential for tourism related activities – the type of activity that maintains Fernando de Noronha's economy today.

The Fernando de Noronha National Park (PARNMAR-FN), created in 1988, includes 55% of the main island, all of the secondary islands and islets, and most of the adjacent waters up to depths of 50 m (FUNATURA, 1990). In 2001 UNESCO declared the archipelago a World Heritage Site.

Coral reefs, in turn, provide innumerable ecosystem services and carry social and economic importance. According to one estimate, reef environments are responsible for services and resources (tourism, coastal protection, food, etc.) that, if calculated in monetary terms, would be worth more than 375 billion dollars a year. Similarly, the destruction of one kilometer of coral reefs can bring about losses of up to US$1.2 million (Bryant *et al*., 1998). It is important to highlight, however, that such estimates are only for comparative educational purposes, as the true value of any given ecosystem is far beyond any amount of money.

There is a population of approximately 2,800 people on the main island, among whom there are social problems such as violence against the elderly (Araújo & Lobo Filho, 2009) and a rate of alcoholism that is much higher than in other regions of Brazil (Filizola *et al*., 2008). The population also suffers from environmental problems related to its poorly conserved ecosystems, including its reef environments (Monteiro Filho & Borges, 2003; Motta *et al*., 1998; Castro, 2010). This directly affects the local food chain and fish stocks and, consequently, the local fish industry and economy. Overall, the conservation challenges faced by the Fernando de Noronha Archipelago are common to small islands in general, where it is especially hard to balance conservation and development (Calado *et al*., 2014a; 2014b).

In Brazil, environmental education is regulated by law. On the federal level, according to the definition included in the National Environmental Education Policy, environmental education "can be understood as the processes through which individuals and collectivity construct social values, knowledge, habilities and attitudes regarding environmental conservation" (Presidência da República, 1999). This policy also states that environmental education must be present in all modalities of formal education, in a transversal manner.

However, Bizerril & Faria (2001) have highlighted that approaching environmental education from an interdisciplinary standpoint is complicated in the country because the inevitable team effort exposes (often insecure) teachers' pedagogical practices to colleagues and involves more need for studying in what is already a tight schedule. Similarly, Steele (2011) has discussed how embedding environmental education in the school curricula must be accompanied by strong professional development and confidence and leadership-boosting programs.

Education programs for school children and teenagers about coral reefs have been provided throughout the world, in locations such as Singapore (Chou & Goh, 1998), Mexico (Rodriguez-Martínez & Ortiz , 1999), the Marshall Islands (Bhandari & Abe, 2000), Tanzania (Howe, 2001), Panama (Goreau *et al*., 2003), Australia (Stepath, 2004; Stepath, 2006), Trinidad and Tobago (Armstrong, 2005), the Philippines (Goreau & Goreau, 2007) and Brazil (Silva Júnior *et al*., 2010).

Positive results were found in most of these studies. In Trinidad and Tobago, Armstrong (2005) successfully evaluated an eight-week pilot environmental education project focusing on coral reefs that was carried out in 15 primary schools. In Australia, Stepath (2004; 2006) applied and assessed a marine education program with 320 high school students of Queensland. Placed into

groups that were exposed to different educational interventions (class presentations and/or field trips), students who participated both in class presentations and field trips scored higher in terms of awareness and attitudes towards reef environments, and stated intentions to act.

Similarly, Howe (2001) analyzed the effects of a marine educational program in southern Tanzania that was carried out with 198 children in 14 schools. A preliminary evaluation showed that the program was important to expand the local knowledge base and to help the community become more active in managing coastal resources.

According to Freire (2002, 2013), teaching practices must consider personal, ethical, social, and cultural dimensions and must be approached both from individual and collective standpoints. When students in coral reef education programs become aware of local problems, they also become potential multipliers of possible local solutions. It is therefore very important that these educational activities take local socio-economic realities into consideration (Dal Pian, 1992), as well as previous knowledge and relationships with nature.

The design of this study focused on referential concepts of corals and reefs and their importance, environmental conservation, and citizenship awareness. All of these concepts are profoundly related to the archipelago's social and environmental well-being, and most especially to the population's main source of income: tourism.

Thus, this study aimed to investigate attitudes towards the conservation of reef environments in Fernando de Noronha Archipelago before and after a series of environmental education interventions with the purpose of increasing knowledge of these ecosystems, promoting citizenship and environmental awareness, and contributing to the conservation of the reef environments.

In addition to presenting findings related to students' attitudes towards conservation of local reef environments, the article follows up by discussing difficulties in the process, possible result distortions, and lessons learned.

2. Methods

The study was undertaken in 2005 at the archipelago's public school (Escola Arquipelago)– the only school in the island of Fernando de Noronha, Pernambuco State, Brazil (Figure 1) at the time – and focused on students from 5th to 8th grade (aged 10-18)[1]. The first step was to carry out a sensibilization activity to which practically all of the island's organizations were invited (school teachers and staff, NGOs, churches, staff of theday care unit, etc.). Approximately 200 people participated – almost 10% of the island's population at the time (2005).

Educational activities were developed around the following reference concepts: corals, reefs and their importance; environmental conservation; and environmental education and citizenship. The school already approached environmental education as a transversal issue.

2.1. Environmental Awareness Strategies

The educational activities included videos, photograph presentations and the display of preserved specimens and/or skeletons of corals and other components of the reef fauna. Such materials were exhibited and also used in talks by the professors from the Federal Rural University of Pernambuco (UFRPE) and some local monitors who participated in the project. Field trips involving group dynamics and guided tours were carried out[2], including diving in the local reef environments (Figure 2a-f)[3]. Although teachers did not participate actively, they were present and followed the educational activities.

In order to create a public and permanent visitation area and to promote continuous construction and dissemination of knowledge, the Reef Environment Museum (Museu do Ambiente Recifal – MAR) was installed inside the school. The material used included posters and photographs of Fernando de Noronha's reef environment, as well as preserved specimens of the reef fauna and flora. The museum was opened by the project team on June 10th, 2005, with the presence of local authorities and the school community.

2.2. Data sampling

A questionnaire completed by the archipelago's school students included 13 questions. The first five provided a profile of the students (age, gender, grade and time living on the island). The eight remaining questions were open-ended and evaluated the progress of the construction of the referential concepts while inquiring about corals and reefs and their importance; environmental conservation; environmental education; and

[1] Although presently Brazilian educational law does not use the grade format to classify class levels (former "séries" are now "anos"), this was not the case at the time of the study.

[2] See studies such as those by Ballantyne & Packer (2002), Morag *et al.* (2013) and Behrendt & Franklin (2013) for the benefits of field trips and outdoor educational programs for students.

[3] As an activity complementary to the project, in September of 2005, two students who participated in the project were selected to receive financial aid (SESU/ MEC) and to visit the research team's laboratory at the UFRPE, as well as reef environments in several beaches of the states of Pernambuco and Alagoas. These students were taught to observe, analyze and compare the biotic and abiotic components of both the continental and the archipelago reef ecosystems and were trained to become ecotourism guides. The initial idea was to train all of the students participating.

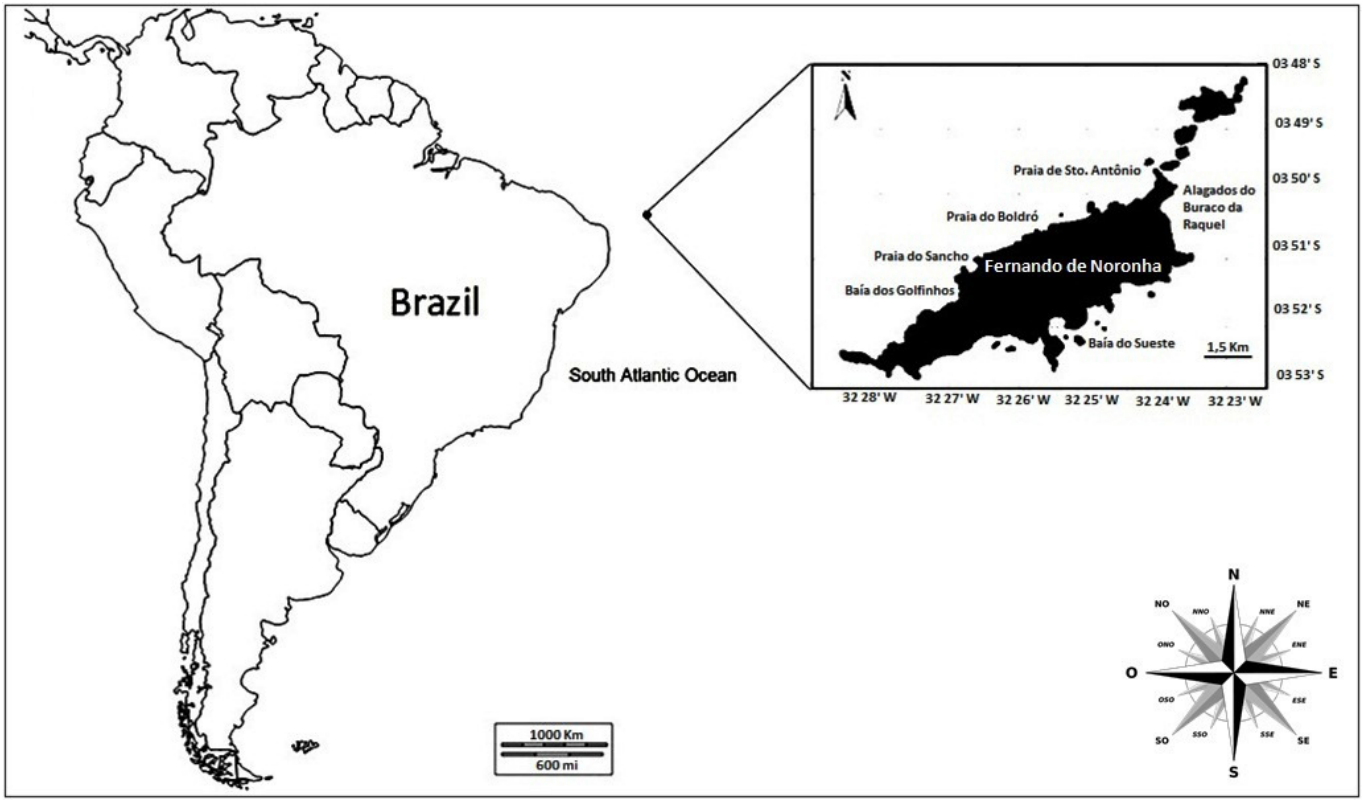

Figure 1 - Location of the Fernando de Noronha Archipelago

Figura 1 – Localização do Arquipélago de Fernando de Noronha.

citizenship awareness. It was also asked that the students list the marine animals they knew inhabited the archipelago's waters.

The questionnaires were applied three times over the 2005 school year (in February, March and June). The first happened before the educational interventions and diagnosed the students' existing perceptions and know edge about the referential concepts. The other two questionnaires were applied after the interventions and served to evaluate changes in these concepts after the educational activities.

The first interventions took place between February 28th and March 7th, 2005, and included lectures, workshops, group dynamics, guided tours, diving and observation of fauna and flora. The second intervention took place between June 6th and 10th and included similar activities[4].

The group who filled in the questionaire before any intervention was made up of 30 students from the (approximately 10% of the total student population) – these being from 5th through 8th grades. The sex ratio was approximately the same (52% male and 48% fe male). Age ranged between 12 and 18. Students had lived between one and 17 years on the island – an average of 12.2 years (half had lived there between 12 and 13 years). After the first intervention, a total of 38 students – 50% male and 50% female, aged 10 to 15 – answered the questionnaire; these students had lived an average of eight years on the island. The results of the third questionnaire will not be considered in the analysis, as explained in the next section. The majority of the students that carried out the educational activities and responded to the questionnaires were the same throughout the project.

2.3. Questionnaire Evaluation

When examining the responses we focused on the knowledge building process in order to analyze students' cognitive stage in relation to each concept in question. In this manner, it was possible to identify which concepts were under-developed (when incomplete answers were provided), which were not developed at all (when the answers were very far from the reference concept) and which were fully developed (when answers satisfactorily covered the main elements of the reference concept) (Vasconcelos *et al*., 2008).

These criteria were based on the evaluation system and terminology adopted by the Department of Education of the State of Pernambuco at the time, to which the island school is bound:

[4] The short amount of time between the interventions and questionnaire evaluations was due to limitations related to funding, as it was required that the entire project be carried out within one year.

Figure 2 - a. Material used in the lectures for students at the Archipelago Public School, Fernando de Noronha. b. Illustration panels showing reef animals, as used at the Archipelago Public School, Fernando de Noronha. c. Guided tour at Atalaia Beach for students of the Archipelago Public School, Fernando de Noronha. d. Preparing for free diving at the reefs of Atalaia Beach, Fernando de Noronha. e. Activity on citizenship for students of the Archipelago Public School, Fernando de Noronha. f. Five-senses workshop carried out with students of the Archipelago Public School, Fernando de Noronha. Photographs by Fátima Santos.

Figure 2 – a. Material utilizado nas palestras para estudantes da Escola Pública do Arquipélago de Fernando de Noronha. b. Painéis de ilustrações utilizados na Escola Pública de Fernando de Noronha mostrando animais dos recifes. c. Turnê guiada à Praia de Atalaia para os alunos da Escola Pública do Arquipélago. d. Preparação para o mergulho livre nos recifes da Praia de Atalaia, Fernando de Noronha. e. Atividade sobre a cidadania para os alunos da Escola Pública do Arquipélago de Fernando de Noronha. f. Oficina dos Cinco Sentidos realizada com os alunos da Escola Pública de Fernando de Noronha. Fotografias de Fátima Santos.

a. Constructed (C) – complete or almost complete answers, which include the main elements of the referential concepts;
b. Under construction (UC) – partial answers, lacking important elements of the referential concept;
c. Not constructed (NC) – questions left unanswered or completely incorrect which do not include any of the elements of the referential concepts.

When the third questionnaire was distributed, the project team observed that one of the teachers openly told students to rush through the questionnaire in order for class to continue, a fact that undoubtedly distorted these results. Thus, in our analysis we will only consider the results of the first and second questionnaires.

3. Results

Although this was not used as part of the evaluation, it is important to mention that students easily located and identified several organisms during the guided tours to the local beaches, such as corals, mollusks, shrimp, polychaetes, fish, starfish, sea urchins, algae, etc. They also showed that they had understood the activities carried out by enthusiastically pointing out movement, structures and relationships between these organisms.

Table 1 – Evaluated responses of the questionnaires answered by students of the Archipelago Public School (Fernando de Noronha, Brazil). Data collected during the 2005 school year before the intervention (February) and after the 1st intervention (March). Classification criteria terminology followed that adopted by the Department of Education of the State of Pernambuco/Brazil at the time of the study: not constructed (NC), under construction (UC) and constructed knowledge (C).

Tabela 1 – Avaliação das respostas aos questionários dadas pelos alunos da Escola Pública do Arquipélago (Fernando de Noronha, Brasil). Os dados foram coletados durante o ano letivo de 2005, antes da intervenção (fevereiro) e após a primeira intervenção (março). A terminologia dos critérios de classificação seguiu a adotada pela Secretaria de Educação do Estado de Pernambuco na época do estudo: não construído (NC), em construção (UC) e conhecimento construído (C).

	Before the intervention			After the 1st intervention		
Criteria/ Question	NC %	UC %	C %	NC %	UC %	C %
"Cite examples of marine animals that you know."	33	27	40	13	47	40
"What do you know about corals? And reefs?"	63	37	0	24	74	2
"Are corals important to you and to your community? Why?"	90	10	0	48	50	2
"Do reefs provide any benefits to you and to your community? Explain."	83	17	0	65	31	2
"Have you observed any kind of difference or change in the marine environment throughout time? Describe it."	77	20	3	61	39	0
"What is your understanding of environmental education?"	73	27	0	53	39	8
"Would you be interested in participating in an environmental education project related to the protection of corals and reef environments?"	80	0	20	66	24	10
"To you, what does it mean to practice citizenship?"	83	17	0	47	42	11

Students paradoxically fared worse in the third questionnaire, even though at that point they had received more information and undergone both theoretical and practical activities both in the classroom and in the field. As described previously, in this case the project team observed that one of the teachers openly told students to rush through the questionnaire in order for class to continue, a fact that undoubtedly distorted these results. The way teachers and staff treated the project might also have negatively affected the results by giving students the wrong idea that reef conservation is not that important.

In relation to the number of marine animals known before the interventions, 40% of students cited more than seven animals (thus their knowledge was considered to be constructed). The average number of animals cited amongst all students was seven, when considering the entire group. Of the 207 citations, the animals most mentioned were dolphins (13%), sharks (12%), turtles (8%), and moray eels (8%). After the first intervention, again, 40% of the students cited more than seven animals, but the general average number cited rose to eight. Out of a total of 144 citations, the animals most mentioned were sharks, fish, and rays (9% each), and corals, turtles, and dolphins (8% each).

The knowledge on corals and reefs was considered not constructed for 63% of the students before the first intervention. Among the remaining 37% (who showed knowledge under construction) responses for corals were limited to concepts such as "fragile live beings" and "barriers to contain the ocean", or "home to several marine organisms". After this first intervention the rate of responses with knowledge considered to be under construction rose to 74%, with respect to the same content as that used before the intervention. Overall, most students had trouble distinguishing the terms "reef" and "coral", which were often used interchangeably, even after the two interventions. Some considered reefs and corals a physical threat to surfers and tourists, while others saw them as ornaments that "should be softer so that tourists and surfers could take better advantage of them". Nevertheless, some students clearly absorbed new concepts and complemented their answers by citing coral symbiosis with zooxanthellae, for instance.

Regarding the importance of corals, before any intervention, most students (90%) cited solely the generation of income from tourist visitation. Only 10% listed these organisms' ecological importance. However, after the first intervention 50% of the responses mentioned at

least one kind of importance unrelated to economic profit, such as food and shelter for other marine organisms (knowledge under construction). Only 2% cited more than one kind of ecological importance, which was considered to be constructed knowledge.

Eighty-three percent of the students who answered the initial questionnaires did not see any possible benefits brought about by reefs (with the exception of the financial benefit of attracting tourists cited in some responses). As mentioned previously, many considered reefs to be an obstacle for surfers, with no advantages whatsoever. The remaining 17% (whose knowledge was considered to be under construction) cited only one service or benefit aside from profit, either as protection against the sea or as a source of food for the community. After the first intervention the number of responses with non-constructed knowledge decreased to 66%, which now included profits for the diving industry. Only 3% of the students had noticed at least one type of change in the marine environment over the past few years. Most (77%) did not answer or did not believe that the environment was being impacted in any way, which also included answers such as "corals and reefs are always being preserved in order to decorate the ocean". Twenty percent, however, demonstrated knowledge under construction by citing general problems they believed to be affecting the local marine ecosystems, such as pollution (as that recorded by Sul *et al.,* 2009, for instance), and species extinction (there are no records of recent extinctions in the archipelago). After the first intervention the rate of responses that showed non-constructed knowledge decreased to 61%, yet out-of-place comments like "new species are appearing" or "corals are reproducing themselves more and more lately" were still common.

Before any intervention, most students (73%) presented non-constructed knowledge about environmental education; the remaining students (27%) had a partial concept that "we must bring about awareness in order to preserve the environment". However, after the first intervention 8% of the responses showed constructed knowledge, while 39% showed knowledge under construction (which included responses such as "not stepping on corals" and "not removing corals from the sea") and 53% showed non-constructed knowledge.

Before the interventions, only 20% of students said they would agree to participate in an educational project to preserve coral reefs and reef environments. The other 80% either answered incoherently or openly said they would not participate (classified as non-constructed knowledge). After the first intervention, 10% thought it was important to participate (constructed knowledge) and 24% said they would participate but also showed they did not really understand the practical meaning of such participation.

Regarding the concept of citizenship, 83% of the students initially demonstrated non-constructed knowledge and responded incoherently. Even after the first intervention, 47% still showed non-constructed knowledge, with answers such as "a way for teachers to evaluate students".

4. Discussion

This project was received with enthusiasm by students and parents, who openly demonstrated their appreciation in learning more about their island's marine ecosystems and organisms. However, it did not receive the same support from the school staff. One clear example was the Reef Environments Museum. Created with the participation of the students to be a lasting educational tool inside the school, it was deliberately removed by staff before the end of the project. Unfortunately, coral reef museums directed at children are rare. In fact, Goreau & Goreau (2007) have stated that the Museo Sang Bata Sa Negros, in the Philippines, is believed to be the only children's coral reef museum in the world.

Parlo & Butler (2007) in an evaluation of partipants of a coastal marine teacher workshop in the state of Georgia (USA), revealed that teachers found it difficult to apply what was learned in the workshop because they felt compelled to follow the standard curriculum. Additionally, teachers thought it was important to focus on preparation for standardized tests.

As mentioned previously, students paradoxically fared worse in the third questionnaire despite the fact that at that point they had received more information and undergone more.

A previous study carried out in 2002 at the same school also investigated students' conservation attitudes and knowledge of corals and reefs. Steiner *et al.* (2004) studied the environmental perception of students from grades 6-9 and found different results. In that study, almost half of the students interviewed gave correct definitions of corals, while roughly one-quarter gave incorrect or partially correct answers; most also cited the importance of corals in the food chain. Regarding reefs, most students defined these structures as groups of corals.

Similarly, a study that also involved educational interventions and before and after questionnaires filled in by the students, obtained excellent results in changing the attitudes of 6th and 9th grade students of six schools located in the Metropolitan Area of Recife, also in the state of Pernambuco (Vasconcelos *et al.,* 2008). Additionally, the number of animals cited by the students of this study before the interventions was higher (40) than that found by Steiner *et al.* (2004), where only 21 organisms were listed. Both studies found similar difficulty among students regarding the distinction between

the concepts of reefs and corals. Oigman-Pszczol *et al.* (2007) encountered confusion in conceptual knowledge as well in the difference between algae and corals in a coastal tourist town in southeastern Brazil.

In Fernando de Noronha, despite the fact that many students had been born or lived on the island for several years, most of the changes observed in the marine environment were not specific to the island, but rather general responses such as "species extinction" or "marine pollution".

The fact that most students related the importance of reef environments and corals to profit is not surprising, as tourism is probably the main source of income for many of their parents. Nevertheless, the low rate of responses that included references to the ecological or intrinsic importance of the reefs is worrysome. These results were similar to those of Rodriguez-Martínez & Ortiz (1999), who in a study with primary and secondary students of Quintana Roo, a coastal state in southeastern Mexico, found that the children had little awareness of coral reefs and their importance.

Likewise, the concept of citizenship was not familiar among the students in Fernando de Noronha and had probably never been mentioned in school, as was clear in students' accounts during the interventions and in the results even after these activities.

Kaza (1995) has stated that "While traditional education programs are often aimed at school children, in its first years a marine protected area may need to direct its programs towards local leaders, government officials or influential community members". Unfortunately there was a complete lack of interest in the project by key community leaders. . Future educational projects in the area might benefit if accompanied by professional development programs directed at the school teachers, such as the one described by Rivera *et al*. (2013).

Aside from its initial intention, this study also showed that support from indirect actors (teachers, parents, etc.) is just as important as the participation of the targeted group itself (see also Sauvé, 2005). With the benefit of hindsight, our project may have been more effective if an initial phase had been dedicated exclusively to school teachers and staff.

Additionally, it is important that future programs reflect not only what is thought to be right by external perceptions (such as those of researchers), but also that of the local community. Projects that inform the social and environmental importance of the island's ecosystems but also reflect how locals value reef environments will certainly make a difference in the long run.

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References

Amaral, F.M.D.; Ramos, C.A.C.; Leão, Z.M.A.N.; Kikuchi, R.K.P.; Lima, K.K.M.; Longo, L.L.; Cordeiro, R.T.S.; Lira, S.M.A.; Vasconcelos, S.L. (2009) - Checklist and morphometry of benthic cnidarians from the Fernando de Noronha Archipelago, Brazil. *Cahiers de Biologie Marine* (ISSN: 2262-3094). 50(3):277-290, Station Biologique de Roscoff, Roscoff. France. Available on-line at http://www.sb-roscoff.fr/cbm/pdf/214135 0703

Araújo, L.F.; Lobo Filho, J.G. (2009) - Análise psicossocial da violência contra idosos. *Psicologia: Reflexão e Crítica*, 22(1):153-160. DOI: 10.1590/S0102-79722009000100020

Armstrong, H.G. (2005) - Environmental education in Tobago's primary schools: a case study of coral reef education. *Revista de Biología Tropical* (ISSN: 0034-7744), 53(1):229-238, *Universidad de Costa Rica,* São José, Costa Rica. Available on-line at http://www.redalyc.org/pdf/449/44920889024.pdf

Ballantyne, R.; Packer, J. (2002) - Nature-based Excursions: School Students' Perceptions of Learning in Natural Environments. *International Research in Geographical and Environmental Education*, 11(3):218-236. DOI: 10.1080/10382040208667488.

Behrendt, M.; Franklin, T. (2014) - A review of research on school field trips and their value in education. *International Journal of Environmental & Science Education*, 9(3):235-245. DOI: 10. 12973/ijese.2014.213a.

Bhandari, B.B.; Abe, O. (2000) - Environmental Education in the Asia-Pacific Region: Some Problems and Prospects. *International Review for Environmental Strategies* (ISSN: 1345-759), 1(1):57-77, Institute for Global Environmental Strategies, Tokyo, Japan. Available on-line at http//pub.iges.or.jp/modules/envirolib/upload/405/attach/057_077_bhandari_abe.pdf

Bizerril, M.X.A.; Faria, D.S. (2001) - Percepção de professores sobre a educação ambiental no ensino fundamental. *Revista Brasileira de Estudos Pedagógicos* (ISSN: 2176-6681), 82(200/201/202):57-69, Inep, Brasília, DF, Brazil. Available on-line at http://rbep.inep.gov.br/index.php/RBEP/article/view/414

Bryant, D.; Burke, L.; Mcmanus, J; Spalding, M. (1998) - Reefs at Risk: A Map-Based Indicator of Threats to the World´s Coral Reefs. *World Resources Institute* (ISSN: 0258-6150), 60p., Washington, D.C., U.S.A. Available on-line at http://coralreef.noaa.gov/aboutcrcp/strategy/reprioritization/wgroups/resources/climate/resources/reefsatrisk.pdf

Calado, H.; Fonseca, C.; Vergílio, M.; Costa, A.; Moniz, F.; Gil, A.; Dias, J.A. (2014a) - Small Islands Conservation and Protected Areas. *Revista Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 14(2):167-174. DOI: 10. 5894/rgci523

Calado, H.; Vergílio, M.; Fonseca, C.; Gil, A.; Moniz, F.; Silva, S.F.; Moreira, M.; Bragagnolo, C.; Silva, C.; Pereira, M.

(2014b) - Developing a Planning and Management System for Protected Areas on Small Islands (The Azores Archipelago, Portugal): the SMARTPARKS Project. *Revista Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 14(2):335-344. DOI: 10.5894/rgci496

Castro, J.W.A. (2010) - Ilhas oceânicas da Trindade e Fernando de Noronha, Brasil: Uma visão da Geologia Ambiental. *Revista Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, 10(3):303-319. DOI: 10.5894/rgci170.

Chou, L.M.; Goh, B.P.L. (1998) - Singapore coral reefs – balancing development and conservation. *In:* B. Morton (ed.), *Proceedings of the Third International Conference on the Marine Biology of the South China Sea*, pp.355-368, Hong Kong University Press, Hong Kong, China. ISBN: 978-9622094611.

Dal Pian, M.C. (1992) - O Ensino de Ciências e Cidadania. *Em Aberto* (ISSN 0104-1037), 11(55):49-55, INEP, Brasília, DF, Brazil. Available on-line at http://www.livrosgratis.com.br/arquivos_livros/me000628.pdf#page=50

Filizola, P.R.B.; Nascimento, A.E.; Sougey, E.B.; Meira-Lima, I.V. (2008) - Alcoolismo no Nordeste do Brasil – prevalência e perfil sociodemográfico dos afetados. *Jornal Brasileiro de Psiquiatria* (ISSN 0047-2085), 57(4):227-232, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil. Available on-line at http://www.scielo.br/pdf/jbpsiq/v57n4/a01v57n4.pdf

Freire, P. (2002) - *Pedagogia da Autonomia*. 54p., Paz e Terra, São Paulo, SP, Brazil. Available on-line at http://www2.uesb.br/pedh/wp-content/uploads/2014/02/Pedagogia-da-Autonomia.pdf

Freire, P. (2013) - *Educação e mudança*. 46p., Paz e Terra, Rio de Janeiro, RJ, Brazil. ISBN 978-8577532209. Available on-line at http://www.hdbr.org.br/data/site/uploads/arquivos/Paulo%20Freire%20-%20 Educação%20e%20Mudança.pdf

FUNATURA (1990) - *Plano de Manejo do Parque Nacional Marinho de Fernando de Noronha*. 253p., Fundação Pró-Natureza (FUNATURA) / Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Brasília, DF, Brasil. Available on-line at http://www.icmbio.gov.br/portal/images/stories/biodiversidade/_PARNA_MARINHA_DE_FERNANDO_ DE_NORONHA.pdf

Goreau, M.; Goreau, T.J. (2007) - *Children's Coral Reef Education Programs in Sagay: Progress Report to the Sagay Marine Reserve, the Museo Sang Bata Sa Negros, the Snorkel Bob Foundation & the Global Coral Reef Alliance*. Global Coral Reef Alliance, Cambridge, MA. U.S.A.. Available on-line at http://www.snorkelbob.com/Childrens%20Coral%20Reef%20Education%20Programs%20in%20Sagay.pdf

Goreau, M.; Goreau, T.J.; Solis, R. (2003) – Children's Environmental Education Program: Kuna Yala, Panama, Phase II. s.p., Global Coral Reef Alliance, Cambridge, MA, U.S.A.. Available on-line at http://www.globalcoral.org/_oldgcra/Children's%20Environmental%20Education%20Program,%20Kuna%20Yala, % 20Panama, %20Phase%20II.htm

Howe, V. (2001) - Local community training and education in southern Tanzania – a case study. *Marine Policy*, 25(6):445-455. DOI: 10.1016/S0308-597X(01)00029-X

Kaza, S. (1995) - Marine education and interpretation. *In:* Susan Gubbay (ed.), *Marine Protected Areas*, pp.174-198. Springer Netherlands, Dordrecht, The Netherlands. ISBN: 978-9401042345. DOI: 10.1007/978-94-011-0527-9_9.

Laborel, J.L. (1970) - Les peuplements de madreporaires des côtes tropicales du Brésil. Annales de l´Université d'Abidjan, Série E, II(3):39-47, Abidjan, Ivory Coast.

Monteiro Filho M, Borges J: (2003) - Sombras no paraíso: Pousadas domiciliares de Fernando de Noronha lutam para manter espaço. *Revista Problemas Brasileiros* (ISSN: 0101-4269), 357 (May-June): 16-18. SESC, São Paulo, São Paulo, Brazil. Available on-line at http://www.sescsp.org.br/online/artigo/1860_SOMBRAS+NO+PARAISO

Morag, O.; Tal, T.; Rotem-Keren, T. (2013) - Long-term educational programs in nature-parks: Characteristics, outcomes and challenges. *International Journal of Environmental & Science Education*, 8(3):427-449. DOI: 10.12973/ijese. 2013.213a.

Motta, M.; Silva, V.L.; Montenegro, A.A.A.; Montenegro, S.M.G.L.; Correa, M.M. (1998) - Avaliação da qualidade da água dos mananciais na ilha de Fernando de Noronha. *Revista Ambiente e Água*, 3(3):114-127. DOI:10.4136/ambi-agua.66.

Oigman-Pszczol, S.S.; Oliveira, A.E.S.; Creed, J.C. (2007) - Perceptions of coral in a coastal tourist town in Brazil. *Coral Reefs*, 26(3):667-670. DOI: 10.1007/s00338-007-0239-5

Parlo, A.T.; Butler, M.B. (2007) - Impediments to Environmental Education Instruction in the Classroom: A Post-Workshop Inquiry. *Journal of Environmental Science and Education* (ISSN: 1306-3065), 2(1):32-37, International Society of Educational Research (iSER), Turkey. Available on-line at http://www.ijese.com/IJESE_V3_N1_Parlo&Butler.pdf

Presidência da República (1999) - *Lei 9.795, de 27 de abril de 1999. Dispõe sobre a educação ambiental, institui a Política Nacional de Educação Ambiental e dá outras providências*. publicado no D.O.U. de 28.4.1999, Brasília, DF, Brazil. Available on-line at http://www.planalto.gov.br/ccivil_03/leis/l9795.htm

Rivera, M.A.J.; Manning, M.M.; Krup, D.A. (2013) - A Unique Marine and Environmental Science Program for High School Teachers in Hawai'i: Professional Development, Teacher Confidence, and Lessons Learned. *International Journal of Environmental & Science Education*, 8(2):217-239. DOI: 10.12973/ijese.2013.202a.

Rodriguez-Martínez, R.; Ortiz, L.M. (1999) - Coral reef education in schools of Quintana Roo, Mexico. *Ocean & Coastal Management*, 42(12):1061-1068. DOI: 10.1016/S0964-5691(99)00061-7

Sauvé, L. (2005) - Currents in Environmental Education: Mapping a Complex and Evolving Pedagogical Field. *Canadian Journal of Environmental Education* (ISSN 1205-5352), 10:11-37, EECOM / Lakehead University, Ontario, Canada. Available on-line at http://cjee.lakeheadu.ca/index.php/cjee/article/view/175/9

Silva Júnior, J.M.; Gerling, C.; Venturi, E.; Araújo, L.L.; Silva, F.J.L. (2010) - Em Férias Ecológicas: um programa de educação ambiental marinha em Fernando de Noronha. *In:* Alexandre de Gusmão Pedrini (org.), *Educação ambiental marinha e costeira no Brasil*, pp. 201-226, Editora da Universidade do Estado do Rio de Janeiro (EDUERJ), Rio de Janeiro, RJ, Brasil. ISBN: 978-8575111802.

Steele, A. (2011) - Beyond Contradiction: Exploring the work of secondary science teachers as they embed environmental education in curricula. *International Journal of Environmental & Science Education* (ISSN 1306-3065), 6(1):1-22, International Society of Educational Research (iSER), Turkey. Available on-line at http://www.ijese.com/IJESE_v6n1_Steele.pdf

Steiner, A.Q.; Melo, K.V.; Tavares, S.; Amaral, F.D.; Barradas, J.I.; Santos, M.F.A.V. (2004) - Moradores e estudantes do Arquipélago de Fernando de Noronha (Pernambuco/Brasil) e a percepção do ambiente recifal. *OLAM* (ISSN 1982-7784), 4(1),394-408, Rio Claro, São Paulo, Brazil.

Stepath, C.M. (2004) - Coral reef education and Australian high school students. *Proceedings of the Marine Education Society of Australasia*, n.p. (16p.). Available on-line at http://files.eric.ed.gov/fulltext/ED491455.pdf

Stepath, C.M. (2006) - *Coral reefs as sites for experiential environmental education: learning with Australian students – a foundational study*. 265p., PhD thesis, James Cook University, Queensland, Australia. Available on-line at http://researchonline.jcu.edu.au/1253/

Sul, J.A.I.; Spengler, A.; Costa, M.F. (2009) - Here, there and everywhere. Small plastic fragments and pellets on beaches of Fernando de Noronha (Equatorial Western Atlantic). *Marine Pollution Bulletin*, 58(8):1236-1238. DOI: 10.1016/j.marpolbul. 2009. 05.004.

Vasconcelos, F.A.L.; Amaral, F.D.; Steiner, A.Q. (2008) - Students' view of reef environments in the Metropolitan Area of Recife, Pernambuco State, Brazil. *Arquivos de Ciências do Mar* (ISSN 0374-5686), 41(1):104-112, Fortaleza, Ceará, Brazil.

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):591-596 (2014)

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Sampling and quantification methodology for floating solid wastes in beaches *

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Abstract

The suggested methodology aims to typify the solid waste found on the aquatic surface of the touristic beaches in Cartagena de Indias. In addition, it was designed and implemented water samplers for floating solid waste to evaluate, in a wide swath, the composition of the waste that is cast into the seawaters and affects the quality of the beach as a touristic attraction as well as disturbing a healthy aquatic ecosystem. Such developed methodology comprises both the optimal sampler´s size based on information from the waste accumulation curves, plus the sample´s size standardization for estimations of total waste content through statistical sampling techniques such as MAS and MSL. This sampling was performed in parallel and perpendicular to the coastline by using devices with specifications of 1.0 m, 0.75 m and 0.5 m width; therefore the 0.75 m width device came to be the most efficient one, whereas the movement is perpendicular due to the variety of solid waste collected. The results, along with the process of the Project implementation, provide valuable information for the development of protocols and new parameters according to environmental quality index for touristic beaches up-to-date; thus abiding by the environmental quality program framework for beaches in the Colombian Northern Caribbean area.

Keywords: aquatic ecosystem, coastline, touristic beaches

Resumo **

Metodologia para amostragem e quantificação de resíduos sólidos flutuantes nas praias

A metodologia sugerida pretende tipificar os resíduos sólidos encontrados na parte aquática superficial de praias turísticas em Cartagena das Índias. Além disso, foram desenhados e implementados amostradores de água para resíduos sólidos flutuantes, visando avaliar, de forma ampla, a composição dos resíduos que são lançados na água do mar e que afetam a qualidade das praias e das atrações turísticas, assim como a saúde dos ecossistemas aquáticos.

A metodologia desenvolvida compreende ambos, o tamanho ótimo do amostrador baseado na informação a partir de curvas de acumulação de resíduos, e a estandardização do tamanho amostral para a estimação do conteúdo total de resíduos através de técnicas estatísticas amostrais tais como MAS e MSL. A amostragem foi realizada paralelemente e perpendicularmente à linha de costa com o uso de instrumentos com 1,0m, 0,75m e 0,5m de largura, sendo que o amostrador com largura de 0,75m demostrou ser o mais eficiente entre eles para movimentos perpendiculares, devido à variedade de sólidos coletados.

Os resultados, juntamente com o processo de implementação do Projeto, aportaram uma valiosa informação para o desenvolvimento de protocolos e de novos parâmetros, de acordo com o atual índice de qualidade para praias turísticas, atendendo, dessa forma, o contexto do programa de qualidade ambiental de praias para a área Colombiana no Norte do Caribe.

***Palavras-chave**: ecossistemas aquáticos, linha de costa, praias turísticas.*

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1. Introduction

Measurement of quality of waters on beaches is generally based on chemical and microbiological parameters; however, we must consider that the visitors' perception of the beach has nowadays gained much value in the selection of it and its constant turnout (Palomino de Dios *et al*., 2012), so it is then when the presence of solid waste, either in the sand or seawater becomes a significant quality parameter (Araújo & Costa, 2006). Currently, there is a set up procedure to sort out the solid waste in the beach sand, by unit, amount and type of waste found with which it is determined the percentage of distribution of this throughout the sand as well as how hazardous it could be for visitors. Regarding the measurement of floating solid wastes, authors such as Botero (INVEMAR, 2007) have stated methods that suggest the use of multifilament devices by moving on a boat at a constant speed along the coast line in a parallel way in order to catch the floating solid waste in seawater.

According to the statement above, it was necessary to come up with a model which could be able to assess the efficiency of the method applied considering the sampling both in parallel and perpendicular to the coastline. Additionally, sample collection is proposed to be performed by a field auxiliary technician around the most crowded beach area and so the impact of a boat moving around may be diminished. Finally, as a last component, several size multifilament devices were tested (Zavala-García & Flores-Coto, 2005).

The main objective of the developed model attempted to find the effective combination among all the given variables in order to come with an easy process to monitor parameters in a reliable way.

Through this method, it is possible to get information with regards the type and percentages of floating solid waste at every beach in contrast with sanitary quality and the density of visitors in order to determine the nature of waste found in the seawater.

2. Experimental setup

The experimental setup was implemented within an area of 240 m along the touristic beach of Bocagrande in Cartagena de Indias, whose coordinates are 75º 33` 41.0``LO and 10º 28` 56.7`` LN (Google Earth). Three multifilament devices were used and assembled resembling the Bentos samplers with a 0.05 mm net and PVC piping of 0.5 inch-diameter, the net length is 2.5 in proportion to the device width (Donato, 2002), as it is shown in Figure 1.

Two movements were performed: parallel and perpendicular to the coast line, using the three different devices at each direction. The samplings were carried out in the morning before noon time, and in the afternoon before 5:00 p.m., for the beach to be analyzed from its initial and final conditions related to its user's behavior.

Therefore, for the shifting in parallel to the coast line it was determined that the ideal depth to take the sample should be between 1m and 1.5m. as it evidenced the area where most visitors gathered. During the monitoring the net was immersed down to reach the calibration mark of 0.25m. Five sections to go across were marked off with a distance of 20 m approximately and a 10m gap among each other (Figure 3).

Likewise, the second type of displacement perpendicular to the coastline was traced from the shore to waters that may reach near 1m and 1.5 m. depth, plunging the device down to the calibration mark of 0.25 m. Five section routes were outlined corresponding to each sampling device at a 30 m gap length among sections (Figure 4).

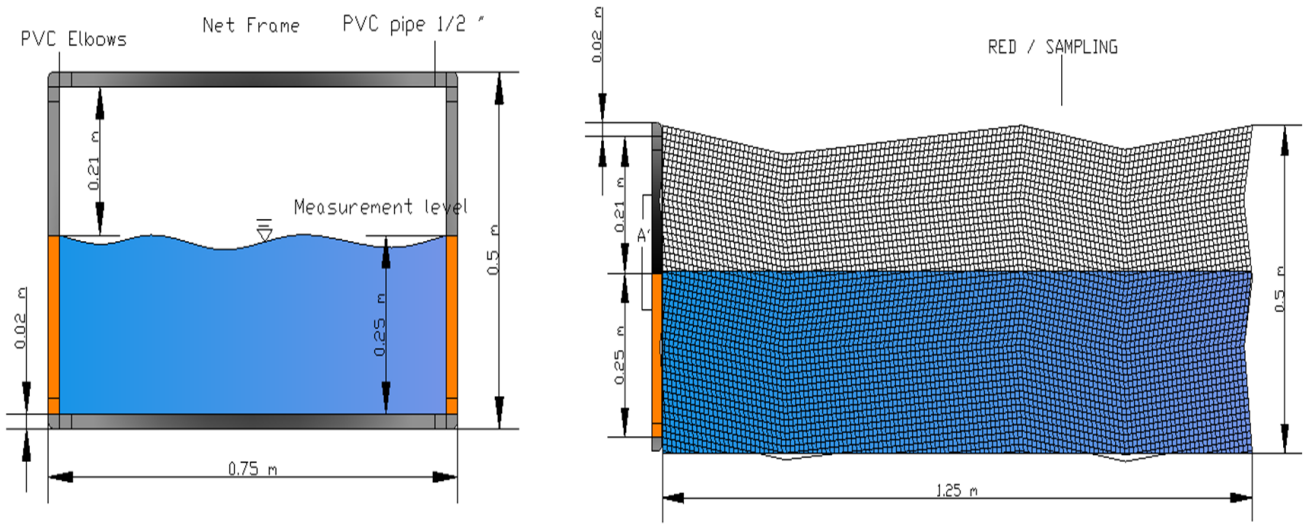

Figure 1 - Multifilament device diagram for sample collecting.

Figura 1 - Diagrama do instrumento com multifilamentos para coleta de amostras

Figure 2 - Field and Lab process

Figura 2 - Procedimentos de campo e de laboratório

Going across the outlined routes, the device is able to pick up every floating solid waste in the seawater which could be taken to the lab, labeled and stored for further classification and weighing.

For the developed model, five samples were carried out, between December 2012 and February 2013. The periods in which the research was conducted included both high and low season periods for tourism including the weather changes due to rains as documented on one of the monitoring.

Afterwards, in order to process and analyze the information statistically, the results were tabulated on an EXCEL data sheet and subsequently read through the R statistical software 3.0.2 version. Following the procedure, the density of waste average values were contrasted between sampling periods (morning and afternoon) as well as the two types of net dragging (perpendicular and parallel) by using the "T Student" test; unlike the comparison among net type (0.5, 0.75 y 1.0 m) and sampling periods for which it was applied the analysis of variance (ANOVA), one way. When comparisons were statistically meaningful with P-value < 0.05, Tukey test was employed for multiple comparison of means. (Gonzáles *et al*., 2011).

3. Results and discussion

The samples collected along the monitorings, were transported to the laboratory for drying and weighing. In order to determine the drying time length of the collected waste, a set of representative samples were taken with a weight variety considering 10 gr the minimum average and 118gr the maximum average, also containing many kinds of waste such as organic matter, plastic, paper, cardboard and fabric which dried off in an electrical oven after 5 hours at a 60°C temperature. The relationship between waste dry weight and the drying time length was obtained as shown in Figure 5, in which it is observed how the very waste tends to stabilize its weight after 3 hours drying.

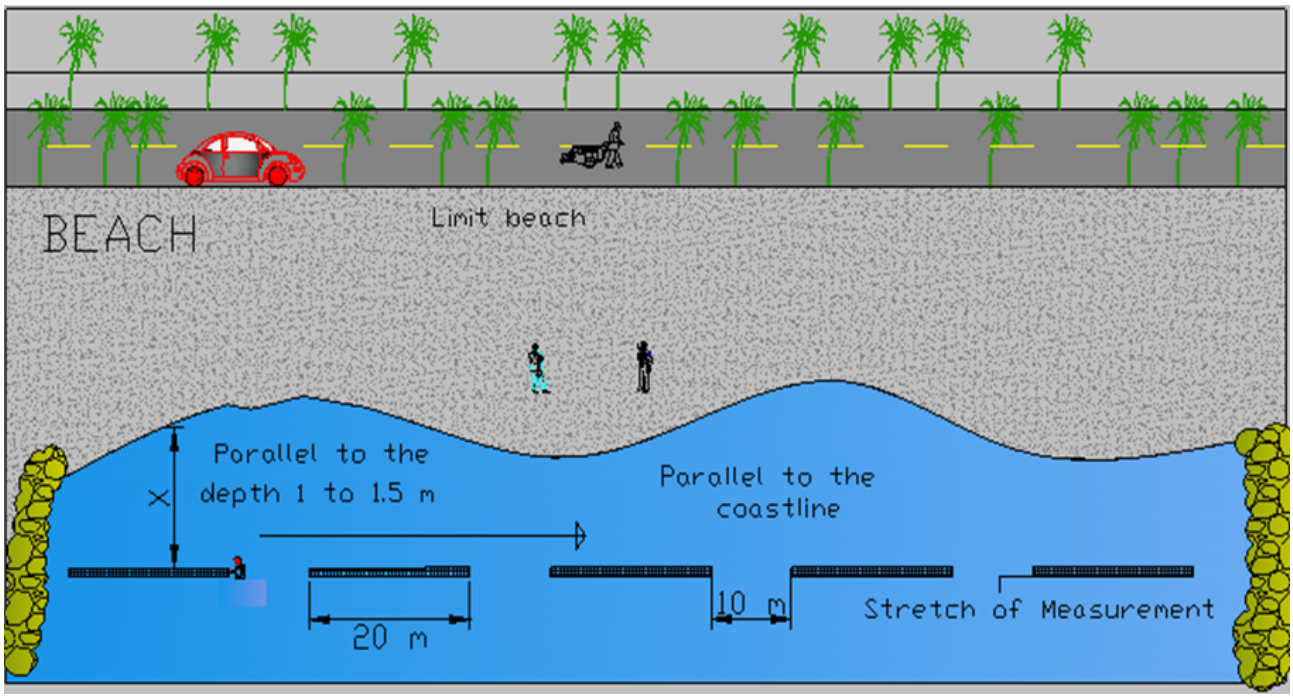

Figure 3 - Diagram of parallel displacement to the coastline.

Figura 3 - Diagrama do deslocamento paralelo à linha de costa.

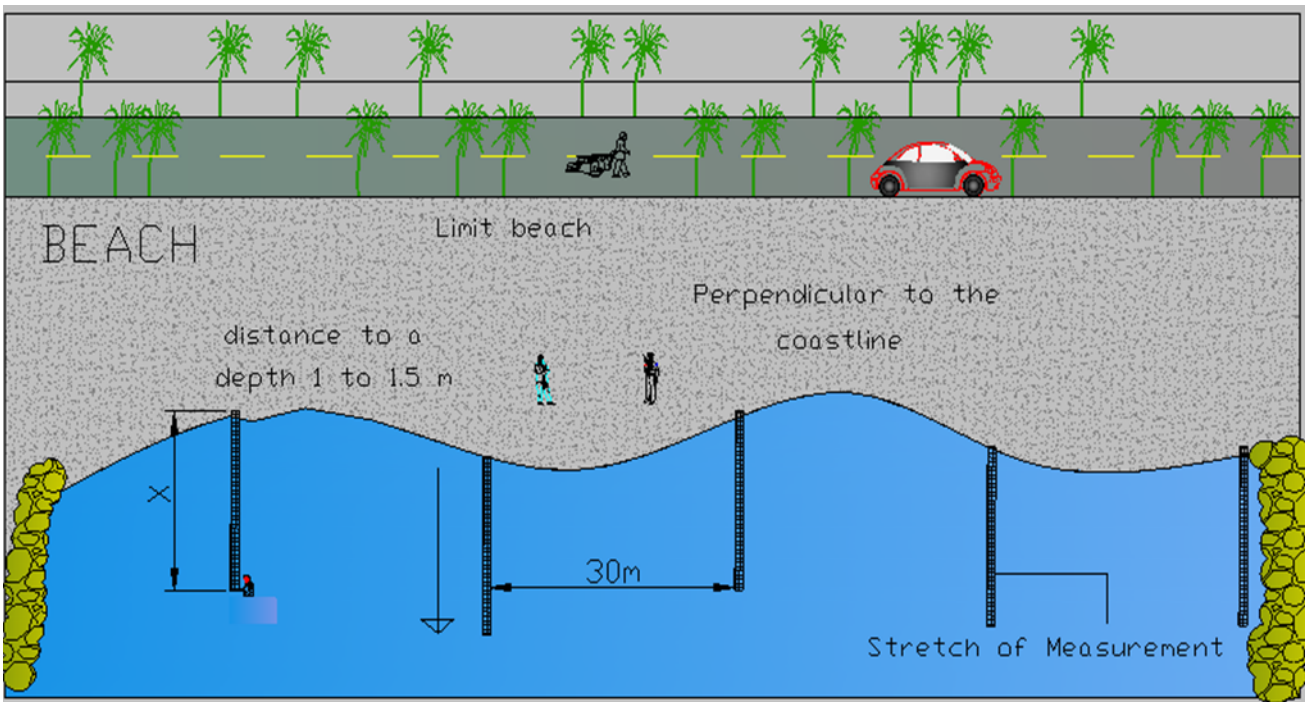

Figure 4. Diagram of perpendicular displacement to the coastline.

Figura 4. Diagrama do deslocamento perpendicular à linha de costa

According to the variables taken into account for the project, such as the device width, displacement direction, and monitoring collection period, the analysis of data through parametric model determined that this did not adjust to normal distribution, hence non- parametric tests were then applied to each analyzed variable.

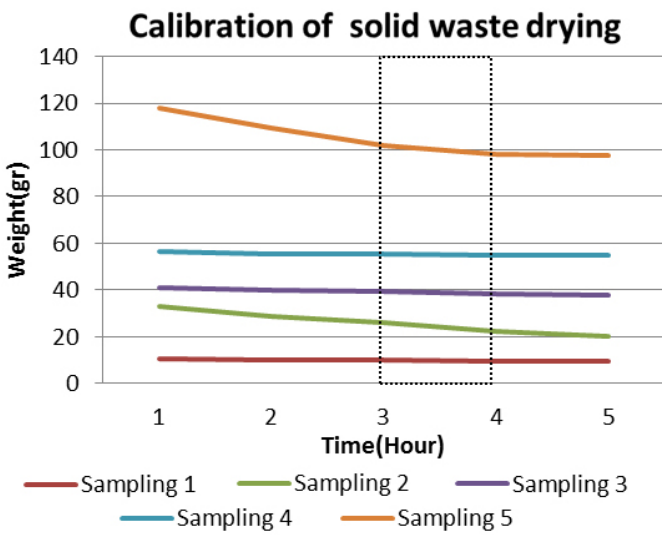

Figure 5 - Waste drying time length calibration

Figura 5 - Calibração do tempo de secagem de resíduos

The behavior of floating solid waste average density in contrast with the net type revealed no significant statistical dissimilarity (F = 2.59; p-valor > 0.05) among the three different kinds of nets used as it is observed in Figure 6. Despite the former results, the same figure evidences that the 0.75 cm net can reach greater values (2.51 g/m^3) than the ones obtained through 0.5 and 1.0 m nets whose averages came to 1.24 and 1.31 g/m^3 respectively.

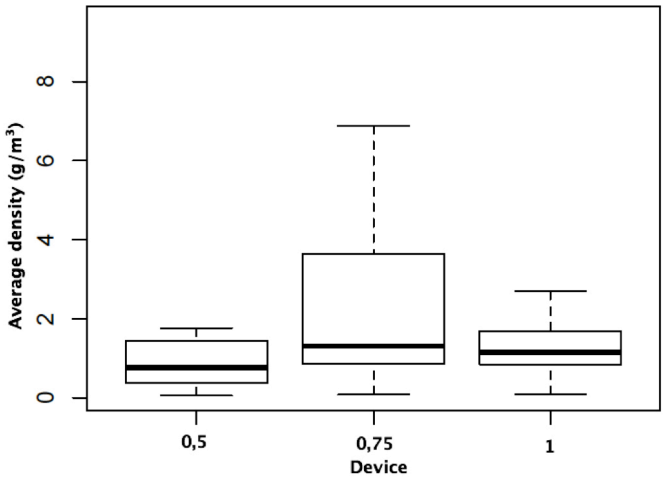

Figure 6 - Comparison of the average of floating solid waste density in terms of device width

Figura 6 - Comparação da densidade média dos resíduos sólidos flutuantes em relação à largura do instrumento.

The relation between of solid waste density average and sampling day monitoring generated an outcome that established it could be collected 1.49 g/m^3 waste in the morning whilst in the afternoon this number may increase to 1.92 g/m^3. Nevertheless the comparative analysis through the T test clearly evidenced there were no significant differences between them (T = 0.80; P-value > 0.05). The results are visualized on Figure 7.

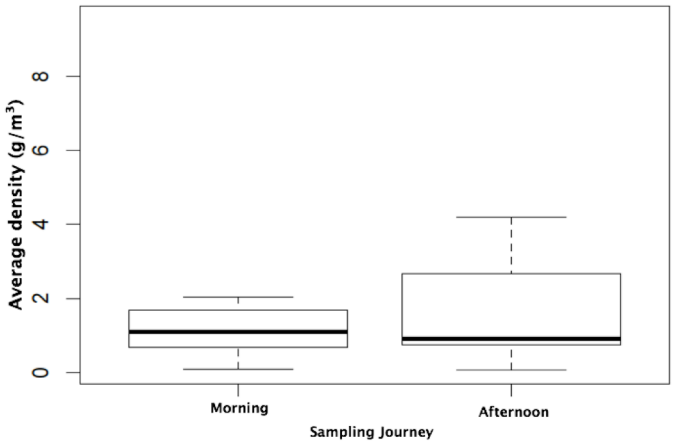

Figure 7 - Relation between average floating solid waste density and monitoring displacement.

Figura 7 - Relação entre a densidade média dos resíduos sólido flutuantes e o monitoramento por deslocamento.

By analyzing the direction of the trip around the sampling route for floating solid waste, it was found that values of collected waste density registered 1.51 on the way parallel to the coastline and 1.87 g/m^3 on the way perpendicular to the coastline; thus the relation between these values evidence there is no significant statistical dissimilarities for both mid points (T = 0.70; P >> 0.05), as it is shown in Figure 8.

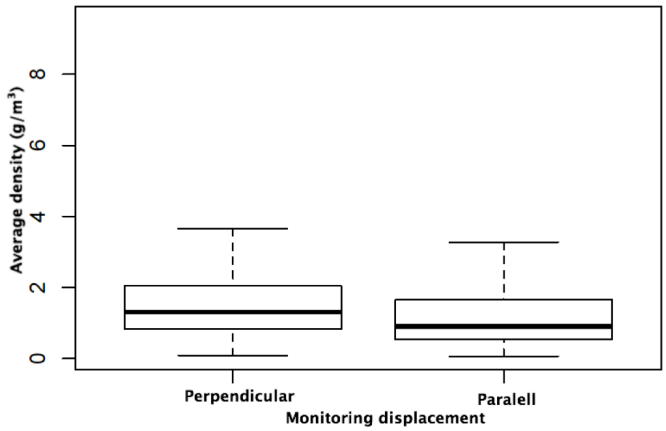

Figure 8 - Comparison between the average density range of floating solid waste and sampling collecting route.

Figura 8 - Comparação entre a amplitude média da densidade dos resíduos sólidos flutuantes e a rota para coleta de amostras

The temporary behavior of average density range of floating solid waste in the samplings around bathing areas from the beaches of study, it was registered a significant increase of its values related to its last sampling; denoting additionally, based on ANOVA, the clear differences (P-value > 0.05; F = 3.27) among previous samplings; on the other hand, through the Tukey paired test it was proved such differences were only present between sampling five with sampling one, and sampling five with sampling two (Figure 9).

As a result from the five sampling monitoring carried out comprised the period from December 2012 to March 2013, variation on the density average it is demonstrated through the fourth and fifth monitoring. This variation is attributed to weather changes, such as the rain registered during the fifth sampling, as well as to the rough seas along the fourth one where there was an evident growth of plastic material found that could have been dragged from shallow waters disposal sites towards the sampling monitoring area.

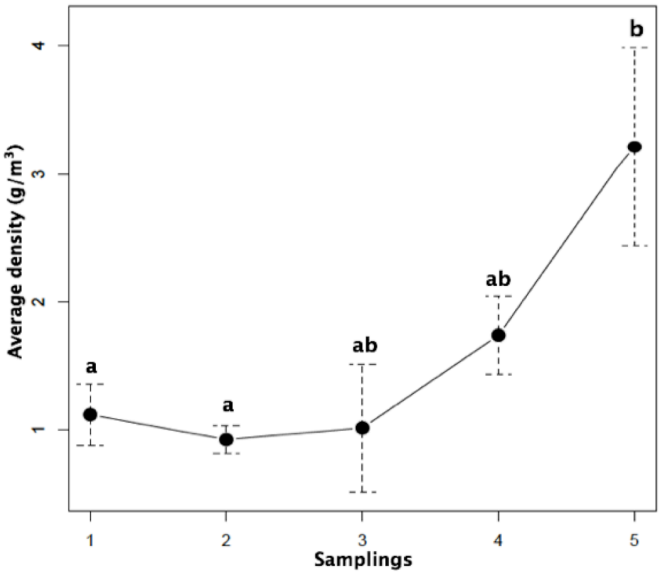

Figure 9 - Relation between Sampling monitoring and average density range of floating solid waste.

Figura 9 - Relação entre o monitoramento amostral e a amplitude da densidade média dos resíduos sólidos flutuantes

According to the data obtained in the two previous sampling displacements evaluated, the parallel displacement showed the collection of mostly vegetable waste and plastic, while the perpendicular one showed a wide variety of matter containing plastics (Silva, 2008), vegetable waste, food waste and paper which presented the highest percentage of composition. These facts demonstrated that the perpendicular displacements generate a wider range of solid waste composition and covers an area that allows comparison between the solid waste composition found in the sand and into the water. Therefore it explains how efficient the perpendicular displacement sampling monitoring can be as it encompasses the greatest area for users and swimmers (Figure 10).

3. Results and discussion

The most effective width for the sampling device was found to be 0.75 m, since it obtained the highest floating solid wastes density range, in terms of weight per filtered water cubic meter, even the device turned out to be the easiest to handle compared to the others due to its ideal dimensions for the project.

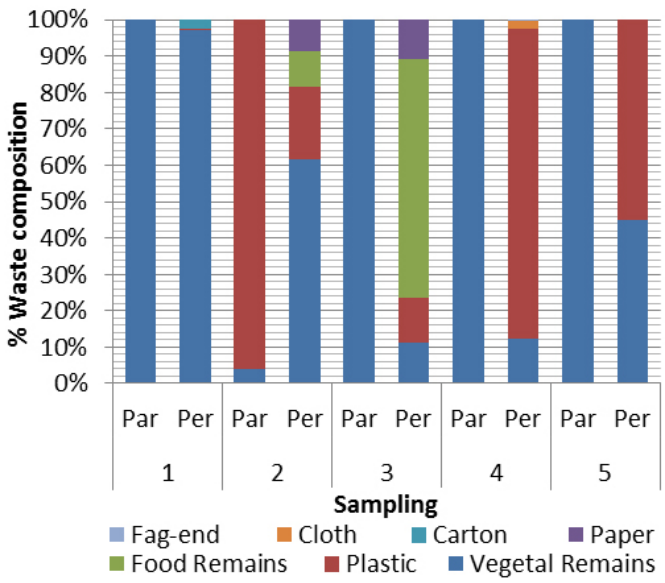

Figure 10 - Wastes composition percentage *vs* displacement type per monitoring.

Figura 10 - Percentagem da composição de resíduos vs tipo de deslocamento por monitoramento

The samples drying optimum conditions were proved to be during 3 hours and at a 60ºC temperature, for their further weighing.

From the technical point of view, the most favorable displacement for monitoring was the perpendicular to the coast line which covered a trajectory from the shore up to a 1m ± 1.5 m depth, by immersing the sampling device down to the calibration mark at 0.25 m depth within at least five sections with a 30 m gap separation.

The predominant solid waste found was plastic, which affects the recreational quality of beaches and the ecosystem equilibrium. However, a great amount of vegetable waste, generally algae was also collected and whose contaminants presence was related to the unhealthy sanitary quality of it.

Acknowledgements

The authors would like to take this opportunity to thank the collaboration throughout the development of this research process by Fundación Universitaria Tecnológico Comfenalco, ICAPTU program for the Touristic Beaches Quality Index, Engineer Shirchan Moreno and every student who belongs to the environmental engineering breeding ground of research on **Sampling and quantification methodology for floating solid wastes in beaches** and took part on such a project along sampling and process periods.

Referências bibliográficas

Araújo, M.C.B.; Costa, M.F. (2006) - Municipal Services on Tourist Beaches: Costs and Benefits of Solid Waste Colletion. *Journal of Coastal Research*, 22(5):1070-1075. DOI: 10.2112/03-0069.1

Donato J.C. (2002) - Métodos para el estudio del fitoplancton en sistemas lénticos. *In:* Guillermo Rueda-Delgado (ed.), *Manual de métodos de limnología*, pp.23-28, Asociación Colombiana de Limnología, Bogotá, Colombia. ISBN: 978-9583334634

Gonzáles, C.G.; Liste, A.V.; Felpeto, A.B. (2011) - *Tratamiento de datos con R Statistica y SPSS.* 996p., Ediciones Díaz de Santos, Madrid, Spain. ISBN: 978-8479789985.

INVEMAR (2007) - *Ordenamiento Ambiental de la Zona Costera del Departamento del Atlántico*. 588p., Instituto de Investigaciones Marinas y Costeras José Benito Vives de Andréis (INVEMAR), Santa Marta, Colombia. ISBN: 978-9589810422. Available on-line at http://www.invemar.org.co/redcostera1/invemar/docs/zcatlantico.pdf

Palomino de Dios, A.; Cabrera, S.M.; Martinez, G.E, Sanchez, J.A. (2012)- Environmental quality of Sitges (Catalonia, NE Spain) beaches during the bathing season. *Ocean & Coastal Management*, 55:128-134. DOI: 10.1016/j.ocecoaman.2011.10.004

Silva, J.S.; Barbosa, S.C.T; Costa, M.F. (2008) - Flag Items as a Tool for Monitoring Solid Waste from Users on Urban Beaches. *Journal of Coastal Research*, 24(4):890-898. DOI: 10.2112/06-0695.1

Zavala-García, F.; Flores-Coto, C. (2005) - Marco soporte para muestreo de plancton y nesuton en áreas someras canales. *Ciencia y mar*, (ISSN 1665-0808), 9(25):21-24, Universidad del Mar, Puerto Ángel, OAX, Mexico. Available on-line at http://www.umar.mx/revistas/25/nota25.pdf

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):597-609 (2014)

http://www.aprh.pt/rgci/pdf/rgci-506_Moreira-Gonzalez.pdf | DOI:10.5894/rgci506

Spatial and temporal distribution of phytoplankton as indicator of eutrophication status in the Cienfuegos Bay, Cuba *

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Alain Muñoz-Caravaca[a]; Augusto Comas-González[a]; Carlos Alonso-Hernández[a]

ABSTRACT

An important consequence of eutrophication is the increased prevalence of harmful algal blooms that affect transitional and coastal waters, and ecosystems in open seas. In this work, data on phytoplankton biomass, presence of harmful/toxic algal blooms and bottom dissolved oxygen were analyzed as indicators of overall eutrophic condition in the Cienfuegos Bay, Cuba. Samples were collected every three months during the year 2009 at fifteen representative stations within the bay. In the dry and early rainy seasons, high chlorophyll *a* values, harmful/toxic dinoflagellate blooms and fish mortality episodes were encountered within riverine-urban wastewater discharge zones, whilst most part of the bay did not evidence symptoms of eutrophication. During the rainy season, some stations showed biological stress-hypoxia for the bottom water oxygen, and a strong increase in spatial dispersion was observed in the phytoplankton biomass, due to a substantial increment in not toxic diatom abundance, resulting in a moderate level of eutrophic conditions for chlorophyll *a* in the entire bay. The key factor that supports the seasonal variation in phytoplankton composition and abundance appears to be the water residence time inside the bay.

Keywords: Cienfuegos Bay, chlorophyll *a*, ecological quality, eutrophication, harmful algal blooms

RESUMO

Distribuição espacial e sazonal do fitoplâncton como indicador do estado de eutrofização na Baía de Cienfuegos, Cuba

Uma importante consequência da eutrofização é o incremento e persistência das florações algais nocivas que afetam as águas de transição e costeiras, e ecossistemas em mar aberto. Neste trabalho, dados sobre a biomassa do fitoplâncton, presença de florações algais nocivas/tóxicas e oxigénio dissolvido no fundo foram analisados como indicadores da condição eutrófica geral na Baía de Cienfuegos, Cuba. Foram recolhidas amostras a cada três meses durante o ano de 2009 em quinze locais representativas dentro da baía. Nas estações da seca e do começo do período chuvoso, altos valores de clorofila a, florações algais nocivas/tóxicas e episódios de mortandades de peixes foram encontrados dentro de zonas de descargas de rios e de resíduos urbanos, enquanto a maior parte da baía não evidenciou sintomas de eutrofização. Durante o período chuvoso, alguns locais mostraram estresse biológico-hypoxia para o oxigénio dissolvido no fundo e um forte incremento na dispersão espacial foi observado na biomassa do fitoplâncton devido a um incremento substancial na abundancia de diatomáceas não tóxicas, resultando num nível moderado de eutrofização para a clorofila a em toda a baía. O fator chave que suporta a variação sazonal na composição e abundância do fitoplâncton parece ser o tempo de residência da água dentro da baía.

Palavras-chave: *Baía de Cienfuegos, clorofila a, eutrofização, florações algais nocivas, qualidade ecológica*

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1. Introduction

Vulnerability of coastal and estuarine systems to natural and anthropic forcings is increasing as a consequence of direct and indirect human interventions in these environments. Coastal erosion and consequent shoreline retreat, inlet migration, infilling of estuaries and lagoons, and water quality problems, are often linked to coastal morphodynamic processes, and have highly significant socioeconomic impacts. If systems' resilience is surpassed, serious environmental and human losses may occur. Moreover, in several coastal stretches, sustainable exploitability limits have already been exceeded resulting from human-induced alterations. Collapse of some fishing activities due to changes in the bottom sediment distribution patterns, the reduction of nursery areas, and the loss of seaside resort areas, are some examples of these changes (Dias *et al*., 2011).

Nutrient enrichment of both land and water is a result of increased human population growth and many associated activities for food and energy production, and discharge of associated sewage and waste. The final result of nutrient loading to inland and coastal waters is often an increase in algal biomass, frequently dominated by one or more species or species groups; this process is called eutrophication (GEOHAB, 2006). In general, the primary producer changes, which may in part results from perturbations of natural ratios of nutrient elements, include shifts from diatoms to cyanobacteria or flagellates. Such degradation includes: aesthetic effects such as the appearance of red tides or excessive foam; decreases in water transparency resulting from greater biomass of phytoplankton; and decreases in bottom water or sediment pore-water oxygen content because of the decay of increased primary production (Bricker *et al*., 2003; Ferreira *et al*., 2007; Glibert *et al*., 2005).

In many cases, the responding dominant species of phytoplankton are not toxic and, in fact, are beneficial to coastal productivity until they exceed the assimilative capacity of the system, after which hypoxia and other adverse effects occur (suffocation of fish, direct toxic effects on fish and shellfish, suffocation of fish from stimulation of gill mucus production, mechanical interference with filter feeding by fish and bivalve molluscs, and deleterious effects on submerged grasses and benthic habitat organisms). When that threshold is reached, seemingly harmless species can have negative impacts (Ferreira *et al*., 2011).

Many methods have been developed to evaluate and track trends in eutrophication in order to fulfil requirements of legislation designed to monitor and protect coastal water bodies from degradation. Most eutrophication assessment methods recognize that the immediate biological response is increased primary production reflected as increased chlorophyll *a* and/or macroalgal abundance. These are direct effects or primary symptoms that indicate the first stages of eutrophication. Indirect effects or secondary symptoms such as low dissolved oxygen, losses of submerged aquatic vegetation, and occurrences of nuisance and/or toxic algal blooms are indicative of a more advanced phase of ecosystem degradation (Borja *et al*., 2008; Bricker *et al*., 2003, 2008; Ferreira *et al*., 2007; Xiao *et al*., 2007).

In general, harmful algal blooms cause significant ecological and economic damage, for example through impacts on wild life, fisheries, aquaculture, human health and tourism (GEOHAB, 2006). Management and mitigation strategies of these different problems are needed; monitoring activity (early detection of cells or toxins) is an essential element in order to take management actions. For example, it is useful to have flow charts or action plans outlining the steps to be taken in different circumstances, such as a human poisoning or fish mortality episode. The retentive nature of some semi-enclosed coastal systems, such as estuaries and fjords, can produce long residence times leading to prolonged suitable periods for harmful/toxic cells to thrive (Cembella *et al*., 2005).

The Cienfuegos Bay and its coastal line represent the most important natural resource in the Cienfuegos province, southern-central coast of Cuba due to fishing (6%) and industrial activities (7%), agriculture (2%), maritime transport (7%), natural parks (70%), urbanization and tourism (8%). Several rivers flow towards the bay, forming an estuarine system (Seisdedo & Muñoz, 2005). Up to now, only a few biological studies have been carried out in the area, mainly concerning seaweeds, meio and macrobenthos and fishing resources (Aguilar *et al*., 1992; Armenteros *et al*., 2009; Helguera *et al*., 2011; Moreira *et al*., 2006). Although the composition of phytoplankton in the Cienfuegos Bay has been reported previously (Moreira *et al*., 2007), the analysis of chlorophyll *a* concentrations as indicator of phytoplankton primary productivity (first stage of eutrophication) and nuisance and toxic algal blooms as secondary symptoms of water quality degradation remain unexplored. Recent observations on areas close to sewage from the Cienfuegos city have shown deterioration of benthic communities, large blooms of filamentous seaweeds, and dead fish coinciding with the occurrence of red tides. Also, the Cienfuegos Bay has been affected by the invasive species green mussel (*Perna viridis*), an edible filter-feeding bivalve, which can accumulate in their tissues contaminants (pesticides, heavy metals) and toxins from microalgae (Alonso-Hernández *et al*., 2012; Chang *et al*., 2004).

The main objective of this study is to describe the spatial and temporal distribution of phytoplankton compo-

sition and biomass, with emphasis on harmful algal blooms and other parameters as indicators of the overall eutrophic condition in the Cienfuegos Bay, Cuba, during the year 2009. These indicators will provide adequate information to guide management decisions critical to mitigate harmful algal blooms in the Cienfuegos Bay.

2. Material and methods

2.1. Study Area

The Cienfuegos Bay, situated in the southern central part of Cuba, is a semi-enclosed bay with a surface area of 90km^2 and an average depth of 14m. It is connected to the Caribbean Sea by a narrow channel 3km long. The bay is divided in two well-defined hydrographic basins due to the presence of a submerged ridge 1m below the surface, just North of the connection channel (Fig. 1).

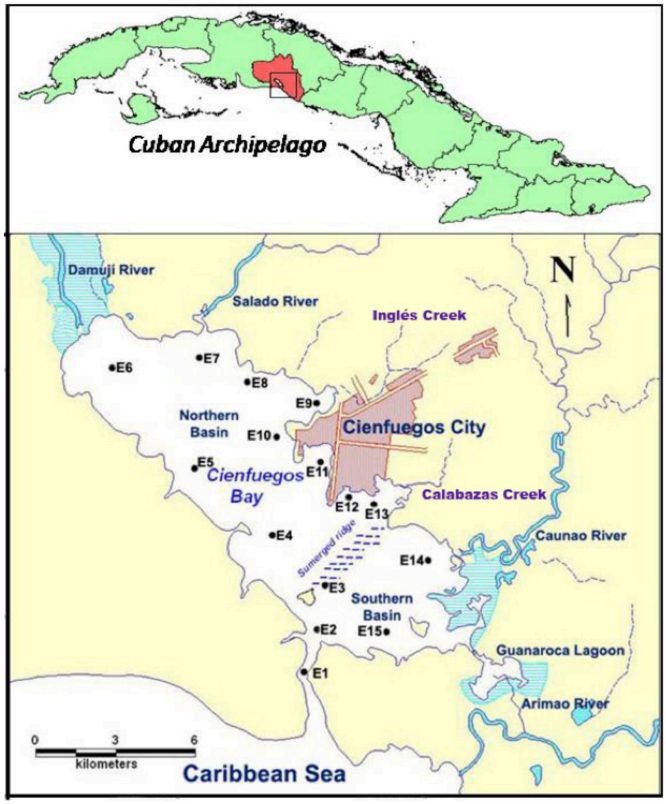

Figure 1 - *Map of the Cienfuegos Bay showing the sampling stations.*

Figura 1 - Mapa da Baía de Cienfuegos assinalando as estações de amostragem.

The northern basin receives most of the anthropic impact from the outfall of the Cienfuegos city (140 734 inhabitants), industrial pole in the country, the freshwater input of the Damuji and Salado rivers and other less extensive river basins such as El Inglés, Calabazas and Manacas creeks. In the region, the rate of population growth is low; and despite the introduction of actions by the government to reduce the pollution in the bay, the wastewater treatment is inadequate. The southern basin is subject to a smaller degree of anthropic pollution originated from the Caonao and Arimao rivers (Muñoz-Caravaca *et al*., 2012). The Guanaroca lagoon, located in the southern basin is a natural park, a niche for protected migratory birds and marine species.

Weather conditions in the study area can be divided in two seasons: dry (November – April) and rainy (May – October) season. The annual mean temperature is 24.7°C, the highest monthly temperature occurs in the rainy season, 27.0°C in June, and the lowest occurs in the dry season, 21.6°C in January. From a rainfalls time series (1967 – 2006) in Cienfuegos province, the annual accumulated rainfall was 1507.5 mm; 81 % of this accumulated fall in the rainy season and 19 % in the dry season (Barcia *et al*., 2009). The bay has a marked vertical haline stratification caused by runoff from land and low tidal mixture. During the rainy season (May – October) the mean values of surface salinity are low (16 – 20), but remain high at the bottom. During the dry season, salinity takes values between 30 and 32 throughout the water column (Seisdedo & Muñoz, 2005).

2.2. Water sampling and analyses

In order to describe wet and dry conditions, throughout 2009, four oceanographic cruises were carried out in April (dry), June (early rainy), September (rainy) and November (early dry). Samples were collected in the surface waters (0–1m), at 15 fixed stations. The bay was surveyed, always, during high tide. The stations were selected taking into account the spatial variability and their locations in defined vulnerable areas: incidence of freshwater discharges (E6-7, E14-15), industrial and urban activity (E8-13). Water samples were collected with a Niskin bottle for temperature, salinity, dissolved oxygen, chlorophyll *a*, nitrite, nitrate, ammonium and phosphate analysis.

At each station, subsurface–water temperature and salinity were sampled with a multisonde YSI-30. Nitrite, nitrate and ammonium were measured following the technique proposed in Grasshoff (1999). The concentration of dissolved inorganic nitrogen (DIN) was calculated as the sum of the ammonium, nitrate and nitrite concentrations. Phosphate was measured using the method described in UNEP (1988). The concentration of bottom dissolved oxygen in seawater was determined using the Winkler method. Total chlorophyll *a* concentration was measured by filtering sea water (0.2 – 2.5 L) through glass fiber filters (Whatman GF/F). Pigments were extracted in 10 ml of 90% acetone, for 48 h, in dark and cold conditions. The absorbance of the extract was measured by spectrophotometric method following UNEP (1988).

A 250 ml subsurface-water sample was collected for phytoplankton community structure analysis and preserved with 2.5 ml of neutral Lugol' iodine solution. For quantitative analysis, samples were settled using sedimentation chambers of 25 ml, and phytoplankton cells were counted in an inverted microscope Zeiss (Axiovert 40) (Utermöhl, 1958). For taxonomic purposes, water samples were concentrated with a 20 µm phytoplankton net and were fixed with neutral Lugol' iodine solution. Algal taxa were identified almost always to species using a number of taxonomic texts (Hallegraeff *et al*., 2003; Tomas, 1997).

2.3. Water data analysis

For each parameter (dissolved nutrients, DIN/DIP ratios, bottom dissolved oxygen and chlorophyll *a*), whenever statistical analysis was conducted for one variable (campaign or month) with 15 groups (sampling stations), the exploratory analysis was followed by a Mann-Whitney test (when data did not obey normality and homoscedastic assumptions) (Zar, 2009). The relationship between chlorophyll *a* and nutrient concentrations was established by Spearman's correlation coefficient. SPSS software (IBM SPSS Statistics V15**)** was used for the statistics methodology, with a 0.05 value of significance. The geographic information system (GvSIG.1.10) was used to create maps of salinity, chlorophyll *a* and bottom dissolved oxygen.

2.4. Overall Eutrophic Condition

Some parameters of ASSETS (Assessment of Estuarine Trophic Status) methodology (Bricker *et al*., 2003) such as chlorophyll *a*, bottom dissolved oxygen and harmful/toxic algal blooms were applied comparatively to rank the eutrophication status of the Bay. Excessive concentration of chlorophyll *a* is a primary symptom of eutrophication; the thresholds and ranges (µg/L) used were: Hypereutrophic >60; High 20-60; Moderate 5-20; Low 0-5. The occurrence of nuisance/toxic algal blooms and low dissolved oxygen are secondary symptoms or indicators of well-developed problems with eutrophication. The thresholds and ranges (mg/L) for dissolved oxygen were: Anoxia: 0; Hypoxia 0-2; Biologically stressful 2-5.

3. Results and discussion

3.1. Physic-chemical conditions

Mean values of sea surface water temperature ranged between 26.3 ^{o}C in dry and 30.2 ^{o}C in rainy, and salinity from 30.3 in rainy to 34.9 in dry season. During the studied sampling period, mean values of salinity were never below 25, thus the entire system should be classified as a Seawater Zone (Fig. 2), based on the National Estuarine Inventory classification (NEI; NOAA, 1985).

Mean values of dissolved inorganic nutrient concentrations, DIN/DIP ratios, bottom dissolved oxygen and chlorophyll *a* concentration during 2009 campaigns are listed in Table 1.

The concentrations of DIN and DIP were highest in early rainy and early dry seasons, respectively. The mean values of DIN:DIP (<16) ratios showed that nitrogen was the limiting nutrient. This molar ratio did not change significantly from dry to early rainy season (maximum value) ($p > 0.05$), contrary to the following periods from early rainy to rainy season and from rainy to early dry season. Although the nutrient concentrations were moderate in general, the higher peaks of nitrogen and DIN/DIP ratios in areas close to sources of pollution during dry and early rainy seasons could induce algal blooms during these seasons in the Cienfuegos Bay. Altered nutrient ratios have been

Table 1 - Values of dissolved nutrients, chlorophyll *a*, bottom dissolved oxygen and DIN/DIP ratio during 2009 campaigns.

Tabela 1 - Valores dos nutrientes dissolvidos, clorofila a, oxigênio dissolvido no fundo e a relação NID/PID durantes os monitoramentos de 2009.

Parameters	April		June		September		November	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DIN (µmol/L)	2.97	3.76	3.46	1.72	2.79	2.19	1.21	0.99
DIP (µmol/L)	<0.52	-	<0.52	-	1.34	2.77	2.45	0.73
DIN/DIP ratio	5.75	7.28	6.70	3.33	3.56	3.27	0.55	0.60
Chlorophyll *a* (µg/L)	5.62	9.58	3.70	2.51	6.56	1.55	3.58	1.29
Bottom Diss.O_2 (mg/L)	5.82	0.49	4.88	1.83	4.71	1.93	6.32	1.03

DIN Dissolved Inorganic Nitrogen, **DIP** Dissolved Inorganic Phosphorous, **SD** Standard deviation.

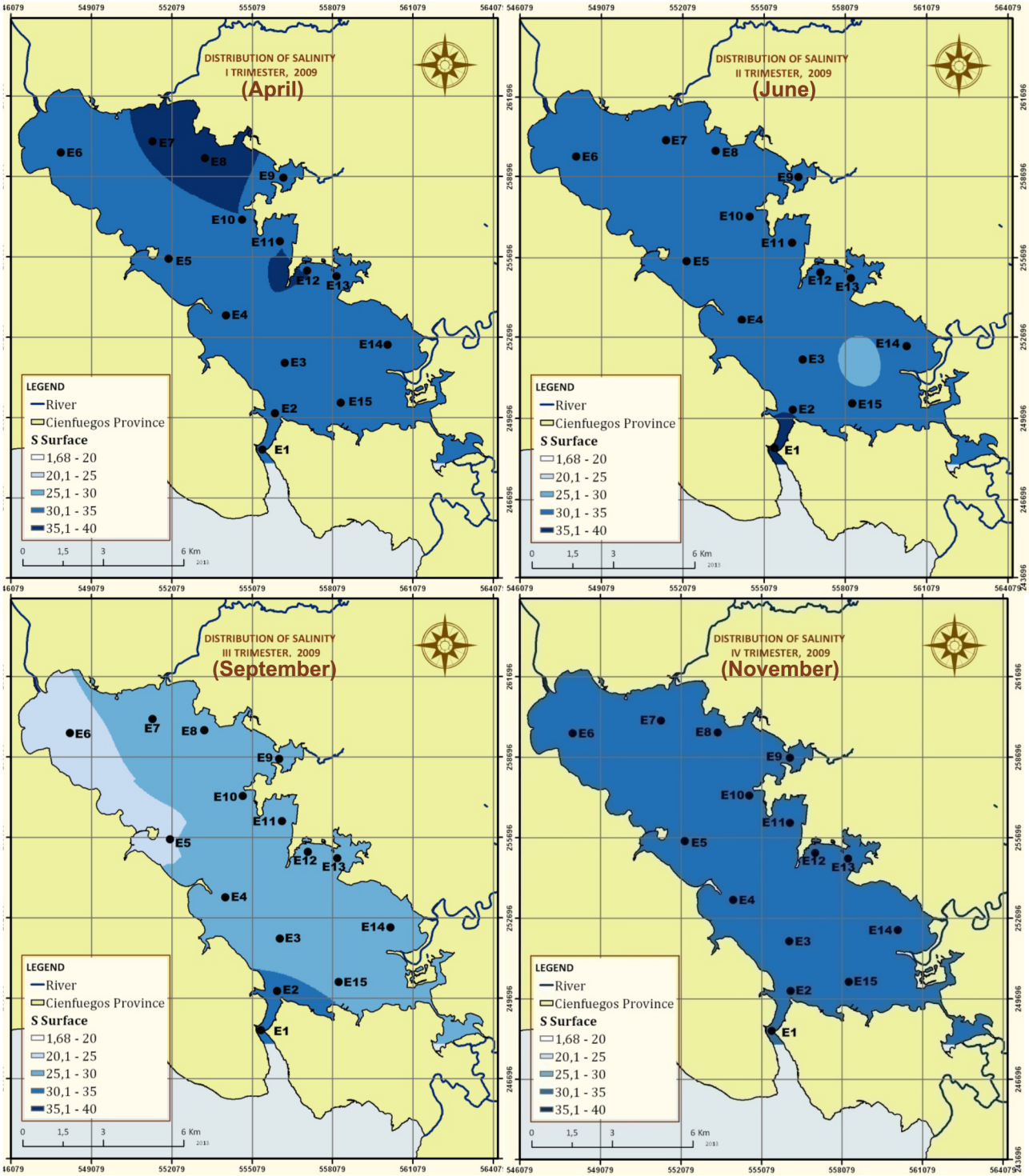

Figure 2 - Seasonal and spatial variation of surface salinity during the year 2009 in the Cienfuegos Bay, Cuba.

Figura 2 - Variação espacial e sazonal da salinidade da superfície durante o ano 2009 na Baía de Cienfuegos,

correlated with the increase of harmful algal blooms and shifts from diatom-dominated to flagellate-dominated assemblages in coastal water worldwide (Glibert *et al*., 2005). From early rainy to rainy season, DIN values decreased, yet nitrate concentrations showed a significant increase ($p < 0.05$), which could be related to increased concentrations of chlorophyll *a*. In fact, we find significant positive Spearman correlations between chlorophyll *a* and nitrate concentrations (0.312). From rainy to early dry season, phosphate concentrations increased significantly ($p < 0.05$), which led to a decrease in the DIN:DIP ratios ($p < 0.05$).

Although most of the bottom water oxygen values were within the range of 5 to 7 mg/L, stations E4, E7, E8, E13 and E15 showed values below this threshold (Biological Stress), and particularly in stations E5 and E10 hypoxia values were observed during the early rainy and rainy seasons. (Fig. 3).

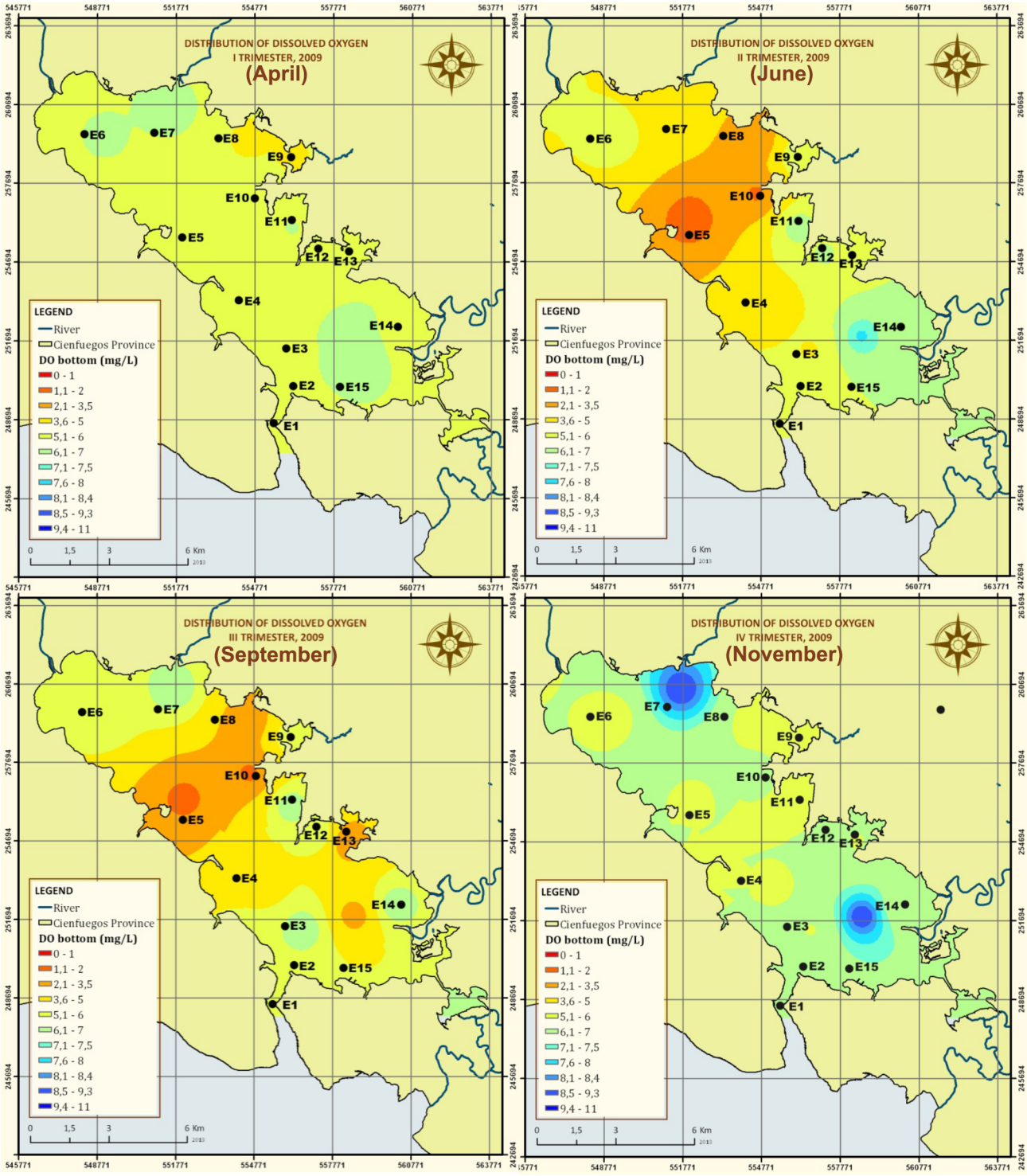

Figure 3 - Seasonal and spatial variation of bottom dissolved oxygen during the year 2009 in the Cienfuegos Bay, Cuba.

Figura 3 - Variação espacial e sazonal do oxigênio dissolvido no fundo durante o ano 2009 na Baía de Cienfuegos, Cuba.

The concentrations of dissolved oxygen at bottom waters showed statistically significant differences ($p < 0.05$) between rainy and early dry seasons when hypoxic conditions disappeared in some areas. The low concentrations of oxygen at bottom waters observed during the rainy season could be caused by the stratification and removal of sediments due to runoff from land (Seisdedo & Muñoz, 2005). Also, it could reflect the natural and anthropogenic pressures that the Cienfuegos Bay has suffered. According to Helguera *et al*. (2011), high organic enrichment and heavy metal concentrations in sediments have been reported in this semi-enclosed bay of low hydrodynamic regime and high sedimentation rates (Alonso-Hernández *et al*.,

2006). Also, the sink and decay of algal blooms contribute to eutrophication and oxygen depletion in bottom waters (Ferreira *et al*., 2011; Glibert *et al*., 2005). This environmental variable can be considered as dissolved oxygen saturation, which depends on both salinity and temperature (Millero, 2006). Thus, we also analyzed its values and obtained correspondence with the previous results. The lowest concentrations were obtained in stations E5 (17.8 %) and E10 (27.9 %) during the early rainy and rainy seasons, respectively.

3.2. Chlorophyll *a*

The highest concentrations of chlorophyll *a* were registered during the dry season, only at three stations influenced by anthropogenic pressures: 9.95 µg/L (station E7), 11.85 µg/L (station E9) and 38.17 µg/L (station E8). With the exception of these peaks, the values of chlorophyll *a* observed at the other stations during the dry season were relatively low (average of 5.62 µg/L). The highest average concentrations (6.56 µg/L) of chlorophyll *a* were found in the rainy season (Fig. 4).

According to the ASSETS thresholds, the maximum values of chlorophyll *a* obtained for the dry season (stations E7, E8 and E9) fall within the High and Moderate level of eutrophic conditions, while the values observed during rainy season are classified as Moderate. Most values observed in early rainy (average of 3.70 µg/L) and early dry seasons (average of 3.58µg/L) were always lower than the thresholds of 5 µg/L, which classifies these periods in the Low category of eutrophic conditions (Fig. 4).

Dinoflagellate blooms were associated with the highest values of chlorophyll *a*, although hypoxia symptoms were not observed. The key factors supporting the high concentration of chlorophyll *a* near areas of sewage and riverine discharges (around the Cienfuegos city, E7-9) in the dry season appear to be the availability of nutrients, both inorganic and organic, in these enclosed areas; and the long residence time of the system during the dry season. The higher dissolved inorganic nitrogen and DIN/DIP ratios reported in the area of higher chlorophyll *a*, could be the result of nitrogen loading from the Salado River and El Inglés creek, which deliver over 50% of nitrogen and phosphorous present in the Cienfuegos Bay (Seisdedo & Arencibia, 2010). In this context, natural resource managers in the bay should include action plans to reduce riverine inputs of nitrogen, with the aim to mitigate harmful algal bloom since the growth of phytoplankton in this area is limited primarily by nitrogen.

Recent studies have reported that the Cienfuegos Bay system has a slow exchange rate, with an average residence time of 39 days during the rainy period and 50 days during the dry one (Muñoz-Caravaca *et al*., 2012). Organic nutrients have been shown to be important in the development of blooms of various harmful algal species, in particular cyanobacteria and dinoflagellates (Glibert *et al*., 2001); and long water residence times in enclosed seas lead to blooms triggered to a large degree by internal and external nutrient pools (Ferreira *et al*., 2011). However, the spatial coverage for high concentrations of chlorophyll *a* was low (only for three stations close to sewage and riverine discharges), indicating that the Cienfuegos Bay seems to have a high capacity to dilute nutrients.

The high chlorophyll *a* concentration observed near areas of sewage during the dry season in Cienfuegos Bay has been recorded in other small semi-enclosed bays from Cuba. High densities of phytoplankton (1.02 x 10^7cells/L) and chlorophyll *a* concentrations (25.2 ug/L) have been observed in the Havana Bay. Eutrophic conditions in this bay were related to increased sewage discharges from Havana city (Reyes, 2008). More recently, during the dry season of 2012 (March), high chlorophyll *a* concentration due to a bloom of *Phaeocystis* sp. has been observed for the first time in the Cuban archipelago, in Cayo Largo; a small island located in the south-western platform of Cuba. This site represents a highly hydrodynamic system. A red-brown bloom persisted for the next 15 days, affecting the tourism in the area because of the presence of abundant foam, water discoloration and bad odours. High concentrations of ammonium and organic nitrogen were subsequently recorded along the beaches. The high content of organic nitrogen relative to phosphorus suggests an excess of nitrogen during bloom conditions (Loza *et al*., 2013).

The progressive and spatially uniform increase in the chlorophyll *a* observed from early rainy to rainy seasons in the Cienfuegos Bay can be explained in response to delivery of nutrients from rainfall events (GEOHAB, 2006). During the present study, the rainfall period was moderate and below the average historical flows (Seisdedo & Muñoz, 2005). This environmental conditions favour the dominance of chain-forming and large marine diatoms which achieve moderate chlorophyll *a* concentrations (Smayda, 1997), relative to the values observed during the dry season.

3.3. Phytoplankton composition and abundance

The taxonomic composition of phytoplankton communities and the mean values of cell abundance are listed in Table 2. A total of 94 species were identified during the study: 44 Dinoflagellates, 36 Diatoms, 9, Cyanophyceans, 3 Chlorophyceans, 1 Cryptophycean, 1 Chrysophycean, 1 Raphidophycean and 1 Prasinophycean. During the dry season, the community was dominated by diatoms, with relatively low abundances and species richness (Fig. 5 and Anexo I [at Supporting Information]).

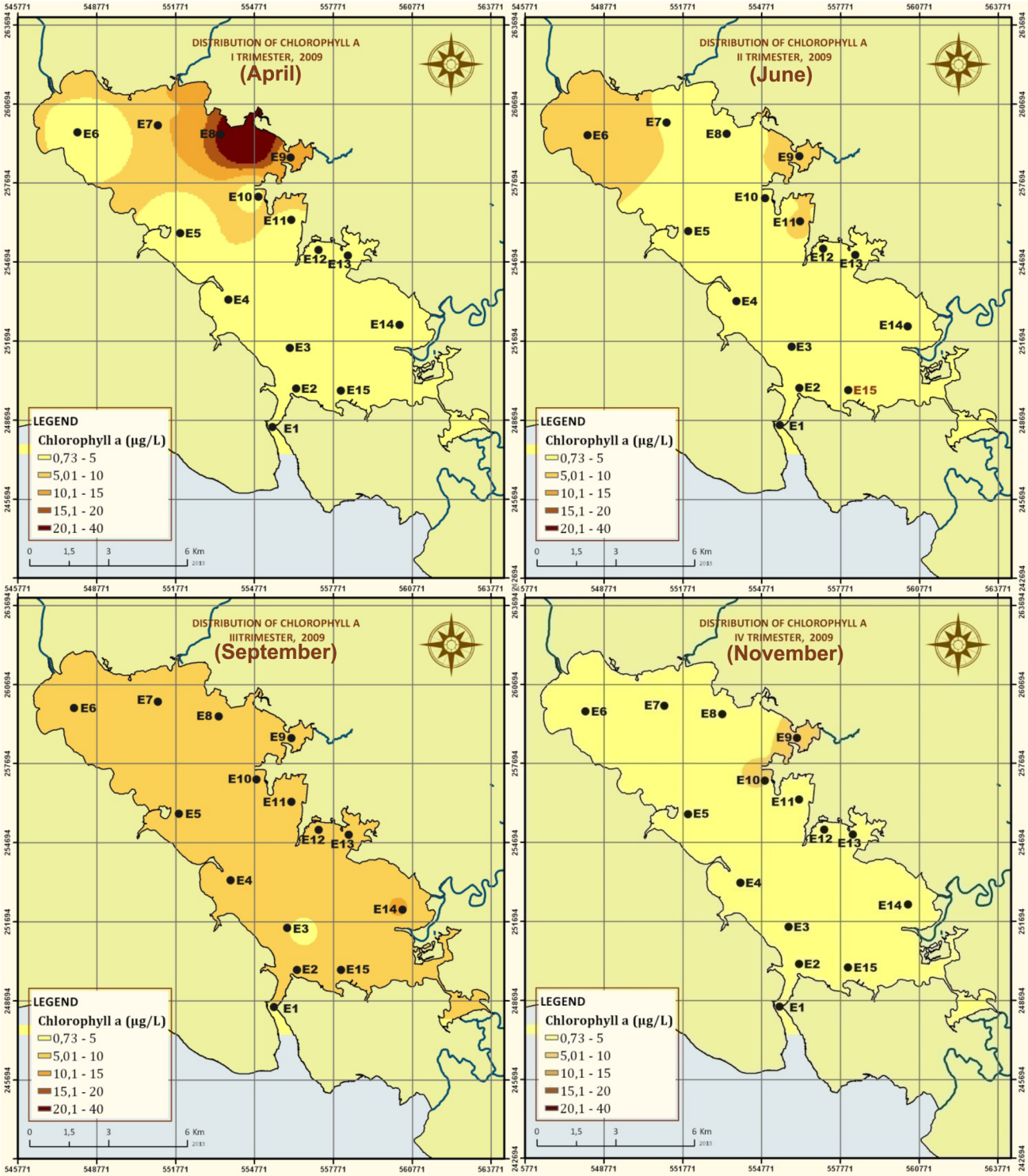

Figure 4 - Seasonal and spatial variation of chlorophyll *a* during the year 2009 in the Cienfuegos Bay, Cuba.

Figura 4 - Variação espacial e sazonal da clorofila a durante o ano 2009 na Baía de Cienfuegos, Cuba.

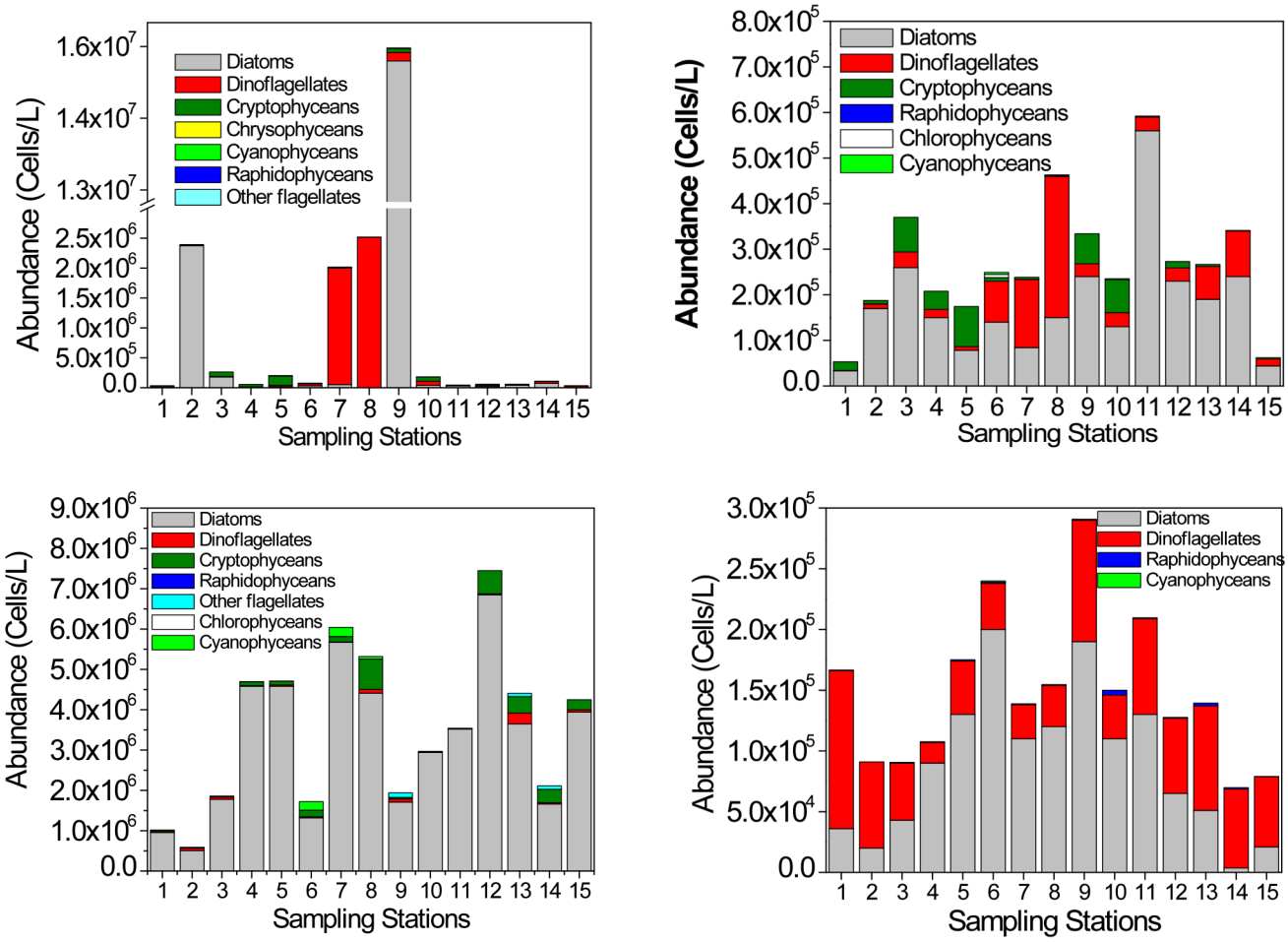

Figure 5 - Seasonal and spatial variation of the abundance (cells/L) of the main phytoplankton groups during the year 2009 in the Cienfuegos Bay, Cuba.

Figura 5 - Variação espacial e sazonal da abundancia (céls./L) dos principais grupos do fitoplâncton durante o ano 2009 na Baía de Cienfuegos, Cuba

The community was composed mainly of chain-forming species of the genus *Pseudo-nitzschia*. However, high abundance of phytoplankton at stations E7, E8 and E9, during the dry season, was related to enhanced growth of dinoflagellates and diatoms, resulting in discoloured water. Blooms of the non toxic dinoflagellate *Gymnodinium estuariale* was observed in stations E7 and E8; while a mixed species assemblage of diatoms was observed at station E9, dominated by the species *Cyclotella* sp., *Nitzschia longissima* and the potentially toxic *Pseudo-nitzschia multistriata* (amnesic shellfish poisoning producing). No problems with oxygen depletion and marine life due to excessive growth of microalgae were observed at these stations. Large blooms of the filamentous brown seaweed *Feldmannia irregularis* were observed in shallow areas near the city (stations E8-13) during April and May coincident with the occurrence of microalgal blooms.

These blooms of macrophytes were shading the seagrass *Halodule wrightii* and in some beaches were the most likely responsible for bad odours due to their decomposition/degradation. These results give an overall rating of Moderate for Harmful and Toxic Algal Blooms at the stations near the Cienfuegos city (stations E8-13) in the dry season.

During the early rainy season, the abundance and diversity of large marine diatoms increased, due to the presence of several species of *Chaetoceros*, *Cerataulina pelagica*, *Coscinodiscus centralis*, *Cyclotella* sp., *Dactyliosolen fragilissimus*, *Guinardia striata*, *Nitzschia longissima*, *Pseudoguinardia recta*, *Pseudo-nitzschia multistriata*, *Rhizosolenia hebetata* f. *semi-spina*, *Thalassionema nitzschioides* and *Thalassiosira* sp. Dinoflagellates were only occasionally important; for example, at the E6, E7, E8 and E14 stations, dominated by the species *Akashiwo sanguinea*, *Gymno-dinium estuariale* and *Prorocentrum micans* (Fig. 5 and Table 2). High abundance and richness of phyto-plankton species associated with freshwater runoff is generally found in other studies from coastal lagoons in the Caribbean region (Álvarez-Góngora & Herrera-Silveira, 2006; Troccoli *et al*., 2004).

However, in a shallow area outside of the monitoring network close to the station E11 and sewage effluents a red tide of the toxic dinoflagellate *Heterocapsa circularisquama* was recorded which was associated to a small episode of fish kill. Other potentially toxic or red tide dinoflagellates were observed in this area (Fig. 6), such as *Akashiwo sanguinea* (red tide producing); *Alexandrium* cf. *minutum* and *Gymnodinium catenatum* (paralytic shellfish poisoning producing); *Dinophysis caudata*, *D. ovum* and *D. tripos* (diarrhetic shellfish poisoning producing); *Amphidinium carterae*, *Cochlodinium polykrikoides*, *Gonyaulax polygramma* and *G. spinifera* (icthiotoxic compounds producing); *Prorocentrum minimum* (neurotoxic compounds producing) and *P. rathymum*, potentially producer of hemolytic compounds which could be associated to the ciguatera due to its benthic life.

Blooms of other non toxic dinoflagellates were also observed during this period in shallow near shore areas: *Peridinium quinquecorne* near station E11, *Prorocentrum compressum* near station E9 and *Scrippsiella trocoidea* near station E14. Due to the association of toxic red tides (*H. circula-risquama*) with fish kills an overall rating of Bad for Nuisance and Toxic Algal Blooms is attributed to the station E11 during the early rainy season. Several dinoflagellate genera, such as *Prorocentrum, Phaeocystis, Heterocapsa, Scrippsiella, Cochlodinium, Heterosigma* and others, have adaptations making them suitable for thriving in nutrient-rich waters. Increasing evidence suggests that some of these species may also be increasing in their global extent (GEOHAB, 2006).

Cochlodinium polykrikoides and *Heterocapsa* cf. *circularisquama* blooms have been recently associated with the kill of many marine organisms (*Crassostrea virginica* = ostión, *Callinectes sapidus* = jaiba, *Cetengraulis edentulus* = bocón) in the Cienfuegos Bay, specifically within the protected area Guanaroca lagoon during the dry season (Moreira, unpublished data). This lagoon is located in the southern basin of the bay, which has more exchange with the Caribbean Sea. Previous reviews have supported that *Cochlodinium* is not a true ‘‘eutrophic’’ dinoflagellate (Kudela & Gobler, 2012). These reports noted that both *C. polykrikoides* and *C. fulvescens* are capable of utilizing a variety of N compounds, but exhibit characteristics indicative of more pelagic rather than neritic/eutrophic dinoflagellates.

In the rainy season, a strong spatial gradient was observed in cell abundance, due to a substantial increment in diatoms' abundance. The peak during the rainy season was mainly caused by the diatom *Dactyliosolen fragilissimus* (average of 2.1 x 10^6 cells/L), followed by other species of diatoms as *Rhizosolenia hebetata* f. *semispina*, *Cyclotella* sp., *Nitzschia longissima*, *Nitzschia* sp., and cryptophytes of the genus *Plagioselmis*. The contribution of the dinoflagellates was very low (Figure 5 and Table 2). Freshwater species such as the diatom *Aulacoseira granulata*, the chloro-phytes *Coenococcus* sp., *Coelastrum indicum*, *Desmodesmus abundans*, and the potentially toxic cyano-bacteria *Anabaena* sp., *Cylindrospermopsis curvispora*, *Microcystis aeruginosa*, *Oscillatoria* sp., *Phormidium* sp., *Planktothrix isothrix* and *Pseudo-*

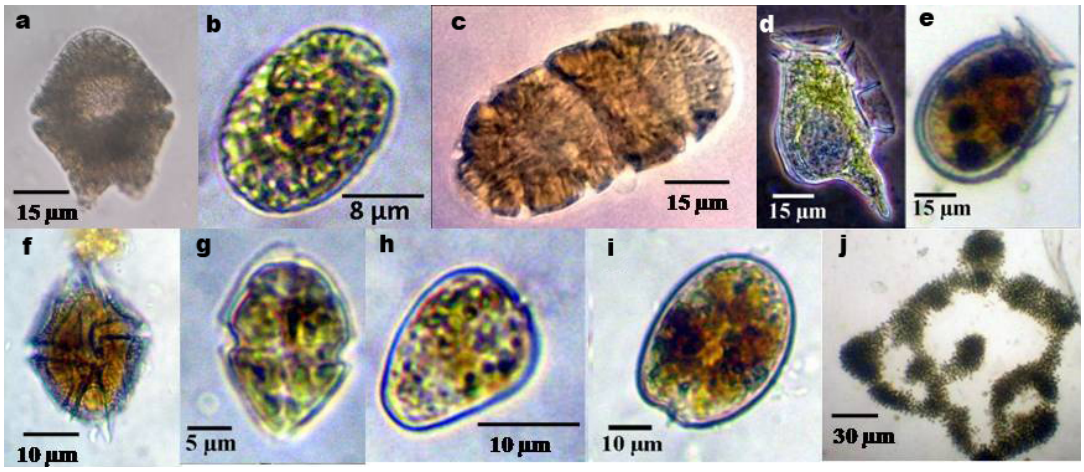

Figure 6 - Some potentially harmful/toxic marine and freshwater microalgae found during the year 2009 in the Cienfuegos Bay, Cuba. a. *Akashiwo sanguinea*. b. *Amphidinium carterae*. c. *Cochlodinium polykrikoides*.d. *Dinophysis caudata*. e. *Dinophysis ovum*. f. *Gonyaulax polygramma*. g. *Heterocapsa circularisquama*. h. *Prorocentrum minimum*. i. *Prorocentrum rathymum*. j. *Microcystis aeruginosa* (freshwater).

Figura 6 - Algumas microalgas potencialmente nocivas/tóxicas, marinhas e de água doce, encontradas durante o ano 2009 na Baía de Cienfuegos, Cuba. a. Akashiwo sanguinea. b. Amphidinium carterae. c. Cochlodinium polykrikoides. d. Dinophysis caudata. e. Dinophysis ovum. f. Gonyaulax polygramma. g. Heterocapsa circularisquama. h. Prorocentrum minimum. i. Prorocentrum rathymum. j. Microcystis aeruginosa (água doce).

anabaena sp. were observed in low concentrations. These results are evidences that the phytoplankton species composition in an estuary can be linked to flushing time (Ferreira *et al*., 2005).

Dinoflagellates tend to be associated with slower flushing (dry season), reflecting both higher chlorophyll *a* values and increased occurrence of harmful algal blooms, whilst diatoms depend on higher flushing and turbulence (rainy season), and the abundance of freshwater species in the estuary will represent an integrative measure of the phytoplankton community response to highest freshwater inflow.

Within the bay, during the early dry season, the abundance of dinoflagellates tended to increase and the contribution of diatoms was also important. The community was dominated by the diatom *Thalassionema nitzschioides*, together with the dinoflagellates *Prorocentrum balticum*, *Prorocentrum micans* and *Protoperidinium steinii* (Fig. 5 and Table 2). In the early dry season, phytoplankton abundance was lower compared with the rainy season. The overall composition of phytoplankton indicates that there are no problems with Harmful and Toxic Algal Blooms during the rainy and early dry seasons.

4. Conclusions

In summary, the Cienfuegos Bay is not particularly affected by problems associated with harmful algal bloom according to the Low-Moderate conditions diagnosed by two indexes, the concentration of Chlorophyll *a* and the occurrence of harmful/toxic algal blooms. The level of expression for chlorophyll *a* did not change significantly in the different scenarios, which is a consequence of the high dilution potential of the system, and the hydrodynamic limitations to bloom development in broad parts of the bay.

However, high levels of chlorophyll *a*, and the occurrence of harmful and toxic algal blooms were observed during the dry season in small enclosed areas with restricted water circulation/ renewal, and associated to direct discharges of urban/industrial effluents into the bay. The high water residence times found in the bay during the dry season is a factor within the estuary that contributes to maintain bloom conditions in these enclosed areas.

Management plans in the Cienfuegos Bay should be addressed to reduce sewage discharges into the receiving body. It will appear to be adequate for preserving and improving environmental quality as regards eutrophication and harmful algal blooms, principally in the waters of more restricted exchange of the bay.

The presence of harmful/toxic algal blooms during the dry period, suggests the need to continue monitoring the occurrence of these organisms, and to control the harvesting of molluscs during the periods of blooms, such as the edible bivalve green mussel (*Perna viridis*), which is an invasive species in the Cienfuegos Bay.

In order to mitigate the mortality of marine fauna (invertebrates and fishes) associated with the fish-killing dinoflagellate *Cochlodinium polykrikoides*, special attention should be focused on the study red tide events of this toxic microalga in the bay.

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References

Aguilar, C.; González-Sansón, G.; Guevara, E.; Bosch, A. (1992) – Estructura de las comunidades de peces en la Bahía de Cienfuegos y la Laguna Guanaroca, Cuba. *Revista de Investigaciones Marinas* (ISSN: 0252-1962), 13(3):222–232, Centro de Investigaciones Marinas, Universidad de La Habana, Habana, Cuba.

Alonso-Hernández, C.M; Díaz-Asencio, M.; Muñoz-Caravaca, A.; Delfanti, R.; Papucci,C.; Ferretti, O.; Crovato, C. (2006) – Recent changes in sedimentation regime in Cienfuegos Bay, Cuba, as inferred from 210Pb and 137Cs vertical profiles. *Continental Shelf Research*, 26(2):153–167. DOI: 10.1016/ j.csr.2005.08.026.

Alonso-Hernández, C.M; Gómez-Batista, M.; Cattini, C.; Villeneuve. J.P.; Oh, J. (2012) – Organochlorine pesticides in green mussel, Perna viridis, from the Cienfuegos Bay, Cuba. *Bulletin of Environmental Contamination and Toxicology,* 89(5):995-999. DOI: 10.1007/s00128-012-0835-0.

Álvarez-Góngora, C.; Herrera-Silveira, J.A. (2006) – Variations of phytoplankton community structure related to water quality trends in a tropical karstic coastal zone. *Marine Pollution Bulletin*, 52(1):48–60. DOI: 10.1016/j.marpolbul.2005.08.006.

Armenteros, M.; Ruiz-Abierno, A.; Fernández-Garcés, R.; Pérez-García, J.A.; Díaz-Asencio, L.; Vincx, M.; Decraemer, W. (2009) – Biodiversity patterns of free-living marine nematodes in a tropical bay: Cienfuegos, Caribbean Sea. *Estuarine, Coastal and Shelf Science*, 85(2):179–189. DOI: 10.1016/j.ecss. 2009.08.002.

Barcia, S.; Orbe, G.; Regueira, V.; Sánchez, R.; Núñez, E.; Rodríguez, C.; Hernández, A.L.; Angulo, R.; Ceballo, R.; Millán, J. (2009) – *Guía Climática de la Provincia Cienfuegos.*

58p., Centro Meteorológico Provincial de Cienfuegos, INSMET, Cienfuegos, Cuba. *Unpublished*.

Borja, A.; Bricker, S.B.; Dauer, D.M.; Demetriades, N.T.; Ferreira, J.G.; Forbes, A.T.; Hutchings, P.; Jia, X.; Kenchington, R.; Marques, J.C.; Zhu, C.B. (2008) – Overview of integrative tools and methods in assessing ecological integrity in estuarine and coastal systems worldwide. *Marine Pollution Bulletin*, 56(9):1519-1537. DOI: 10.1016/j.marpolbul.2008.07.005.

Bricker, S.B.; Ferreira, J.G.; Simas, T. (2003) – An integrated methodology for assessment of estuarine trophic status. *Ecological Modelling*, 169(1):39-60. DOI: 10.1016/S0304-3800(03)00199-6.

Cembella, A.D.; Ibarra, D.A; Diogene, J; Dahl, E. (2005) – Harmful algal blooms and their assessment in fjords and coastal embayments. *Oceanography,* 18(2):158-171. DOI: 10.5670/oceanog. 2005.51.

Chang, I.; Rojas, L.; Franco, J.; La Barbera-Sánchez, A. (2006) – Paralytic shellfish poisoning toxin profiles in green mussels from Trinidad and Venezuela. *Journal of Food Composition and Analysis*, 19(1):88–94. DOI: 10.1016/j.jfca.2004.11.006.

Dias, J.A.; Freire, P.; Freitas, C.; Klein, C.; Silva, P. (2011) – The importance of estuarine and coastal morphodynamics in littoral management. *Journal of Integrated Coastal Zone Management*, 11(3):271-272. DOI: 10.5894/rgci304.

Ferreira, J.G.; Andersen, J.H.; Borja, A.; Bricker, S.B.; Camp, J; Silva, M.C.; Garcés, E.; Heiskanen, A.S.; Humborg, C.; Ignatiades, L.; Lancelot, C.; Menesguen, A.; Tett, P.; Hoepffnerm, N.; Claussen, U. (2011) – Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. *Estuarine, Coastal and Shelf Science*, 93(2):117-131. DOI: 10.1016/ j.ecss.2011.03.014.

Ferreira, J.G.; Bricker, S.B.; Simas, T.C. (2007) – Application and sensitivity testing of an eutrophication assessment method on coastal systems in the United States and European Union. *Journal of Environmental Management*, 82(4):433-445. DOI: 10.1016/ j.jenvman.2006.01.003.

Ferreira, J.G.; Wolff, W.J.; Simas, T.C.; Bricker, S.B. (2005) – Does biodiversity of estuarine phytoplankton depend on hydrology?. *Ecological Modelling*, 187(4):513–523. DOI: 10.1016/j.ecolmodel .2005.03.013.

GEOHAB (2006) – *Global Ecology and Oceanography of Harmful Algal Blooms. HAB in Eutrophic Systems*. P. Glibert (ed.). IOC and SCOR, Paris and Baltimore, 74p. Available on-line at http://www.jodc.go.jp/info/ioc_doc/Other/FINAL_GEOHAB_Eutro_corrected.pdf

Glibert, P.M.; Magnien, R.; Lomas, M.W.; Alexander, J.; Fan, C.; Haramoto, E.; Trice, M.; Kana, T.M. (2001) – Harmful algal blooms in the Chesapeake and Coastal Bays of Maryland, USA: Comparison of 1997, 1998, and 1999 events. *Estuaries*, 24(6):875-883. DOI: 10.2307/1353178.

Glibert, P.M.; Seitzinger, S.; Heil, C.A.; Burkholder, J.M.; Parrow, M.W.; Codispoti, L.A.; Kelly, V. (2005) – The role of eutrophication in the global proliferation of harmful algal blooms. *Oceanography*, 18(2):198-209. DOI: 10.5670/oceanog. 2005.54.

Grasshoff, K.; Ehrhardt, M.; Kremling, K. (1983) – *Methods of seawater analysis*, 2nd edn. VerlagChemie, Weinheim, Germany. ISBN: 3527259988.

Hallegraeff, G.M.; Anderson, D.M.; Cembella, A.D. (2003) – *Manual on harmful marine microalgae*. Monographs on Oceanographic Methodology, 11. UNESCO Publishing: Paris, 793 pp. ISBN: 9231038710.

Helguera, Y.; Díaz-Asencio, L.; Fernández-Garcés, R.; Gómez-Batista, M.; Guillén, A.; Díaz-Asencio, M.; Armenteros, M. (2011) – Distribution patterns of macrofaunalpolychaete assemblages in a polluted semi-enclosed bay: Cienfuegos, Caribbean Sea. *Marine Biology Research*, 7(8):757-768. DOI: 10.1080/17451000.2011 .569552.

Kudela, R.M.; Gobler, C.J. (2012) – Harmful dinoflagellate blooms caused by Cochlodinium sp.: Global expansion and ecological strategies facilitating bloom formation. *Harmful Algae*,14:71–86. DOI: 10.1016/j.hal.2011.10.015.

Loza, S.; Moreira, A.; Comas, A.; Sánchez, M.; Carmenate, M.; Álamo, B.; Dobal, V.; Montalvo, J.; García, I.; Lorenzo, S.; Arriaza, L.; Hernández, M.; Montesinos, D.; Gutierréz, J.; M. Alcolado, P. (2013) – A Phaeocystis bloom in Cuban Archipelago. *Harmful Algae News* (ISSN: 0020-7918), 47:20-21, UNESCO, Paris, France. Available on-line at https://www.researchgate.net/publication/237080347_A_Phaeocystis_bloom_ in_the_Cuban_Archipelago

Millero, F.J. (2006) – *Chemical Oceanography, 3rd ed.,* 496p., CRC Press, Boca Raton, FL, U.S.A. ISBN: 978-0849322808.

Moreira, A.; Armenteros, M.; Gómez, M.; León, A.R.; Cabrera, R.; Castellanos, M.E.; Muñoz, A.; Suárez, A.M. (2006) – Variation of macroalgae biomass in Cienfuegos Bay, Cuba. *Revista de Investigaciones Marinas*. (ISSN: 1991-6089), 27(1):3-12, Centro de Investigaciones Marinas, Universidad de La Habana, Habana, Cuba. Available on-line at http://www.cim.uh.cu/rim/OldSite/ 2006/1.html.

Moreira, A., Seisdedo, M.; Leal, S.; Comas, A.; Delgado, G.; Regadera, R.; Alonso, C.; Muñoz, A.; Abatte, M. (2007) – Composición y abundancia del fitoplancton de la bahía de Cienfuegos, Cuba. *Revista de Investigaciones Marinas* (ISSN: 1991-6089), 28(2):97-109, Centro de Investigaciones Marinas, Universidad de La Habana, Habana, Cuba. Available on-line at http://www.cim.uh.cu/rim/pdf/2007/2/2007-097.pdf.

Muñoz-Caravaca, A.; Doulliet, P.; Díaz-García, O.; Fichez, R.; Herrera, R.H.; Alcántara-Carrió, J.; García-Rodriguez, A. (2012) – Flushing time in the Cienfuegos Bay. *Natural Resource Modeling*, 25(3):434-455. DOI: 10.1111/j.1939-7445. 2012.00126.x.

NOAA (1985) – *National estuarine inventory: Data atlas, vol.1: Physical and hydrologic characteristics*. 103p., National Oceanic and Atmospheric Administration (NOAA), Strategic Assessment Branch, Ocean Assessments Division, Rockville, MD, U.S.A.

Reyes, T. (2008) – *Niveles de eutrofización en las bahías de La Habana, Mariel, Matanzas, Cárdenas y Puerto Padre, Cuba*. Dissertation of Bachelor, Universidad de La Habana, La Habana, Cuba. *Unpublished*.

Seisdedo, M.; Muñoz, A. (2005) – Efecto de las precipitaciones en la calidad de las aguas de la bahía de Cienfuegos. *Revista Cubana de Meteorología* (ISSN: 0864-151X), 12(2):64–67, Habana, Cuba.

Seisdedo, M.; Arencibia, G. (2010) – Estimación de carga contaminante de nutrientes en la bahía de Cienfuegos. *Transporte, Desarrollo y Medio Ambiente* (ISSN: 0864-151X), 30(64):33–37, La Habana, Cuba.

Smayda, T.J. (1997) – Harmful algal blooms: Their ecophysiology and general relevance to phytoplankton blooms in the sea. *Limnology and Oceanography*, 42(5 pt 2): 1137-1153. DOI: 10.4319/lo.1997.42.5_part_2.1137

Tomas, C. R. (1997) – *Identifying Marine Phytoplankton*. 858p., Academic Press, San Diego, CA, U.S.A. ISBN:978-0126930184.

Troccoli, G.L.; Herrera-Silveira, J.A.; Comín, F.A. (2004) – Structural variations of phytoplankton in the coastal seas of Yucatan, Mexico. *Hydrobiologia*, 519(1-3):85–102. DOI: 10.1023/B:HYDR.0000026487.78497.b6.

UNEP (1988) – *Standard chemical methods for marine environmental monitoring* 50p., United Nations Environment Programme (UNEP), Nairobi, Kenya.

Utermöhl, H. (1958) – Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. Mitt. Int. *Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie*, 9:1-38. Available on-line at http://www.schweizerbart.de/pubs/series/verhandlungen-ivl.167.html

Xiao, Y.; Ferreira, J.G.; Bricker, S.B.; Nunes, J.P.; Zhu, M.; Zhang, X. (2007) – Trophic assessment in Chinese coastal systems - Review of methodologies and application to the Changjiang (Yangtze) estuary and Jiaozhou Bay. *Estuaries and Coasts*, 30(6):1-18. DOI: 10.1007/BF02841384

Zar, J. (2009) – *Biostatistical analysis*. 5th ed., 960p., Prentice Hall, Englewood Cliffs, NJ, U.S.A. ISBN: 978-0131008465.

The article
"Spatial and temporal distribution of phytoplankton as indicator of eutrophication status in the Cienfuegos Bay, Cuba", by Moreira *et al.* (2014),
contains supporting information online at
http://www.aprh.pt/rgci/pdf/rgci-506_Moreira_Supporting-Information.pdf

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):611-624 (2014)

http://www.aprh.pt/rgci/pdf/rgci-449_Loiola.pdf | DOI: 10.5894/rgci449

Definition of priority areas for the conservation of a coastal reef complex in the eastern Brazilian coast *

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ABSTRACT

Coral reef integrity is currently threatened by natural and human activity. The reefs of the eastern Brazilian coast, which stand out as the largest and richest of the South Atlantic Ocean, are not an exception. Tourism exploitation, destructive fishing practices, increased pollution and uncontrolled coastal development are the major human impacts on reefs. The creation of new no-taken zones (NTZs) has thus become an urgent issue because NTZs represent the best measure to guarantee the conservation of reef ecosystems, which are considered biodiversity hotspots. The objective of this work was to define priority areas for implementing NTZs in a coastal reef complex located on the eastern Brazilian coast (southern coast of Bahia State, in the Tinharé Archipelago), which is within an environmental protection area (Tinharé and Boipeba Islands State Environmental Protection Area ['*Área de Proteção Ambiental Estadual das Ilhas de Tinharé e Boipeba*']). Here we performed a detailed ecological survey of the benthic community in a set of coastal reefs and calculated quantitative conservation priority indices (CPIs) based on ecological attributes associated with the cover of key benthic organisms (corals, macroalgae, filamentous algae, branching and encrusting calcareous algae, sponges and zoanthids) and quantitative indices related to coral species richness and the mean age of the reefs in question. Five coral reefs were classified as high priority for conservation. The large spatial extent of the adjacent fringing reefs of the islands of Tinharé and Boipeba justifies the creation of two rectangular NTZs. We recommend therefore the implementation of two 12 km^2 areas spanning two reefs considered of high conservation priority located on the island of Tinharé ("Boca da Barra Norte and Sul") and one reef located on the island of Boipeba ("Ponta dos Castelhanos"). With this design, two of the reefs that were classified as high priority for conservation, "Piscinas de Moreré" and "Tassimirim" (Boipeba), which are extensively used by local populations (for fishing and tourism), would not be covered by the NTZs. The effectiveness of the conservation of these ecosystems also depends on popular acceptance and participation and on combating destructive anthropogenic activities in the region, which include destructive fishing practices and exploratory tourism.

Keywords: Coral reefs; Designing protected area; Reef degradation, Conservation plan; No-taken zones.

RESUMO

Definição de áreas prioritárias para a conservação de um complexo recifal costeiro na costa leste brasileira

Atualmente a integridade dos recifes de corais está ameaçada por conta de impactos naturais e humanos. Os recifes da costa leste brasileira, que se destacam como os maiores e mais ricos do Oceano Atlântico Sul, não fogem a esta regra. A exploração turística, as práticas de pesca predatória, o aumento da poluição e o desenvolvimento costeiro desordenado representam os principais impactos humanos sobre os recifes. Por conta disso a criação de novas áreas de exclusão de uso (AEUs) se tornaram demandas urgentes e representam a melhor medida para que a conservação desses ecossistemas, considerados como 'hotspots' de biodiversidade, seja garantida. A partir disso o objetivo deste trabalho foi definir áreas prioritárias para a implantação de AEUs em um complexo de recifes costeiros localizado na costa leste brasileira (mais especificamente no litoral sul do estado da Bahia, no Arquipélago de Tinharé), os quais estão dentro dos limites de uma área de proteção ambiental (APA estadual das ilhas de Tinharé e Boipeba). Para tanto, aqui nós realizamos um levantamento ecológico detalhado

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da comunidade bentônica de um conjunto de recifes costeiros e calculamos para cada um destes índices quantitativos de prioridade de conservação (IPC), baseados em atributos ecológicos associados à cobertura de organismos bentônicos chaves (corais, macroalgas, algas filamentosas, algas calcárias ramificadas e incrustantes, esponjas e zoantídeos), e também em índices quantitativos relacionados à riqueza de espécies de corais e à idade média dos recifes em questão. De acordo com o IPC, cinco recifes foram classificados como recifes de alta prioridade de conservação. A grande extensão territorial da franja recifal adjacente às ilhas de Tinharé e Boipeba justifica a criação de duas AEUs com formato retangular (formato mais eficiente para esse tipo de unidade de conservação, segundo a literatura especializada). Sugerimos a implantação de duas áreas com 12 km^2, abrangendo dois recifes considerados como de alta prioridade de conservação localizados na ilha de Tinharé (Boca da Barra Norte e Sul) e um recife localizado na ilha de Boipeba (Ponta dos Castelhanos). A partir desse arranjo, dois dos recifes classificados como de alta prioridade para conservação, respectivamente Piscina de Moreré e Tassimirim (ambos localizados na ilha de Boipeba), extensivamente usados pelas populações locais (exploração pesqueira e uso turístico), não seriam contemplados pelas AEUs. Ressaltamos que a efetividade da conservação desses ecossistemas depende, também, da aceitação e participação popular e do combate às ações antropogênicas destrutivas, relacionadas na região às práticas de pesca destrutiva e turismo exploratório.

***Palavras-chave**: Recifes de corais; Criação de áreas marinhas protegidas; Degradação recifal; Plano de Conservação; Áreas de exclusão de uso.*

1. Introduction

Despite their ecological and economic importance (Connel, 1978; Reaka-Kudla, 1997; Constanza *et al*., 1997; Moberg & Folke, 1999; Hughes *et al*., 2002), coral reefs have declined during the last 50 years as a result of natural and human impacts along coastal areas (Bryant *et al*., 1998; Aronson & Precht, 2003; Worm *et al*., 2006) to such an extent that Bellwood *et al.* (2004) define the decline as a global crisis for coral reefs. According to Wilkinson (2008), human activities have destroyed 20% of reefs, while another 35% are threatened. Given the current state of degradation, several studies suggest that between 20-30% of coral reefs need to be protected to ensure the conservation of biodiversity and of the resources and services offered (Souter & Lindén, 2000; Halpern, 2003; Bellwood *et al.,* 2004; Wilkinson, 2004; Roberts, 2003a, 2003b; Wood *et al*., 2008). Because they harbor a large part of marine diversity, coral reefs should be considered priority areas for conservation (Moberg & Folke, 1999; Spalding, 2000), and the creation of No-taken zones (NTZs), which prohibit any type of anthropogenic activity, is the best instrument for the protection of these ecosystems (Pandolfi *et al*., 2003; Aronson & Precht, 2006; Hoegh-Guldberg, 2006). Recently, based on the urgent demand for reef conservation, the Great Barrier Reef Marine Park in Australia expanded its NTZs from 4.5% to 33% of the reef area (Wilkinson, 2004; Fernandes *et al.,* 2005).

In coral reefs, the exclusion of human use promoted by NTZs allows the recovery and maintenance of ecological integrity (Edmunds & Carpenter, 2001). A consequence is increased environmental resilience resulting from the recovery and stabilization of populations of functional groups, such as herbivorous and carnivorous fish, which control algae populations capable of eliminating corals by competition and perform top-down control in trophic webs, respectively (Jackson *et al*., 2001; Bellwood *et al*., 2004; Mumbay, 2006; Nystrom, 2006; Moura *et al*., 2007; Mumbay *et al*., 2007; Francini-Filho & Moura, 2008; Nyström *et al*., 2008). NTZs also facilitate an increase in the number, size and reproductive ability of populations and facilitate the recovery of neighboring environments, serving as natural repositories for the migration of larvae, juvenile and adult organisms (McClanahan *et al*., 1999; Bellwood *et al*., 2004; McClanahan, 2006).

The economic importance of coral reefs for much of the coastal population makes it impossible to exclude their use entirely (Kalikoski, 2007). For this reason, studies that aim to select potential sites for the establishment of protected areas should consider a number of criteria designed to reflect the patterns and processes of the environment at a particular scale (Salm *et al*., 2000). According to Roberts *et al.* (2003a), the efficiency of a NTZ is related to the integrity of the environment; thus, an area with greater environmental integrity provides more benefits to the environment in general. For marine ecosystems, Salm *et al.* (2000) together with the International Union for the Conservation of Nature (IUCN) established the following useful criteria for identifying priority areas for conservation: (1) biodiversity, not only of species but also of populations and ecosystems; (2) representativeness, which expresses how the species of a given area reflect the biodiversity of the biogeographical area; (3) the degree of naturalness, which expresses the influence of human interference; (4) the degree of integrity, which indicates the resilience of the ecosystem; (5) the degree of dependency, defined as the importance of a particular area for an adjacent ecosystem; (6) uniqueness, which is the amount of endemism; (7) productivity, which reflects the system's ability to generate and maintain biomass; and (8) vulnerability, which reflects the susceptibility of the system to human activities or stochastic effects.

In Brazil, as in other parts of the world, numerous human impacts threaten the health of coral reefs (Leão &

Kiluchi, 2005; Loiola *et al*., 2013), endangering the goods and services offered, including fish stocks and aesthetic enjoyment through tourism (Constanza *et al*., 2007), and therefore the viability of coastal communities that rely on the commercial exploitation of reef areas (Kalikoski, 2007; Moura *et al*., 2007; Francini-Filho & Moura, 2008). Within the national scenario, the Brazilian east coast brings together the largest and richest coral reefs of the South Atlantic Ocean (Leão *et al*., 2003), harboring a fauna of corals and fish marked by high rates of endemism (Leão *et al*., 2003; Moura, 2002). Thus, the east coast of Brazil should be considered as a key area for the conservation of these systems.

In this context, the objective of this work was the ecological description of the benthic community associated with a set of coastal reefs located on the east coast of Brazil, in the south of the state of Bahia (the islands of Tinharé and Boipeba), that are within the limits of a marine conservation unit (State Environmental Protection Area of the Tinharé and Boipeba Islands – '*Área de Proteção Ambiental Estadual das Ilhas de Tinharé e Boipeba*'). The most appropriate locations for the establishment of NTZs were identified to ensure the conservation of this group of coastal reefs threatened by uncontrolled urban development. A set of ecological attributes was used to calculate a conservation priority index (CPI) based on criteria including the integrity of the benthic community, the richness of coral species and the reef-building capacity, as defined by Cruz *et al*. (2013) in a study that choice priority areas for the conservation of the reefs in the Todos os Santos Bay (TSB), Bahia/Brazil. The work aims to provide agencies responsible for managing these reef ecosystems with an unprecedented overview of the status of the coral reefs sampled, indicating possible locations where NTZs can be established, which are hitherto nonexistent in the region (Conder, 1998) and which can serve as repositories of larvae and adults necessary for the preservation and maintenance of stocks of the local marine ecosystem.

2. Material and methods

2.1. Study area

The study area encompasses a set of coastal reefs located on the southern coast of Bahia, at the islands of Tinharé and Boipeba (13° 22' and 13° 40' S and 38° 51'and 39° 03' W; Datum SAD 69), which are located within a 433 km^2 state environmental protection area ('*Área de Preservação Ambiental Estadual*' [EPA]) consisting of an estuarine ecosystem bordered by coral reefs and seagrass banks. This conservation unit, regulated by the National System of Conservation Units ('*Sistema Nacional de Unidades de Conservação*' - SNUC), is equivalent to category V as defined by the IUCN (Silva, 2005). According to the criteria defined by Salm *et al.* (2000), reefs in the Tinharé and Boipeba islands are vulnerable to human interference due to exploratory tourism, clearing of mangroves and other riparian vegetation and pollution from domestic sewage. Three of the sampled sites were located on the island of Tinharé, and six were on the island of Boipeba. In Tinharé, the sites included Ilha do Caitá (Caitá 13.3808° S and 38.9049° W), Boca da Barra Norte (BBNorte 13.4737° S and 38.8973° W) and Boca da Barra Sul (BBSul 13.4841° S and 38.9038° W), and in Boipeba, the sites included Tassimirim (Tass 13.5815° S and 38,9086° W), Piscinas de Moreré (PMor 13.5944° S and 38.8948° W), Massabuçu (Mass 13.6051° S and 38.8979° W), Mateus (Mat 13.6231° S and 38.8902° W), Cais (Cais 13.6391° S and 38.8893° W) and Ponta dos Castelhanos (PCast 13.6678° S and 38.8947° W) (Figure 1).

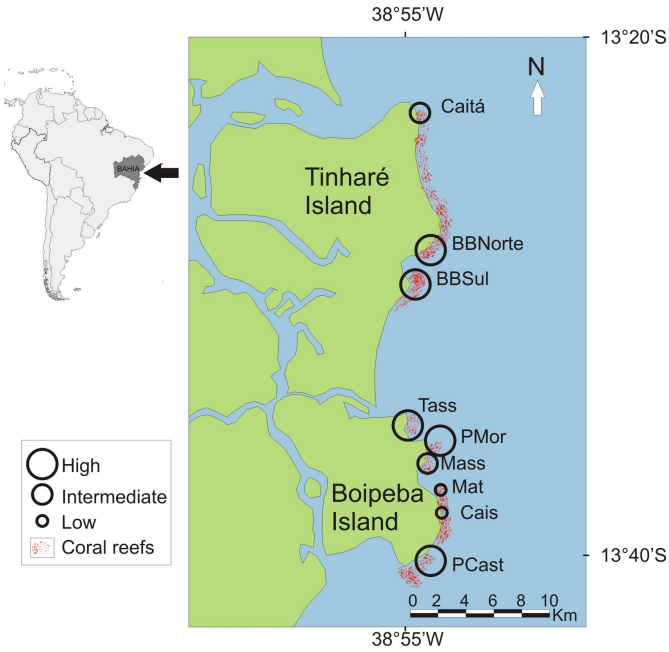

Figure 1 - Location of the Tinharé and Boipeba reefs and sampled stations. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus and PCast = Ponta dos Castelhanos station.

Figura 1 - Localização dos recifes e das estações de coleta nas ilhas de Tinharé e de Boipeba. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus e PCast = Ponta dos Castelhanos.

2.2. Data collection

Data collection was conducted in January and March 2003, applying the video transect technique (Carleton & Done, 2001), which consists of filming a strip of the reef substrate with defined dimensions along under

water line transects using digital video. At each station, six parallel transects were conducted, spaced 10 m apart. The sampled image area was standardized using a 40 cm aluminum rod coupled to the filming system. At this distance, the width sampled by the camera is 0.2 m. Each transect was 20 m long, covering an area of 4 m^2, totaling 24 m^2 per station. In addition to the video transects, we also collected data on the coral community richness because small species are difficult to identify in the videos (Carleton & Done, 2001; Cruz *et al.*, 2008).

2.3. Image processing

The transects were analyzed by selecting points on successive frames generated throughout the video. Each video transect was separated into 90 frames. Using the program CPCe 3.6, we selected 20 points per frame on an image overlaid with a grid with 450 possibilities. Benthic organisms falling under the randomly selected points were identified. For scleractinians, hydrocorals, zoanthids and octocorals, species-level identification was performed following Laborel (1970) and Hetzel & Castro (1994), except for the genus *Siderastrea* due to the difficulty in identifying species of this genus in the field and/or with photography (Neves *et al.*, 2008). In addition to cnidarians, we identified the following groups: macroalgae, filamentous algae, encrusting and articulated calcareous algae (including rhodophytes and *Halimeda* sp.), sponges, crinoids, sea urchins and sea squirts. Despite being sampled in the videos, the percentages of octocorals, crinoids, sea urchins and sea squirts were not used in the analysis due to the low estimated values for the stations. The results are expressed as the percentage of cover of the groups of organisms. All the coral colonies were grouped into size classes according to Done (1995). The colony size classes varied in 5 centimeter intervals from under 5 cm to over 30 cm in diameter. The data were presented as the number of colonies per class per square meter.

2.4. Conservation priority index (CPI)

A CPI was calculated for each station following Cruz *et al.* (2013). The calculation was based on nine ecological attributes estimated from the empirical data collected: (1) index of coral species richness, (2) index of mean coral colony age, (3) percentage of coral cover, (4) percentage of cover of encrusting calcareous algae, (5) percentage of cover of articulated calcareous algae, (6) percentage of cover of macroalgae, (7) percentage of cover of filamentous algae, (8) percentage of cover of sponges and (9) percentage of cover of the zoanthid *Palythoa caribaeorum*. Table 1 presents the rationale for each of the criteria used. Because of the differences among the units of measurement of each attribute, the scores were converted into dimensionless numbers (Table 1) so they could be used to create a distinctive CPI for each station, as follows:

$$CPI = S(R_i \times C_i)$$

where R_i is the rank value for the abundance of attribute 'i' (1-5), and C_i is the weighting of the 'i' attribute based on its ecological role and total abundance in the overall dataset. Therefore, attributes that are functionally important but are rare in the study area, such as the density of coral recruits or the percentage of cover of herbivorous urchins, did not significantly affect the CPI. The R_i abundance values were therefore progressive (for desirable attributes) or regressive (for the attributes that when significantly abundant are sympto-matically neutral or harmful to reef construction and/or recovery of building corals). Thus, the coral richness, mean colony age and coverage of corals and calcareous algae (encrusting and articulated) were progressive attributes (intervals increasing from 1-5 according to the increase in raw scores), while the coverage of macroalgae, filamentous algae, sponges and zoanthids (*P. caribaeorum*) were all considered negative attributes (interval classes decreasing from 5 to 1 as the raw value of the scores increases). The per capita weighting of each attribute type was assigned subjectively based on literature reviews, and its C_i was calculated as the product of its weight per capita and its global maximum in the sampled dataset. Before being scaled from 1 to 5, the scores were standardized to a scale of 0 to 100, which represents the absolute value of benthic coverage for the benthic attributes measured as a percentage of the total cover or a score relative to the maximum value observed for the numerical attributes (such as the index of species richness and the mean age index calculated for the coral colonies).

The species richness index of corals for each station was calculated as follows:

$$VSR = \Sigma (S_i)$$

where S_i is the proportion of reefs where the species occurs, with 'i' equal to 1 for common species (> 50% of the stations), 2 for uncommon species (26-50% of the stations) and 3 for rare species (≤ 25% of the stations). Table 2 present the number of reefs where each coral species was identified and, consequently, the value of each species based on the proportion of reefs where the species occurs.

The index of mean age of coral colonies for each of the stations was calculated as follows:

$$AA = \Sigma (A_i \times M_i)$$

where A_i is the mean class 'i' (in years), and M_i is the proportion of individuals in the size class 'i'. The index of age of the corals was estimated from the size of the sampled colonies of species with known annual growth rates, more specifically *Mussismilia braziliensis*

Table 1 - Rationale for the use of each of the ecological attributes considered for the calculation of the Conservation Priority Index (CPI). Adapted from Cruz *et al*. (2013).

Tabela 1 - Justificativa para a utilização de cada um dos atributos ecológicos considerados para o calculo do Índice de Prioridade de Conservação (IPC). Adaptado de Cruz et al. (2013).

Criteria	Justification	Rating	Maximum amplitude	Ecological relevance	Conservation relevance
Species richness index	Score both rare species and number of species (Done, 1995).	Progressive	15,0	-	100
Average 'age' index	Reflects both the abundance of corals and reef-building community maturity (Done, 1995), Kyears.	Progressive	157,0	-	150
Coral cover	Corals are the major builders of the reef structure (Jameson *et al.*, 1998, Knowlton & Jackson, 2001; McField & Kramer, 2007).	Progressive	10,0	5	50
Encrusting calcareous algae cover	These are reef-building organisms (Knowlton & Jackson, 2001) and induce coral recruting (Heyward & Negri 1999, Negri *et al*. 2001).	Progressive	10,4	2	21
Articulated calcareous algae cover	These algae can be important producers of calcium carbonate, contributing sediments that fill the pores of the reef structure (Leão & Ginsburg, 1997, Leão *et al*., 2006).	Progressive	47,6	1	48
Macroalgae cover	Macroalgae are agressive coral competitor (Lirman, 2001). They are principal causes for the decline of coral reefs (McCook, 1999; McCook *et al.*, 2001; Bellwood *et al*., 2004; Hoegh-Guldberg, 2006). Cause a permanent stage alternative in reef community Norström *et al*., 2009). High abundances can indicate eutrophication and/or overfishing of herbivorous fish (Bellwood *et al*., 2004; Hoegh-Guldberg, 2006).	Regressive	72,2	2	144
Filamentous cover	These algae are compete with corals (Jompa & McCook, 2002; Nugues & Roberts, 2003), can disrupt or inhibit coral recruting and may also store bacteria that are pathogenic for corals (Smith et al., 2006).	Regressive	28,2	1	28
Sponges cover	Sponges, in addition to eroding reefs (Gly nn, 1997), can be a coral competitors (Diaz & Rützler, 2001). High coverage of sponges characterizes an alternative stage in reef community (Norström *et al*., 2009) and may indicate eutrophication (Diaz & Rützler, 2001).	Regressive	7,5	2	15
Palythoa caribeorum cover	In high abundance they are aggressive competitors of corals (Tanner, 1997).	Regressive	14,1	1	14

(6.5 mm), *M. hispida* (4.7 mm), *M. harttii* (2.1 mm), *Montastraea cavernosa* (6.2 mm) and *Siderastrea* sp. (2 mm), as reported by Suggett *et al*. (2012). Thus, colonies of *M. cavernosa*, *Siderastrea* sp., *M. braziliensis*, *M. hispida* and *M. harttii* with a 30 cm diameter would be approximately 48, 150, 46, 64 and 143 years old, respectively (Cruz *et al*., 2013).

2.5. Statistical analysis

We used non-parametric multidimensional scaling (MDS) to visualize the ordination pattern of the sampled reefs represented by the percentage of cover of benthic groups, indices of mean colony age and coral species richness.

The MDS plot was subsequently subdivided into three distinct domains associated with the CPI. Thus, three reef categories of high, medium and low conservation priority were identified. The ordination analysis was performed using PRIMER 6.0 (Plymouth Routines in Multivariate Ecological Research) and was based on the Bray Curtis similarity index (Riegl & Luke, 1998; Clarke & Warwick, 2001; McField *et al.,* 2001; Khalaf & Kochzius, 2002).

Table 2 - Weighting of coral species according to commonness or rarity and the distribution in the study area. For each coral species classified as common (observed in five or more reefs) was attributed a value equivalent to 1; 2 for uncommon species (sampled in 3-5 reefs) and; 3 for rare species (observed in less than 3 reefs).

Tabela 2 - Valor atribuído para cada espécie de coral de acordo com a proporção de recifes de corais onde a mesma é observada. Para cada espécie de coral classificada como comum (presentes em mais do que a metade dos recifes amostrados) foi atribuído um valor equivalente a 1; 2 para as espécies incomuns (presentes entre 5 a 3 recifes) e; equivalente a 3 para as espécies raras (observadas em menos do que três recifes). Adaptado de Cruz et al. (2013).

Species	Number of sites	Species Value	Total
Agaricia agaricites	9	1	1
Favia gravida	9	1	1
Siderastrea spp.	9	1	1
Montastraea cavernosa	9	1	1
Mussismilia braziliensis	9	1	1
Mussismilia hartti	7	1	1
Mussismilia hispida	9	1	1
Porites astreoides	8	1	1
Porites branneri	9	1	1
Scolymia wellsi	1	3	3
Millepora alcicornis	9	1	1

3. Results

3.1. Characterization of the benthic reef communities

Sponges and zoanthids were rare overall, with coverage values across the nine stations equal to, or very close to zero (Table 3). Macroalgae showed, almost always, the greatest abundance according to the video-transect data. Only at the PMOR station (Boipeba), with the equivalent of 14.3% cover, was this class of organisms not the most abundant in terms of percentage of cover. The highest macroalgal cover value was observed at Mateus station on the island of Boipeba, where the organisms covered 72% of the reef substrate. At the Massabuçu and Cais stations in Boipeba Island and at the Boca da Barra Norte station in Tinharé Island, the macroalgal cover exceeded 50% (Table 3). Filamentous algae were most abundant at the Ponta dos Castelhanos station (Boipeba), with a cover value of 20%. The lowest value was observed at Cais station, where filamentous algae covered 2% of the sampled reef area (Table 3). Articulated calcareous algae were abundant at the Piscinas de Moreré station, with 48% cover or double the cover at Ilha do Caitá, which had the second-highest cover value for this class of organisms. Overall, Ilha do Caitá and considerable portion of the reef substrate. Globally, Tassimirim had much higher values than the other stations. Aside from Boca da Barra Sul (Tinharé), with 12% cover, the other six stations had cover values that did not exceed 5%, with the lowest value observed at Mateus with 1% articulated calcareous algae cover (Table 3). Encrusting calcareous algae were more abundant at the Piscinas de Moreré, Tassimirim and Ilha do Caitá stations, with values of approximately 10% cover. At Mateus, this coverage reached 2.5%, and at Ponta dos Castelhanos, encrusting calcareous algal cover was almost zero (Table 3). Coral cover (hard scleractinians and *Millepora* hydrocorals) was highest at Boca da Barra Norte station, with approximately 10% of the reef substrate covered by reef-building species. At the Mateus and Cais stations, the coverage values did not exceed 5% (Table 3).

The species abundance patterns of reef-building corals were similar across all the reefs. The species *Mussismilia hispida*, *M. braziliensis* and *Siderastrea* spp. were among the most abundant species together with *Montastraea cavernosa*, with the exception of the BBNorte and Cais stations (Table 3). These four coral species represented approximately 80% of the estimated total coral cover. The average coralline cover considering all the stations sampled was equivalent to 5.2% (including the hard coral order Scleractinia and *Millepora* hydrocorals).

In total, 11 coral species were observed, with *M. hispida*, *M. braziliensis*, *Montastraea cavernosa*, *Porites branneri*, *Agaricia agaricites, Favia gravida*, *Siderastrea* spp. and *Millepora alcicornis* recorded at the 10 sampled reefs (Table 3).

3.2. Conservation priority indices (CPIs)

The values calculated for the conservation priority indices ranged from 97 to 1110 (Table 4). Stations Boca da Barra Norte, Ponta dos Castelhanos, Piscinas de Moreré, Tassimirim and Boca da Barra Sul were considered reefs of high conservation priority according to the attributes defined by Cruz *et al.* (2013). The two worst indices were calculated for the Mateus (97) and Cais (167) stations. These two reefs were classified as having low conservation priority. The Massabuçu and Ilha do Caitá stations were classified as reefs of intermediate conservation priority. According to the MDS plot, three distinct reef categories were grouped according to the ecological attributes considered (Figure 2).

4. Discussion

The reefs studied are characterized by a high percentage of algal cover, especially macroalgae, low percentages of sponge and zoanthid cover and a satisfactory per

Table 3 - Percent coverage of each benthic group and the most abundant corals. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus and PCast = Ponta dos Castelhanos station.

Tabela 3 - Percentual de cobertura para cada um dos grupos bentônicos considerados e para as espécies de corais mais abundantes. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus e PCast = Ponta dos Castelhanos.

groups of organisms	**sampled reefs**								
	Caitá	**BBNorte**	**BBSul**	**Tass**	**Pmor**	**Mass**	**Mat**	**Cais**	**Pcast**
Macroalgae	41,70	54,54	32,89	29,52	14,26	54,93	72,18	65,94	47,74
Filamentous algae	6,53	5,71	18,59	15,88	10,51	16,06	9,38	2,92	20,40
Incrusting calcareous algae	23,41	4,22	12,43	20,77	47,61	4,64	1,23	2,78	3,73
Articulated calcareous algae	9,04	5,45	10,17	9,70	10,42	5,73	2,77	5,51	0,19
Sponge	0,52	-	0,02	0,23	0,01	0,02	0,04	-	0,26
Zoanthid	-	0,72	-	8,03	-	-	-	-	-
Coral	4,81	9,70	7,11	5,51	5,39	5,66	1,49	4,17	6,81
Montastraea cavernosa	1,94	-	0,68	0,52	1,40	0,68	0,05	-	0,50
Mussismilia hispida	0,22	2,03	5,66	0,40	2,99	1,57	1,02	1,43	2,37
Mussismilia harttii	0,22	0,10	0,35	0,10	0,06	0,04	-	-	1,05
Mussismilia braziliensis	0,03	0,55	0,23	0,27	0,81	0,10	0,30	0,82	0,48
Siderastrea spp.	0,21	6,74	0,13	1,05	0,13	3,01	0,12	0,40	2,24
Porites astreoides	-	0,28	-	0,07	-	0,26	-	0,29	0,12
Millepora alcicornis	2,19	-	0,06	3,10	-	-	-	1,23	0,05

Note 1: The coral species *Porites branneri, Agaricia agaricites and Favia gravida* (founded in all sampled stations) and *Scolymia wellsi* (only in Ponta dos Castelhanos reef) are not present in this table because of they small value of coverage (approximatelly zero).

Note 2: Despite showed null values of coverage in BBNorte and Cais reefs, *Montastraea cavernosa* was observed in these two sampled stations. The same can be said for the fire coral *Millepora alcicornis,* observed in BBNorte, PMor, Mass and Mat reefs.

centage of coral cover. Algae naturally occupy a considerable portion of the reef substrate. Globally, algal cover, particularly macroalgae, has increased dramatically in many reefs in response to environmental impacts, such as global warming, decreasing water quality (increased sedimentation and nutrient enrichment) and decreasing biomass of herbivorous organisms (McCook, 1999; McCook *et al*., 2001; Jompa & McCook, 2002).

The consequence of dramatic increases in algae abundance on reefs is the emergence of phase shifts in which the algae, which include competitor, tolerant and non-reef-building organisms (with the exception of encrusting calcareous algae), tend to cover corals, directly affecting the construction of the reef structure and hence the associated biodiversity (McCook, 1999; Lirman, 2001; Nughes, 2002; Nughes & Roberts, 2003; Nughes *et al*., 2004). The values observed for the coral communities reflect the pattern of Brazilian reefs, which are usually characterized by low abundance percentages and low richness (Leão *et al*., 2003) compared, for example, to Caribbean and Indo-Pacific reefs (Reaka-Kudla, 1997; Hughes *et al*., 2002).

The reefs studied are within the geographic boundaries of an environmental protection area (Tinharé and Boipeba Islands EPA), the implementation of which was aimed to protect an area of significant environmental value, aligning development with environmental conservation of the area, with the objective of improving the quality of life of local populations and promoting adequate protection of the ecosystems for the permanent and sustained enjoyment of present and future generations (Conder, 1998). Fragments or remnants of tropical forest, sandbanks, mangroves and coral reefs are among the most appealing ecosystems for conservation within this EPA. These landscapes, among oth

Table 4 - Estimated values and assigned scores for each of the criteria (coverage of benthic key organisms, species richness of corals and average age of reef systems) used for the calculation of conservation priority indexes (CPIs) for each coral reef. CPIs were calculated from the sum of the three scores assigned for each one of the criteria. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus and PCast = Ponta dos Castelhanos station.

Tabela 4 - Valor estimado e pontuação atribuída para cada um dos critérios considerados (percentuais de cobertura dos grupos bentônicos, riqueza de espécies de corais e valor de idade média recifal) para o cálculo dos índices de prioridade de conservação (IPCs) dos recifes. IPCs foram calculados a partir do somatório das três pontuações referentes a cada um dos critérios considerados. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus e PCast = Ponta dos Castelhanos.

			Coral	**Macroalgae**	**Filamentous algae**	**Crustose coraline algae**	**Artuculate coraline algae**	**Sponge**	***Palythoa caribaeorum***	**Richness**	***Average 'age' index***
Conservation Relevance			42	116	17	10	46	1	8	100	150
Rating			Progressive	Regressive	Regressive	Progressive	Progressive	Regressive	Regressive	Progressive	Progressive
Sites	Conservation Priority Index	Conservation Priority	-	-	-	-	-	-	-	-	-
Boca da Barra Norte	1110	High	4	1	4	2	0	4	4	1	4
Castelhanos	1092	High	3	2	0	0	0	2	4	4	2
Moreré	944	High	2	4	2	4	4	4	4	1	0
Tassimirim	877	High	3	3	1	4	2	2	0	1	1
Boca da Barra Sul	866	High	3	3	1	3	1	4	4	1	1
Massabuçu	673	Intermediate	2	1	1	2	0	4	4	1	2
Caitá	535	Intermediate	2	2	3	4	2	0	4	0	0
Cais	167	Low	1	0	4	2	0	4	4	0	0
Mateus	97	Low	0	0	3	1	0	4	4	0	0

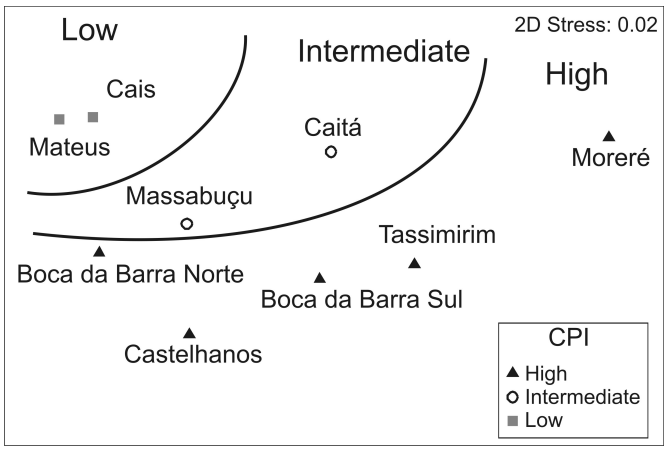

Figure 2 - MDS diagram representative of stations classified as reefs of high, intermediate and low priority for conservation according to benthic organisms coverage, index of coral richness and average age of coral colonies. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus and PCast = Ponta dos Castelhanos station.

Figura 2 - Diagrama MDS apresentando o agrupamento das estações classificadas como recifes de alta, intermediária e baixa prioridade de conservação de acordo com o percentual de cobertura de organismos bentônicos e com os índices de riqueza de espécies de coral e de idade média recifal. Caitá = Ilha do Caitá; BBNorte = Boca da Barra Norte; BBSul = Boca da Barra Sul; Tass = Tassimirim; PMor = Piscinas de Moreré; Mass = Massabuçu; Mat = Mateus e PCast = Ponta dos Castelhanos.

ers, were defined as rigorous protection zones ('*Zonas de Proteção Rigorosa*'), a category that restricts anthropogenic activities that result in damage to the ecosystem and allows tourism, research and fishing by traditional communities in a controlled manner (Conder, 1998).

For developing and implementing a management plan that enables more efficient environmental planning and management, quantitative and qualitative knowledge of the natural resources and human activities undertaken in an area are required (Fernandez *et al*., 2005, 2009). Despite recognition of the value of coral reefs in the current management plan, no study to describe the ecosystem in detail had been conducted. A detailed description enables an evaluation of the health of the environment in question and, consequently, the definition of priority areas for conservation (DeVantier *et al*., 1998; Beger *et al.,* 2003). In the present study, the ecological status of the reefs was assessed according to a number of attributes related to the reef's benthic community in addition to indicators of the mean age of the reefs and quantitative indices associated with the richness of the coral fauna, as suggested by Cruz *et al.* (2013). From the results, it was possible to identify the areas where, based on these ecological descriptors, it is most advantageous to invest in conservation. According to Cruz *et al.* (2013), the indices used here were effective in defining priority areas for conservation of the reefs in Todos os Santos Bay (TSB). Nevertheless, the authors emphasize that the indices should not be interpreted as indicative of preserved or degraded reefs because the indices are related only to the current state of conservation of these environments. It is noteworthy that the three criteria adopted are complementary, thus offering a more complete assessment of environmental quality, as because each index evaluated the reefs based on different ecological parameters.

In the specific case of Brazilian reefs, ecosystems that remain understudied, the use of criteria associated with bio-construction (an index of mean reef age) may skew the results of the computed indices due to the lack of knowledge about the growth rates of some reef-building species (*e.g*., *Porites astreoides*, *P. branneri* and *Millepora alcicornis*) because the estimate of accumulated ages of colonies is based on previously described colony sizes and growth rates (Cruz *et al.,* 2013). Nevertheless, for the reefs studied here, the most abundant species are exactly those with known annual growth rates: *Mussismilia braziliensis*, *M. hispida*, *M. harttii*, *Montastraea cavernosa* and *Siderastrea* spp. (Suggett *et al.,* 2012), which represent approximately 86% of the estimated coral cover of the sampled reefs. Among the species with unknown growth rates that were recorded, *M. alcicornis* was the only species that showed a significant percentage of cover (12%). Greater knowledge of Brazilian reefs, especially in relation to the ecology of native coral species, is thus required so that corals can be optimally used as good models and ecological indicators in conservation studies.

Based on the 9 attributes considered in the calculation of the CPI and in the qualification of the conservation priority status of reefs (high, intermediate or low), attention should focus on establishing NTZs in the high-priority reefs of Boca da Barra Norte, Ponta dos Castelhanos, Piscinas de Moreré, Tassimirim and Boca da Barra Sul because the efficiency of an NTZ is directly associated with the environmental quality of the area (Roberts *et al*., 2003b). With the establishment of NTZs, these reefs can function as repositories of reef marine life (McClanahan *et al*., 1999; McClanahan, 2006), acting directly in the recovery of reefs that today are under more pronounced states of degradation, such as reefs of intermediate conservation value (Massabuçu and Caitá) and reefs classified as low priority for conservation (Cais and Mateus).

The recovery of these reefs is directly related to compliance with the standards presented in the management plan prepared for the islands' EPA (Conder, 1998), which prohibits destructive human use, such as the practices of overfishing and destructive tourism. These areas would also benefit from the establishment of

NTZs, which would serve to enable the recovery of depleted reef stocks (Edmunds & Carpenter, 2001; Pandolfi *et al*., 2003; West & Salm 2003; Bellwood *et al*., 2004). Two central objectives have motivated the establishment of most marine reserves: conservation and sustainable supply for human use. Conservation objectives include, among others, (1) biodiversity conservation, (2) conservation of rare species and species with restricted distributions, (3) conservation of genetic diversity, (4) preservation and/or restoration of natural ecosystems at a local and regional scale and (5) conservation of areas vital to vulnerable life stages. Human-use objectives include (1) management of fish stocks (using protected areas to sustain or increase production, restore or rebuild stocks of overexploited species and provide insurance against management failures), (2) recreation, (3) education, (4) research and (5) aesthetic requirements (Roberts *et al*., 2003a; Roberts *et al*., 2003b). The Tinharé and Boipeba Islands EPA includes as goals both the conservation and sustainable use of the natural resources by the human population (Conder, 1998). However, the minimum degree of protection (without excluding use) is not the best way to meet these goals.

There are different types of marine protected areas (MPAs) around the world, and each type is associated with different levels of protection and use and is implemented through different institutional arrangements. A MPA can be established to support multiple uses, including the establishment of areas of complete exclusion within the span of the EPA. Some authors consider that at least one NTZ is essential to implement a MPA to achieve the goals of biodiversity conservation and restoration of stocks (Aronson & Precht, 2006; McClanhan *et al*., 2006; Kalikoski, 2007).

To accomplish this objective within the Tinharé and Boipeba Islands EPA, the area should be covered with at least two NTZs. The establishment of the two areas is justified because of the spatial extent of the area where the reefs are located. The distance between the stations that marked the northernmost and southernmost sampled points, is approximately 35 km. Shanks *et al*. (2003) state that two NTZs should be separated by a maximum distance of 20 km and that exceeding this distance prevents the connection between adjacent benthic populations based on propagule dispersal (spores, eggs and larvae). According to the authors, for NTZs to act as areas of restoration and maintenance of marine diversity, the areas should be circular or rectangular with dimensions between 12.7 and 28.3 km^2. Moura *et al*. (2007) suggested the establishment of an NTZ of 18.5 km^2 in the Corumbau Extractive Reserve (Reserva Extrativista de Corumbau, extreme south of Bahia, Brazil), which has shown good results related to the recovery of overexploited fishing resources.

The size and location of the two NTZs proposed for the Tinharé and Boipeba Islands EPA must take into account not only the ecological traits of the sampled reefs but also the use that the local community makes of the region (mainly fishing and tourism) in an attempt to preserve the major reefs with minimal interference in the lives of local people. We therefore suggest two rectangular no-taken zones for the EPA in question (Shanks *et al*., 2003), each approximately 12 km^2, which is the minimum viable size suggested by Shanks *et al.* (2003), with one located on the island of Tinharé and the other in Boipeba. Of the five reefs classified as high conservation priority, two are extensively used by local populations, mainly through the extraction of fish (Tassimirim and Piscinas de Moreré) and tourism (Piscinas de Moreré) (M. Loiola, personal communication). In an investigative study conducted on the reefs of Piscinas de Moreré, Albu-querque *et al.* (2014) assessed the impact of tourism on the reef fish communities and estimated the presence of hundreds of tourists daily at this reef station. Therefore, the exclusion of human use in these reefs would involve a conflict with the social groups that use the environments as sources of goods and services. However, the other three reefs classified as high con-servation priority, two located on the Island of Tinharé (Boca da Barra Norte e Boca da Barra Sul) and one located in Boipeba (Ponta dos Castelhanos), must be included in any NTZ established. These two areas are separated by a distance of less than 20 km, which, according to Shanks *et al.* (2003), would enable connectivity between the benthic populations. We emphasize that based on this design (NTZs of 12 km^2), at most one strip of 12 km from a total of almost 40 km, which is the coastal extent of the Tinharé and Boipeba islands, would be closed to human use.

Connectivity with other ecosystems, such as mangroves and algal banks, is critical for coral reefs. As dynamic systems, reef environments must be connected to adjacent reefs and associated ecosystems, which act as external sources of resources, such as larvae and juveniles of benthic and nektonic groups. In addition, many key processes, such as reproduction and recruitment, occur at a scale that exceeds the limits of a single reef (Nyström *et al*., 2000; Cruz, 2008; Moura *et al*., 2011). Coral reefs, algal banks and mangroves are not, therefore, independent units but are part of ecologically and hydrodynamically interrelated processes in the marine environment (Nyström *et al*., 2000; Moberg & Ronnback, 2003).

Therefore, ensuring both the connectivity and conservation of reef environments and their associated marine ecosystems is essential to ensure the protection of this rich deposit of marine biodiversity. Mangroves, in particular, are considered sources of a variety of natural resources and ecological services and also serve as a

temporary habitat for a large portion of the fauna associated with reef environments, which depend on mangroves during at least some stage of their life cycles (Moberg & Ronnback, 2003; Moura *et al*., 2011). Mangroves are widely represented in the Tinharé and Boipeba Islands EPA and like the coral reefs are considered by the existing management plan to be rigorous-protection zones (Conder, 1998). Therefore, it is essential to ensure the conservation of mangroves to guarantee the resilience of reefs and fishery sustainability (Nyström *et al*., 2000; Moberg & Ronnback, 2003).

Simply creating conservation units does not guarantee their effectiveness in the protection of biodiversity. Effective protection requires the responsible managing body to establish appropriate infrastructure, personnel and land regulations that protect the area. Good management plans, appropriate to the reality of the location, are also an important tool for the implementation of CUs (Artaza-Barrios & Schiavetti, 2007). Tissot *et al*. (2003) demonstrated through their work in Hawaii that well-established protected areas are fundamental in the protection and conservation of biodiversity.

Proper management of the Tinharé and Boipeba Islands EPA should focus on strict prohibition of human use within NTZs and on the control of water quality and of destructive tourism and fisheries practices over the entire EPA. Local participation should be a focus of the management of the unit because several studies (*e.g.,* Kalikoski, 2007 and Moura *et al.,* 2007) indicate that the efficiency of conservation units is directly related to the degree of participation by the local population. These types of measures will enable both the conservation and the recovery of the reefs studied, allowing for the future sustainable use of resources.

5. Conclusions

Overall, the coral reefs of the Tinharé and Boipeba islands have similar benthic community composition and structure, with high percentages of algal cover (especially macroalgae) and a satisfactory percentage, by Brazilian reef standards, of reef-building corals. Considering the conservation priority index (CPI), the BBNorte, PCast, PMor, Tas and BBSul reefs (in descending order) had the highest CPIs and therefore represent the best areas for the establishment of NTZs. However, the intensive use of the PMor and Tas reefs (Boipeba) by local people complicates the implementation of NTZ systems. The large spatial extent of the EPA, which includes the sampled reefs (35 km), justifies the creation of two NTZs. We recommend the establishment of two rectangular areas covering approximately 12 km^2 of the BBNorte and BBSul reefs (Tinharé) and PCast reef (Boipeba). With this design, only 30% of the coastline of the Tinharé and Boipeba islands would be protected by the exclusion of human use.

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References

Albuquerque, T.; Loiola, M.; Nunes, J.A.C.C.; Reis-Filho, J.A.; Sampaio, C.L.S.; Leduc, A.O.H.C. (2014) - *In situ* effects of human disturbances on coral reef-fish assemblage structure: temporary and persisting changes are reflected as a result of intensive tourism. *Marine and Freshwater Research* [published on-line before inclusion in an issue]. DOI: 10.1071/MF13185.

Aronson, R.B.; Precht, W.F. (2006) - Conservation, Precaution, and Caribbean Reefs. *Coral Reefs*, 25(3):441–450. DOI: 10.1007/s00338-006-0122-9

Artaza-Barrios, O.H.; Schiavetti, A. (2007) - Análise da Efetividade do Manejo de duas Áreas de Proteção Ambiental do Litoral Sul da Bahia. *Revista de Gestão Costeira Integrada,* 7(2):117-128. DOI: 10.5894/rgci13.

Beger, M.; Jones, G.P.; Munday, P.L. (2003) - Conservation of coral reef biodiversity a comparison of reserve selection producers for corals and fishes. *Biological Conservation*, 111(1):53–62. DOI: 10.1016/S0006-3207(02)00249-5.

Bellwood, D.R.; Hughes, T.P.; Folke, C.; Nystrom, M. (2004) - Confronting the Coral Reef Crisis. *Nature*, 429:827-833. DOI: 10.1038/nature02691.

Bryant, D.; Burke, L.; McManus, J; Spalding, M. (1998) - *Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs*. 56p., World Resources Institute (WRI) / International Center for Living Aquatic Resources Management (ICLARM) / World Conservation Monitoring Centre (WCMC) / United Nations Environment Programme (UNEP) / World Resource Institute, Washington, DC, USA. ISBN: 1559632574. Availabte on-line at http://coralreef.noaa.gov/aboutcrcp/strategy/reprioritization/wgroups/resources/climate/resources/reefsatrisk.pdf.

Carleton, C.B.; Done, T.J. (1995) - Quantitative Video Sampling of Coral Reef Benthos: Large-Scale Application. *Coral Reefs*, 14(1):35-46. DOI: 10.1007/BF00304070.

Clarke, K.R.; Warwick, R.M. (2001) - *Changes in Marine Communities: An Approach to Statiscal Analysis an Interpretation*. 234p., Plymouth Marine Laboratory, Plymouth, United Kingdom. ISBN: 13: 978- 1855311404.

CONDER. (1998) - *Plano de Manejo: APA das Ilhas de Tinharé e Boipeba. Governo de Estado da Bahia*. Secretária do Planejamento, Ciência e Tecnologia, Centro de recursos ambientais (CRA.), Salvador, Bahia, Brasil.

Connell, J.H. (1978) - Diversity in tropical rain forests and coral reefs. *Science*, 199(4335):1302–1310. DOI: 10.1126/science.199.4335.1302.

Constanza, R.; d'Arge ,R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P; van den Belt, M. (1997) - The value of the world's ecosystem services and natural capital. *Nature*, 387: 253-260. DOI: 10.1038/387253a0.

Cruz, I.C.S.; Kikuchi, R.K.P.; Leão, Z.M.A.N. (2008) - Use of Video Transect Method for Characterizing the Itacolomis Reefs, Eastern Brazil. *Brazilian Journal of Oceanography,* 56(4):271-280. DOI: 10.1590/S1679-87592008000400002.

Cruz, I.C.S.; Kikuchi, R.K.P.; Leão, Z.M.A.N.; Done, T.J. (2013) - Reef quality criteria for marine reserve selection: an example from eastern Brazil. *Aquatic Conservation: Marine and Freshwater Ecosystem*, Early View (Online Version of Record published before inclusion in an issue). DOI: 10.1002/aqc.2417.

Cruz, I.C.S.; Kikuchi, R.K.P.; Longo, L.L.; Creed, J.C. (2014) - Evidence of a phase shift to *Epizoanthus gabrieli* Carlgreen, 1951 (Order Zoanthidea) and loss of coral cover on reefs in the Southwest Atlantic. *Marine Ecology*, Early View (Online Version of Record published before inclusion in an issue). DOI: 10.1111/maec.12141.

DeVantier, L.M.; De'ath, G.; Done, T.J.; Turak, E; 1998 - Ecological assessment of a complex natural system a case study from the Great Barrier. Reef. *Ecological Applications*, 8(2):480–496. DOI: 10.1890/1051-0761(1998)008%5B0480:EAOACN%5D2.0.CO;2.

Diaz, M.C.; Rützler, K. (2001) - Sponges: an essential component of Caribbean coral reefs. *Bulletin of Marine Science*, 69(2): 535–546. Available on-line at http://docserver.ingentaconnect.com/deliver/connect/umrsmas/00074977/v69n2/s26.pdf?expires=1397237096&id=77838861&titleid=10983&accname=Guest+User&checksum=4B5438FA5BD59A3E1E0371FA26C64FE7

Done, T.J. (1992) - Phase shifts in coral reefs and their ecological significance. *Hydrobiologia*, 80:121–132. DOI: 10.1007/978-94-017-3288-8_13.

Done, T.J. (1995) - Ecological criteria for evaluating coral reefs and their implications for managers and researchers. *Coral Reefs*, 14(4):183-192. DOI: 10.1007/BF00334340.

Edmunds, P.J.; Carpenter, R.C. (2001) - Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. *Proceedings of the National Academy of Sciences,* 98(9):5067-5071. DOI: 10.1073/pnas.071524598.

Fernandes, L.; Day, J.; Lewis, A.; Slegers, S.; Kerrigan, B.; Breen, D.; Cameron, D.; Jago, B.; Hall, J.; Lowe, D.; Innes, J.; Tanzer, J.; Chadwick, V.; Thompson, L.; Gorman, K.; Simmons, M.; Barnett, B.; Sampson, K.; De'ath, G.; Mapstone, B.; Marsh, H.; Possingham, H.; Ball, I.; Ward, T.; Dobbs, K.; Aumend, J.; Slater, D.; Stapleton, K. (2005) - Establishing Representative No-Take Areas in the Great Barrier Reef: Large-Scale Implementation of Theory on Marine Protected Areas. *Conservation Biology*, 19(6):1733–1744. DOI: 10.1111/j.1523-1739.2005.00302.x.

Fernandes, L.; Day, J.; Kerrigan, B.; Breen, D.; De'ath, G.; Coles, R.; Done, T.; Marsh. H.; Poiner, I.; Ward, T.; Williams, D.; Kenchington, R. (2009) - A process to design a network of marine no–take areas: Lessons from the Great Barrier Reef. *Ocean & Coastal Management*, 52(8):439–447. DOI: 10.1016/j.ocecoaman.2009.06.004.

Francini-Filho, R.B.; Moura, R.L. (2008) - Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil. *Aquatic Conservation: Marine and Freshwater Research*, 18(7):1166-1179. DOI: 10.1002/aqc.966.

Halpern, B.S. (2003) - The Impact of Marine Reserves: Do Reserves Work and Does Reserve Size Matter? *Ecological Applications*, 13(1):117-137. DOI: 10.1890/1051-0761(2003)013[0117:TIOMRD]2.0.CO;2.

Hetzel, B.; Castro, C.B. (1994) - *Corais do Sul da Bahia*. 189p., Nova Fronteira, Rio de Janeiro, Rio de Janeiro. ISBN: 978-8516068820 .

Hoegh-Guldberg, O. (2006) - Complexities of coral reef recovery. *Science*, 311(5757):42-43. DOI: 10.1126/science.1122951.

Hughes, T.P. (1994) - Catastrophes, phase shifts, and large-scale degradation of Caribbean coral reefs. *Science*, 265(5178):1547–1551. DOI: 10.1126/science.265.5178.1547.

Hughes, T.P.; Bellwood, D.R.; Connolly, S.R. (2002) - Biodiversity hotspots, centres of endemicity, and the conservation of coral reefs. *Ecology Letters*, 5(6):775-784. DOI: 10.1046/j.1461-0248.2002.00383.x.

Jackson, J.B.C.; Kirby, M.X.; Berger, W.H.; Bjorndal, K.A.; Botsford, L.W.; Bourque, B.J.; Bradbury, R.H.; Cooke, R.; Erlandson, J.; Estes, J.A.; Hughes, T.P.; Kidwell, S.; Lange, C.B.; Lenihan, H.S.; Pandolfi, J.M.; Peterson, C.H.; Steneck, R.S.; Tegner, M.J.; Warner, R.R. (2001) - Historical overfishing and the recent collapse of coastal ecosystems. *Science*, 293(5530):629–638. DOI: 10.1126/science.1059199.

Jameson, S.C.; Erdmann, M.V.; Gibson Jr., G.R.; Pott, K.W. (1998) - *Development of Biological Criteria for Coral Reef Ecosystem Assessment*. 79p., United States Environmental Protection Agency, Office of Science and Technology, Health and Ecological Criteria Division, Washington, DC, United States. Available online in: http://www.epa.gov/owow/oceans/coral.

Jompa. J.; McCook, L.J. (2002) - Effects of competition and herbivory on interactions between a hard coral and a brown alga. *Journal of Experimental Biology and Ecology*, 271(1): 25–39. DOI: 10.1016/S0022-0981(02)00040-0.

Kalikoski, D.C. (2007) - Áreas Marinhas Protegidas, Conservação e Justiça Social: Considerações à Luz da Teoria dos Comuns. *In*: Ana F. Caminha; Ana P. Prates; Ângela E. M. Duarte; Danielle Blanc; João L. F. Ferreira; Maria C. Hazin; Mariana S. Viana; Paula M. Pereira (eds.), *Áreas Aquáticas Protegidas como Instrumento de Gestão Pesqueira, Série Áreas protegidas do Brasil 4*, pp. 65-77, Ministério do Meio Ambiente, Secretaria de Biodiversidade e Florestas, Núcleo de Zona Costeira e Marinha, Brasília, Brazil. ISBN 978-8577380770.

Khalaf, M.A.; Kochzius, M. (2002) - Changes in trophic community structure of shore fishes at an industrial site in the Gulf of Aqaba, Red Sea. *Marine Ecology Progress Series,* 239: 287-299. DOI: 10.3354/meps239287.

Knowlton, N.; Jackson, J.B.C. (2001) - The ecology of coral reefs. *In*: Mark D. Bertness; Steve D. Gaines; Mark E. Hay (eds.), *Marine Community Ecology*, pp. 395-422, Sinauer Associates, Sunderland, Massachusets, United States. ISBN: 087-8930574550.

Leão, Z.M.A.N.; Kikuchi, R.K.P.; Testa, V. (2003) - Corals and Coral Reefs of Brazil. *In:* Jorge Cortés (ed.), *Latin American Coral Reefs*, pp. 9-52, Elsevier B.V., Amsterdam, Netherlands. ISBN: 0444513884.

Leão, Z.M.A.N.; Kikuchi, R.K.P. (2005) - A relic coral fauna threatened by global changes and human activities, Eastern Brazil. *Marine Pollution Bulletin*, 51(5-7):599-611. DOI: 10.1016/j.marpolbul.2005.04.024.

Leão, Z.M.A.N.; Dutra, L.X.C.; Spanó, S. (2006) - The characteristics of bottom sediments. *In*: Guilherme F. Dutra; Gerald R. Allen; Timothy Werner; Sheila A. McKenna (eds.), *A Rapid Marine Biodiversity Assessment of Abrolhos Bank, Bahia, Brazil*, pp. 75–81, Conservation International, Washington DC, United States. ISBN: 1881173941.

Lirman, D. (2001) - Competition between macroalgae and corals: effects of herbivore exclusion and increased algal biomass on coral survivorship and growth. *Coral Reefs,* 19(4):392-399. DOI: 10.1007/s003380000125.

Loiola, M.; Oliveira, M.D.M.; Kikuchi, R.K.P. (2013) - Tolerance of Brazilian brain coral *Mussismilia braziliensis* to sediment and organic matter inputs. *Marine Pollution Bulletin*, 77(1-2):55-62. DOI: 10.1016/j.marpolbul.2013.10.033.

McClanahan, T.R.; Muthiga, N.A.; Kamukuru, A.T.; Machano, H.; Kiambo, K.W. (1999) - The effects of marine parks and fishing on coral reefs of northern Tanzania. *Biological Conservation*, 89(2):161-182. DOI: 10.1016/S0006- 3207(98)00123-2.

McClanahan, T.R.; Marnane, M.J.; Cinner, J.E.; Kiene W.E. (2006) - A Comparison of Marine Protected Areas and Alternative Approaches to Coral-Reef Management. *Current Biology,* 16(14):1408–1413. DOI: 10.1016/ j.cub.2006.05.062.

McCook, L.J. (1999) - Macroalgae, nutrients and phase shifts on coral reefs: Scientific issues and management consequences for the Great Barrier Reef. *Coral Reefs*, 18(4): 357–367. DOI: 10.1007/s003380050213.

McCook, L.J.; Jompa, J.; Diaz-Pulido, G. (2001) - Competition between coral and algae on coral reefs: a review of evidence and mechanisms. *Coral Reefs*, 19(4): 400-417. DOI: 10.1007/s003380000129.

McField, M.D.; Hallock, P.; Jaap, W.C. (2001) - Multivariate Analysis of Reef Community Structure in the Belize Barrier Reef Complex. *Bulletin of Marine Science,* 69(2):745-758. Available online in: http://docserver.ingentaconnect.com/deliver/connect/umrsmas/00074977/v69n2/s40.pdf?expires=1397239662&id=77839178&titleid=10983&accname=Guest+User&checksum=EC1B4F6E1092B76693C3DD0755CF3398

Moberg, F.; Folke, C. (1999) - Ecological goods and services of coral reef ecosystems. *Ecological Economics*, 29(2):215-233. DOI: 10.1016/S0921-8009(99)00009-9.

Moberg, F.; Rönnbäck, P. (2003) - Ecosystem services of the tropical seascape: Interactions, substitutions and restoration. *Ocean and Coastal Management*, 46(1-2): 27–46. DOI: 10.1016/S0964-5691(02)00119-9.

Moura, R.L. (2002). Brazilian reefs as priority areas for biodiversity conservation in the Atlantic Ocean. *Proceedings of the 9th International Coral Reef Symposium*, 2; 917–920. Available on-line in: http//www.coremap.or.id/downloads/ICRS9-tha_Moura.pdf

Moura, R.L.; Dutra, G.F.; Francini-Filho, R.B.; Minte- Vera, C.V.; Curado, I.B.; Guimarães, F.J.; Oliveira, R.F.; Alves, D.C. (2007) - Gestão do Uso de Recursos Pesqueiros na reserva Extrativista Marinha do Corumbau - Bahia. *In*: Ana F. Caminha; Ana P. Prates; Ângela E. M. Duarte; Danielle Blanc; João L. F. Ferreira; Maria C. Hazin; Mariana S. Viana; Paula M. Pereira (eds.), *Áreas Aquáticas Protegidas como Instrumento de Gestão Pesqueira, Série Áreas protegidas do Brasil 4*, pp. 179-191, Ministério do Meio Ambiente, Secretária de Biodiversidade e Florestas, Núcleo de Zona Costeira e Marinha, Brasília, Brazil. ISBN 978-8577380770.

Moura, R.L.; Francini-Filho, R.B.; Chaves, E.M.; Minte-Vera, C.V.; Lindeman, K.C. (2011) - Use of riverine through reef habitat systems by dog snapper (*Lutjanus jocu*) in eastern Brazil. *Estuarine, Coastal and Shelf Science*, 95(1):274–278. DOI: 10.1016/j.ecss.2011.08.010.

Mumby, P.J. (2006) - The Impact of Exploiting Grazers (Scaridae) on The Dynamics of Caribbean Coral Reefs. *Ecological Applications,* 16(2):747–769. DOI: 10.1890/1051- 0761.

Negri, A.P.; Webster, N.S.; Hill, R.T.; Heyward, A.J. (2001) - Metamorphosis of broadcast spawning corals in response to bacteria isolated from crustose algae. *Marine Ecology Progress Series*, 223(1):121-131. DOI: 10.3354/meps223121.

Neves, E.G.; Andrade, S.C.; Silveira, F.L.; Solferini, V.N. (2008) - Genetic Variation and Population Structuring in two Brooding Coral Species (*Siderastrea Stellata* and *Siderastrea Radians*) from Brazil. *Genetica*, 132(3):243-254. DOI: 10.1007/s10709-007-9168-z.

Norström, A.V.; Nyström, M.; Lokrantz, J.; Folke, C. (2009) - Alternative states on coral reefs: beyond coral-macroalgal phase shifts. *Marine Ecology Progress Series*, 376:295–306. DOI: 10.3354/meps07815

Nughes, M.M.; Roberts, C.M. (2003) - Coral mortality and interaction with algae in relation to sedimentation. *Coral Reefs*, 22(4):507-516. DOI: 10.1007/s00338-003-0338-x.

Nughes, M.M.; Smith, G.W.; van Hooidonk, R.J.; Seabra, M.I.; Bak, R.P.M. (2004) - Algal contact as a trigger for coral disease. *Ecology Letters*, 7(10):919-923. DOI: 10.1111/j.1461-0248.2004.00651.x.

Nyström, M.; Folke; C.; Moberg, F. (2000) - Coral reef disturbance and resilience in a human-dominated environment. *Trends in Ecology and Evolution*, 15(10):413-417. DOI: 10.1016/S0169-5347(00)01948-0.

Nyström, M.; Graham, N.A.J.; Lokrantz, J.; Norström, A.V. (2008) - Capturing the cornerstones of coral reef resilience: linking theory to practice. *Coral Reefs*, 27(4):795-809. DOI: 10.1007/s00338-008-0426-z.

Pandolfi, J.M.; Bradbury, R.H.; Sala, E.; Hughes, T.P.; Bjorndal, K.A.; Cooke, R.G.; McArdle, D.; McClenachan, L.; Newman, M.J.H.; Paredes, G.; Warner, R.R.; Jackson, J.B.C. (2003) - Global Trajectories of the Long-Term Decline of Coral Reef Ecosystems. *Science*, 301(5635): 955-958. DOI: 10.1126/ science.1085706.

Reaka-Kudla, M.L. (1997) - The global biodiversity of coral reefs: a comparison with rain forests. *In*: Marjorie L. Reaka-Kudla; Don E. Wilson; Edward O. Wilson (eds.), *Biodiversity II: Understanding and Protecting our Biological Resources*, pp. 83-108, Joseph Henry Press, Washington, DC, United States. ISBN: 0-309-05227-0.

Riegl, B.; Luke, K.E. (1998) – Ecological Parameters of Dynamited Reefs in the Northern Red Sea and their Relevance to Reef Rehabilitation. *Marine Pollution Bulletin,* 37(8-12):488-489. DOI: 10.1016/S0025-326X(99)00104-6.

Roberts, C.M.; Andelman, S.; Branch, G.; Bustamante, R.H.; Castilla, J.C.; Dugan, J.; Halpern, B.S.; Lafferty, K.D.; Leslie, H.; Lubchenco J.; Deborah, M.; Possingham, H.P.; Ruckelshaus, M.; Warner, R.R. (2003a) - Ecological criteria for evaluating candidate sites for marine reserves. *Ecological Applications*, 13(1):199-214. DOI: 10.1890/1051-0761(2003)013[0199:ECFECS]2.0.CO;2.

Roberts, C.M.; Branch, G.; Bustamante, R.H.; Castilla, J.C.; Dugan, J.; Halpern, B.S.; Lafferty, K.D.; Leslie, H.; Lubchenco, J.; McArdle, D.; Ruckelshaus, M.; Warner, R.R. (2003b) - Application of ecological criteria in selecting marine reserves and developing reserve networks. *Ecological Applications*, 13(1):215-228. DOI: 10.1890/1051-0761(2003)013[0215:AOECIS]2.0.CO;2.

Salm, R.V.; Clark, J.R.; Siirila, E. (2000) - *Marine and Coastal Protected Areas: A Guide for Planners and Managers*, 371p., joint publication by International Union for Conservation of Nature and Natural Resource, Washington DC, United States. ISBN: 2831705401.

Shanks, A.L.; Grantham, B.A.; Carr, M.H. (2003) - Propagule Dispersal Distance and the Size and Spacing of Marine Reserves. *Ecological Applications.* 13(1):159-169. DOI: 10.1890/1051-0761(2003)013%5B0159:PDDATS%5D2.0.CO;2

Silva, M. (2005) - The Brazilian Protected Areas Program. *Conservation Biology*. 19(3):608-611. DOI: 10.1111/j.1523-1739.2005.00707.x

Souter, D.W.; Lindén, O. (2000) - The Health and Future of Coral Reef Systems. *Ocean & Coastal Management,* 43(8-9):657-688. DOI: 10.1016/S0964-5691(00)00053-3.

Spalding, M.D. (2000) - Spatial Variation in Coral Reef Fish Biodiversity at Intermediate Scales Arround Oceanic Islands. *Proceedings 9th International Coral Reef Symposium*, 1: 23-27. Available on-line at http://www.researchgate.net/publication /228452786_Spatial_variation_in_coral_reef_fish_biodiversity_at_intermediate_scales_around_oceanic_islands.

Suchanek, T.H.; Green, D.J. (1981) - Interspecific competition between *Palythoa caribaeorum* and other sessile invertebrates on St. Croix Reefs, US Virgin Islands. *Proceedings of the 4th International Coral Reef Symposium* 2: 679–684. Available on-line at http://www.aoml.noaa.gov/general/lib/CREWS/Cleo/St.Croix /salt_river85.pdf.

Suggett, D.; Kikuchi, R.K.P.; Oliveira, M.D.M.; Spanó, S.; Carvalho, R.; Smith, D.J. (2012) - Photobiology of corals from Brazil's near-shore marginal reefs of Abrolhos. *Marine Biology*, 159(7):1461-1473. DOI: 10.1007/s00227-012-1925-6.

Tanner, J.E. (1997) - The effects of density on the Zoanthid *Palythoa caesia*. *Journal of Animal Ecology*, 66(6):793–810. Article Stable URL: http://www.jstor.org/stable/5996

Tissot, B.N.; Walsh, W.J.; Hallacher, L.E. (2003) - *The Effectiveness of Marine Protected Areas and the Impacts of Aquarium Fish Collecting in Hawaii. West Hawaii Aquarium Project Technical Report*. 22p., joint publication by Hawaii Coral Reef Initiative, University of Hawaii, Honolulu, Hawai and National Oceanic and Atmosferic Administration (NOAA), Silver Springs, Florida, USA. Available on-line at: http://www.hcri.ssri.hawaii.edu/files/research/pdf/tissot.

Vermeij, M.J.A. (2005) - Substrate composition and adult distribution determine recruitment patterns in a Caribbean brooding coral. *Marine Ecology Progress Series*, 295:123–133. DOI: 10.3354/meps295123.

West, J.M.; Salm, R.V. (2003) - Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management. *Conservation Biology,* 17(4): 956–967. DOI: 10.1046/j.1523- 1739.2003.02055.x.

Wilkinson, C. (ed.) (2008) - *Status of Coral Reefs of the Worlds: 2008.* 304p., joint publication by Global Coral Reef Monitoring Network and The Australian Institute of Marine Science, Townsville, Queensland, Austrália. ISSN: 1447-6185.

Wood, L.J.; Fish, L.; Laughren, J.; Pauly, D. (2008) - Assessing progress towards global marine protection targets: Shortfalls in information and action. *Oryx*, 42(3):340–351. DOI: 10.1017/S003060530800046X.

Worm, B.; Barbier, E.B.; Beaumont, N.; Duffy, E.; Folke, C.; Halpern, B.S.; Jackson, J.B.C.; Lotze, H.K.; Micheli, F.; Palumbi, S.R.; Sala, E.; Selkoe, K.A.; Stachowicz, J.J.; Watson, R. (2006) - Impacts of Biodiversity Loss on Ocean Ecosystem Services. *Science*, 314(5800):787-790. DOI: 10.1126/science. 1132294.

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http://www.aprh.pt/rgci/pdf/rgci-455_Morais.pdf | DOI: 10.5894/rgci455

PSR framework applied to the coastal management of "Complexo Estuarino-Lagunar Iguape-Cananéia" – CELIC (São Paulo, Brazil), in terms of sanitation and public health*

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ABSTRACT

The Coastal Zone (CZ) is of great importance in maintaining natural resources and life. This region presents multiple anthropic activities of economic, social and environmental interest, which can be potentially harmful to natural ecosystems. Furthermore, it is estimated that one third of the world's population inhabits the CZ. In Brazil, neither the intensification of CZ activities nor population growth have frequently been followed by the implementation of the basic infrastructure required, which has caused the CZ to become an area with conflicts of interest and uses. In this study, the Complexo Estuarino-Lagunar Iguape-Cananéia (CELIC) region was chosen for an analysis of basic sanitary conditions, because it presents a profile that is unique along the São Paulo coast. This region was chosen in an attempt to understand whether it is managed in a way that promotes both quality of life and a healthy environment. To achieve that, information on different indicators involving sanitation, the healthcare system, the population, the economy and the environment were collected from public databases and the pressure-state-response (PSR) framework was used to integrate all of the collected information. The study presents relatively mild pressures when compared to other coastal regions from the state of São Paulo, although in CELIC, pressures present an increasing pattern. Status indicators show that there are structural deficiencies in terms of basic needs, such as health and sanitation. Government responses, however, have not addressed these problems, especially the health issues. Though the local economy has evolved consistently, the current status of sanitation and health structures reveals failings in these services, a situation which shows that economic gains did not effectively result in improvements to these structures. Thus, despite favorable conditions (low population size, the presence of protected areas, and the concentration of the population in urban areas), which should facilitate the planning and management of the aforementioned institutions, the pressure seems to keep increasing. It has resulted in a scenario in which the lack of infrastructure for healthcare and sanitation stand out and there seems to be a lack of political initiative toward actions that aim to mitigate or resolve the problems.

Key-words: coastal management**,** Estuarino-Lagunar Iguape-Cananéia, basic sanitation.

RESUMO

Modelo PSR aplicado na gestão costeira do "Complexo Estuarino-Lagunar Iguape-Cananéia" – CELIC (São Paulo, Brasil), em termos de saneamento e saúde pública

A zona costeira (ZC) é uma região de características únicas e de grande relevância à manutenção dos recursos e da vida, e que representa um local onde se desenvolvem diversas atividades de grande interesse econômico, social e ambiental. O crescimento populacional e a intensificação das atividades desenvolvidas na ZC brasileira geralmente não são acompanhados pela instalação das infraestruturas básicas necessárias, transformando essa região em um cenário de conflitos de interesses e usos. No estado de São Paulo o Plano Estadual de Gerenciamento Costeiro (PEGC) divide a ZC paulista em: Litoral Norte, Baixada Santista, Complexo Estuarino-Lagunar de Iguape-Cananeia (CELIC) e Vale do Ribeira. No presente estudo escolheu-se a região do CELIC para análise das condições de saneamento básico, por apresentar um perfil diferente do restante do litoral paulista; e com a finalidade de compreender se nessa região do litoral existe uma gestão que efetivamente

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promova a qualidade de vida e ambiental. Para isso foram coletados índices disponíveis em bases de dados públicas e utilizou-se o modelo pressão - estado – resposta (PER) com o intuito promover a integração das informações. A região estudada encontra-se numa situação onde as pressões são relativamente brandas ao comparadas com as demais regiões litorâneas do estado de São Paulo, porém com um comportamento crescente. Os indicadores de estado demonstram que há uma carência estrutural referente a aspectos básicos como: saúde e saneamento básico. Por sua vez não são evidenciadas respostas que atendam a essas carências, principalmente no que diz respeito à saúde. Mesmo que os aspectos econômicos na região tenham evoluído bastante, o atual estado das estruturas de saúde e saneamento reflete uma precariedade desses serviços, que por sua vez revelam que os ganhos econômicos obtidos não foram revertidos, pelo poder público, de maneira eficaz visando à melhora dessas estruturas. O que se pode observar é que apesar das condições – baixa população, presença de áreas protegidas e a concentração da população na área urbana – o que teoricamente facilitaria o planejamento e a gestão dos aspectos aqui abordados, as pressões parecem aumentar ao longo do tempo, repercutindo em um estado em que se destaca a falta de infraestrutura de saneamento e saúde, que não é acompanhada de ações que procurem mitigar ou resolver esse cenário.

Palavras-chave: *gerenciamento costeiro, Complexo Estuarino-Lagunar Iguape-Cananéia, saneamento básico.*

1. Introduction

About one third of the world's population lives on or close to the coastal zone (CZ), which puts intense pressure on ecosystems and represents a challenge for spatial planning (UNEP, 2006). The CZ is usually characterized as a region where several anthropic and economic activities take place; thus these regions are of high economic, social and environmental importance. Furthermore, major urban centers, industries, ports, marinas, and aquaculture, among other anthropic activities and structures, tend to be concentrated around the CZ. This region is continually experiencing growing tourism demands and intense real estate speculation, particularly in Brazil (Jablonski & Filet 2008).

The Brazilian CZ is approximately 8500 km long and covers 17 states (Federal Law nº 7.661/88). This region is inhabited by 25%-35% of the country's population (Moraes, 2007; Scherer et al., 2009); the exact percentage depends on the definition of the CZ. Moreover, economic activities performed in the CZ correspond to approximately 70% of gross domestic product (GDP) (Freitas, 2005), a number which reflects the importance of these areas to the country. In addition, over the last few decades, the CZ has experienced an intensification of economic activities combined with accelerated population growth and economic development, which have rarely been followed by the proper allocation of space and the installation of the required infrastructure. Thus, throughout Brazil's history, the country's CZ has been the backdrop for many conflicts of interest and uses that need to be solved through the use of different strategies. One strategy includes coastal management plans at different levels of administration, which play an important role since they can be implemented at various levels.

The Brazilian Coastal Zone Management Plan (CZMP) includes several interconnected topics related to the promotion of sustainability in the CZ. These topics are aimed toward monitoring, controlling and maintaining environmental quality, and also toward addressing critical issues such as urbanization, the occupation and use of lands, the use of mineral resources and waters, urban mobility, the production and distribution of energy, and also tourism, housing, sanitation, public healthcare and environmental conservation. Sanitation is one of the most important issues involved in sustainability, because it is involves both public healthcare and impacts on natural ecosystems (IBGE, 2008). Therefore, the variables related to this particular topic represent key aspects for CZ management, as well as for the appropriate diagnosis for a determined region, and they may subsidize relevant future decision making.

The Brazilian CZMP strongly supports the decentralization of management efforts, because it offers a structure composed of state and municipal CZMPs in order to provide different types of governance at local, regional and federal levels. Despite the slowness in the implementation of actions to improve coastal management, these plans represent an advance in terms of CZ planning, especially because they stimulate integration among different sectors of society, an objective which had not been achieved by previous forms of managing CZ. These characteristics are fundamental in the development of Integrated Coastal Zone Management (ICZM), which is a multi-faceted process that seeks to overcome the fragmentation inherent in the sectorial management approach and to enable multiple uses of coastal and marine resources by different sectors of society in a sustainable way by taking the different scenarios present in the CZ into account (Cicin-Sain & Knecht, 1998).

In light of this information, the state of São Paulo established its State CZMP (State Law nº 10.019/98), which divided the CZ into four administrative sectors: North Coast, Central Coast (known as the Baixada Santista), South Coast (or the Complexo Estuarino-Lagunar Cananéia-Iguape – CELIC) and the Ribeira de Iguape River Valley. Among the São Paulo coastal regions, the CELIC presents a unique profile when compared to the central and northern regions, particularly because it is

known for its natural conservation features (it is comprised of the important Atlantic rainforest and estuarine areas, which make up a biosphere reserve and relevant wetland sites according to the Ramsar Convention). In addition, the CELIC is characterized by low population density, a lack of large-scale economic activities, the presence of a wide set of terrestrial and aquatic protected areas, despite its proximity to major urban and industrial centers such as the Baixada Santista Metropolitan Region, the São Paulo Metropolitan Region and the Curitiba Metropolitan Region. Moreover, there are few studies on the CELIC to support the CZMP in this region, despite its ecological importance.

The goal of this investigation was to evaluate the status of the conditions and management of the CELIC in terms of the region's water resources and sanitation in order to understand whether the management is being effective in promoting both environmental quality and the quality of life in the region. To achieve this, the Pressure- State-Response (PSR) framework was applied to the CELIC. This approach was developed in 1993 by the Organization for Economic Cooperation and Development (OECD), and it is based on the concept of causality; in other words, human activities exert pressures on the environment (Pressure), which, in turn, may exhibit altered quality and/or availability of natural resources (State), and the society usually responds to these changes through policies and/or economic, environmental and governmental actions (Response) (OECD, 1993). Methodological procedures of this nature have been rarely or under-used in Brasil (Carvalho & Barcellos, 2009; Chaves & Alipaz, 2007; Marotta et al., 2008), despite the relevance of results that this approach may provide for the coastal management.

2. Material and Methods

2.1. Study area

The CELIC is located on the south coast of São Paulo state (Figure 1) and includes the cities of Iguape, Cananéia and Ilha Comprida, as well as their respective non-urbanized areas. According to the SEADE Foundation, this region corresponds to 3409.30 km² and has a population of 50,477, which presents a significant set of environmental and landscape attributes that are reflected in the large number of protected areas.

2.2. Collection and interpretation of data

Temporal series data were collected from public databases on the websites of the SEADE Foundation, IBGE, CVE and environmental reports issued by the CETESB. In this study, the following pressure indicators were obtained and evaluated: Gross Domestic Product (GDP)

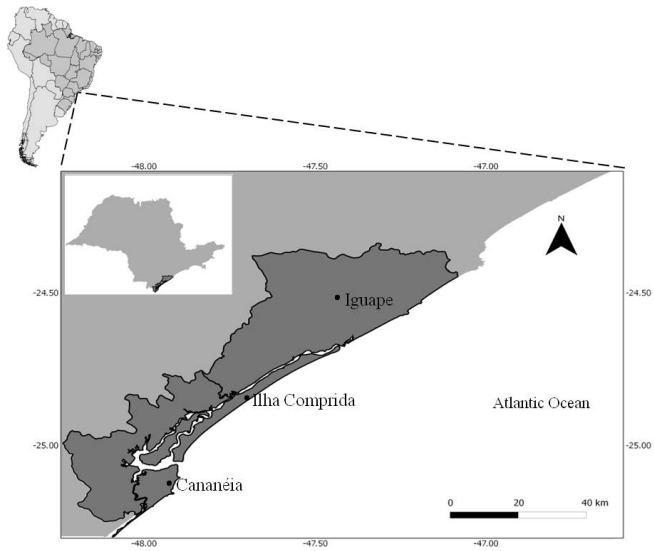

Figure 1 - Map of CELIC and the cities included in this region.

Figura 1 – Mapa da CELIC com as cidades incluídas nesta região.

of the municipalities of CELIC; resident population; population density; and urbanization rate. We highlight that in Brazil, the GDP for states, municipalities and regions have been calculated by the governmental agencies and are available at their official websites. The collected status indicators were the index of urban landfill quality; the beach bathing quality; the proportion of wastewater collected in relation to the total wastewater generated; the reduction ratio of domestic organic pollutant load; the number of cases of diarrhea; and the child mortality rate. Finally, the response indicators were the number of health professionals; the coefficient of hospital beds from the Brazil's public healthcare system (named “Sistema Único de Saúde – SUS”, or Unified Health System) per thousand residents; and the percentage of households reached by water supply and sewage collection services.

First of all, the data were plotted and organized into graphs or tables in order to observe trend curves and / or make comparisons to national or state standards. Information had been collected since 1993 whenever possible; however, for many variables, the available data did not include every year between 1993 and 2013. Furthermore, the PSR framework was applied in order to organize the data according to its characteristics, interactions, and effects on the environment and society, as indicated in the OECD (1993).

The data were organized according to the PSR framework as shown in Figure 2. This framework employs the concept of cause and effect, and takes the flow of information and the recognition of societal responses into account for data integration.

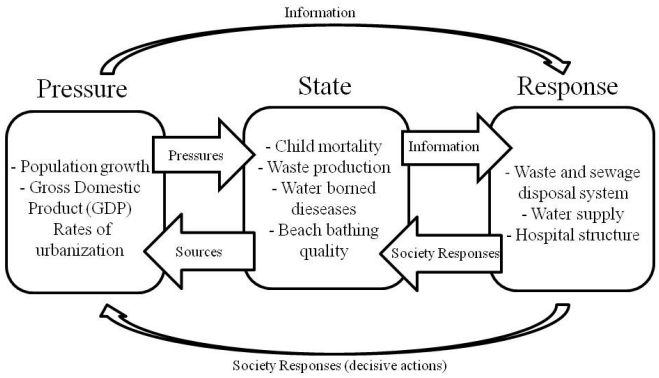

Figure 2 - PSR framework applied to coastal management sector of CELIC, in terms of sanitation and public health.

Figura 2 - PSR framework applied to coastal management sector of CELIC, in terms of sanitation and public health.

3. Results and Discussion

3.1. Pressure

The cities of Cananéia and Iguape experienced relatively low population growth in the period sampled (1993-2011), but in the last decade, Cananéia presented a decline in its population and Ilha Comprida presented a more pronounced population growth (Figure 3). However, it must be highlighted that these three cities all possess low populations. Urbanization rates observed are high in the three cities (Table 1), and reach up to 100% in Ilha Comprida. These factors indicate that the population of the three cities is largely concentrated in urban areas. Population growth, urbanization and economic demands in coastal regions have been indicated as some of the main vectors of pressure, either by increasing the demand for natural resources or by promoting the loss of habitats and landscapes (UNEP, 2006).

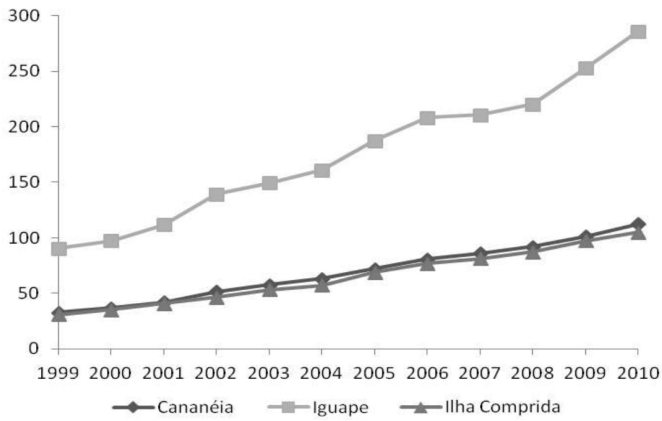

Figure 3 - Population growth in CELIC cities (Source: SEADE Foundation).

Figura 3 - Population growth in CELIC cities (Source: SEADE Foundation).

Cananéia, Iguape and Ilha Comprida have low population densities (Table 1), and they possess the lowest values along the coast of São Paulo. They are also much lower than the average density observed for the state CZ (261.66 inhabitants/km²). This situation is partly due to the fact that Iguape and Cananéia have the largest territorial areas of the São Paulo coast.

Because of their tourist attractions, the cities in the CELIC have a periodic seasonal variation in their population, and the population increases during the summer months. Thus, it would be useful to analyze the data of this temporal fluctuation for a better understanding of the population dynamics in this region; however, there are no official data available. Furthermore, according to the SIG-RB (2012), the study of fluctuating populations is important for planning the demands and needs for public services. Therefore, due to the unavailability of data, the present study focused only on the data on the resident population. For a global analysis, and considering the fact that the tourist season currently occurs only 1 to 2 months a year, the resident population data allows for a trend analysis and a reliable diagnosis.

Between 1999 and 2010, GDP has more than tripled in each of the cities; Iguape has presented the highest revenue (Figure 4). These increases follow state and national trends which, in turn, are a consequence of the relative stability and economic growth experienced by Brazil in recent years.

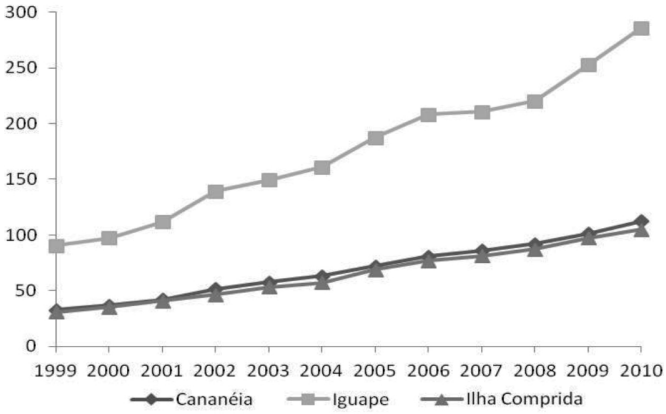

Figure 4 - Time series of the Gross Domestic Product of CELIC cities (Source: SEADE Foundation).

Figure 4 - Time series of the Gross Domestic Product of CELIC cities (Source: SEADE Foundation).

GDP provides a measure of the degree of economic activity in cities, and thus provides an estimate of the economic pressures induced by the population. However, GDP is an index largely used to measure market production (Stiglitz et al., 2009), and does not necessarily reflect a measure of population welfare, or quality of life and/or environment (Stiglitz et al., 2009; Cavalcanti, 2004). Tsalik & Schiffrin (2005) pointed out that, over the last forty years, many places around the world have experienced an increase in GDP due to petroleum

Table 1 - Time series data on land occupation in CELIC cities.

Tabela 1 - Time series data on land occupation in CELIC cities.

Year	Urbanization Rate (%)			Demographic Density hab/km²		
	Cananéia	Iguape	Ilha Comprida	Cananéia	Iguape	Ilha Comprida
1993	81,12	76,48		8,03	13,14	19,95
1994	78,93	75,33	100	8,29	13,24	22,15
1995	79,62	75,99	100	8,56	13,35	24,34
1996	80,27	76,65	100	8,82	13,45	26,53
1997	80,88	77,32	100	9,08	13,54	28,71
1998	81,43	77,98	100	9,34	13,63	30,9
1999	81,97	78,64	100	9,61	13,72	33,1
2000	82,49	79,31	100	9,88	13,84	35,29
2001	82,97	79,97	100	9,9	13,97	36,51
2002				9,92	14,07	37,76
2003				9,91	14,16	39,01
2004				9,88	14,25	40,21
2005	85,25	80,99	100	9,88	14,33	41,43
2006				9,88	14,41	42,69
2007	82,88	79,97	100	9,89	14,47	43,97
2008				9,88	14,50	45,27
2009	82,97	79,97	100	9,86	14,54	46,52
2010	85,36	85,6	100	9,84	14,55	47,75
2011				9,84	14,63	49,22
2012				9,86	14,63	48,21

activities in the CZ, but these same areas have seen a major deterioration in the indicators related to social, economic, and environmental aspects.

The evolution of demographic data does not follow the GDP trend, since the latter has grown at a more accelerated rate. In regions where there is an increase in the resident population, it is expected that there is also an increase in the consumption of natural resources, waste generation and exploration of new areas. However, the study area has experienced low population growth, including periods of population decline. In turn, the GDP has grown at a rapid rate and economic issues may play a crucial role in the intensity of resource use and consumption, and the generation of increased volumes of waste.

3.2. State

The urban landfills of the three cities were classified as inadequate (Table 2) for most of period evaluated, according to the Quality Index regarding urban landfills (CETESB, 2010), which considers locational, structural and operational characteristics of landfills. However, only in the last two years there was a relative improvement because solid wastes started to be disposed into better structured landfills located in other cities outside

Table 2 - Structural quality evaluation of urban landfills used by CIEC cities.

Table 2 - Structural quality evaluation of urban landfills used by CIEC cities.

Year	Quality Index of Urban Landfills		
	Cananéia	Iguape	Ilha Comprida
1997	3	2,5	4,5
1998	6	2,6	0,9
1999	4,9	2,6	1,3
2000	4,1	3	1,2
2001	3,4	3,5	1,2
2002	3,9	4,5	1,2
2003	3,5	8,8	1,2
2004	4,1	7,9	1,6
2005	4,4	8,2	2,1
2006	3,1	3,7	2,3
2007	3,2	3,5	2,8
2008	4,3	5	1,6
2009	6,2	9,5	9,5
2010	6,2	8,2	8,2

Inadequate Conditions; Controlled Conditions; Appropriate Conditions

Table 3 - The beach bathing quality of CELIC, based on microbiological indicators of fecal pollution.
Tabela 3 - *The beach bathing quality of CELIC, based on microbiological indicators of fecal pollution.*

Year	Iguape					
	Optimal	good	regular	poor	very poor	Systematically good
2000		67				33
2001		33	67			
2002						100
2003						100
2004						100
2005						100
2006			67			33
2007						100
2008						100
2009						100
2010						100
2011		50		50		

Year	Ilha Comprida					
	optimal	good	regular	poor	very poor	Systematically good
2000						100
2001						100
2002						100
2003			33			67
2004			33			67
2005						100
2006			67			33
2007				33		67
2008			33			67
2009			67			33
2010	34			33		33
2011	33					67

the CELIC (CETESB, 2010). Thus, the three cities need to cover the costs of transporting and disposing their residues in outer localities because they do not have landfills that meet the necessary requirements. Nevertheless, Cananéia pays to dispose its wastes in a location that is not considered completely appropriate according to the legal state requirements (CETESB, 2010). The National Policy on Solid Residues (Federal Law nº 12.305/10) established a goal of doing away with the illegal dumping sites of urban wastes throughout the country by 2014. However, according to the IBGE (2011), only 33% of Brazilian cities dispose their domestic residues in appropriate sanitary landfills.

The beach bathing quality (Table 3) is determined through an analysis of the amount of bacteria belonging to the group of fecal coliforms or enterococcus, which are found in large amounts in feces and have been used to assess sanitary conditions (CETESB, 2011). Until 2007, three beaches in each city were monitored, but since 2007, Iguape has had only two beaches monitored. Cananéia is not monitored for these parameters, because all of its beaches are located within the Ilha do Cardoso State Park, which is a protected area. Despite limited visitation and primary contact with water (Federal Law nº 9.985/00), it is not yet monitored by the system adopted for the beaches of the São Paulo coast.

Data from Table 4 indicate that Cananéia has experienced a relative deterioration in the sewage collection and treatment services, even though population growth has remained relatively stable. Iguape was found to

have the worst conditions in terms of the total sewage collected, but this city has experienced improvements in its wastewater treatment system; since 2002, efficiency in treating the collected sewage has increased to 48% and remained close to this value through the last sampling. Ilha Comprida has evolved the most in these two aspects, but it still has the worst results. The IBGE (2008) data show that the sewage collection and treatment services evolved slightly, increasing from 52.2% in 2000 to 55.2% in 2008, but the cities that already had this service presented an average improvement of 22%. The results indicate that, in the three studied cities, both the collection and the efficiency of wastewater treatment need to be significantly improved.

Among the water-borne diseases that may be related to sanitation conditions, diarrhea exhibited relevant results (figure 5). The recorded number of cases of diarrhea over the last few years has decreased only in Iguape. According to WHO (2009), diarrhea is the second leading cause of death in children under five years of age in developing countries, behind only of pneumonia, and according to Maranhão et al. (2011), this statistic is valid to Brazil.

The most recent results reported for the three municipalities indicated that the cities reduced their child mortality rates overall, in spite of high oscillations and the existence of some gaps in the available data (table 5). Cananéia has a relatively high rate of child mortality compared to the state average, which is 11.86 deaths per thousand live births (SEADE, 2010). The reduction of child mortality rates is among the Millennium Development Goals (MDGs) established by the United Nations Development Program (UNDP). According to the OMS (2013), this reduction requires a strong effort, since it largely depends on initiatives that can provide access to clean water and basic sanitation, which are the main primary causes of child mortality.

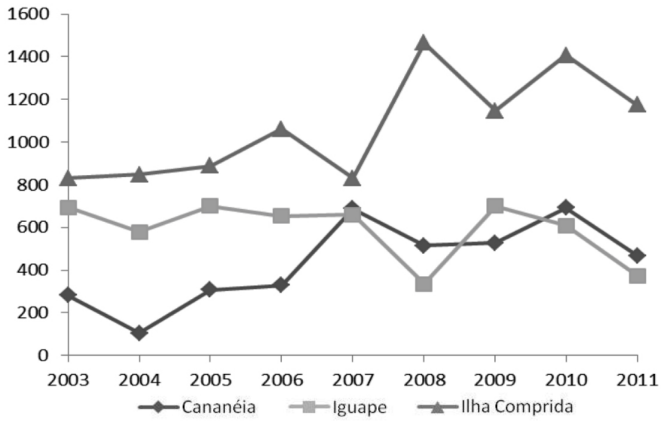

Figure 5 - Number of diarrhea cases in CELIC cities.

Figura 5 - *Number of diarrhea cases in CELIC cities.*

Brazil has a goal to reduce child mortality to at least 17.9 deaths per thousand live births by 2015 (IPEA, 2010), and the CELIC cities achieved that goal. However, when it comes to public health, the ideal goal is to make these rates get as close to zero as possible, and the right of access to basic sanitation should be guaranteed to the entire population.

Table 4: Rates of sewage collection and treatment in CELIC cities.

Table 4: Rates of sewage collection and treatment in CELIC cities.

Year	Proportion of collected sewage in relation to the total sewage generated (%)			Reduction of organic load pollution (%)		
	Cananéia	Iguape	Ilha Comprida	Cananéia	Iguape	Ilha Comprida
2000	53	67	13	47	0	11
2001	53	67	13	47	0	11
2002	45	60	12	36	48	10
2003	45	61	15	36	49	13
2004	45	62	19	36	50	16
2005	46	59	22	37	48	21
2006	47	59	25	38	47	20
2007	49	58	26	60	58	25
2008	49	58	30	40	50	8
2009	49	58	30	80	86	25
2010	49	60	35	38,8	51,4	33,4
2011	49	60	35	35,9	51,6	33,6

The decrease in child mortality rates may also be related to the increase in GDP, since the increased purchasing power of a population often results in infrastructural improvements to their homes and the consumption of products related to health and hygiene. Such improvements enable the population to reach and experience better sanitary conditions. However, it is evident that GDP evolves much faster than health and sanitation indicators.

Table 5 - Child mortality rates (per thousand live births) in CELIC cities (Source: SEADE Foundation).

Tabela 5 - Child mortality rates (per thousand live births) in CELIC cities (Source: SEADE Foundation).

Year	Child mortality rates (per thousand live births)		
	Cananéia	Iguape	Ilha Comprida
1993	16,6	28,78	
1994	15,56	27,54	21,74
1995	19,38	25,82	
1996	30,04	19,08	27,4
1997	41,49	15,49	44,12
1998	14,04	24,25	
1999	20,24	21,63	12,05
2000	11,67	21,91	11,11
2001	20,92	22,26	22,22
2002	8,44	9,52	27,03
2003	28,57	13,67	27,03
2004	9,35	9,45	9,17
2005	4,81	9,9	
2006		13,13	
2007	19,05	16,51	17,7
2008	5,13	12,59	7,69
2009	11,11	11,99	
2010	15,87	8,26	8,33

3.3. Response

The pressure indicators demonstrate a growth in economic activities that has not been accompanied by the improvement of sanitation facilities (sewage /wastes). State indicators reveal slow progress and the persistence of an inadequate situation; thus, the analysis of response indicators allows for an evaluation of government actions to improve sanitary conditions and public health, which would be mandatory to the achievement of the coastal management goals.

When it comes to healthcare facilities, although the cities had significantly increased their respective numbers of employees (Table 6), not enough information on the number of hospital beds has been made available (Table 7).

Table 6 - Number of employees in the public healthcare system in CELIC cities.

Tabela 6 - Number of employees in the public healthcare system in CELIC cities.

Year	Professionals hired under the public healthcare system		
	Cananéia	Iguape	Ilha Comprida
2000	32	148	15
2001	40	170	23
2002	46	189	32
2003	47	191	30
2004	52	193	31
2005	56	197	37
2006	60	215	45
2007	60	210	52
2008	76	236	64
2009	85	259	63
2010	78	248	75

The number of hospital beds is commonly used in Brazil as an indicator of progress in investment in the public healthcare system. This is a relevant lack of official information that prevents a proper analysis of the actions taken to solve this issue. Cananéia has presented no data since 2003, and Ilha Comprida has not presented any data since the beginning of the sampling period, which can portray either the lack of hospital beds in this city or simply the lack of data collection. In the case of Cananéia, there has been a dramatic decrease in the number of hospital beds, and the coefficient of hospital beds from the public healthcare system (SUS) per thousand inhabitants is much lower than the amount recommended by the Brazilian Ministry of Health, which is between 2.5 and 3.0 beds per thousand residents (Federal Law nº 1101/GM). Thus, it can be inferred that the population of these municipalities have been underserved in relation to their right to access to health care, which is guaranteed by the Federal Constitution (1988).

These data show that there are no effective responses by the government in terms of investments in healthcare, which should be given in order to keep up with or anticipate population increases in the region (Iguape and Ilha Comprida). In addition, there has been an increase in the number of cases of diarrhea, which indicates unsuitable conditions and may have a relationship to the low percentages of sewage collection and treatment. At the same time, though child mortality rates have dropped, the values are still relatively high, and the

Table 7 - Structure of hospital admission into public healthcare services (number of public hospital beds) in CELIC cities.

Tabela 7 - Structure of hospital admission into public healthcare services (number of public hospital beds) in CELIC cities.

Year	Number of hospital beds			SUS beds (per thousand inhabitants)		
	Cananéia	Iguape	Ilha Comprida	Cananéia	Iguape	Ilha Comprida
1995	17	85		1,17	3,28	
1996	17	85		1,17	3,26	
1997	17	85		1,78	3,26	
1998	17	85		1,78	3,25	
1999	17	35		1,44	1,29	
2000	17	35		1,4	1,28	
2001	17	85		1,38	3,07	
2002	17	35		1,38	1,26	
2003	17	35		1,38	1,25	
2004						
2005		34		1,14	1,2	
2006		34			1,19	
2007		34			1,19	
2008		34			1,18	
2009		34			1,18	
2010		34			1,18	
2011		34			1,18	

number of hospital beds is not increasing in proportion to the population growth, nor has it increased proportionally to the increase in the area's cases of diarrhea. The lack of public hospital beds forces the CELIC population to seek out the private healthcare system and pay for those services, and it also leads to overflow into hospitals in the neighboring cities, as their respective healthcare services are demanded to care for patients from CELIC locations.

There are not enough data available regarding basic sanitation in this region, and the coverage of sewage service is small (Table 8). Iguape, which provides the best service, has only 57.62% households reached by this service, which is well below the state average of 82% service (IBGE, 2008). The data on water supply in the region (Table 8) are relatively high and are between 77.76% (Cananéia) and 82.32% (Ilha Comprida). However, it was also noted that there was scarce evolution of this service, and the values are still below average for the Brazilian southeast region, which is 87.5% (IBGE, 2008).

In addition to the lack of data on sanitation, these data often conflict with each other; in other words, it is possible to find different values in different databases dealing with the same variable. For example: the data on basic sanitation, generated by the public water company (SABESP) and those available in the reports from the local Geographical Information System of Ribeira (Sistema de Informações Geográficas do Ribeira - SIG-RB) are different from those generated by National System of Sanitation Information (Sistema Nacional de Informações Sanitárias - SNIS).

4. Conclusions

When it comes to sanitary conditions, the CELIC is in a situation in which the pressures exerted on environmental issues are relatively mild but exhibit an increasing pattern. State indicators show that there is a lack of structure in terms of basic needs such as health and sanitation. Though the pressures in the current situation have not reached large-scale values, they may have already had relevant impacts to the environment and public health. Although economic factors have evolved considerably, the current lack of both sanitation and healthcare system infrastructure reflects the insufficiency of these public services, which, in turn, shows that the economic gains obtained are not efficiently turned into improvements in health and sanitation systems by the government. The public sector has also failed to produced consistent and organized responses to this problem; on the contrary, it tends to consider such constitutional obligations as superfluous. This problem is worsened by the weakness or complete lack of reliable data that can be obtained over the long term, despite the coastal management plan theoretically predicts some tools that are not performed by the govern

Table 8 - Index of households served by sanitary systems (water supply and sewage collection) in CELIC cities.

Tabela 8 - Index of households served by sanitary systems (water supply and sewage collection) in CELIC cities.

Year	Water Supply Service (%)			Sewage Collection Service (%)		
	Cananéia	Iguape	Ilha Comprida	Cananéia	Iguape	Ilha Comprida
2003		73,45				
2004	72,44	71,75		41,35	54,66	
2005	71,68	71,24		43,45	54,87	
2006	72,22	70,87	86,49	44,28	54,93	23,46
2007	85,94	70,28	98,95			
2008	85,48	67,49	95,21	44,97	56,78	28,35
2009	86,53	67,23	96,69	44,46	57,11	30,4
2010	77,76	71,53	82,32	44,92	57,62	31,89

ment, as the annual Environmental Quality Reports and the Action Plans.

The consequence of this management of the CELIC is that the basic sanitation structure and system are insufficient, and actions taken are not consistent with local demand. In spite of the local conditions (a low population, the presence of protected areas, and the concentration of the population in urban areas), which should facilitate the planning and management of sanitation measures, the pressures seem to increase, resulting in a state with a serious lack of infrastructure. For seemingly political reasons, there have not been enough actions taken that seek to mitigate or resolve this scenario. Therefore, it is necessary that government management of the CELIC take sanitation and public health into account so that the economic gains can effectively translate into improvements in quality of life and environment.

References

Carvalho, P.G.M.; Barcellos, F.C. (2009) - Políticas públicas e sustentabilidade ambiental. Construindo indicadores de sustentabilidade. *Indicadores Econômicos FEE* (ISSN: 0103-3905), 37(1):s/p, Fundação de Economia e Estatística Siegfried Emanuel Heuser, Porto Alegre, RS, Brazil. Available on-line at http://revistas.fee.tche.br/index.php/indicadores/article/view/2280/2656

Cavalcanti, C. (2004) – Uma Tentativa de Caracterização da Economia Ecológica. *Ambiente & Sociedade*, 7(1):149-156. DOI: 10.1590/S1414-753X2004000100009

Chaves, H.M.L.; Alipaz, S. (2007) – An Integrated Indicator Based on Basin Hydrology, Environment, Life, and Policy: The Watershed Sustainability Index. *Water Resource Management*, 21(5):883 – 895. DOI: 10.1007/s11269-006-9107-2

Cicin-Sain, B.; Knecht, R.W. (1998) – *Integrated coastal and ocean management: concepts and pratices*. 517p., Island Press Washington, D.C. U.S.A. ISBN: 1559636041.

SIG-RB (2012) - *Relatório de Situação dos Recursos Hídricos da Unidade de Gerenciamento nº 11*. 98p., Sistema de Informações Geográficas do Ribeira de Iguape e Litoral Sul (SIG-RB), Comitê da Bacia Hidrográfica do Ribeira de Iguape e Litoral Sul, Registro, SP, Brasil. Available on-line at http://www.sigrb.com.br/projetos /consulta.php?id=5

CETESB (2010) – *Inventário Estadual de Resíduos Sólidos Domiciliares. – 2010*. 186p., Companhia Ambiental do Estado de São Paulo (CETESB), São Paulo, SP, Brasil. Available on-line at http://www.cetesb.sp.gov.br/userfiles/file/residuos-solidos/residuos Solidos2010.zip

CETESB (2010) - *Balneabilidade das Praias Paulistas – 2010*. 257p., Companhia Ambiental do Estado de São Paulo (CETESB), São Paulo, SP, Brasil. Available on-line at http://www.cetesb.sp.gov.br/Agua/relatorios/praias/relatorio_balneabilidade_2010.zip

CETESB (2011) - *Balneabilidade das Praias Paulistas – 2011*. 342p., Companhia Ambiental do Estado de São Paulo (CETESB), São Paulo, SP, Brasil. Available on-line at http://www.cetesb.sp.gov.br/userfiles/file/agua/praias/relatorios/relatorio_balneabilidade_2011.zip

Freitas, M.A.P. (2005) - *Zona Costeira e Meio Ambiente – Aspectos Jurídicos*. 232p., Juruá Editora, Curitiba, PR, Brasil. ISBN: 853620972-0.

SEADE (2010) – *São Paulo: Objetivos de Desenvolvimento do Milênio. Relatório Estadual de Acompanhamento*. 63p., Fundação Sistema Estadual de Análise de Dados (SEADE), Secretaria de Planejamento e Desenvolvimento Regional, São Paulo, SP, Brasil. Available on-line at http://www.seade.gov.br /produtos/odm/pdf/ODM_2010_publicacao_completa.pdf

IBGE (2008) – Pesquisa Nacional de Saneamento Básico 2008. 219p., Instituto Brasileiro de Geografia e Estatística (IBGE), Rio de Janeiro, RJ, Brasil. ISBN: 978-8524041358. Available on-line at http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/pnsb2008/PNSB_2008.pdf

IBGE (2011) – *Atlas Nacional de Saneamento Básico 2011*. 268p., Instituto Brasileiro de Geografia e Estatística (IBGE), Rio de Janeiro, RJ, Brasil. ISBN: 978-85-240-4202-7. Available on-line

at ftp://geoftp.ibge.gov.br/atlas/atlas_saneamento/atlas_saneamento_2011.zip

Ipea (2010) – *Objetivos de Desenvolvimento do Milênio – Relatório Nacional de Acompanhamento 2010*. 184p., Instituto de Pesquisa Econômica Aplicada (Ipea), Ministério do Planejamento, Orçamento e Gestão, Secretaria de Planejamento e Investimentos Estratégicos, Brasília, DF, Brasil. ISBN: 857811043-9. Available on-line at http://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=1061&Itemid=9

Jablonski, S.; Filet, M. (2008) - Coastal management in Brazil – A political riddle. *Ocean & Coastal Management*, 51(7):536-543. DOI: 10.1016/j.ocecoaman.2008.06.008

Maranhão, A.G.K.; Vasconcelos, A.M.N.; Porto, D.L.; França, E. (2011) - *Mortalidade infantil no Brasil: tendências, componentes e causas de morte no período de 2000 a 2010*. 20p., Secretaria de Vigilância em Saúde, Brasíla, DF, Brasil. Available on-line at http://repositorio.unb.br/bitstream/10482/12478/1/CAPITULO_MortalidadeInfantilBrasil.pdf

Marotta, H.; Santos, R.O.; Enrich-Prast, A. (2008) – Monitoramento liminológico: um instrumento para a conservação dos recursos hídricos no planejamento e na gestão urbano-ambientais. *Ambiente & Sociedade,* 11(1):67-79. DOI: 10.1590/S1414-753X2008000100006

Moraes, A.C.R. (2007) – *Contribuições para a gestão costeira no Brasil: elementos para uma geografia do litoral brasileiro*. 232p., Annablume, São Paulo, SP, Brasil. ISBN: 978-8574196770.

ONU (1992 [1995]) – Agenda 21. *Conferência das Nações Unidas sobre o Meio Ambiente e Desenvolvimento.* 472p., Tradução do Ministério das Relações Exteriores com a colaboração do Programa das Nações Unidas para o Meio Ambiente (PNUMA). Câmara dos Deputados, Brasília, DF, Brasil. Available on-line at http://www.onu.org.br/rio20/img/2012/01/agenda21.pdf

OMS (2013) – *Estadísticas Sanitarias Mundiales*. 172p., Organización Mundial de la Salud (OMS), Genebra, Suíça. ISBN: 9789243564586. Available on-line at http://apps.who.int/iris/bitstream/10665/82218/1/9789243564586_spa.pdf?ua=1

OECD (1993) - OECD Core Set of Indicators for Environmental Performance Reviews. A synthesis report by the Group on the State of the Environment. 39p., Organisation for Economic Co-operation and Development (OECD), Paris, France. Available on-line at http://www.fao.org/ag/againfo/programmes/pt/lead/toolbox/Refer/gd93179.pdf

Scherer, M.E.G.; Sanches, M.; Negreiros, D.H. (2009) Gestão das Zonas Costeiras e as Políticas Públicas no Brasil: um diagnóstico. *In:* Juan Manuel Barragan Muñoz (Coord.), *Manejo Costero Integrado y* Política Pública *en Iberoamérica: Un diagnóstico. Necesidad de Cambio,* pp. 291-330 , Red Ibermar (CYTED), Cádiz, Espanha. *ISBN*: 978-8469303559. Available on-line at http://hum117.uca.es/HUM117/ibermar/Resultados y descargas/publicaciones/brasil

Stiglitz, J.E.; Sen, A.; Fitoussi, J.P. (coord.) (2009) - *Report by the Commission on the Measurement of Economic Performance and Social Progress*. 291p., Commission on the Measurement of Economic Performance and Social Progress, Paris, France. Available on-line at http://www.stiglitz-sen-fitoussi.fr/documents/rapport _anglais.pdf

WHO (2009) - *Diarrhoea: Why Children Are Still Dying and What Can Be Done*. 68p., United Nations Children's Fund (UNICEF)/World Health Organization (WHO), New York, NY, U.S.A. ISBN: 978-9280644623. Available on-line at http://www.unicef.org/media/files/Final_Diarrhoea_Report_October_2009_final.pdf

Tsalik, S.; Schiffrin, A. (org.) (2005) – *Reportando o petróleo: Um Guia Jornalístico sobre Energia e Desenvolvimento*. 170p., Open Society Institute, New York, NY, U.S.A. Available on-line at http://archive.revenuewatch.org/reports/072305po.pdf

UNEP (2006) - *Marine and coastal ecosystems and human wellbeing: A synthesis report based on the findings of the Millennium Ecosystem Assessment*. 76p., United Nation Environment Programme (UNEP), Nairobi, Kenya. Available on-line at http://www.unep.org/pdf/Completev6_LR.pdf

Legislation

1988 - *Constituição da República Federativa do Brasil*. Publicado no DOU DE 05/10/1988. Available on-line at http://www.planalto.gov.br/ccivil_03/Constituicao/Constituicao.htm.

1988 - *Lei Estadual nº 10.019/88* - Dispõe sobre o Plano Estadual de Gerenciamento Costeiro, e dá outras providências. Available on-line at http://www.jusbrasil.com.br/diarios/68889145/dosp-legislativo-10-04-2014-pg-26

1988 - *Lei Federal nº 7.661/88 - Institui o Plano Nacional de Gerenciamento Costeiro e dá outras providências*. Publicado no D.O.U. de 18.5.1998. Available on-line at http://www.planalto.gov.br/ccivil_03/leis/l7661.htm.

2000 - *Lei Federal n 9.985/00 - Regulamenta o art. 225, § 1o, incisos I, II, III e VII da Constituição Federal, institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências*. Publicado no D.O.U. de 19.7.2000. Available on-line at http://www.planalto.gov.br/ccivil_03/leis/l9985.htm

2002 - *Portaria n.º 1101/GM (12 de junho de 2002).* Ministério da Saúde, Brasil, DF. 2002. Available on-line at http://www.saude.mg.gov.br/images/documentos/PORTARIA_1101.pdf

2010 - *Lei Federal nº 12.305/10 - Institui a Política Nacional de Resíduos Sólidos; altera a Lei nº 9.605, de 12 de fevereiro de 1998; e dá outras providências*. Publicado no DOU de 3.8.2010. Available on-line at http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm.

Internet web-pages

CVE (s/d) – Dados Estatísticos. Centro de Vigilância Epidemológica (CVE), São Paulo, SP, Brasil. http://www.cve.saude.sp.gov.br/htm/hidrica/hidri_estat.html

IBGE (s/d) – Banco de Dados. Cidades. Instituto Brasileiro de Geografia e Estatística (IBGE), Rio de Janeiro, RJ, Brasil. http://www.ibge.gov.br/cidadesat/index.php

SNIS (s/d) – Banco de Dados. Sistema Nacional de Informações sobre Saneamento (SNIS), Brasília, DF, Brasil. http://www.snis.gov.br/PaginaCarrega.php?EWRErterterTERTer=29

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):637-644 (2014)

http://www.aprh.pt/rgci/pdf/rgci-520_Romero.pdf | DOI:10.5894/rgci520

Self-diagnosis method as an assessment tool for environmental management of Brazilian ports *

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ABSTRACT

This study aimed to provide an alternative approach for the use of a situational diagnosis to evaluate the environmental management systems of the main Brazilian ports. Through this diagnosis, both the enabling factors and barriers to the implementation of an effective environmental management system were identified. The study design was based on Self-Diagnosis Method (SDM) developed by EcoPorts, with the application of a survey on issues involving the various aspects of environmental management scenarios. The responses to the surveys were analyzed using the SWOT matrix in order to identify the strengths, opportunities, weaknesses and threats to the environmental management of the ports under study. Then, gap analysis was performed in order to determine the actions that should be taken for management to evolve from an unsatisfactory status to a desired status. Analysis of the questionnaires revealed a tendency of respondents to minimize the negative aspects of environmental management, and to emphasize the positive aspects. There was also an inconsistency between the responses to the questionnaire and the actions that have actually been taken by the port authorities. This disparity suggests that managers are not willing to confront their problems publicly. The results demonstrated that there is a need for an adoption of the conceptual pillars of Environmental Management in the management of Brazilian ports, as well as for the awareness among all stakeholders involved in the activities, from workers to senior management.

Keywords: environmental management; ports; environmental diagnosis; environmental checklist

RESUMO

Método de auto-diagnóstico como ferramenta de avaliação da gestão ambiental em portos brasileiros

Este trabalho teve como principal objetivo oferecer uma alternativa metodológica para a realização de um diagnóstico da Gestão Ambiental Portuária dos principais portos brasileiros. Através desse diagnóstico foi possível determinar os aspectos facilitadores e os entraves para a implantação de uma gestão ambiental. O método utilizado foi baseado no auto-diagnóstico desenvolvido pela ECOPORTS, com a aplicação de um questionário envolvendo questões relacionadas à gestão ambiental portuária. Foram avaliados os portos de Santos (SP), Itaguaí (RJ), Rio de Janeiro (RJ) e Fortaleza (CE). A análise das respostas ao questionário foi realizada através da matriz SWOT, que permite identificar os pontos fortes, oportunidades, fraquezas e ameaças à gestão ambiental dos portos em estudo. Em seguida, foi utilizada análise Gap para determinar as ações que devem ser tomadas para evoluir de uma gestão insatisfatória para uma gestão desejada. A análise dos questionários evidenciou uma tendência dos respondentes em minimizar os aspectos negativos da gestão ambiental portuária, enfatizando os positivos. Além disso, pode-se identificar uma inconsistência entre as respostas dadas ao questionário e as ações que realmente são tomadas pelas autoridades portuárias, ficando claro que os gestores não estão dispostos a confrontar seus problemas publicamente. Os resultados demonstraram que há uma necessidade urgente de internalização dos pilares conceituais da gestão ambiental na gestão dos portos brasileiros, com a conscientização de todos os atores relacionados com a atividade, desde a alta administração, incluindo todos os níveis de trabalhadores.

Palavras-chave: *gestão ambiental; porto; diagnóstico ambiental*

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1. Introduction

Port activities can have both effective and potentially negative environmental impacts during their installation and operation phases. Such impacts include the suppression of vegetation, emission of particulates and gases into the atmosphere, noise generation, the production and release of solid and dangerous wastes, discharge of effluents and wastewater into the environment, and negative effects resulting from dredging, soil contamination, and oil and chemical spills (Wooldridge *et al.*, 1999; Xue *et al.*, 2004, Caplat *et al.*, 2005, Saengsupavanich *et al.*, 2009). Due to these consequences, the stakeholders responsible for and involved in port management have recently begun to consider new actions to support environmental sustainability of port activities. These measures form an extensive list that includes environmental certification, an environmental agenda for the port, the implementation of programs and/or environmental management systems, and environmental licensing.

Environmental management of the ports is made up of administrative and operational programs that seek to protect the environment, workers, the port community, and users of the port, as is the case of some environmental management programs conducted mainly in European ports as ECO-Information, NOMEPorts, PEARL and PORTOPIA. This management plans considers aspects such as the management of solid and liquid wastes, air emissions, and the management of dangerous cargo, in addition to the synthesis of port development, regional environmental contexts, and public policies (Kitzmann and Asmus, 2006). Environmental management of ports represents an important tool for supporting port managers in the minimization or mitigation of environmental impacts caused by port activities.

Despite the importance of conducting environmental management of ports, few Brazilian ports have a satisfactory environmental management systems (Cunha *et al.*, 2006; Kitzmann and Asmus, 2006). The necessity of keeping the port activities going hinders the imposition of sanctions, as do political interferences and the lack of enforcement of environmental laws. All of these factors contribute to the inadequacy of the ports' environmental management systems.

The lack of information on port environments and their agents and users, as well as the deficiencies in the flow of internal and external information, all lead to difficulties in the establishment of efficient environmental management. Problems such as the lack of senior management committed to environmental goals and the difficulty in understanding what sustainability is hinder the establishment of a culture of environmental management in Brazilian ports (Donaire, 2009).

The steps for implementing an environmental management system include planning, action, evaluation, and, if necessary, corrections to these plans and a new cycle of planning and action, in which the measures established during the planning stage will be put into practice. In the planning stage, the environmental aspects, their potential impacts, the action plans, and the goals and objectives must all be identified. Thus, the preparation of an environmental diagnosis should be the first step taken in the environmental management of ports (Roman and Royston, 2007). In the case of ports, the environmental diagnosis must consider all aspects to be controlled by the port in order to allow for the implementation of control and management plans that are based on reliable, detailed, and robust knowledge (Wooldridge *et al*. 1999; Grota, 2009.).

There are different approaches to achieving environmental diagnosis for ports, and one is Self-Diagnosis Method (SDM), developed by EcoPorts. EcoPorts was created through an initiative of the European Sea Ports Organization (ESPO) in an attempt to integrate the environmental and economic needs of European ports (Roman and Royston, 2007). The diagnosis generated through this analysis can determine both the enabling factors and the barriers to the implementation of effective environmental management systems. An important feature of this method is the ease of implementation and therefore the straightforwardness of the evaluation, since it was formulated by the port itself. Moreover, this method is flexible and can be adapted to the specific conditions of each port.

Despite the importance of environmental diagnoses in the environmental planning of ports, the Brazilian ports have not made efforts toward this issue. This lack of effort represents a barrier to environmental management. The main objective of this investigation was to make a situational diagnosis of the environmental management systems in some of the main Brazilian ports based on Self-Diagnosis Method, which was adapted in order to take Brazil-specific factors into account.

1.1. Study area

The choice of ports to be studied was based on the largest amount of traffic during the execution of the research and application of questionnaires (2011). The data on the movement of the main Brazilian ports was obtained from the National Agency of Waterway Transportation - ANTAQ (www.antaq.gov.br).

According to the agency, the ports with the largest amount of traffic in Brazil are the Port of Santos (SP-86

millions of tons), the Port of Itaguaí (RJ-58.1 millions of tons). Other ports that presented great movement in 2011 as the Port of Paranaguá (37.4 millions of tons) and Port of Rio Grande (17.9 millions of tons) were contacted unsuccessfully for the questionnaire. The Port of Rio de Janeiro (RJ-7.706.623t) and the Port of Fortaleza (CE-4.231.826t) was also an object of study in this investigation, since it constitutes important ports of the Brazilian southeast and northeastern region, respectively (Figure 1).

Figure 1 - Locations of the Port of Santos (SP), the Port of Itaguai (RJ), the Port of Rio de Janeiro (RJ) and the Port of Fortaleza (CE).

Figura 1 - Localização do Porto de Santos (SP), Porto de Itaguaí (RJ), Porto do Rio de Janeiro (RJ) e Porto de Fortaleza (CE).

The Port of Santos is located between the cities of Santos, Guarujá and Cubatão, on the Sao Paulo State coast, and occupies an area of approximately 7.7 million m^2, according to information provided by the port authority (http://www.portodesantos.com.br). The main cargoes handled by the Port of Santos are: sugar, soybeans, containers, coffee, corn, wheat, salt, citrus pulp, orange juice, paper, automobiles, ethanol, and other liquid bulk.

The Port of Itaguaí is located in the Sepetiba Bay, on the coast of Rio de Janeiro state, and occupies a territory of 5.1 km^2. Its main cargoes are coal, iron ore, mineral concentrates, perishable goods, general cargo, and containers. Meanwhile, the Port of Rio de Janeiro is located in the city of Rio de Janeiro (RJ), presenting 6740 m of wharves and a pier of 883 meters, according to the port authority. The main cargoes handled by this port are grain, scrap iron, pig iron, salt, ore concentrates, liquid chemicals, mineral oils, vehicles, perishable goods, general cargo, crude oil, lubricating oil, naphtha, and containers (www.portosrio.gov.br). The Port of Mucuripe is located in the Fortaleza Bay, in Fortaleza (CE), and its main cargoes are cashew nuts, carnauba wax, metal, fabrics, fruits, wheat, malt, lubricants, and fuels and petroleum derivatives.

2. Method

To assess the environmental management systems of the ports being studied, a questionnaire was developed based on Self Diagnosis Method (SDM) (Darbra *et al*., 2004; ECOPORTS, 2004.). This method consists of the application of a questionnaire on the aspects involved in the port authority's environmental management of the ports in order to identify risks and establish priorities for action.

Because the EcoPorts questionnaire was originally developed for European ports, the questions were revised and adapted to Brazilian ports. Issues of legal compliance of the ports were inserted after the main Brazilian environmental regulations were consulted.

Thus, issues related to environmental licensing, development of Environmental Agenda, black smoke control, control of ballast water and project developments for characterization and monitoring of the area where the port is inserted process were included, according to requirements of legislation Brazilian. The remaining questions were maintained according to the original SDM.

The questionnaire includes questions on environmental policy, personnel management and organization, environmental training, internal and external communication, operational management, emergency planning, monitoring and recording of environmental data, and environmental auditing. Most of the questions were multiple choice, in which the manager checked off the most appropriate option for the port he or she represented. The questionnaire also presented a space for other observations to ensure that the particularities of each port would be considered in the analysis (Figure 2). SDM was designed to be both implemented and answered by the manager of the port, but in this study, the questionnaire was administered by a third person (the authors of this paper). Thus, in this case, transparency on the part of respondents was required – we assumed, on principle, that the information provided would be true.

2.1. Data analysis

The information provided by the ports was individually analyzed for each specific topic in order to obtain an overview of the actions, planning and performance of each port. In order to identify flaws, or gaps, in the environmental management of ports, the information obtained was used as input data for gap analysis, which allowed for the establishment of priorities so that the

Subsection A.3. - Environmental Regulation, Port Activities and Aspects

6) Does the Port Authority have an inventory of the most important environmental regulations and requirements related to port activities?

☐ Y ☐ P ☐ N

If **NO**, go to question 11.

- Is there a specific procedure for revising and updating this inventory?

☐ Y ☐ N

- Is this inventory easily accessible? ☐ Y ☐ N
- Is this inventory distributed to persons of concern in the port? ☐ Y ☐ N

Observations:_____

Figure 2 - Example of questions from the environmental management assessment checklist. (Y) Yes; (P) Partly; (N) No.

Figura 2 - Exemplo de questão presente no questionário de avaliação da gestão ambiental portuária. (Y) Sim; (P) Parcialmente; (N) Não.

issues identified could be incorporated into the environmental management system. Gap analysis is a technique used to determine the actions that should be taken to evolve from an unsatisfactory management system to a desired management system. Gap analysis is performed by comparing the characteristics of the current administration (attributes, skills, performance) with the characteristics necessary to achieve the desired objectives. This process highlights the existing gaps that need to be fulfilled. Identifying these gaps in compliance with legal environmental requirements, such as ballast water management, waste management, audits, environmental permits, and preparation of emergency plans, makes it possible for managers to establish and take the necessary actions in pursuit of legal compliance, thus avoiding penalties or lawsuits. Compliance with the law is a basic condition for any environmental management system, and a lack of compliance with legal environmental requirements can lead to restrictions on the domestic products that can be handled in the ports (Kitzmann and Asmus, 2006).

After Gap analysis, the data was evaluated from a strategic perspective using the SWOT (Strength Weakness Opportunities Threats) matrix. For this analysis, good environmental management practices were classified as "force," the elements that can be avoided or treated as a priority within a program of environmental management were classified as "weakness," and "opportunities" were those actions that have the potential for immediate improvement. "Threats" were defined based on gap analysis and are the issues related to legal non-conformities.

This approach is widely used in the planning of management systems, since it allows for the identification of internal aspects that are both positive (strengths) and negative (weaknesses) and also the external factors that pose threats that would weaken management or opportunities that can strengthen management. The forces should be explored in order to obtain maximum results, as should the other variables. The weaknesses must be eliminated or overcome and, if possible, converted into internal forces. Opportunities should be exploited and the threats must be annulled, avoided or mitigated through appropriate measures (Valeriano, 2001).

3. Results and Discussion

This investigation made it possible to identify aspects that were both specific to certain ports and common among all ports evaluated in terms of the positive and negative aspects of environmental management. Gap analysis showed that the ports studied comply with most of the legal requirements considered in the self-diagnosis. The Port of Mucuripe met 92% of the legal requirements; the ports of Santos and Itaguaí met 84% of the requirements; and the Port of Rio de Janeiro met 62% of the requirements. However, it is important to note that all legal requirements should be met as part of the basic premise of efficient environmental management. There were gaps in terms of the environmental permits (required by law): only the Port of Mucuripe was found to possess what is known as an Operating Environmental License (OL). The ports of Santos, Rio de Janeiro and Itaguaí do not have OLs, but two of these ports (Santos and Rio de Janeiro) reported that

they are in the process of obtaining the license. Another legal requirement is the conduction of studies on the archaeological heritage of the area of influence of the port. This study was conducted by the port of Santos and by the Passengers Terminal at the Port of Mucuripe. The other ports did not meet this legal requirement. The control of black smoke from vehicles that travel in ports is a legal requirement that is met only by the port of Santos.

The Environmental Agenda of the port is an important tool for the planning of actions to be taken in order to comply with the environmental laws for ports and port facilities. The ports of Rio de Janeiro, Mucuripe and Itaguai each possess a Port Environmental Agenda, whereas the agenda of the Port of Santos is currently under preparation.

Ports are legally required to manage ballast water from vessels, since this water can introduce exotic species into the environment and thus lead to the suppression of native species and the overpopulation of exotic species. Therefore, all ports must submit a Ballast Water Management Plan. However, none of the four ports possess this document. According to legal provisions, environmental audits should be performed at every two years by an outside representative of the port. The Port of Santos's last audit was carried out over two years ago, and the remaining ports are in compliance with the environmental audit laws. Failure to comply with legal

Table 1 - Aspects classified as "force", common to all four ports studied.

Tabela 1 – Aspetos classificados como "força", comuns a todos os portos estudados.

A	Existence of reports with the inventory of impacts and environmental performance in the port area, facilitating the identification of priorities and encouraging the establishment of monitoring protocols and control measures.
B	Existence of easily accessible inventory of the most important environmental regulations and their requirements for port activities, which promotes compliance with these regulations.
C	Existence of a Zoning and Development Plan that considers environmental issues, which reflects a commitment to and interest in the quality of the environment where the port is located.
D	Existence of objectives and targets set for environmental improvement, which allow for an evaluation of the effectiveness of actions taken in pursuit of achieving these goals and targets.
E	Existence of a specific budget for environmental issues to ensure necessary resources for implementing programs and environmental initiatives.
F	Existence of procedures for internal communication of environmental information.
G	Existence of procedures to communicate environmental information from the port to partners of interest and to get opinions from outside groups.
H	Environmental management plans and action plans being prepared or already in use.
I	Existence of a Plan for Solid Waste Management and an employee who is responsible for its maintenance and operation.
J	Control and treatment of sanitary waste.
K	The transport of solid waste is done in a vehicle that is appropriate for the characteristics of each residue, and meets the legal constraints for protecting the environment and public health.
L	Legal requirements are met in relation to the presentation of the Environmental Risk Prevention Program (PPRA) and Emergency Control Plan (PCE).
M	Existence of procedures for dealing with non-conformities; existence of the Emergency Plan and Individual Emergency Plan (IEP).
N	Environmental aspects are monitored, and monitoring is used as support for the decision.
O	The monitoring of noise generated by port activities and the quality of water bodies under the influence of these activities is performed in accordance with standards established by law.
P	Existence of an employee in charge of environmental issues who reports to senior management.

In the SWOT analysis, the studied ports had many aspects in common in terms of the characteristics of their management, which were classified as "forces." These commonalities are described in Table 1. For example, the port of Mucuripe presents an environmental management manual, and this manual is rated as "strength" of that port.

The managing "weaknesses" that were common to the four studied ports include the fact that not all employees are informed about the importance of adjusting port operations to meet environmental policies; the potential environmental impacts of the ports' activities; and the responsibility of each port to act in accordance with environmental policies and the objectives of the environmental management. Also, the employees were not aware of the environmental programs, objectives and actions conducted by the respective Port Authorities. The ports of Santos, Rio de Janeiro and Itaguaí do not have their own environmental management manual, and this aspect was rated as "weakness".

Issues classified as "opportunities" included those that can be easily converted to "strengths." Three of the ports studied (ports of Santos, Port of Rio de Janeiro and Itaguaí) showed commonalities in what could be classified as "opportunities": (a) the inventory of environmental regulations is not distributed to the respective port's stakeholders); and (b) the specific environmental responsibilities are not documented. The knowledge of relevant environmental legislation for port activities encourages a greater commitment to complying with the legal and internal requirements.

One aspect classified as a common "opportunity" for the four ports studied is the environmental training of employees. The ports of Fortaleza and Santos offer environmental training to less than 25% of their employees; thus, actions are required to increase the number of employees served by the training programs. The ports of Itaguaí and Rio de Janeiro do not control of the number of employees who have received such training; thus, these ports first need to quantify the number of employees already served by the training programs, and then need to establish goals to increase the number of trained staff, if necessary.

The need to prevent the port from being subjected to lawsuits and legal penalties often leads to actions to turn the threats into opportunities. The adoption of a proactive stance on the part of the institution is required; they must act before being charged by the environmental agency or public prosecutor. The responses provided by the port managers made it possible for them to identify priority actions for their respective ports. These priority actions included the preparation of ballast water management plans, the conduction of studies on the archaeological heritage sites that may be affected by the port activities, the monitoring and controlling of black smoke emissions by the vehicles in the port area, and the compliance with all conditions required for each of the licensing processes.

Ports worldwide normally present strengths and weaknesses, as is the case of the strengths reported for some ports from the United States, Belgium, Holland and Germany. These ports monitor the species of birds in the port areas and have implemented recovery programs for the aquatic environments as compensation for the environmental impact caused by the port activities (Snep and Ottburg, 2008). However, according to the authors, such programs are concerned only with the aquatic environments, and they disregard other environments that are impacted by port activities. This disregard represents a "weakness" in the environmental management of the respective ports. Other examples of weaknesses are provided by the port of Maptaphut, in Thailand, where the water quality around the port is unsuitable for the legal requirements of the country. In addition, the environmental programs do not consider the specific parameters of industrial activities, and there is no program to control pollution from vessels (Saengsupavanich *et al.*, 2009).

The use of SDM for these Brazilian ports also revealed some aspects that must be addressed when this approach is used. The first issue involves adaptations for local specificities. In Brazil, the ports built before the laws on environmental licensing are not subject to obtaining Provisional Licenses (PLs) or Installation Licenses (ILs), but they must present the Operating License (OL), or a document known as the "Terms of Conduct Adjustment" (TCA) which are documents that may replace the OL for legal purposes and which are requested by the Brazilian Environmental Agency (IBAMA). This detail was not considered during the preparation of the questionnaire, but throughout the analysis, the need for improving the questionnaire became evident. This topic should be included, with options for ports built before and after the legislation for environmental licensing, and questions on the existence of TCAs should be included as well. Therefore, the use of SDM requires that the questionnaires be adjusted to the specific conditions of the site or topic being studied.

The second issue was found to be the use of SDM by a third party that is not the port's environmental manager. Because SDM was created to be employed by the manager, the presence of the researcher during the questionnaires, and more importantly, the fact that the questionnaires are analyzed by people outside of the port authority, may bias the responses. During the questionnaires, we noticed a clear tendency of the respondents to minimize negative aspects and emphasize the positive ones. Responders often seek to present scenarios in which the problems were already

solved or were in the process of being resolved. Thus, topics that were considered problematic may have caused the respondents to respond insincerely, to undervalue negative aspects, or to overvalue positive aspects. This factor made the analysis difficult. This bias probably will not occur when SDM is conducted directly by the port's environmental manager. Thus, SDM tends to be more efficient when conducted by the port authority itself. Moreover, it is important that the senior management teams of ports improve the corporate mentality and encourage the development of a culture that is more transparent to the stakeholders and which recognizes the importance of implementing an environmental management system for the port.

The focus on positive responses (although not consistent with reality) and the omission of negative aspects demonstrate the ports' difficulties in dealing with adverse situations. This problem becomes evident when the given responses are compared to the information in the literature. The Port of Santos, for example declared that it performs environmental monitoring and management, but it presents serious problems of sediment contamination as a result of dredging operations (Torres *et al.*, 2009).

The analysis of the responses provided by the ports showed inconsistencies in some aspects of management, such as the non-compliance with some laws or regulations, or the fact that the existence of environmental management in a specific port was not accompanied by the establishment of respective environmental policies. Considering the fact that environmental management systems rely on the company's environmental policy, and because this policy constitutes a main guideline for all of those involved in the environmental management, it is improbable that the goals of the environmental management plan would be achieved without an environmental policy.

The inconsistencies between discourse and effective actions demonstrate difficulties in adopting a transparent approach and increasing the governance of environmental management at ports. The port authorities did not demonstrate a willingness to publicly confront their problems, which may lead to inefficient management that is more focused on covering up the problems than facing and resolving them.

According to Kitzmann and Asmus (2006), it is necessary that a change occur in the Brazilian port management culture. Port authorities must begin to include environmental issues in the processes, actions, goals, and objectives. This change must be part of a larger adjustment of the regulations of the port in general and it must also include support tools to enable the perception and understanding of the port's conditions and its effect on the environment (Koehler and Asmus, 2010).

The institutions presented difficulties in recognizing the importance of environmental issues. Few port employees were found to be trained in environmental management, and the corporate stance was often reactionary; it was largely motivated by the immediate need to comply with the legal regulations (e.g., solving the issues which may result in immediate economic problems for the ports).

By not adopting proactive stances in general, the ports studied will end up having trouble setting goals for the continuous improvement of environmental performance (a fundamental condition of any environmental management system). Currently they seem to be motivated to comply minimally with legislation, and they tend to disregard some activities that generate impacts on the port system (Adamenas, 2009).

This reactionary stance of seeking to only minimally fulfill the legal requirements can help the port to avoid penalties and actions by environmental agencies and public prosecutors, and thus prevent bad press on the ports in the media. However, this behavior does not prevent strains in relationships with close stakeholders, and it substantially impairs the effective adoption of processes geared toward sustainability in port management. The lack of pro-activity in the development of environmental management is a common characteristic in different types of Brazilian, European, and American companies, in which most acts are based on legal requirements or market pressure (Sanches, 2000).

Therefore, this study demonstrated that there is an urgent need for both the internalization of the conceptual pillars of Environmental Management in the management of Brazilian ports and the awareness of all stakeholders involved, including senior management and all levels of workers. For this to happen, ports must systematically provide environmental data and training programs (which must also be evaluated), so that each port has a sufficient amount of information to support decision making. The lack of data is an obstacle to the development of the environmental management systems at ports (Grota, 2009). Thus, the application and analysis of the questionnaire used herein provides important information that can help ports to implement environmental management systems.

4. Conclusion

SDM is a suitable tool for beginning and/or continuing the establishment of a port's environmental management plan, since aspects specific to the port are considered and since the approach is conducted by the port authority. This approach allows for the analysis of different aspects of environmental performance in order to obtain an overall understanding of the actions, plans, and performance, of the port that is assessed. SDM can show when ports have problems and challenges that

may be faced by adopting improvement strategies. These strategies should be practical, economically feasible, and consistent with the specific conditions of the port in question. The combined use of SDM and Gap and SWOT analyses allows managers to better visualize the challenges and to plan strategies to improve the environmental management of their ports. This study on Brazilian ports revealed problems that were common to all of the ports evaluated, the most significant of which was the inconsistency between reported answers and reality; this truncated flow of information both internally and externally represents institutional difficulties in adopting more transparent actions and facing their problems publicly.

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References

Adamenas, T.P.C. (2009) - Práticas de Gestão Ambiental Portuária. *In:* I. A. Cunha & M. F. B. Neves (orgs.), *Gestão Ambiental na Costa, portos e sustentabilidade*, pp.201-211, Ed. Leopoldianum, Santos, SP, Brasil. ISBN: 97885-60-360116.

Cunha, I.A. (2006) - Fronteiras da gestão: os conflitos ambientais das atividades portuárias. *RAP - Revista de Administração Pública*, 40(6):1019–1040, Fundação Getulio Vargas, Rio de Janeiro, RJ, Brasil. Available on-line at http://www.scielo.br/pdf/rap/v40n6/05.pdf

Darbra, R.M.; Ronza, A.; Casal, J.; Stojanovic, T.A.; Wooldridge, C. (2004) - The Self Diagnosis Method: A new methodology to assess environmental management in sea ports. *Marine Pollution Bulletin*, 48(5-6):420–428. DOI: 10.1016/j.marpolbul.2003.10.023

Donaire, D. (2009) - *Gestão Ambiental na Empresa*. 169p., Editora Atlas, São Paulo, SP, Brazil. ISBN: 978-8522421855.

Grota, A. S. (2009) - Discutindo o Plano de Gestão Ambiental do Porto de Santos. *In:* I. A. Cunha & M. F. B. Neves (orgs.), *Gestão Ambiental na Costa, portos e sustentabilidade*, pp.67-88, Editora Leopoldianum, Santos, SP, Brasil. ISBN: 978-8560360116.

Kitzmann, D; Asmus, M. (2006) - Gestão Ambiental Portuária: desafios e possibilidades. *RAP – Revista de Administração Pública,* 40(6):1041-1060, Fundação Getúlio Vargas, Rio de Janeiro, RJ, Brasil. Available on-line at http://www.scielo.br/pdf/rap/v40n6/06.pdf.

Koehler, P. H. W.; Asmus, M. L. (2010) - Gestão ambiental integrada em Portos Organizados: uma análise baseada no caso do porto de Rio Grande, RS – Brasil. *Revista da Gestão Costeira Integrada*. 10(2):201–215. DOI: 10.5894/rgci171.

Saengsupavanich, C.; Coowanitwong, N.; Gallardo, W.G.; Lertsuchatavanich, G. (2009) - Environmental performance evaluation of an industrial port and estate: ISO14001, port state control-derived indicators. *Journal of Cleaner Production*, 17(2):154–161. DOI: 10.1016/j.jclepro.2008.04.001.

Sanches, C. S. (2000) - Gestão Ambiental Proativa. *Revista de Administração de Empresas*. 40(1):76-87. DOI: 10.1590/S0034-75902000000100009.

Snep, R. P. H.; Ottburg, F. G. W. A. (2008) - The 'habitat backbone' as strategy to conserve pioneerspecies in dynamic port habitats: lessons from the natterjacktoad (Bufocalamita) in the Port of Antwerp (Belgium). *Landscape Ecology*, 23(10):1277–1289. DOI: 10.1007/s10980-008-9266-z.

Torres, R. J.; Abessa, D. M. S.; Santos, F. C.; Maranho, L. A.; Davanso, M. B.; do Nascimento, M. R. L.; Mozeto, A. A. (2009) - Effects of dredging operations on sediment quality: contaminant mobilization in dredged sediments from the Port of Santos, SP, Brazil. *Journal of Soils and Sediments*, 9(5):420–432. DOI: 10.1007/s11368-009-0121-x.

Valeriano, D. L. (2001) - *Gerenciamento estratégico e administração por projetos*. 328p., Editora Makron Books, São Paulo, SP, Brasil. ISBN: 8534612080.

Wooldridge, C. F.; McMullen, C.; Howe, V. (1999) - Environmental management of ports and harbours – implementation of policy through scientific monitoring. *Marine Policy*, 23(4/5):413-425. DOI: 10.1016/S0308-597X(98)00055-4.

Xue, X.; Honga, H.; Charles, A. T. (2004) - Cumulative environmental impacts and integrated coastal management: the case of Xiamen, China. *Journal of Environmental Management,* 71(3):271–283. DOI: 10.1016/j.jenvman.2004.03.006.

The article "Self-diagnosis method as an assessment tool for environmental management of Brazilian ports", by Romero *et al.* (2014), contains supporting information online at http://www.aprh.pt/rgci/pdf/rgci-520_Romero_Supporting-Information.pdf

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http://www.aprh.pt/rgci/pdf/rgci-461_Caviedes.pdf | DOI:10.5894/rgci461

Una contribución a la política pública para el manejo costero integrado de Honduras: análisis diagnóstico *

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RESUMEN

Los procesos de apropiación y uso insostenible del litoral hondureño demandan de una política pública expresa orientada a la conservación y restauración de su valioso y diverso patrimonio natural y cultural. Honduras, como otros países de la región, ha suscrito instrumentos internacionales en este sentido, pero aún carecen de una política nacional apropiada para abordar los desafíos que impone el Cambio Global sobre sus zonas costeras y marinas. Este artículo presenta en primer lugar una síntesis del diagnóstico del estado biofísico y socioeconómico del litoral nacional que ha servido como insumo básico para la política de Manejo Costero Integrado (MCI) en proceso de formulación. A continuación se presenta para Honduras el diagnóstico propositivo sobre su subsistema administrativo-jurídico actualmente existente y relacionado con el MCI, análisis que creemos útil en el diseño de la política para un mejor gobierno de sus espacios litorales. La metodología seguida para este último diagnóstico es el Decálogo, herramienta ampliamente utilizada en la región, especialmente por los 13 países miembros de la Red Iberoamericana de Manejo Costero Integrado (Red IBERMAR). Los asuntos analizados fueron: Políticas públicas, normativa, instituciones, competencias, instrumentos, información pública, recursos, formación y capacitación, educación para la sostenibilidad y participación pública. Se concluye que el país está en la fase pre-inicial de implantación del MCI, no obstante se constata la existencia de algunos asuntos claves para esta gestión: voluntad política, programas de formación superior relacionados y un marco jurídico que favorece la participación ciudadana,

Palabras clave: Centroamérica, litoral, sostenibilidad, Decálogo de gestión.

ABSTRACT

The processes of appropriation and unsustainable use of the Honduran coast demand of an effective public policy aimed at the conservation and restoration of its valuable and distinct natural and cultural heritage. Honduras, like other countries in the region, has signed international regulations in this regard, but their is still a lack of a proper public policy to address the challenges posed by global changes on coastal areas. This Central American country has initiated in 2012 the development of a coastal and marine policy for Integrated Coastal Management-MCI. This article first presents an overview of the diagnosis of biophysical and socio-economical status of the national coastline that has served as a basic input for policy. Below is the diagnosis on the legal-administrative subsystem, that currently exists related to MCI of Honduras, we believe a useful analysis in policy design for better governance of coastal areas. The methodology used for this diagnosis is the Decalogue (Decálogo in spanish), a widely used tool in the region, especially by the 13 countries members of the Latin American Network of Integrated Coastal Management-Network IBERMAR. The topics discussed here were: Public policies, rules, institutions, skills, tools, public information, resources, education and training, education for sustainability and public participation. It is concluded that Honduras is in the pre-inicial implementation phase of the MCI, however it is noted the existence of political will, higher education related programs and a legal framework that promotes citizen participation, key issues for this management.

Keywords: *Centroamerica, littoral, sustainability, Management Decalogue.*

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1. Introducción

El creciente desarrollo de usos y actividades en las zonas costeras de Centroamérica, junto al ineficaz manejo de este espacio y sus recursos, ha llevado a que estos frágiles y dinámicos ámbitos enfrenten cada día fuertes impactos y presiones claramente insostenibles. Según Barragán (2003) este es un sistema complejo donde convergen e interactúan tres subsistemas: bio-físico, socio-económico, y jurídico-administrativo. Todos ellos necesarios a considerar para comprender su problemática y sobre todo para identificar y abordar soluciones adecuadas a los múltiples conflictos que allí se evidencian.

Se ha constatado en varios países de Iberoamérica, tanto en los llamados desarrollados como en desarrollo, los beneficios de la implantación de programas de Manejo Costero Integrado o MCI en relación con la calidad de vida de las comunidades que dependen de los recursos del litoral, como de la protección y restauración de sus ecosistemas (Arenas, 2011). Estos beneficios están estrechamente relacionados con la participación ciudadana durante los ciclos continuos y característicos de los procesos de aplicación de políticas públicas para el MCI, como así declaran Olsen *et al.* (1999) al señalar que el éxito de esta gestión reside en la implementación de un sistema participativo eminentemente democrático.

En la República de Honduras ya es clara la pertinencia de abordar cuanto antes la formulación de la Política de Estado para reorientar hacia la sostenibilidad los usos en su espacio marino costero. Este artículo tiene el objetivo de contribuir primero al diagnóstico del objeto de interés, el litoral hondureño, y segundo al análisis desde una perspectiva histórica reciente de los asuntos estructurales de carácter administrativo-jurídico relacionados en este país centroamericano con el manejo integrado de estos espacios.

Se evidencia actualmente en Honduras un mayor reconocimiento y apropiación de su territorio y recursos marino-costeros. Aunque el país no ha definido aún por completo sus fronteras marítimas, en agosto del año 2012, coincidiendo con el aniversario de los 30 años de la subscripción a la Convención de las Naciones Unidas sobre el Derecho del Mar, se definieron por fin los límites marítimos con Cuba. En el mismo mes de agosto, se confirmó la voluntad política, desde la Secretaría de Recursos Naturales y Ambiente (SERNA) que corresponde a la máxima autoridad ambiental hondureña, para asumir el liderazgo en el proceso de formulación de la Política Pública de MCI. Confiamos que en el nuevo gobierno presidencial elegido el pasado 24 de noviembre del año 2013 para el período 2014-2018; el objetivo de la sostenibilidad del bienestar humano en el litoral hondureño, y por tanto también la protección y conservación de sus ecosistemas, sea un asunto también de particular relevancia en su agenda política.

2. Metodología

Varios métodos interrelacionados fueron utilizados para el análisis en consideración a dos asuntos: el carácter espacial del objeto de estudio y el carácter cíclico del Manejo Costero Integrado por su identificación dentro de la teoría de ciclo en el tiempo de las políticas públicas, ya señalado por varios autores (Clark, 1996; Vallega, 1999; Olsen, 2003).

En este trabajo el objeto específico de análisis es el espacio costero y marino hondureño. Es entonces un análisis de carácter geográfico, y por lo tanto desde la teoría de la geografía como ciencia de la organización del espacio (Chica, 2008), donde se encuentra la guía metodológica general para comprender los acontecimientos biofísicos, socioeconómicos, culturales y políticos que allí tienen lugar. Esta teoría señala dos caminos posibles, la inductiva y la deductiva y ambos han sido utilizados. El primer camino ha permitido por ejemplo el análisis de experiencias u otros diagnósticos previos existentes. El segundo ha logrado el análisis nacional de los asuntos claves para el MCI siguiendo la metodología del Decálogo estrechamente relacionada con el proceso de las políticas públicas.

El *Decálogo* fue propuesto por Barragán (2001; 2004), impulsado por el Grupo de Gestión Integrada de Áreas Litorales de la Universidad de Cádiz, siendo comprobado y perfeccionado en la península ibérica, en varios países del norte de África y en América Latina y el Caribe (Barragán, 2012; Bello *et al*., 2006; Arenas, 2012; Diederichsen *et al*., 2013). Es un instrumento eficaz y sencillo que a partir de 10 elementos estructurales del subsistema jurídico-administrativo de una determinada escala territorial de la administración pública, permite valorar y comparar entre distintos niveles la situación de esos espacios costeros en relación con el objetivo de su MCI. Estos asuntos son la política pública (voluntad), la normativa (reglas), las competencias (responsabilidades), el tipo y grado de convergencia de las instituciones públicas (la administración), los instrumentos o formas de intervención pública (las herramientas), la oferta y el tipo de formación de los gestores públicos vinculados al MCI (los administradores), el presupuesto y las inversiones públicas estatales implicadas (los recursos), el conocimiento disponible para la toma de decisiones que afectan al litoral (la información), la educación de los ciudadanos relacionada con la sustentabilidad (educación) y finalmente, los mecanismos de interacción para la toma de decisiones entre la administración pública y la ciudadanía (la participación).

Los miembros de los 13 países/estados participantes inicialmente en la Red Iberoamericana de Manejo Cos

tero Integrado (Red IBERMAR) realizaron los diagnósticos, tanto del espacio litoral como de su gestión, utilizando la metodología del Decálogo a partir de un Manual de Trabajo previamente acordado. Los resultados del presente trabajo sobre Honduras permiten además complementar los análisis realizados y ya publicados por la Red IBERMAR (Barragán, 2009).

3. Resultados y discusión

3.1. Diagnóstico biofísico y socioeconómico del litoral hondureño

3.1.1. Caracterización sintética del subsistema natural

La República de Honduras tiene un territorio continental, incluidas las islas, de 112,492 km² (ver Figura 1.), un espacio marino de 229,501.96 km^2 (SERNA-ICF-SAG, 2011), una plataforma continental en el Caribe de 68,700 km^2 (IICA, 1995) y 5,000 km^2 en el Pacífico (FAO, 2002). El relieve del país es montañoso en un 82% e hidrológicamente se divide en 21 cuencas, 19 cuencas en el Pacífico que drenan el 17,28% de este territorio (Carbajal & Rodriguez, 2005).

La costa Caribe tiene una extensión de 671 km, con el 16% de planicies costeras, y una superficie de arrecifes coralinos que asciende al menos a 1,120 km² (Burke & Maidens, 2004), 8 islas y 25 cayos, mientras que el Pacífico tiene 133 km de litoral con un 2% de planicies costeras y cuatro islas (SERNA, 2001).

La morfología costera está determinada por ambientes sedimentarios fluviales y por una deriva litoral predominante de este a oeste. Esto da paso a un diverso relieve costero tanto en el Caribe, como en el Pacífico, los cuales son sitios de mucho interés económico y fronterizo con Belice y Guatemala en el Caribe, y El Salvador Pacífico, más del 25%. Procedentes de Honduras y Nicaragua en el Pacífico. Según el Análisis de Vacíos y Omisiones de Representatividad Ecológica de la Biodiversidad Marina de Honduras (SERNA-ICF-SAG, 2011), de toda la ZEE del Caribe hondureño solo un 4% decreto de Área Protegida, estando protegidos en el drenan al Golfo de Fonseca los ríos Choluteca,

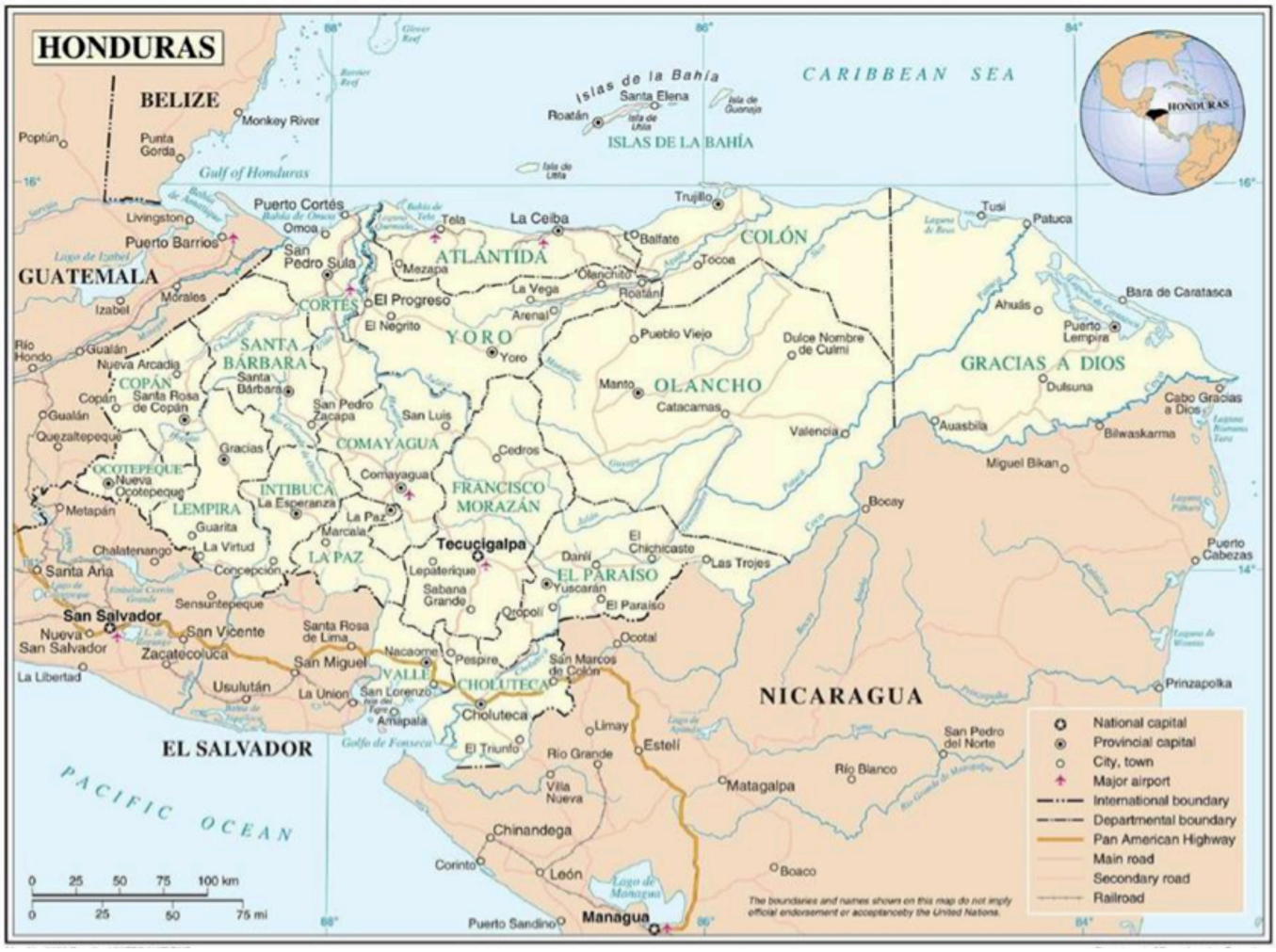

Figure 1 - Mapa político de la República de Honduras. Fuente: Naciones Unidas, 2004.

Figure 1 - Political map of the Republic of Honduras. Source: United Nations, 2004.

Nacaome, Negro y Lempa. Los manglares en esta área constituyen un ecosistema de gran importancia para la economía de estos países. Estos ecosistemas proveen importantes servicios como las pesquerías artesanales de peces, post-larva de camarón, bivalvos, cangrejos, colecta y venta de huevos de tortuga, acuicultura de camarón, turismo, además de la producción de sal y la actividad portuaria internacional.

En las cuencas marginales de los ríos mayores en la costa Caribe se forman los deltas de los ríos Segovia, Kruta, Patuca, Sico, Ulúa y Chamelecón y diversos tipos de humedales. Características son las lagunas costeras con estrechas barras de arena y manglares de tipo ribera, borde, matorral y cuenca, en general dominados por *Rhizophora mangle* mezclados con *Laguncularia racemosa*, *Avicennia germinans* y *Conocarpus erectus,* asociados en transiciones cortas con selvas inundables de agua dulce. En las partes marginales de las cuencas de los ríos Segovia, Kruta y Patuca se forma el sistema lagunar Karataska, que incluye cinco lagunas menores, y en total crea una extensión de humedales de 800 mil ha, que representan el 60% de los humedales del país (Carrasco & Flores, 2008).

Los ríos Patuca, Plátano y Sico forman las lagunas de Brus e Ibans, que son parte de los humedales de la Reserva del Hombre y la Biosfera de Río Plátano, declarada Patrimonio de la Humanidad y Reserva de la Biósfera por la UNESCO en 1980. Los ríos Ulúa y Chamelecón, drenan más del 25% de la cuenca nacional, la cual incluye la zona de mayor desarrollo agroindustrial, urbano y portuario del país, situándose en su desembocadura el Parque Nacional Blanca Jeannette Kawas Fernández. Al oeste del parque se forma una flecha litoral sobre la cual está establecido Puerto Cortés, el mayor puerto comercial de Centroamérica.

3.1.2. Aspectos administrativo-políticos y socio-económicos

Honduras está organizada en 18 departamentos, de los cuales siete son costeros, y tiene un total de 298 municipios, de los cuales, 27 están en el frente litoral. El dato poblacional es de 8.215.313 (PNUD, 2012), con una tasa de crecimiento anual de la población para 2010 de 1.7%. El país se caracteriza por su gran variedad étnica y cultural, teniendo siete pueblos indígenas (Lenca, Maya-Chortí, Tolupán, Pech, Tawahka (sumo), Miskito y Nahua), así como la etnia afro-descendiente de los Garífunas asentada en la costa norte del país.

La pesca, tanto industrial como artesanal, es uno de los rubros más productivos del país. La pesca artesanal es una fuente fundamental de pescado y mariscos para el consumo nacional y soporte de la economía tradicional entre las comunidades costeras. Solo en la costa Caribe están asentadas alrededor de 200 comunidades, en un 90% ajenas a servicios públicos básicos, siendo ellas mismas las que se auto emplean mediante la pesca artesanal. Hay poca información actualizada sobre el aporte de la actividad pesquera a la economía Hondureña, especialmente sobre pesca artesanal. Datos de la FAO del 2002 hablan de 47,7 millones de $ en exportaciones. Información más reciente de DIGEPESCA (2012) facilitada por la Iniciativa Langosta Espinosa hablan de 2457 t extraídas en 2010, entre langosta, escama y camarón, siendo este último el rubro con mayor aporte y sin tener en cuenta estos datos la producción artesanal. Un estudio realizado por PNUMA en 2012 sobre el valor económico de los servicios ecosistémicos que provee el área protegida marino costera, Parque Nacional Jeannette Kawas, valoró las pesquerías artesanales (escama y jaiba) realizadas solo en la laguna de Los Micos, y teniendo en cuenta toda la economía asociada a esta pesquería, en 2,9 millones de dólares anuales (PNUMA, 2013).

En cuanto a la actividad portuaria, Honduras cuenta con cinco puertos comerciales. El principal y más importante para el país es Puerto Cortés, situado en el mar Caribe, que en 2010 estaba en el puesto 23 entre los 100 puertos con mayor movimiento de contenedores de América Latina y Caribe (Naciones Unidas / CEPAL, 2012). A pesar de esta y otras actividades económicas sectoriales existentes, Honduras se encuentra entre los países con mayor inequidad social de América Latina. Según el Informe sobre Desarrollo Humano del PNUD, presentaba un Índice de Desarrollo Humano de 0.705 en el año 2011, colocándolo en el puesto 121 del mundo (PNUD, 2012).

3.1.3. La problemática del litoral

Desde finales del siglo XIX e inicios del siglo XX, comenzando por las concesiones de tierras a las transicionales bananeras (Barahona, 2005), el litoral hondureño ha venido siendo fuertemente presionado por monocultivos de banano, palma africana, tilapia y camarón. Esto ha provocado una fuerte fragmentación y homogenización del paisaje costero. En el Caribe se pasó de bosque inundable a banano y posteriormente a palma africana, con un área sembrada de 140.000 ha (SAG, 2012) mientras solo se da la protección de 34.000 ha de bosques inundables fragmentados. Las áreas invadidas por palma africana dispersada comprenden el 80% del litoral continental.

En cuanto a los manglares se infiere que han sido afectados por cambios en el hidroperiodo y calidad de agua por extensas redes de drenaje y el uso de agroquímicos. Un estudio de más de 400 cuencas que drenan al sistema arrecifal mesoamericano, indica que el 80% del nitrógeno y fosforo vertidos sobre este, proviene de la cuenca del río Ulúa (Burke & Sugg, 2006). En el Golfo

de Fonseca el paisaje se ha visto modificado por la camaricultura en aproximadamente un 30% (Carrasco & Flores, 2008). Esto causa efectos negativos sobre los ecosistemas de manglares y sobre su biodiversidad asociada. Además de la homogenización de las comunidades acuáticas costeras, de las que no hay estudios específicos, sin embargo, se ha reportado la existencia de especies exóticas como la tilapia la cual está dispersa en todos los cuerpos de agua costeros (SERNA, 2010; Carrasco, 2010; Matamoros *et al*., 2009).

Con respecto a problemas de erosión costera, la costa Caribe está siendo sometida a un fuerte proceso de retroceso. Un ejemplo de esto es lo que ocurre en la desembocadura del río Cangrejal donde la intensa actividad minera no metálica provoca un desbalance en el aporte de sedimentos y consecuentemente la erosión del delta donde está asentada la ciudad de La Ceiba. Concretamente en la zona de Omoa, la infraestructura costera mal planificada, o la desviación del cauce del río Motagua en tramos próximos a la costa en Guatemala, ha provocando erosión y fuertes pérdidas materiales. Actualmente en los mayores ríos del país, Patuca y Ulúa, se están construyendo y planificando al menos seis proyectos hidroeléctricos. Un aspecto que se debe considerar en la evaluación de impactos ambientales de este tipo de proyectos, es el balance hidrológico y sedimentario, enfatizando en la dinámica de humedales y posible erosión en playas, barras de arena de las lagunas, así como en la exacerbación de estos efectos por cambio climático. El Análisis de Vulnerabilidad ante el Cambio Climático del Caribe de Belice, Guatemala y Honduras preparado por el Programa Regional de USAID/MAREA (USAID, 2012) mostró que las zonas costeras de los ríos Lean, Cangrejal y Aguan son altamente vulnerables al aumento del nivel del mar por encontrase a menos de un metro de elevación.

3.2. Diagnóstico de la gestión costera de Honduras: El Decálogo

3.2.1. Políticas públicas

En este primer apartado se pretende analizar la existencia o no de políticas explicitas dirigidas a contribuir a la sustentabilidad de los espacios marino costeros hondureños en atención a los diversos compromisos internacionales de la Nación como por ejemplo la Agenda 21 de la Cumbre de la Tierra de Rio 1992 o la Iniciativa de América Latina y el Caribe para la Cumbre de Johannesburgo 2002. Un compromiso internacional importante es la definición de sus fronteras marítimas, las cuales aún no están totalmente definidas (ver Figura 2.).

El país comparte frontera en el Caribe con Guatemala, Belice, México, Cuba, Gran Cayman, Jamaica, Colombia y Nicaragua, de las cuales se han definido, hasta el momento, los límites fronterizos con México, Gran Cayman, Colombia, Nicaragua y recientemente con Cuba. Por el lado del Océano Pacífico, comparte fronteras con Nicaragua y El Salvador, sin estar estas aún definidas tampoco.

Honduras cuenta con múltiples políticas públicas de carácter sectorial que inciden en el Manejo Costero Integrado (MCI), pero que carecen de un enfoque intersectorial, espacializado y de carácter integrado. Entre estas políticas, llama la atención que de todas ellas, la única que tiene en cuenta al espacio en cuestión es la Política Hídrica Nacional (aprobada en el año 2008) que menciona la pertinencia del continúo cuenca hidrográfica-zona costera y más adelante plantea la necesidad de un buen manejo de estas zonas bajo los principios de la gestión integrada de los recursos hídricos. Este enfoque adecuado que subraya la obvia interdependencia de los sistemas hídricos continentales y sus litorales adyacentes no se ha visto plasmado en las acciones de ejecución de dicha política. Indicar adicionalmente que del análisis del documento de Política Ambiental de Honduras (SERNA, 2005), el instrumento de más alto nivel en el país para la gestión del espacio, de los ecosistemas y recursos, no se encuentra referencia alguna relacionada con el manejo hacia la sostenibilidad de la Honduras también costera y marítima. Estos ámbitos estratégicos sencillamente no son abordados por la política en cuestión.

Es de vital importancia la existencia de una iniciativa estatal relativa a la formulación de la política pública explicita de Manejo Costero Integrado. En relación con esta cuestión, se han detectado procesos importantes. La ONG hondureña INCEBIO (Fundación para la Investigación, Estudio y Conservación de la Biodiversidad) a comienzos del año 2012 estableció alianzas con los miembros de la Red IBERMAR-CYTED para el ingreso de Honduras en dicha Red y poder participar en un enriquecedor intercambio de experiencias orientado a apoyar desde IBERMAR el proceso de diseño y formulación de la política pública de MCI del país. A raíz de esta relación es que en el mes de agosto del mismo año, tuvieron lugar una serie de encuentros entre la Red IBERMAR, el Ministro de la Secretaría de Recursos Naturales y Ambiente (SERNA), e INCEBIO, que con el apoyo de la Universidad Nacional de Honduras (UNAH), permitieron confirmar la voluntad del Gobierno de Honduras de impulsar la política pública nacional de MCI. Se llevó a cabo también un taller interinstitucional para dar a conocer la iniciativa y asegurar la necesaria participación de las distintas instituciones relacionadas con el manejo de estos espacios, tarea impostergable para el país. Este primer taller permitió asentar algunas bases del proceso de formulación y validación de la política y también del posible establecimiento de un comité integrado como ámbito participativo ideal para lograrla. Este proceso que se inicia, ha

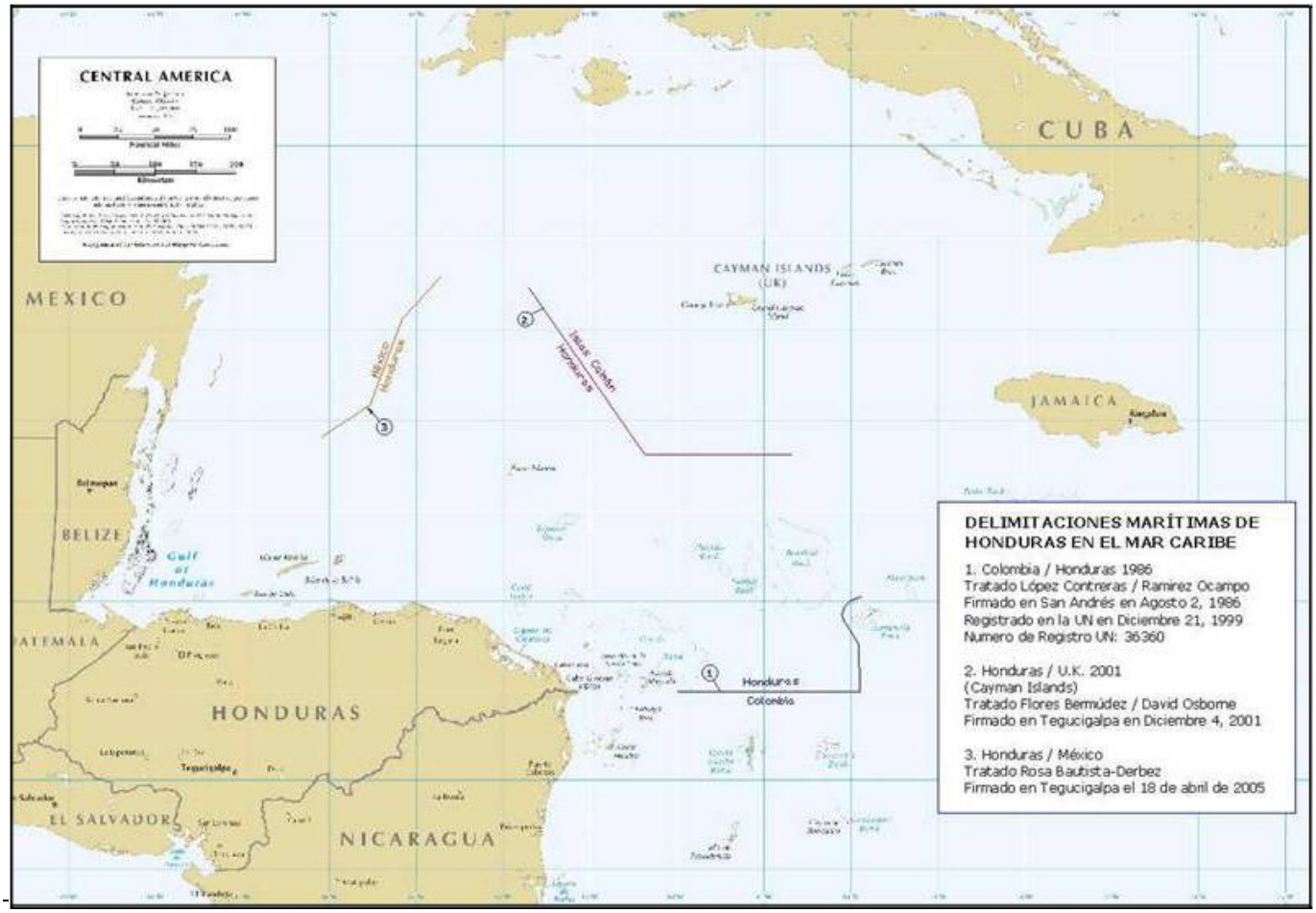

Figura 2 - Mapa de las delimitaciones marítimas de la República de Honduras. Fuente: Secretaría de Relaciones Exteriores, 2012

Figure 2 - Map of the maritime boundaries of the Republic of Honduras. Source: Ministry of Foreign Affairs, 2012

de tener la fuerza suficiente para convertir el propósito de lograr un mejor gobierno del espacio marino y costero hondureño en una prioridad de Estado con plena vigencia en el corto, mediano y largo plazo, más allá de los ciclos cuatrienales de los gobiernos nacionales.

Es claro que Honduras debería abordar con decisión y celeridad un proceso interinstitucional, participativo y bien informado orientado a disponer de la política expresa para la sostenibilidad ecológica, socioeconómica y cultural de su litoral en el Caribe y en el Pacífico, incluido el espacio y los recursos de su Mar Territorial y Zona Contigua, así como los de su Zona Económica Exclusiva. Este objetivo, además de soportarse en esta explicita voluntad política del gobierno nacional, debería también armonizarse con procesos similares en los otros países con quien Honduras tiene fronteras marítimas. El Sistema de Integración Centroamericana (SICA), sería el marco idóneo para lograr la armonización y complementariedad de los esfuerzos de los estados para establecer una política común orientada a la sostenibilidad de sus extensos, singulares y estratégicos espacios costeros y marinos. Asunto también reafirmado en la reciente Conferencia Mundial de Medioambiente y Desarrollo Rio+20 (2012).

Se concluye así que el MCI, que ha estado práctica mente ausente en las políticas públicas nacionales, hoy está en la agenda gubernamental del país. Es claro que el resultado final del proceso de formulación de la Política, actualmente en ciernes, deberá ser incluida en la estrategia nacional de carácter superior: Visión de País 2010 – 2038 y el Plan de Nación 2010-2022 (Comisión Técnica del Plan de Nación, 2010). En esta no se menciona nada acerca de la integridad de los espacios costeros y marinos como parte también de la Nación, ni de la necesidad de su mejor gestión.

3.2.2. Normativa

En este apartado se analiza la normativa hondureña vigente referida al espacio y recursos marino costeros. Existe un amplio número de leyes marcadamente sectoriales relacionadas con el uso y aprovechamiento de recursos. En el Cuadro 1 se presentan las leyes sectoriales vigentes más relevantes relacionadas con el

marco de competencias, jurisdicción y administración de los recursos y del espacio marino costero en el país.

De lo indicado en el Cuadro 1 es clara la dispersión de normas relacionadas en menor o mayor medida con el espacio de interés. Hay un asunto del análisis que debe resaltarse: La ausencia hasta ahora en Honduras de una normativa específica que determine claramente los conceptos y los límites de la zona costera nacional, el litoral, el área de dominio público, etc. El Acuerdo Ejecutivo sobre las Normas Generales para el Control del Desarrollo de las Islas de la Bahía en vigor desde 2005, constituye una regulación para su desarrollo turístico que estableció zonas específicas medidas desde la línea de costa y hacia el interior, para restringir su ocupación privada. Establece que alturas de edificaciones y porcentajes de ocupación deberán considerarse al construir inmuebles según su distancia al mar (10, 15 y 80 m) y según sea "Zona de Playa" u otro tipo de "línea costera".En el año 2010 se aprobó la Ley Especial de las Áreas Protegidas de las Islas de la Bahía, donde aparece una denominación legal y geográficamente determinada de lo que es la Zona Costera (Artículo 4), de la cual se dice que se extiende "desde la Línea de Marea Alta (LMA) hasta 10 metros dentro del territorio insular". Esta delimitación tuvo como único objetivo asegurar que esta estrecha franja de territorio emergido insular quede incluida dentro de la correspondiente Área Protegida Marina y como tal, no pretende definir ámbito geográfico alguno para la planificación y ordenación integrada de este sistema insular costero - marino. Indicar que las normas existentes para la denominada "zona costera" en Islas de la Bahía son el resultado de la reciente reacción del gobierno ante el intenso desarrollo turístico previo y prácticamente desregulado.

Para la parte continental, la Ley General de Aguas de 2009, en el artículo 31 estableció una faja de Dominio Público para la libre circulación de 25 metros de ancho en el caso de las playas, indicando que "el Dominio Público de las aguas marítimas se extiende hasta la línea de playa y límite de subida de la marea alta o al límite de los acantilados". En el caso de la Ley de Pesca de 1959, se determinan algunos usos con respecto a los 50 m medidos desde la línea de marea alta hacia el interior, en los que los pescadores artesanales podrán realizar específicos menesteres en cuanto a sus actividades pesqueras. Así como también queda regulado por el Reglamento de 2001 de la Ley de Pesca la delimita

Cuadro 1 - Normativa sectorial relacionada con la zona costero marina hondureña.

Table 1 - Sectorial legislation related to the marine coastal area of Honduras.

RECURSO O ACTIVIDAD REGULADA	NORMATIVA
Recursos pesqueros y acuicultura	Ley de Pesca (1959).
Recursos hídricos	Ley Constitutiva del Servicio Autónomo Nacional de Acueductos y Alcantarillados -SANAA- (1961). Ley Marco del Sector Agua Potable/Saneamiento (2003) Ley General de Aguas (2009). Ley del Sistema Nacional de Gestión de Riesgos (2009).
Áreas Protegidas, flora y fauna, medio ambiente.	Ley General del Ambiente (1993). Ley Forestal, Áreas Protegidas y Vida Silvestre (2007).
Turismo	Ley para la declaratoria, planeamiento y desarrollo de las zonas de turismo (1980). Ley del Instituto Hondureño de Turismo (1993). Ley de la zona Libre Turística del Departamento de Islas de la Bahía (2007). Acuerdo Ejecutivo n.º 002-2004 Normas Control del Desarrollo de las Islas de la Bahía (2005). Ley de Incentivos al Turismo (1998).
Instalaciones marítimas y portuarias, transporte marítimo	Ley de la Marina Mercante (1994).
Urbanismo y Ordenamiento Territorial	Ley de Municipalidades (1993). Ley de Ordenamiento Territorial (2004).
Sociedad (educación, patrimonio, información, participación)	Ley Orgánica de Educación (1966). Ley de Transparencia y Acceso a la Información Pública (2006). Ley de Participación Ciudadana (2006). Ley Especial para el Desarrollo Integral de los Pueblos Indígenas y Negros de Honduras (2007). Ley Especial de Educación y Comunicación Ambiental (2009). Ley para la Protección del Patrimonio Cultural de la Nación (1984).

ción de 3 millas náuticas exclusivas para pesca artesanal. Estos son los únicos artículos existentes que hacen algún tipo de delimitación en Honduras relacionada con su extenso espacio costero (Figura 3).

Señalar ahora que el Artículo 55 de la Ley General del Ambiente (1993) indica que "se entienden por recursos marinos y costeros las aguas del mar, las playas, playones y la franja del litoral, bahías, lagunas costeras, manglares, arrecifes de coral, estuarios, belleza escénica y los recursos naturales vivos y no vivos contenidos en las aguas del mar territorial, la zona contigua, la zona económica exclusiva y la plataforma continental". Resaltar como esta definición amplia de los recursos y el espacio marino costero de Honduras de 1993, no se corresponde con la declaración formal de "Dominio Público" de la Ley General de Aguas (2009) donde queda restringido este "dominio" tan solo a una franja de 25 m exclusivamente en playas y tan solo para la libre circulación.

Se constata que la normativa relacionada con las costas y el mar en Honduras es profusa y algunas están claramente desactualizadas, donde es frecuente hallar artículos contrapuestos entre ellas. Las normas desconocen el carácter unitario y sistémico del litoral y la necesidad de hacer converger y armonizar las diferentes reglas para un mejor gobierno de este espacio geográfico.

Urge que las normas ambientales enfaticen más, para su aplicación, en procesos participativos y educativos, bajo los principios de la gobernanza, ya que su carencia conduce a su mayor incumplimiento, pérdida de recursos económicos y de eficiencia. Es común para el caso de ciudadanos que interponen demandas por causas de atentados contra el medio ambiente, que estas no se resuelvan, y cuando lo hacen generalmente no terminan favoreciendo a los afectados, lo que hace que la población desista en su empeño de acudir a la justicia. Por esto último conviene mencionar que la Estrategia Nacional de Cumplimiento de la Legislación ambiental (2009), realizada dentro del Proyecto Manejo Integrado de Recursos Naturales (USAID/MIRA) en el marco de DR-CAFTA (Tratado de Libre Comercio entre Estados Unidos, Centroamérica y República Dominicana), una de las acciones estratégicas propuestas es fortalecer el sistema jurídico hondureño con Tribunales Ambientales Administrativos, la implementación de esta estrategia aún no se ha hecho patente.

Como conclusión de este apartado, señalar la inexistencia en Honduras de norma alguna específicamente orientada al manejo integrado de su muy valioso territorio costero-marino y recursos. Es una prioridad definir con claridad los conceptos y delimitación del Dominio Público y del espacio costero marino para su adecuado manejo. Igualmente urge la revisión de la normatividad vigente y dispersa relacionada con este espacio, y la decisión del Legislativo de impulsar en el mediano plazo la ley de la costa o del litoral para ordenar sus múltiples usos desde una perspectiva integrada y por tanto orientada a la sostenibilidad.

3.2.3. Competencias

En este apartado del Decálogo se analizará el reparto de competencias existente entre el Estado y sus Secretarias (ministerios). En Honduras existen tres escalas administrativas: El Estado (Nacional), 18 Departamentos (subregional) y las Municipalidades (local), teniéndose en cuenta una escala comunal al interior de los municipios.

Es sobre la Administración del Estado en la que recaen la mayor parte de responsabilidades para la gestión de las costas y el mar, siendo la descentralización meramente nominal lo que impide un rol relevante de los departamentos y las entidades locales en el manejo mismo de estos espacios. Y esto se refleja en la poca capacidad y recursos con los que disponen estas entida

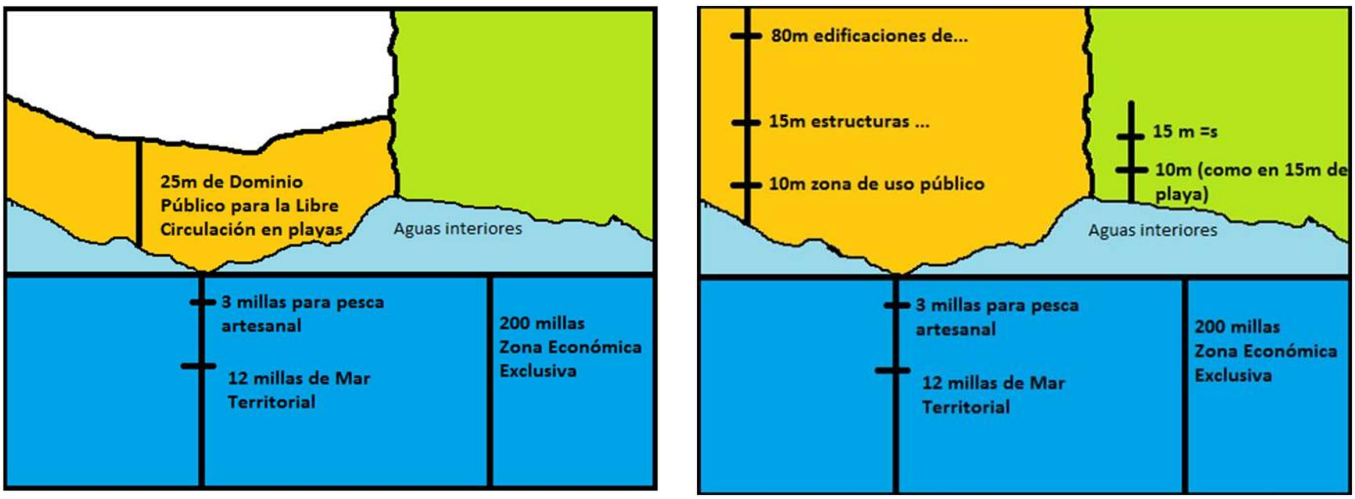

Figura 3 - Delimitaciones de la zona zostera de Honduras según diferentes normas nacionales.

Figure 3. Boundaries of the eelgrass zone of Honduras according to different national standards.

des territoriales. Destacar que no todas las instituciones del Estado están siempre representadas en todas las municipalidades. Suele ocurrir que son estas y las comunidades locales las que tienen que resolver en el día a día, y con carácter reactivo cuando pueden, los crecientes conflictos entre usos y sus impactos nocivos sobre las personas y ecosistemas.

La coordinación entre las diferentes escalas político-administrativas es de vital importancia ya que convergen múltiples funciones en un mismo ámbito territorial, así como las competencias de las diferentes instituciones. Y es que en Honduras en la zona marino costera se solapan diferentes usos y actividades como el monocultivo generalizado de palma africana, camaronicultura, desarrollo urbano desregulado, represas hidroeléctricas, turismo, protección de Áreas Protegidas, ganadería, pesca, etc.

Dentro de este apartado de competencias se ha de incluir la cuestión de cómo abordar mejor en el país la aplicación del concepto de cuenca hidrográfica y su integridad con la costa y el mar para una mejor gestión del agua. En Honduras ha sido muy notable en los últimos años la preocupación por la gestión integrada de las cuencas hidrográficas y del recurso hídrico continental, no obstante esto no se ha traducido en la clara definición de competencias y de mecanismos de coordinación entre las distintas instituciones públicas, a todas las escalas, responsables de la ejecución y evaluación de los planes de gestión de cuencas y de los territorios costeros y marinos adyacentes. Para ello también la coordinación y cooperación entre países se convierte en asunto transcendental para la debida gestión de estos espacios que no saben de fronteras políticas, siendo esta situación más acuciante en América Central. El logro de la sostenibilidad del espacio y recursos en cuestión en Honduras está estrechamente relacionado también con los resultados de la implantación de políticas expresas con igual objetivo en Belize, Guatemala, México, Nicaragua y el El Salvador. Honduras dispone de instrumentos de gestión de carácter Centroamericano que pueden contribuir de manera importante al establecimiento de un arreglo competencial y administrativo armónico internacional en la región orientado hacia el MCI. Algunos de estos instrumentos y otras iniciativas se indican a continuación:

- Desde 2009 iniciaron relaciones y compromisos bilaterales Nicaragua y Honduras para la protección y buen manejo de la cuenca del Río Coco.
- Proyecto Golfo de Honduras entre Belize, Guatemala y Honduras, "Protección Ambiental y Control de la Contaminación originada por el Transporte Marítimo en el Golfo de Honduras".
- Manejo Integral de la Cuenca Binacional del río Goascorán entre Salvador y Honduras.
- Proyecto Gestión integrada de ecosistemas en el Golfo de Fonseca financiado por GEF/BID entre 2007 y 2012.
- Proyecto Trinacional Corredor del Mangle Golfo de Fonseca financiado a través del Fondo España de la Agencia Española de Cooperación al Desarrollo (AECID) a través del Sistema de Integración Centroamericano (SICA).
- URPAGOLF: Unión Regional de Pescadores Artesanales del Golfo de Fonseca.
- Programa Regional para el manejo de recursos acuáticos y alternativas económicas de USAID, en coordinación con CCAD, OSPESCA, SICTA y BCIE, entre 2010 y 2014.
- El Corredor Biológico Mesoamericano y el Sistema Arrecifal Mesoamericano.
- Otros programas y proyectos regionales en el marco de la CCAD-SICA.

Concluir que las responsabilidades para la gestión del espacio marino costero no están claramente definidas en Honduras, se dan casos de superposición de competencias y de vacíos, generando conflictos y respuestas inadecuadas a la compleja problemática de estos ámbitos. Esta situación conduce a la pérdida de recursos económicos y a una mayor ineficiencia, desmotivando la participación ciudadana, al mismo tiempo que se intensifican los procesos de degradación del entorno litoral y de calidad de vida de las personas. Señalar finalmente la necesidad de adecuados mecanismos de coordinación y consulta entre las instancias de gobierno central, departamental y local, y de estos a su vez con los distintos actores sociales con asiento en el litoral (empresas privadas y públicas, academia, ONG´s, comunidades locales, indígenas, etc.).

3.2.4. Instituciones

Este asunto clave para el MCI presenta la organización administrativa institucional pública con competencia y jurisdicción, total o parcial, en el espacio costero y marino hondureño. En el Cuadro 2 se listan las principales instituciones, la actividad o recurso que administran y el órgano colegiado formado bajo la dirección de la administración pertinente.

El Cuadro 2, sin pretender ser exhaustivo, permite remarcar el amplio marco institucional existente y la carencia de una administración intersectorial especifica del nivel central para coordinar la formulación, ejecución y seguimiento de las políticas y normas, a todas las escalas administrativas-territoriales para un mejor gobierno del espacio de interés. No se plantea aquí el crear una institución para el MCI en Honduras, en cambio sí el establecimiento de un *órgano colegiado interinstitucional* cuya secretaría esté vinculada a una administración lo más cercana posible a la Presidencia de la Re

Cuadro 2 - Marco administrativo institucional publico principal relacionado con el espacio y los recursos costeros y marinos en Honduras.

Table 2 - Main institutional administrative framework related to public space and coastal and marine resources in Honduras.

RECURSO O ACTIVIDAD REGULADO	INSTITUCIÓN, ADMINISTRACIÓN, DEPARTAMENTO	ÓRGANO COLEGIADO ASESOR
Aguas continentales y litorales	Dirección General de Recursos Hídricos (Secretaría de Recursos Naturales y Ambiente-SERNA). Departamento de Cuencas Hidrográficas y Ambiente (SERNA). Departamento de Cuencas Hidrográficas y Ambiente de la Subdirección de Áreas Protegidas y Vida Silvestre (ICF).	Consejo Nacional de Recursos Hídricos (CNRH). Consejo nacional de Agua Potable y Saneamiento (CONASA).
Recursos Naturales, Áreas Protegidas y ambiente	SERNA ICF	Consejo Consultivo Nacional del Ambiente.Consejo Consultivo Nacional Forestal, Áreas Protegidas y Vida Silvestre. Comisión de Recursos Naturales Renovables y No Renovables y de Áreas Protegidas. Comité Nacional de Humedales. Comisión Nacional para la Gestión Ambientalmente Racional de los Productos Químicos (2006). Comité Nacional Interinstitucional de P+L.Consejo Nacional de Desarrollo Sostenible (CONADES).
Pesca y Acuicultura	Dirección General de Pesca y Acuicultura (DIGEPESCA)-Secretaría de Agricultura y Ganadería (SAG)	Comisión Nacional Asesora de Pesca y Acuicultura (1993).
Territorio	Dirección General de Ordenación del Territorio (DGOT) de la Secretaría de Gobernación y Justicia (SEDGJ)	Consejo nacional de Ordenación del Territorio.Comisión Ejecutiva de Descentralización (CEDE).
Turismo	Instituto Hondureño de Turismo (IHT)	Consejo Nacional de Turismo.
Puertos comerciales	Dirección General de la Marina Mercante (DGMM)	Comisión Nacional de Protección Portuaria (CNPP)
Ciencia y Educación	Secretaría de Educación	Consejo Nacional de Educación y Comunicación Ambiental. Comité de Ciencias Ambientales de las Universidades (CICA).

pública. En este sentido, un paso importante ya dado, indicado en un apartado anterior, son las reuniones que han tenido lugar a partir de 2012 con motivo de la iniciativa de formulación de la política ya mencionada, cuyo grupo se formó de manera que integrara a los diferentes sectores con implicación en el litoral. La consolidación de esta iniciativa es un objetivo clave para Honduras.

Varias normas apuntan a declarar a la Secretaría de Recursos Naturales y Ambiente (SERNA) como aquella con competencias más generales en la costa. Entre ellos el artículo 39 de la Ley General de Aguas, donde se señala como la Autoridad del Agua, dentro de esta Secretaría, para la conservación de los recursos marinocosteros. También en el artículo 56 de la Ley General del Ambiente es esta misma Secretaría la responsable de fijar épocas de veda para la pesca o recolección de determinadas especies y los criterios técnicos a que se sujetará la población y repoblación de los fondos marinos. En el artículo 57 de la misma ley se le atribuye a la SERNA, en coordinación con las demás instituciones competentes, el delimitar las zonas de protección de determinadas áreas marinas o costeras, las cuales se sujetarán a planes de ordenamiento y manejo. La SERNA cuenta además con un departamento de Ecosistemas Marino Costeros dentro de la Dirección General de Protección y Conservación de la Biodiversidad (DIBIO).

Destacar que en Honduras llama la atención la existencia de dos instituciones públicas con algunas funciones sobrepuestas de carácter ambiental y también relacionados con el litoral. La SERNA y el Instituto de Conservación Forestal (ICF) tienen competencias que se superponen en temas relacionados con Áreas Protegi

das, vida silvestre y cuencas hidrográficas (ICF, 2008), siendo patente en muchas ocasiones los conflictos que ello genera. La reorganización de la administración pública ambiental en Honduras que favorezca su unicidad, eficiencia y que al mismo tiempo fortalezca su gestión, es una necesidad.

3.2.5. Instrumentos: Operativos y estratégicos

Aquí se analizan las diferentes herramientas creadas por la administración pública hondureña orientadas también a la gestión de su espacio y recursos costeros y marinos. En el Cuadro 3 se presentan estos instrumentos discriminados según el recurso o actividad, adicionándose también los llamados instrumentos integrados que combinan una perspectiva amplia que contribuyen creemos al MCI.

Mencionarse también aquellos planes y proyectos formulados pero aún no aprobados, o aprobados que hasta la fecha no se han implantado, como por ejemplo el Plan Regional de Uso Público y Mejora Ambiental de las Playas de la Costa Norte (2008), el cual está incluido en el Programa Nacional de Turismo Sostenible del Instituto Hondureño de Turismo. Importante señalar que el Municipio de Puerto Cortés, desarrolló en 2011 su Plan Municipal con Enfoque en Ordenamiento Territorial con el objetivo adicional de armonizarlo con el Plan de Manejo del Parque Nacional Jeannette Kawas con el que colinda. Esto debe servir de ejemplo para otros municipios de la Costa Norte que no incluyen en sus Planes de Ordenamiento Territorial las Áreas Protegidas de las cuales obtienen claros beneficios.

Los numerosos instrumentos estratégicos y operativos de carácter sectorial existentes inciden sin duda en la gestión de la zona costera, pero se carece de un instrumento estratégico de carácter espacial e intersectorial que armonice y complemente estos esfuerzos tanto en la escala nacional, como en la subregional y específicamente para las unidades homogéneas de paisaje costero o unidades ambientales del litoral. Estas deberían definirse en la política explicita de MCI, constituyendo la herramienta por excelencia para su aplicación.

3.2.6. Formación y capacitación

En este apartado se analiza el perfil formativo profesional dentro de las administraciones públicas en alguna medida relacionada con la gestión del litoral en el país, los mecanismos de actualización existentes y la oferta académica superior de pregrado y postgrado relacionada.

Cuadro 3 - Instrumentos públicos relacionados con el MCI en Honduras.

Table 3 - Public instruments associated with MCI in Honduras.

RECURSO/ ACTIVIDAD	INSTRUMENTOS ESTRATÉGICOS	INSTRUMENTOS OPERATIVOS
Instrumentos integrados	Estrategia Nacional de Cambio Climático. Estrategia y Plan de Acción Nacional de la Política de Producción Más Limpia (2009).	No determinados
Pesca y Acuicultura	Estrategia Nacional de Ordenación y Desarrollo de la Pesca y la Acuicultura (en formulación).	Concesiones, licencias, vedas (espaciales y temporales), línea de 3 millas náuticas, reservas de pesca, tamaño de luz de malla, etc.
Turismo	Estrategia Nacional de Turismo Sostenible Estrategia Nacional de Ecoturismo (2004).	Certificación hotelera (Service Best, Freeman Group).
Medio Ambiente, Áreas Protegidas	Estrategia Nacional de Bienes y Servicios Ambientales de Honduras (2007). Estrategia de biodiversidad (en actualización). Estrategia de Género para el Manejo Sostenible de los Recursos Naturales y Ambiente (2005). Estrategia Nacional de Cumplimiento de la Legislación Ambiental (2009).	Evaluación de Impacto Ambiental, diferentes categorías de Área Protegida, Planes de Manejo, Patrimonio Público Forestal Inalienable, Certificación Forestal, contratos de manejo forestal comunitario.
Recursos hídricos	Estrategia Nacional de Manejo de Recursos Hídricos en Honduras de 2011 (no aprobada aún)	Canon por vertidos y canon por aprovechamiento.
Puertos	Plan de Expansión y Modernización Puerto Cortés	Planes de Contingencia y Certificación Portuaria.
Territorio, usos del suelo	Plan Nacional de Ordenación Territorial, Plan Regional de Ordenación Territorial.	Planes Municipales de Ordenación Territorial, Plan de Ordenación Territorial de Áreas bajo Régimen Especial, Planes Reguladores, Plan de Arbitrios, concesiones.
Recursos y bienes culturales	No determinados.	Definición de Bienes de Patrimonio Cultural, Patrimonio Documental, Zona Arqueológica y Monumento Nacional.

La Universidad Nacional Autónoma de Honduras (UNAH) ofrece algunos programas relevantes en cuanto a la temática. Destacar la Maestría en Manejo Integrado de Recursos Marino Costeros que comenzó a impulsarse en 2012 y las carreras relacionadas con las ciencias marinas. Con la implantación de estos títulos comenzó la difusión del conocimiento, preparación de profesionales e investigación interdisciplinar e integrada tan necesaria para el manejo adecuado de un sistema tan complejo, frágil y estratégico como el litoral hondureño.

En relación a la capacitación ofrecida por las administraciones públicas a los funcionarios y demás personas empleadas en el sector público, no se han detectados cursos o talleres en orientados al fomento del MCI. El país prácticamente carece de profesionales formados a nivel superior en MCI. A este desafío se suma en Honduras el hecho que la carrera administrativa dentro de las instituciones públicas aun no esta consolidada. La remoción periódica de parte del personal formado, con cada nuevo gobierno, es un notable impase en relación con la capacidad y competencia de los funcionarios públicos, asunto fundamental para un buen gobierno del litoral. La meritocracia como criterio único para el acceso de profesionales y técnicos a plazas en la administración pública debería generalizarse.

Señalar finalmente que se hace necesaria la extensión de las capacitaciones sobre los asuntos de la gestión del espacio y recursos marino costeros, desde una perspectiva integrada y espacial, para los funcionarios y personal de todos los sectores públicos, a las diferentes escalas territoriales, relacionados con este territorio.

3.2.7. Recursos

El fuerte énfasis sectorial de la administración pública hondureña, la multiplicidad y dispersión de instituciones, subregionales y locales con algún tipo de competencia en el litoral, y la muy limitada disponibilidad de esta información hacen prácticamente imposible contar con un análisis de conjunto sobre las inversiones públicas orientadas a este ámbito. Además como ya se señaló, no existe una institución específica dedicada al MCI, por lo que el enfoque del análisis debe solo hacerse desde los diferentes sectores públicos con competencias allí, en especial medio ambiente, turismo y pesca. Insistir en que los datos obtenidos brindados por las instituciones (ver Cuadro 4) son de carácter general y no son específicamente destinados al MCI.

Señalar primero que una proporción alta de los recursos orientados a la gestión pública ambiental en Honduras provienen de organizaciones internacionales a través del llamado Fondo Externo y mucho menos del Fondo Nacional. Según la Secretaría de Finanzas (SEFIN) los recursos específicos para la SERNA, según datos de 2011 y 2012, han provenido en un 85-90% del fondo externo y entre el 10-16 % del fondo nacional. Para el ICF, en 2011 se obtuvo el 22,2 % por fondo nacional y el 77,8 % por fondo externo. Estos fondos externos son donados cada año al país por más de veinte organizaciones internacionales correspondiendo una media anual de 650 millones de Lempiras para el periodo 2009-2010, alcanzando en 2011 la cifra de 1.430.220.299,6 Lempiras (SEFIN, 2009, 2010; 2011).

Aclarar que la información presupuestal indicada en el Cuadro 4 corresponde a lo señalado por la SEFIN para la Secretaría de Agricultura y Ganadería (SAG), y que en cambio la señalada para la Dirección General de Pesca (DIGEPESCA) no aparece en los informes de la SEFIN.

Concluir que el hecho de que Honduras carezca aún de una política expresa para el Manejo Costero Integrado, traducida por tanto en un presupuesto orientado específicamente a su ejecución, explica la fragmentaria y difusa información sobre el presupuesto público orientado a la gestión de su litoral. Es claro que los beneficios económicos, sociales y culturales que brinda a la Na

Cuadro 4 - Inversión pública interanual hondureña (2009-2012) relacionada con algunos sectores vinculados al litoral (cifras en Lempiras. US$ 1,00: 19.88 Lempiras). Fuente: SEFIN (Secretaría de Finanzas), 2012.

Table 4 - Honduran inter-annual public investment (2009-2012) related to some sectors linked to the littoral (figures in US $ 1.00 Lempiras. 19.88 Lempiras). Source: MOF (Ministry of Finance), 2012.

Presupuesto inicial/año	Instituto Hondureño de Turismo (IHT)	Instituto de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre (ICF)	Secretaría de Recursos Naturales y Ambiente (SERNA)	Secretaría de Agricultura y Ganadería (SAG)
2009	141.320.200	192.861.134	435.755.266	848.765.050
2010	333.987.604	192.861.134	435.755.266	848.765.050
2011	199.092.200	292.578.800	818.694.199	816.518.377
2012	235.731.888	360.992.416	879.828.778	895.268.983

ción y por tanto a sus ciudadanos, no se corresponde con las inversiones públicas que demandan su protección y restauración. Se tiene la confianza que el reconocimiento expreso de la importancia de las costas y el mar para el alto gobierno se refleje también en el incremento de recursos que demanda su manejo sostenible.

3.2.8. Información Pública

Interesa en este apartado tanto la generación y divulgación de la información científica sobre la estructura y función de los ecosistemas marino-costeros en Honduras y de los procesos socioeconómicos allí establecidos, así como del acceso de la ciudadanía a este tipo de información.

Por su debilidad, se reconoce prioritario en el país mejorar sustancialmente el conocimiento y la difusión sobre los ecosistemas costero marinos de Honduras, su resiliencia, problemática y finalmente los cambios que se evidencian ante presiones humanas. La debida comprensión de los procesos relacionados con la dinámica oceanográfica y sedimentaria, climática y riesgos costeros, es un asunto de máxima prioridad para Honduras. Es necesaria una mayor información científica sobre este espacio y lograr un salto sustancial en la calidad de los datos disponibles, dada la vulnerabilidad del litoral ante el Cambio Global, y por tanto también a los efectos indeseados del Cambio Climático.

Debe mencionarse que dentro de las diferentes instituciones del Estado existen algunos mecanismos para apoyar la divulgación de la información a la ciudadanía. Resaltar por ejemplo:

- El Sistema Nacional de Información Ambiental (SINIA), establecido y operado por la SERNA.
- El Sistema de Información del SINAPH (Sistema Nacional de Áreas Protegidas), el SIS que corresponde a la integración del SINIA con el Sistema Integral de Estadísticas Forestales (SIEF).
- El Sistema Nacional de Información Territorial (SINIT) perteneciente a la Secretaría Técnica de Planificación y Cooperación Externa que genera y brinda la información cartográfica nacional.

Aun existiendo estos mecanismos, la difusión de la información científica está muy limitada a las pocas bases de datos debidamente contrastadas. Al mismo tiempo es frecuente que se sobre diagnostiquen algunos problemas puntuales, y que a otros no se les de continuidad en el tiempo. Se evidencian problemas también en relación con el establecimiento de mecanismos adecuados para la revisión y permanente actualización de información sobre el mar y las costas del país. El flujo de información precisa y actualizada es de suma importancia para los tomadores de decisiones. El vincular la ciencia y las políticas públicas es un asunto particularmente relevante para un mejor gobierno de estos espacios. Facilitar la apertura de una estrecha relación entre investigadores / universidades y gobernantes / administración pública es prioritario en Honduras.

En cuanto al fomento de la investigación científica, es clara la pertinencia de que el país impulse un instituto u organismo marino de ciencia y tecnología, desde donde se comience a financiar la investigación y haya un mayor apoyo a la academia, ya que es difícil concebir la generación este tipo de conocimiento sin que se fortalezca la educación superior. Insistir que Honduras debe establecer y reforzar convenios de investigación y cooperación científica con universidades e institutos de relevancia regional e internacional con probada experiencia en investigación científica en las distintas disciplinas relacionadas con las ciencias del mar en ámbitos tropicales.

En relación a la Información sobre la gestión pública relacionada con la administración del litoral, señalar que desde 2006 existe la Ley de Transparencia y Acceso a la Información Pública la cual creó el Sistema Nacional de Información Pública yel Instituto de Acceso a la Información Pública que actúa como órgano descentralizado. La web de esta institución tiene un apartado de consulta especializado. En general, todas las webs de las diferentes administraciones tiene este tipo de apartado para consulta de usuarios.

Indicar finalmente que muchos de los resultados de trabajos, planes y proyectos públicos que se ejecutan en el país, vinculados o no al litoral, no tienen la difusión adecuada y se quedan en las instituciones o a lo sumo en publicaciones o informes de circulación restringida. Esta situación ocasiona un freno a la concientización ambiental en la ciudadanía, a su corresponsabilidad para abordar soluciones a los conflictos costeros, a la duplicación de esfuerzos, y finalmente a la perdida de recursos.

3.2.9. Educación para la sostenibilidad

Es importante identificar en el país que actividades formativas vinculadas con la educación no formal, orientadas a potenciar el interés de la sociedad por conservar y restaurar el espacio y los recursos del litoral están establecidos. Aquí cabe analizar el papel para tal fin que tienen las administraciones públicas a todas las escalas y las organizaciones no gubernamentales, detectando también los vacíos sobre este asunto clave para la sostenibilidad costera.

En 2009 se aprobó la Ley Especial de Educación y Comunicación Ambiental, la cual establece las bases para la coordinación entre la SERNA y la Secretaría de Educación, de manera que ambas administraciones sumen capacidades para el desarrollo de iniciativas conjuntas acerca de la educación ambiental. Debido a esto, se crea

para dicha coordinación dentro de la SERNA, el Departamento de Educación y Comunicación Ambiental. En esta ley también se difunde el concepto amplio de medio ambiente incluyendo a numerosas instituciones del Estado, empresa privada y ONG´s en la responsabilidad de transmitir y capacitar a la ciudadanía en temas claves para la sostenibilidad. La norma enfatiza que la idea es hacerla extensiva más allá de las Áreas Protegidas, como normalmente se hace, a ámbitos urbanos, rurales, etc. Indicar también que la Estrategia Nacional de Cumplimiento de la Legislación Ambiental, ya mencionada, establece entre sus componentes la Educación y Concienciación Ambiental y su incorporación en el contenido curricular del Sistema Educativo Nacional, además de mecanismos de educación no formal. Importante mencionar que se desconoce el éxito en la implementación de la anterior ley y estrategia, no habiéndose visto por ahora resultados de la misma.

Existen numerosas ONGs ambientalistas en el país, muchas de ellas, co-manejadoras de Áreas Protegidas. Estas por ley están obligadas a incluir un componente de educación ambiental en los planes de manejo. Aun así, los programas de voluntariado ambiental en el espacio marino costero necesitan mayor fortalecimiento, expansión en el espacio y el tiempo, así como mayor difusión que motive a la participación.

Destacar la existencia también en Honduras de organizaciones comunitarias interesadas en la propia gestión del medio costero en que están asentadas. En 2012 tuvo lugar en Puerto Lempira un taller para la formulación de diez proyectos por parte de las mismas comunidades relacionados con la gestión sostenible de la laguna de Karataska y apoyados por técnicos dentro del marco del Proyecto de Pequeñas Donaciones del PNUD y la ONG Dakni Tak Aslika. Cada una de estas comunidades tiene una asociación, la mayoría con personería jurídica. Durante los días que duraron los talleres se establecieron los mecanismos para la empoderación y gestión comunitaria del espacio y los recursos existentes en sus comunidades.

Otro ejemplo que merece mención corresponde a las actividades de restauración de dunas llevadas a cabo por doce comunidades de Santa Rosa (Departamento de Colón). A través del Plan de Protección Ambiental elaborado dentro del marco del Proyecto Recuperación Temprana financiado por la Cooperación Suiza para el Desarrollo (COSUDE) y por el PNUD, estas comunidades llevan a cabo las obras de protección, mantenimiento y recuperación del ecosistema afectado.

Los casos anteriormente indicados confirman una mayor sensibilidad, en una parte de la ciudadanía, para asumir los derechos y deberes que les corresponden en el mantenimiento saludable de sus recursos marino-costeros, sin embargo se evidencia todavía una falta relevante de conciencia social a todos los niveles sobre estos asuntos. Los municipios costeros, por su contacto directo con los conflictos en el litoral, tienen un papel central en la construcción de una mayor conciencia social y pública, pilar fundamental de la sostenibilidad. Y se ha de tener en cuenta siempre que de nada sirven las leyes para conservar si de manera individual, el ciudadano no ve la importancia de cuidar su patrimonio (Caviedes, 2011).

3.2.10. Participación pública

La participación pública es un derecho existente señalado en diversas leyes de Honduras como la Ley General del Ambiente, el artículo 25 de la Ley de Municipalidades, el artículo 69 de la Ley de Ordenamiento Territorial y en particular la Ley de Participación Ciudadana (2006).

El hecho de que la participación pública sea un asunto frecuentemente legislado no implica que su desarrollo sea el esperado. Es necesario que existan sistemas de organización adecuados y de consulta abierta. La Ley de Aguas (2009) creó los Consejos de Cuencas, de Sub-Cuenca y de Micro-cuenca. Su implantación real ha sido débil, pero se ha de tener en cuenta que constituyen una valiosa herramienta de participación para la apropiada gestión del ámbito de transición entre la tierra y el mar.

La Ley de Ordenamiento Territorial crea los llamados Consejos de Ordenación Territorial de las Mancomunidades, los cuales se previó deben estar presentes en los Consejos Departamentales de Ordenación Territorial. Ellos son los espacios de consulta pública para la definición de la zonificación y los usos de estas unidades administrativas territoriales. En la Ley se detallan también los componentes del Consejo Nacional de Ordenamiento Territorial, haciendo parte de él también una amplia representación de asociaciones locales y ONGs. Señalar, además, que en la Ley Forestal, de Áreas Protegidas y Vida Silvestre (2007) se detallan los Consejos Consultivos Regionales, locales y comunales como foros “para un mejor funcionamiento institucional” y como “instancias de participación ciudadana, de consulta y apoyo al ICF”.

Urge en Honduras lograr la implicación de los líderes naturales de las asociaciones locales, con apoyo de las instituciones públicas y otras organizaciones, para que los habitantes costeros participen en la toma de decisiones del gobierno que afectan su espacio y recursos. Es común en el país que las ONGs nacionales e internacionales asuman las tareas relacionadas con organización comunitaria y concientización ambiental entre las comunidades costeras. Las bases para la participación ciudadana están creadas, disponiéndose de un marco normativo que la ampara, no obstante aún hace falta una mayor transparencia en la toma de decisiones y que la ciudadanía constate cada vez más que los instru

mentos participativos existentes son un valioso medio para la gobernanza requerida del territorio costero y marino, del cual dependen en gran medida.

4. Conclusiones

El Cuadro 5 presenta una síntesis diagnóstica conclusiva sobre los asuntos estructurales claves para el Manejo Costero Integrado en Honduras analizados en este trabajo. Es claro que el MCI en ese país centroamericano está en la etapa pre-inicial de avance. Creemos que alrededor de los diez elementos analizados deberá pronto emerger la política pública específica para un mejor gobierno del litoral. Este paso inaplazable y en ciernes, deberá por ejemplo, además de definir claramente el ámbito espacial de la zona costera hondureña, lograr la integración y coordinación horizontal y vertical entre las entidades públicas a todas las escalas para el manejo y administración de este espacio. Urge acometer un proceso de consulta, análisis y evaluación, como soporte de decisiones jurídicas, sobre reorganización institucional, de competencias y de jurisdicción requeridos para establecer un sistema público eficaz para un mejor gobierno de las costas y el mar en el país. La mejora de la eficiencia y efectividad de las prácticas administrativas de las instituciones públicas responsables de la ejecución de la política de MCI que se formula, será asunto de especial importancia.

En cuanto a los instrumentos para el manejo parece conveniente que Honduras cuente con un plan nacional de MCI, como herramienta esencial para gestionar, fortalecer y orientar la implantación de este enfoque, además de señalar las estrategias para armonizar la acción gubernamental. Derivado de este plan, los planes subregionales de manejo de la zona costera, para cada una de sus unidades ambientales costeras, serían los instrumentos para el ordenamiento ambiental territorial

Cuadro 5 - Síntesis conclusiva del diagnóstico del MCI en Honduras.

Table 5 - Summary conclusive diagnosis of MCI in Honduras.

Aspecto	DIAGNÓSTICO GENERAL
Política	El ámbito costero y marino en Honduras no ha sido sujeto de política pública. Estos espacios aparecen de forma fragmentaria en las distintas políticas o estrategias nacionales sectoriales. Sin embargo importantes esfuerzos se identifican recientemente.
Normativa	Existe una profusa, compleja y sobrepuesta normatividad relacionada más con la gestión pública de los diferentes recursos costero-marinos, desde una perspectiva sectorial, que con su manejo integrado. Urge aclarar el concepto y delimitación de la zona costera hondureña.
Competencias	Las responsabilidades para el manejo costero integrado no están definidas. Se constatan importantes conflictos competenciales en la gestión de las áreas litorales que obligan a disponer de apropiados mecanismos de coordinación y cooperación actualmente muy débiles.
Instituciones	La Secretaría de Recursos Naturales y Ambiente es la administración estatal con más funciones relacionadas con el MCI. Aun así no existe una instancia de carácter intersectorial para coordinar la formulación, ejecución y seguimiento de las políticas y normas para el MCI.
Instrumentos	Alta diversidad y elevado número de instrumentos reglamentarios preceptivos y sectoriales. No existe en la escala estatal ningún instrumento de carácter estratégico u operativo específicamente diseñado para el litoral.
Formación y capacitación	Se identifican importantes y recientes avances como la Maestría en Manejo Integrado de Recursos Marino Costeros impulsada por la Universidad Nacional Autónoma de Honduras y algunas carreras relacionadas con las ciencias marinas. No existe programa alguno de capacitación en MCI para funcionarios y técnicos de la administración pública.
Recursos	No existe correspondencia alguna entre los beneficios obtenidos y los recursos económicos destinados a la protección litoral. La fuente principal de las escasas inversiones públicas relacionadas con la conservación costera proviene del Fondo Externo. No existe un rubro específico para el MCI.
Conocimiento e Información	No existe un programa estatal de investigación interdisciplinario y de generación de conocimiento orientado a la gestión integrada de áreas costeras.
Educación y sostenibilidad	En el nivel estatal no existe programa alguno de educación ambiental específicamente relacionado con el litoral. La tarea es asumida básicamente por las ONG,s. Se constatan experiencias valiosas entre las comunidades de base costeras.
Participación	En la normativa es explícito el derecho de la ciudadanía a la participación en la toma de decisiones públicas. No obstante en la mayoría de los casos tiene un carácter meramente representativo.

de estos espacios. Por otro lado hay que mejorar ciertos instrumentos operativos como la Evaluación Ambiental Estratégica, los Estudios de Impacto Ambiental, las certificaciones o las tasas por contaminación, entre otros, para que ellos sí contribuyan a la protección y restauración del patrimonio natural y cultural del litoral hondureño.

Otro asunto que creemos fundamental es que la política de MCI en formulación, incluya un apartado específico que defina metas que sustenten un programa para generar y estimular la capacidad científica hondureña para efectuar investigación interdisciplinaria sobre los subsistemas biofísico, socioeconómico, cultural y jurídico-administrativo, que brinde a los gestores y a la administración pública el conocimiento e información necesaria para un buen gobierno del territorio y los recursos costeros y marinos. El acopio, organización y divulgación, también para los ciudadanos, de esta información pública, son tareas que deberían acometerse.

Referente al asunto de la formación y capacitación de gestores con visión integrada, el inicio de la creación en 2012 de la Maestría en Manejo Integrado de Recursos Marino Costeros por parte de la UNAH es un paso adelante.

A esta iniciativa que cuenta con mecanismos de cooperación académica interuniversitaria de carácter internacional, deben ahora sumarse apoyos económicos para los potenciales alumnos provenientes en especial de la misma administración pública y de los sectores productivos costero-marinos. Resaltar la necesidad, para la generación de información científica en temas marino costero en Honduras, de que se consolide la instauración de carreras en ciencias marinas que se están impulsando también desde la UNAH.

Para la educación ambiental y concienciación, en Honduras desde 2009 existe la Ley Especial de Educación y Comunicación Ambiental. Esta norma, la iniciativa de la política de MCI y los instrumentos que de ella se deriven, deberían fortalecer la vinculación activa de los usuarios, comunidades y etnias en el proceso de administración y mejor gobierno de la zona costera a través de la educación ambiental y participación ciudadana en la planeación, ordenamiento y gestión del litoral. El estado debería promover y facilitar la organización de la educación y la capacitación formal y no formal en materia de procesos ecológicos y ambientales, ordenación integrada y manejo sostenible del litoral. Para ello la acción coordinada efectiva de las ONG´s, con el debido seguimiento de la administración pública, será un fundamental aporte.

Honduras tiene las condiciones y la oportunidad de enfrentar con propiedad soluciones duraderas a la creciente problemática relacionada tanto con los cambios sobre su entorno litoral (degradación de ecosistemas, pérdida de biodiversidad, efectos del cambio y variabilidad climática, erosión e incremento en la producción de residuos y vertidos al mar), como cambios en el bienestar de las personas asentadas en la franja costera (disminución progresiva de los recursos pesqueros, urbanización desregulada, homogenización del paisaje, pérdida del patrimonio cultural y persistente desigualdad, pobreza e inequidad social). El creciente reconocimiento político y de la Sociedad Civil sobre la vital importancia presente y futura de sus mares y costas en el Caribe y en el Pacífico, hacen previsible que el Manejo Costero Integrado se asiente en el país centroamericano y llene de contenidos el discurso generalizado del desarrollo sostenible de estos espacios.

References

Arenas, P. (2011) - *Manejo Costero Integrado y Sustentabilidad en Iberoamérica. Un análisis propositivo de políticas públicas en las dos caras atlánticas: España, Portugal, Colombia y Panamá.* 407p., Editorial Académica Española. LAP LAMBERT. Saarbrucken, Alemania. ISBN: 978-3847354369.

Arenas, P. (2012) - *Manejo Costero Integrado y sustentabilidad en Iberoamérica: aproximación a un diagnóstico*. *In:* J.M. Barragán (coord.), *Manejo Costero Integrado en Iberoamérica: Diagnóstico y propuestas para una nueva política pública.* pp.21-68, Red IBERMAR (CYTED), Cádiz, España. ISBN: 978-8469510186.

Barahona, M. (2005) - *Honduras en el siglo XX. Una síntesis histórica.* 378p., Editorial Guaymuras, Tegucigalpa, Honduras. ISBN: 9992633360.

Barragán, J.M. (2001) - *The Coasts of Latin America at the End of the Century. Journal of Coastal Research*, 17(4):885-899. Article Stable URL: http://www.jstor.org/stable/4300248

Barragán, J.M. (2003) - *Medio Ambiente y desarrollo en áreas litorales. Introducción a la Planificación y Gestión Integradas.* 306p., Servicio de publicaciones Universidad de Cádiz, Cádiz, España. ISBN: 8477868298.

Barragán, J.M. (2004) - *Las áreas litorales de España. Del análisis geográfico a la gestión integrada.* 214p., Editorial Ariel, Barcelona, España. ISBN: 8434480700.

Barragán, J.M. (Coord.) (2009) - *Manejo costero integrado y política pública en Iberoamérica: Un diagnóstico. Necesidad de cambio*, 380p., Red IBERMAR (CYTED), Cádiz, España. ISBN: 978-8469251751.

Barragán, J.M. (Coord.) (2012) - *Manejo Costero Integrado en Iberoamérica: Diagnóstico y propuestas para una nueva política pública*. 149p., Red IBERMAR (CYTED), Cádiz, España. ISBN: 978-8469510186.

Bello, E.; Anfuso, G.; Macias, A.; Nachite, D.; Benavente, J.; Barragán, J.M. (2006) - *Estudios previos para una propuesta de gestión integrada de las costas mediterráneas de Marruecos: el tramo Ceuta-Cabo Negro*. 95p., Junta de Andalucía / Universidad de Cádiz, Cádiz, España.

Burke, L.; Maidens, J. (Org.) (2004) - *Reefs at Risk in the Caribbean*. 80p., WRI - World Resources Institute, Washington, DC, U.S.A. ISBN: 1569735670. Available on-line at http://pdf.wri.org/reefs_caribbean_full.pdf

Burke, L.; Sugg, Z. (2006) - *Modelamiento Hidrológico de la Descarga de las cuencas Hidrológicas en el Arrecife Mesoamericano. Síntesis del Análisis*. World Resource Institute / ICRAN / MAR / USAID. 44p. Available on-line at http://www.icran.org/pdf/MAR-Pages/watershed/docs/mar_ hydrologic_model_ results_spanish.pdf

Carbajal, J.M.; W. Rodriguez. (2005) - *Situación actual de los recursos hídricos y costeros en Honduras* [Presentation]. 21 slides, Secretaría de Recursos Naturales y Ambiente (SERNA), Tegucigalpa, M.D.C., Honduras. Available on-line at http://www.pnuma.org/agua-miaac/REGIONAL/MATERIALADICIONAL/PRESENTACIONES/PARTICIPANTES/HONDURAS/Recursos Hidrico Honduras.pdf

Carrasco, J.C. (2010) - *Diagnóstico de zonificación y de estudios biofísicos para la declaratoria de la Laguna de Bacalar como área protegida. Componente Recursos Acuáticos*. 29p., SAG-Proyecto Ecosistemas-ICF, Fondo para el Medio ambiente Global, PNUD, Reporte Técnico, Tegucigalpa, Honduras.

Carrasco, J.; Flores, R. (2008) - *Inventario de Humedales de la República de Honduras*. 253p., Secretaría de Recursos Naturales y Ambiente / USAID / MIRA, Tegucigalpa, Honduras.

Caviedes, V. (2011) - *El enfoque de la gestión costera en Costa Rica: Necesidad de una gestión integrada para alcanzar el desarrollo sostenible en sus espacios marinos y costeros*. 60p., Tesis Máster GIAL, Universidad de Cádiz, Cádiz, España. *Unpublished*.

Chica, J.A. (2008) - *Conservación y desarrollo en el litoral español y andaluz: Planificación y gestión de espacios protegidos*. 381p, Colección Universidad en Español, CEP editorial, Madrid, España. ISBN: 978-8498827101.

Clark, J.R. (1996) - *Coastal Zone Management Handbook*. 720p., CRC Press, Boca Raton, FL, U.S.A. ISBN: 978-1566700924.

Comisión Técnica del Plan de Nación (2010) - Visión de País 2010 – 2038 y Plan de Nación 2010- 2022, presentados para consideración del Soberano Congreso Nacional. 152p., Tegucigalpa, Honduras.

Diederichsen, S.D.; Gemael, M.K.; Hernandez, A.O.; Oliveira, A.; Paquette, M.-L.; Schmidt, A.D.; Silva, P.G.; Silva, M.S.; Scherer, M.E.G. (2013) - *Gestão costeira no município de Florianópolis, SC, Brasil: Um diagnóstico. Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management,* 13(4):499-512. DOI: 10.5894/rgci425.

DIGEPESCA (2012) - Ayuda de Memoria. *III simposio técnico de la pesquería de la langosta espinosa en Honduras*, USAID / CME-TNC, La Ceiba, Honduras. 10p.

FAO (2002) - *Perfiles sobre la pesca y la acuicultura por países. La República de Honduras*. FAO - Food and Agriculture Organization of the United Nations *web site*, Rome, Italy. Available on-line at http://www.fao.org/fishery/facp/HND/es

ICF (2008) - *Política del Sector Forestal, Áreas Protegidas y Vida Silvestre*. 12p., Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre. Tegucigalpa, Honduras.

IICA (1995) - *Diagnóstico del Sector Agropecuario*. 196p., Agencia de Cooperación Técnica del Instituto Interamericano de Cooperación para la Agricultura en Honduras y Dirección de Planeamiento, Programación, Proyectos y Auditoria Técnica, San José, Costa Rica.

Matamoros, W.; Schaefer, J.; Brian; R. (2009) - Annotated checklist of the freshwater fishes of continental and insular Honduras. *Zootaxa* (ISSN: 1175-5334), 2307:1-38, St. Lukes, Auckland, New Zealand. Available on-line at http://www.mapress.com/zootaxa/2009/f/zt02307p038.pdf

Naciones Unidas (2012) - *El futuro que queremos*. 60p., Resolución aprobada por la Asamblea General el 27 de julio de 2012. Conferencia de las Naciones Unidas sobre el Desarrollo Sostenible en Río de Janeiro del 20 al 22 de junio de 2012. Available on-line at http://www.unwomen.org/~/media/Headquarters/Media/infocus/es/Rio20OutcomedocumentES.pdf

Naciones Unidas-CEPAL. (2012) - *Movimiento portuario contenedorizado de América Latina y el Caribe 2011*. 8p., Boletín FAL, Edición Nº 307, número 3 de 2012, Comisión Económica para América Latina. Available on-line at http://www.cepal.org/usi/noticias/bolfall/7/47377/FAL-307-WEB.pdf

Olsen, S. (2003) - Frameworks and indicators for assessing progress in integrated coastal management initiatives. *Ocean & Coastal Management,* 46(3-4):347–361. DOI: 10.1016/S0964-5691(03)00012-7

Olsen, S.; Lowry, K.; Tobey, J. (1999) - *Una guía para evaluar el progreso en el manejo costero. Hacia una metodología común de aprendizaje*. 74 p., Versión y Edición E. Ochoa, Centro de Recursos Costeros de la Universidad de Rhode Island, Comisión Centroamericana de Ambiente y Desarrollo (CCAD), Programa Ambiental Regional Centroamericano PROARCA/ Costas, ECOCOSTAS, Guayaquil, Ecuador.

PNUD (2012) - *Informe sobre desarrollo humano Honduras 2011. Reducir la Inequidad un Desafío Impostergable*. 323p, Programa de las Naciones Unidas para el Desarrollo (PNUD), Tegucigalpa, Honduras. ISBN: 978-9992679746. Available on-line at http://apps.hn.undp.org/IDH2011/INDH2011Completo_sin anexos .pdf

PNUMA (2013) - *Evaluación Económica de los Servicios Ecosistémicos del Parque Nacional Blanca Jeannette Kawas Fernández. Resultados preliminares*. 87p., Proyecto Manglares - Manejo Integrado de las Zonas Costeras y Gestión Sostenible de los Manglares de Guatemala, Honduras y Nicaragua, Tegucigalpa, Honduras.

SAG (2012) - *Memoria Institucional 2006-2010*. 103p. Secretaría de Agricultura y Ganadería, Tegucigalpa, Honduras.

SEFIN (2009) - *Informe de la Liquidación del Presupuesto General de Ingresos y Egresos de la República. Ejercicio Fiscal 2009*. 76p., Secretaría de Finanzas, Tegucigalpa, Honduras.

SEFIN (2010) - *Informe de la Liquidación del Presupuesto General de Ingresos y Egresos de la República. Ejercicio Fiscal 2010*. 58p., Secretaría de Finanzas, Tegucigalpa, Honduras.

SEFIN (2011) - *Informe de la Liquidación del Presupuesto General de Ingresos y Egresos de la República. Ejercicio Fiscal 2011*. 71p., Secretaría de Finanzas, Tegucigalpa, Honduras.

SEFIN (2012) - *Ejecución Presupuestaria de la Administración General Acumulada al Segundo Trimestre del Año 2012*. 43p., Secretaría de Finanzas, Tegucigalpa, Honduras.

SERNA (2001) - *Estrategia Nacional de Biodiversidad y Plan de Acción*. 51p., Secretaría de Recursos Naturales y Ambiente, Tegucigalpa, Honduras.

SERNA (2003) - *Balance Hídrico de Honduras*. 18p., Secretaría de Recursos Naturales y Ambiente Dirección General de Recursos Hídricos, Tegucigalpa, Honduras.

SERNA (2005) - *Política Ambiental de Honduras*. 23p., Secretaría de Recursos Naturales y Ambiente, Tegucigalpa, Honduras.

SERNA (2008) - *Política Hídrica Nacional*. 54p., Secretaría de Recursos Naturales y Ambiente, Dirección General de Recursos Hídricos, Tegucigalpa, Honduras.

SERNA (2009) - *Estrategia nacional de cumplimiento de la legislación ambiental*. 35p., DR-CAFTA, Proyecto Manejo Integrado de Recursos Ambientales (USAID/MIRA), Secretaría de Recursos Naturales y Ambiente, Tegucigalpa, Honduras.

SERNA (2010) - *Informe de País ante la Comisión sobre Diversidad Biológica*. 185p., Reporte Técnico, Tegucigalpa, Honduras.

SERNA-ICF-SAG. (2011) - *Análisis de Vacíos y Omisiones de Representatividad Ecológica de la Biodiversidad Marina de Honduras. Océanos, Costa e Islas.* 102p., Secretaria de Recursos Naturales y Ambiente (SERNA), Instituto de Conservación Forestal (ICF), Secretaria de Agricultura y Ganadería (SAG) y The Nature Conservancy (TNC), Tegucigalpa, Honduras.

UNICEF (2013) - *Indicadores demográficos para Honduras. Estadísticas*. http://www.unicef.org/spanish/infobycountry/honduras_statistics.html

USAID (2012) - *Análisis de Vulnerabilidad al Cambio Climático del Caribe de Belice, Guatemala y Honduras.* 69p., Programa Regional de USAID para el Manejo de Recursos Acuáticos y Alternativas Económicas. Available on-line at http://190.11.224.74:8080/jspui/bitstream/123456789/2024/1/5.3 Analisis de Vulnerabilidad Arrecife Mesoamericano June 12 2012.pdf

Vallega, A. (1999) - *Fundamentals of Integrated Coastal Management*. 267p., Kluewer Academic Publishers, Dordrecht, Germany. ISBN: 978-0792358756.

Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):663-668 (2014)

http://www.aprh.pt/rgci/pdf/rgci-575_Scherer.pdf | DOI:10.5894/rgci575

Integrated Coastal Management in Latin America: the ever New World*

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ABSTRACT

The advancement of Integrated Coastal Zone Management (ICZM) in Latin American countries may vary from established programs to experimental phase implementation and even inexistence. This creates an opportunity for the development of new ideas and experiments, especially in the quite long stretches of littoral where no occupation has yet been planned or consolidated. However there are localized issues that need to be attended with certain degree of urgency, especially in coastal settings that have been urbanized, developed for industry and/or are situated around port facilities. Spain and Portugal implemented the marine and environmental policies of European Union and may be seen as models for public and private ICZM initiatives. These situations created opportunities and needs that are somehow reflected in dedicated scientific production, as well as in social impact and the related capacity building programs. We surveyed some key costal management journals to know how Latin American based academics are doing in their mission of creating, developing and discussing ICZM along our diverse shores stretching along all climatic zones. Capacity building programs and exchange networks were also scrutinized. Results suggest that the thematic participation in the major publication channels is modest and needs to improve in number and diversity of subjects bringing obvious benefits to the policy and decision makers. Capacity building programs are still in its infancy across the region. There are no, or very few, specialized educational programs to form practitioners and scientists at all academic levels. Training programs integrating countries around all aspects of ICZM are even scarcer. Coordinated actions, such as networks across the political borders are one of the many future needs we point out here as being the next frontier for thinkers and managers in the region.

Keywords: South America; Coastal Governance; Capacity Building; Network

RESUMO

Gestão Costeira Integrada na América Latina: o eterno Mundo Novo.

A Gestão Integrada da Zona Costeira (GIZC) nos países da América Latina se encontra em diferentes níveis de desenvolvimento, desde programas estabelecidos, passando por níveis experimentais e pela não-existência de iniciativas de GIZC em alguns casos. Isso cria uma predisposição para o desenvolvimento de novas ideias e experiências, especialmente nos longos trechos de litoral, nos quais a ocupação ainda não foi planejada e/ou consolidada. Há, no entanto, questões localizadas que precisam ser atendidas de imediato, especialmente em ambientes costeiros que já foram urbanizados, industrializados ou

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ainda que se desenvolveram em torno de instalações portuárias. Espanha e Portugal - agora sob a influência da União Europeia - permanecem como nossos modelos de iniciativas de GIZC, tanto públicas quanto privadas. Estas oportunidades e necessidades de alguma forma refletem na produção local científica e seu impacto internacional, bem como em nossos programas de capacitação para a gestão integrada. Nós examinamos publicações de importância para gestão costeira a fim de averiguar como acadêmicos latino-americanos cumprem a sua missão de criar, desenvolver e discutir a GIZC. Analisamos também programas de capacitação e redes estabelecidas. As revistas mais representativas para a comunidade acadêmica de GIZC e que vem sendo publicadas pelo menos nos últimos 30 anos, e que foram brevemente examinadas nesta revisão foram a Ocean and Coastal Management, Coastal Management, Journal of Coastal Research e Journal of Coastal Conservation. Com relação aos programas de capacitação para a GIZC levou-se em consideração estudos recentes que demonstram que a maioria dos temas tratados nos cursos de pós-graduação acadêmicos relacionados com a GIZC não estão diretamente relacionadas com a gestão, mas sim às ciências natural, ou da terra, ou ainda à descrição da dinâmica costeira e ou poluição. Com apoio da Rede Ibero Americana de Gestão Costeira Integrada pode-se chegar a listagem de diversas redes que atuam na América Latina, Espanha e Portugal e que se relacionam com o tema. Os resultados sugerem que a representação nos principais veículos de publicação é tímido e precisa melhorar em número e diversidade de assuntos. Melhorias na publicação científica poderia levar a uma melhor utilização dos temas para o benefício dos tomadores de decisão. A capacitação também ainda está pouco desenvolvida na região. Existem poucos cursos especializados para formar técnicos e cientistas sobre o tema em níveis elevados de educação, ou nível de pós-graduação. Os programas de treinamento em torno de todos os aspectos da GIZC são ainda mais raros. A tendência em se considerar a perspectiva de integração como uma soma de conhecimentos disciplinares, não necessariamente ligados, são apresentadas em iniciativas de capacitação e produção científica. Esta abordagem é considerada falha pois, estas disciplinas, a maior parte do tempo, não se inter-relacionam para fornecer uma perspectiva holística para a gestão. Ações coordenadas, tais como redes, que ultrapassam as fronteiras políticas são uma das muitas necessidades futuras destacadas aqui como sendo a próxima fronteira para os pensadores e gestores da região.

Palavras-chave: *América do Sul; Governança Costeira; Capacitação; Rede*

1. Introduction

"Latin America" is a term with its roots in 19th century French political writing that, against all odds, survives to this day and developed into something much larger than its initial political goals (see for instance the editorial of this issue).

Consequences of the common historical heritage, marked by the colonial influence, mainly from Spain and Portugal, are part of the identity of Latin American countries. This has, indeed, its highest expression in the use of common language, generalized to Spanish and Portuguese. Nevertheless, other nations left visible marks on their intent to conquer territories in this area, mainly Dutch, French and British, who never accepted the Tordesilhas Agreement, dividing Latin America between the two Iberian countries. As a consequence, despite the common background, the ecological, socio-economic and cultural diversity are still remarkable, as well the diversity in the administrative political organization of the Latin American coastal regions. The geographical weight of Latin American countries is very marked, therefore, by its history but also for its physical geography, its population and economic issues.

The Central and South America correspond to a terrestrial area of more than 2 billion hectares, or 15,31% of the planet surface, not including the Exclusive Economic Zone (EEZs) or territorial seas. The population of this part of the word sums almost 600 million people, corresponding to 8% of the world population. Over 70% of the population of this region is concentrated in South America. It is worth pointing out Brazil, with 35% of the population, followed by Mexico in Central America (21%). However, the general population density of Brazil is very moderate (23 hab./km^2) compared to other Central American countries such as El Salvador (with 0.1% of the area of Latin America, has more than 300 hab. / km^2) and Guatemala (144 hab./km^2)*.

Ten out of the fifteen most unequal countries in the world are in Latin America and the Caribbean, according to indices such as the Human Development Index or Gini Index. This should be highly considered in the regional priority initiatives tackling the use of natural resources and land management, especially in the coastal areas.

It is necessary to remind that the population of Latin America and the Caribbean is even more littoral than other areas. The region's coastal states have a full three-quarters (more than 450 millions) living within 200 kilometres from the coastline. On South America's west coast 50 million people crowd along a thin coastal strips. In Chile, three-quarters of the population live and work along a 500 km stretch of coastline between Valparaiso and Concepcion, on 15% of the country's land area. And the east coast has also very dense areas, such as the Buenos Aires-La Plata-Montevideo region where14 million people live in. But the largest and most crowded coastal area by far is the highly urbanized

* Figures derived from the data contained in the web page from the Department of Economic and Social Affairs, Population Division, from the United Nations [http://www.un.org/en/development/desa/population/publications/database/index.shtml]

region stretching from São Paulo to Rio de Janeiro, Brazil, with more than 40 million people (Arenas-Granados, 2012; Hinrichsen, 1998).

As it is said in the Report of the Intergovernmental Panel on Climate Change (Magrin, 2007), significant impacts of climate change and sea level rise are expected for 2050-2080 on the Latin American coastal areas. It means ICZM is an urgent need to prevent lives and property losses.

The cultural and demographic diversity of this vast region leads to an equally rich diversity of conflicts on the coastal areas. Therefore a coastal and marine manager must face a multidisciplinary approach. Not forgetting the diversity of coastal ecosystems that support and coexist with urban agglomerations, infrastructures and industrial activities.

As some examples of those challenges, one can point out man-made and natural assets that make special cases of integrated coastal zone management (ICZM) needs, as for instance, Panama and Costa Rica.

Panamas' status as biogeographic region of transition between two continents permits an exceptional biodiversity, both terrestrial and marine. However Panama is also the bridge between two oceans, and this diversity must survive intense maritime traffic at the Panama Canal, through which pass about 14,000 ships per year and about 4% of world trade. The canal water basin, primary water source for the transit of vessels (each boat passing requires 52 million gallons of fresh water to cross the locks), provides 95% of the drinking water for the inhabitants' of the cities of Columbus, Panama and San Miguelito (Arenas, 2010).

Despite the high density of population of Costa Rica, this nation, which represents 0.04% of the planet's surface, accounts for 5% of the world's flora and fauna. Thus, leads to ambitious programs of conservation, with a strong commitment to ecotourism. Its National System of Conservation Areas (SINAC) covers the entire national territory, having 26% of its area protected under some category of conservation.

Not all Latin American countries border the sea, though. Paraguay and Bolivia are land-locked. However, the past and present needs for global integration made these countries look for solutions to their geographical position resulting in agreements with their fellow countries (Port of Ilo, in Peru, is used by Bolivia and Port of Paranaguá in Brazil by Paraguay). In addition their territories are integrated through the water catchment that drain to the coast, therefore the actions developed in those rivers (dams, etc.) tends to be reflected in coastal areas.

Some countries have taken off in their solutions to avoid and mitigate coastal conflicts. Both home-made and imported models are present in the continent. Portugal and Spain, especially after their integration to the European Community, remain as fundamental examples and source of inspiration.

The academic community, which numerical contingent and level of development have a close relationship with the general economic and political scene, reflects through its bibliographic production the ideas and results of official choices and actions. Therefore, the representation of Latin American academic production regarding ICZM in a world scale is possibly a measure of our impact and influence over each other and beyond our cultural borders.

We have chosen to reflect the level of development of coastal management in Latin American countries through the number of the scientific publications related to this subject and to general issues at coastal areas, as well as through the capacity building programs existent in this region. Bibliometry measurements are frequently used to assess societal demands for knowledge about public and private investments. Recently (last decade), the pressure to publish hit Latin American universities hard. One of the response-trends identified was to report and discuss, face consistently collected and analysed data, the ICZM state of the art and its future.

The objective of this brief review is to quantify and discuss the bibliographical production of our academics and our capacity building programs as a proxy of the level of development of ICZM over the continent, including in the scenario Spain and Portugal.

2. Results and discussion

The Scopus database* was the only gateway used as the basis of the assessment. The main international journals accessible to every researcher around the world dedicated to coastal management were included. The indicators total number of papers published, timespan, number of papers attributed to Latin American countries, countries, timespan of papers attributed to Latin American countries and citation records were the variables chosen to develop the Results session. Papers published *about* Latina American countries, but prepared by authors based abroad were not considered at this time. Importance was given to works developed within the territories, by researchers directly exposed to its environments.

There are a large number of marine science journals, from many editorial houses, that publish papers dealing with coastal management issues, but not as their focus (e.g. *Estuarine, Costal and Shelf Science*, *Marine Pollution Bulletin*, *Estuaries and Coasts*). In these journals, there is a larger weight on papers about ecology, pollu

* http://www.scopus.com

tion and others as coastal processes. They have a strong, growing, generalist public among marine scientists as both readers and authors. The *Journal of Integrated Coastal Zone Management* (RGCI/JICZM) was not considered in this analysis because it covers a shorter time span, is bilingual, and is still in the process of building its first 3-years Impact Factor. In the same way, the new United Nations journal *Costas* was not taken into account.

Review papers are regarded as some of the most influential forms of academic expression and have therefore been highlighted here. Hopefully, a review paper will have a higher than average citation record, and therefore ideological influence.

The journals found most representative of the ICZM academic community and examined in this review were *Ocean and Coastal Management*, *Coastal Management*, *Journal of Coastal Research* and *Journal of Coastal Conservation* (Table 1). All these journals circulate for at least 30 years. These publications have been stable in terms of periodicity and have grown in volume along the years. They have also been published fully in English since their start, which facilitates access to authors from every nationality, although in Latin America, Spain and Portugal this has always been a more or less sored issue.

By order of numerical importance, *Journal of Coastal Research* (CERF) published until December 2014 a total of 4,725 documents (1985 to 2014), an average of 162.9 papers per year. Papers by Latin American based authors were 975 in total, and were published between 1992 and 2014. These works represent only 19% of the total papers published by the journal in its history. From those, 9 were review papers. The countries represented were, by order of importance, Portugal (316), Brazil (289), Spain (225), Mexico (65), Argentina (52), Colombia (15) and Chile (13).

Ocean and Coastal Management (Elsevier) published until December 2014 a total of 4,547 papers (1975 to 2014), which averaged a number of 116.5 papers per year. Papers by Latin American based authors were 393 in total, and were published from 1984 until present. These works represent only 8% of the total papers published by the journal in its history. From those, 22 were review papers. The countries represented were, by order of importance, Spain (114), Brazil (99), Mexico (89), Portugal (47), Chile (24) and Argentina (20).

The journal *Coastal Management* (Taylor & Francis) published until December 2014 a total of 661 documents (from 1987 to 2014), which averaged a number of 24.5 papers per year. Papers by Latin American based authors produced 29 documents in total, which were published from 1997 until 2013. These works represent only 3.7% of the total papers published by the journal in its history. The countries represented were, by order of importance, Spain (15), Mexico (3), Portugal (3), Ecuador (2), Nicaragua (2), Argentina (2) and Brazil (2). From those, one was a review paper.

Springer publishes *The Journal of Coastal Conservation* since 1995 up to 2014. It has a total of 612 papers, being 93 from Spain, Portugal (72), Brazil (29), Mexico (51), Argentina (6), Colombia (1), summing 252 by Latin American based authors.

The most frequently represented countries, over this time spam, were the same in all four journals: Portugal (458), Spain (447) and Brazil (419), followed by Mexico, Argentina and Chile. Although Colombia, Nicaragua and Ecuador have also appeared in the assessment, these countries remain (together with all other Latin American countries) underrepresented in the international scene in relation to publications in the main ICZM discussion forums. Its is important to note that the Brazilian representation was expected to be one of the biggest due to its academic population and number

Table 1 - Identification characteristics of the studies journals, by order of impact factor.

Tabela 1 – Características identificadoras das revistas consideradas, por ordem dos fatores de impacto

Source title	Editorial house	Academic background	ISSN print ISSN on line	IF 2013 (JCR)	Open access	Base country
Ocean and Coastal Management	Elsevier commercial	ECSA IECS	0964-5691	1.769	Partially (authors choice)	UK / Netherlands
Coastal Management	Taylor & Francis commercial	The Coastal Society	0892-0753 1521-0421	1.013	No	US
Journal of Coastal Research	CERF NGO	CERF	0749-0208 1551-5036	0.755	Partially (authors choice)	US
Journal of Costal Conservation	Springer commercial	EUCC	1400-0350 1874-7841	1.096	Partially (authors choice)	EU

ECSA - Estuarine Coastal Sciences Association / IECS - Institute of Estuarine and Coastal Studies / CERF - Coastal Education and Research Foundation / EUCC - Coastal & Marine Union, formerly called European Union for Coastal Conservation

of researchers. Nevertheless, Brazil has a comparative low representation, in terms of length of coastline and papers, having around 5 published academic works per 100 Km of coastline – considering a length of 8000 km, against, for instance, to Portugal with 23 papers per100 km of coastline (2000 km).

The performance of these journals regarding Latin American countries is a direct result of publication policies (special issues related to events, special issues focused on themes and advertisement). Interpersonal information among scientists also plays an important role. The academic production is still modest and books on ICZM published in Latin American countries are still rare. Text books or translations of English written texts are inexistent. Nevertheless it is worth of pointing out some important production in Spanish, as the brand new book *Política, Gestión y Litoral: una nueva visión de la Gestión Integrada de Áreas Litorales,* from Barragán (2014), currently being translated on to Portuguese. This book has a great potential to influence all Latin America countries.

The lack of a more extended academic production on ICZM ends up constraining the management of our coasts. There is a manifest need of capacity building programs in ICZM in Latin America in order to qualify academics and managers to implement an integrated and participative coastal zone management. Indeed the capacity building initiatives are growing in this region, despite its academic and natural science focus. According to Macías (2013) in recent decades there has been an increasing supply and demand for training in ICZM in Latin America. The author listed 18 postgraduate programs from different countries: Spain (9), Portugal (1), México (1), Costa Rica (1), Uruguay (1), Brazil (1) and two internationals (several countries). Recently a new master was approved in Argentina (Universidad de la Patagonia San Juan Bosco) dealing with tourism and coastal natural resources. Macías (2013) also demonstrated that most of the topics treated at the academic postgraduate courses related to ICZM are not directed related to management, but to natural/earth science or description of coastal dynamics and or pollution.

The trend of considering "Integrated" as a sum of disciplinary knowledge, not necessarily connected, is very present in capacity building initiatives and scientific production – even in the ones listed above. There is a repetitive misunderstanding between integrated / comprehensive approach and a multidisciplinary approach, where these disciplines, most of the time, do not interrelate to provide a holistic perspective. Students and/or managers are trained in specialized disciplines, barely touching specific issues related to the management process, such as leadership, management, decision making, organization, scheduling, planning, etc. This aspect, together with the lack of formal tools to integrate knowledge, will also reflect in a poor management of our coasts.

A training program designed for this purpose was *TrainSeaCoast*, the only UN-chancelled program implanted for local capacity building. However it is not running properly on the two locations in Latin America (South Brazil and Rio de la Plata region), not having any courses in the last years.

On other hand, an interesting instrument that has been having success and concrete results in areas such as training, education or publication on ICZM is the networks. These are generally presented as spaces for exchange and dissemination of knowledge, or a place for meeting and discuss the management of the coastal and marine environment. In many cases education and training activities are incorporated. In recent decades, these networks have proliferated especially in Iberoamerica – including Portugal and Spain - both in academic and institutional level, related to the coasts and seas, ex.: CoPraNet, MedPan, NorBaff, Encora, CoastNet, IMCORE, REGIAL, Bencore, MARINET, ProPlayas, IBERMAR, WATERCLIMA-LAC, among others.

For instance, the "Red Iberoamericana de Manejo Costero Integrado – Red IBERMAR" was formed thinking on the integration existing among Latin American countries and Portugal and Spain. Since 2008 a group of countries organized themselves in a network for exchanging idea, philosophies and experiences on Integrated Coastal Zone Management (ICZM). The Network which was sponsored in its first Stage (2008-2012) by the Ibero-American Science and Technology Development (CYTED), now has the participation of over 250 researchers, teachers, public managers and members of ONG's that make up 15 national / state groups (Mexico, Honduras, Costa Rica, Panama, Cuba, Dominican Republic, Puerto Rico, Peru, Colombia, Chile, Argentina, Uruguay, Brazil, Portugal and Spain). By 2015 IBERMAR national groups in Ecuador and Venezuela will also be established. The network promotes a better approach between science and decision making, reducing the divergence that traditionally exists between scientific knowledge and integrated management (ecological, socioeconomic and cultural) of coastal marine governance.

WATERCLIMA-LAC is another important initiative currently taking shape, in line with the previous approach, particularly aimed at contributing to improving the management of watersheds and coastal areas to increase the resilience of Latin America and the Caribbean to the consequences of climate change. This will be a joint program that will run for three years from 2015, between the European Union and Latin America, based on the agreements reached in May 2008 in Lima during the V Summit between the European Union and Latin America and the Caribbean.

3. Conclusions

An urgent effort to enhance ICZM is required in Latin America, including more academic production, capacity building programs and networks support. An integrated approach is also needed in order to achieve Integrated Coastal Zone Management, rather than a management of different activities and conflicts based on a sectorial approach.

The existing shortcomings of ICZM, which are reflected in academic production and capacity building programs also reveal the lack of government investment and of clear policies for the management of coastal areas. Also, the priority for publications given by the academics relegates the desirable work next to local, regional, national and international bodies to the second plan.

It seems that ICZM is still in its infancy in Latin America, as countries have apparently more pressing priorities to attend before thinking about coastal planning and conservation. Nevertheless, coastal planning and conservation might abate some of the socio-environmental and economic issues that plague Latin American countries, such as depletion of natural resources leading to poverty and natural disasters.

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References

Arenas-Granados, P. (2012) - Manejo costero integrado y sustentabilidad: Un análisis propositivo de políticas públicas en las dos caras atlânticas: España, Portugal, Colombia y Panama. 420p., Editorial Academica Española, Madrid, Spain. ́ISBN: 978-3847354369. Available on-line at http://hum117.uca.es/grupogial/paginas/publicaciones/libropedrodosmildoce

Barragán, J.M. (2014) – *Política, Gestión y Litoral: Nueva visión de la gestión integrada de áreas litorales*. 685p., Editora Tébar Flores, Madrid, Spain. ISBN: 978-8473605182. Partly available on-line at http://hum117.uca.es/grupogial/paginas/publicaciones/2014_librounescobarragan

Hinrichsen, Don (1998) - *Coastal Waters of the World: Trends, Threats, and Strategies*. 298p., Island Press, Washington, DC, U.S.A. ISBN: 978-1559633833.

Magrin, G.; García, C.G; Choque, D.C.; Giménez, J.C.; Moreno, A.R.; Nagy, G.J.; Nobre C.; Villamizar, A. (2007) - Latin America. *In:* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hanson (eds.), *Climate Change 2007. Contribution of Working Group II to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change*, pp.581-615, Cambridge University Press, Cambridge, U.K. Available on-line at http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html

Macías, Ana (2013) - La formación de los futuros gestores costeros: reflexión sobre los conceptos y principios básicos. *In:* J. A. C. Ruiz, J. G. Onetti, J. G. Sanabria, M. L. P. Cayeiro (eds.), *Mejorando la Gestión de las Áreas Litorales de Iberoamérica. I Congreso Iberoamericano de Gestión Integrada de Áreas Litorales. Libro de Comunicaciones*, pp.1685-1703, Grupo de Investigación Gestión Integrada de Áreas Litorales, Universidad de Cádiz, Cadiz, Spain. ISBN13: 978-8469512623. Available on-line at http://hum117.uca.es/grupogial/paginas/cursosymaster/icongresogialiberoamerica/comunicaciones-i-congreso-iberoamericano-de.pdf

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