Development of coastal cities and agglomerations: pressure and impacts on coastal and marine ecosystems

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Abstract

Coastal areas around the world are highly affected by human settlements, due to economic activities and land-use changes. Population growth has increased pressure on coastal and marine ecosystems, leading to their degradation, loss of ecosystem services, and human wellbeing. The main objective on this work is to study the main impacts of coastal development on coastal and marine ecosystems. We analysed the growth of coastal cities and agglomerations (CCAs) with more than 100,000 inhabitants in Latin America and the Caribbean (LAC) during 1945–2014. The analysis targeted the number of CCAs, and their corresponding populations. CCAs located in specific physiographic units, e.g., bays, estuaries or deltas, as well as CCAs located in vulnerable coastal and marine ecosystems, e.g., mangroves and coral reefs. Using remote sensing data and regional mapping, it was possible to identify physiographic units and ecosystems, which are suffering higher pressure due to the urban development. The results of this study revealed the extent of urban development occurred on certain habitats in the coastal zone in LAC. Currently, 42% of CCAs are located in bays. In addition, the urban population associated with deltas and/or estuaries increased eight times during the last seven decades. The number of CCAs located near mangroves increase from 26 to 334 during the same period; while urban population near coral reefs increased 12 times during 1945–2014. The rapid urbanization process has important implications for integrated ecosystem management. It is necessary, therefore, to strengthen integrated coastal zone management in urbanized areas because of its connection to the services that coastal and marine ecosystems provide to population.
Keywords: urban population, evolution, coastal and marine ecosystems, integrated coastal zone management.


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1 Introduction

The world's population is steadily growing, as it is shown by the World Bank data, which reveals an increase from six billion people in the year 2000 to more than seven billion in 2013 (World Bank [1]). This increase in population occurs mainly in urban areas. Tokyo coastal conurbation, for example, has a population of 37 million inhabitants (United Nations [2]).

Coastal areas favour population concentration, due to, among other reasons, the facilities that the marine environment provides for certain activities such as fishing, industry tourism or transportation. Different international institutions and authors place emphasis on a process of concentration in coastal areas (Hinrichsen [3], Burke *et al.* [4], Vallega [5], Creel [6]).

Latin America and the Caribbean (LAC) is mainly an urban area. 80% of the population lives in cities (UN-Habitat [7], Secretariat of the Convention on Biological Diversity [8]), for what is considered the developing region with the highest percentage of urban population (PNUMA [9]). Urban development of this region is concentrated in the coastal zone. This is because in colonial times, the coast was a good strategic place for the settlement of the population and the development of urban areas (UN-Habitat [10], Hardoy [11]).

Coastal and marine ecosystems in LAC are of great importance from an environmental point of view (227 Ramsar sites in LAC (PNUMA [9])), and from a socioeconomic perspective. Mangroves and coral reefs are ecosystems associated with local economy and as a consequence of this population tends to settle near them, causing significant pressure, and thus, compromising the wellbeing of coastal inhabitants (Agardy *et al.* [12]). Examples of this situation are described by UNEP, explaining that 50% of mangroves in Santa Lucia have been lost due to the tourism development (PNUMA [9]). Moreover, in Mexico, coral reefs suffer significant pressure due to human settlements that have taken place mainly since 1980 (Reyes-Bonilla [13]).

This research is based on establishing a relationship between the evolution of the coastal cities in recent decades, and their impacts on wetlands and ecosystems of interest for GIZC. The main objectives of the research are:

- The evolution of the number of cities and coastal agglomerations (CCAs) in LAC over 100,000 inhabitants and its associated population from 1945 to 2014.
- The study of the location of CCAs with regard to certain wetlands and coastal and marine ecosystems, mangroves and coral reefs
- The relationship between the model of coastal urban settlement in LAC and coastal and marine ecosystems.

2 Information sources and method

Three information sources were used in this research. The first one corresponds to United Nations databases (Demographic Yearbook), supplying details about cities and agglomerations with more than 100,000 inhabitants in LAC. United Nations definition of cities and urban agglomerations were used (UN-DESA [14]). *Google*

Earth was the second source used. Photographs and images from remote sensors supplied a great deal of detail for observation. The WCMC-UNEP shapefiles provided the third information source. This information of marine coastal ecosystems in LAC allowed linking these ecosystems to urban development. These sources are normally used (Angel and Sheppard [15], McGranahan and Marcotullio [16]), but what is important about this work is that quantitative aspects from CCAs in LAC were cross-referenced with their qualitative attributes.

The working method encompasses the following tasks:

a) To organise information from original databases. This contains 764 cities in Latin America with over 100,000 inhabitants between 1945 and 2012; Information from national censuses has been used to complete the updated 2014 data.
b) To differentiate between coastal and inland cities and agglomerations. For this reason a 100 km wide band was used in *Google Earth*. When a city or agglomeration is on an island, per UNEP criteria (Dahl [17]), we considered it coastal even if it is more than 100 km from the coast.
c) To enable our results to be compared to others, the CCAs were classified according to number of inhabitants in five groups, taking into account UN DESA intervals. The result is the following:
   - Small cities (100,000 to 500,000),
   - Medium cities (500,000 to 1 million),
   - Large cities (1 million to 5 million),
   - Very large cities (5 million to 10 million),
   - Megacities (over 10 million).
d) To geo-reference all CCAs in Latin America and the Caribbean. *QGIS* shapefiles were done for coastal cities, to geo-reference them and indicate their relationship to the coastal zone.
e) To describe CCAs based on interpretation of *Google Earth* images with respect to their geographic location, habitat type and associated ecosystem.

3 Results and discussion

3.1 Quantification of the urban phenomenon in coastal areas in Latin America and the Caribbean

The increase of cities and urban agglomerations in LAC since the second half of the twentieth century is clear. In 1950, less than 42% of population lived in cities (Pinto [18]). Results of the research show that this region has increased the CCAs number tenfold in the whole study period (from 42 to 420 CCAs). This represents a population increase from 20 to nearly 180 million people living in consolidated cities within 100 km from the coastline (Table 1).

Analysing the growth in each decade, it is observed that the highest growth of CCAs occurs in 1985/94 and 1995/04, in which the growth factor is much higher than in previous years. However, in 2005–2014 the urbanization process is slowing down, but there are still serious urban problems (Bárcena [19]).

Table 1: Evolution of LAC cities with more than 100,000 inhabitants and urban population (× 1000). Differences between coastal and inland cities (1945–2014).

Period	Coastal		Inland	
	Cities	Population	Cities	Population
1945–1954	42	20,487	21	7,072
1955–1964	74	33,148	44	14,341
1965–1974	122	53,474	87	32,426
1975–1984	163	81,169	127	48,763
1985–1994	247	111,138	176	73,180
1995–2004	358	153,921	299	108,137
2005–2014	420	179,828	344	137,619

A comparison between coast and inland shows increases in the number of inland cities of 1.6 times on average in each study period, while CCAs grew 1.5 times. This process does not indicate a decline of urban settlement on the coast, but only that the growth rate is lower in CCAs than in inland.).

The evolution of CCAs size is also studied. Small cities have increased from 34 to 356 between 1945 and 2014, which means that 40% of the urban population lives in small cities. Medium-sized cities in LAC are 9% of the total CCAs, hosting 17% of the coastal urban population (30 million inhabitants). Large CCAs have increased from 7 to 21 in the whole study period, representing a quarter of the urban population. Of all coastal megacities, there is one of them in LAC (Sao Paulo), although Buenos Aires and Rio de Janeiro would exceed ten million if we considered their metropolitan areas (United Nations [20]). This research considers all nearby cities to establish metropolitan areas and conurbations.

3.2 CCAs and coastal marine physiographic units very sensitive to human activities

3.2.1 Evolution of CCAs associated to bays

Bays were the first coastal environments in which people began to settle. They provided natural refuge, allowing the construction of many ports, which led to the population settlement in these areas (Hardoy [11]). Nowadays, it is known that bays are habitat of coastal ecosystems, which provide numerous services to population (Barragán [21]). The importance of these coastal areas is shown in the evolution of cities close to them. In 2005–2014, 42% of LAC cities are located in bays, representing 50% of urban population. These cities had the highest growth in the period 1995–2004, while the biggest population increase was recorded in the last study period (Table 2). Regarding the size of city development in bays, most of people lived in large cities until 1995, but the great growth of small cities in recent decades has led to the fact that, nowadays, more than 30 million people live in these CCAs. This is mainly due to the economic development of cities associated with ports and tourist activities. As an example, Valparaiso (Chile) had a great increase of population in the surrounding area as a result of the expansion

of its port (Borsdorf *et al.* [22]). The growth of small cities in bays implies a clear process of new occupation or intensification of previous occupation in physiographic units that have important coastal and marine ecosystems. These ecosystems are often polluted by urban activities, as for example in Acapulco Bay or Ensenada with wastewater discharge (Barragán [23]).

Table 2: Evolution of CCAs and urban population (× 1000) near bays (1945–2014).

Period	Cities	Population
1945–1954	18	9,147
1955–1964	36	16,040
1965–1974	60	26,904
1975–1984	75	39,040
1985–1994	107	54,094
1995–2004	157	73,960
2005–2014	176	88,165

3.2.2 Evolution of CCAs associated to a delta or estuary

There are currently 174 CACs close to a delta or estuary; this represents 42% of coastal urban population. Currently, almost 100 million people live in cities associated with fragile ecosystems (Table 3).

Table 3: Evolution of CCAs and urban population (× 1000) close to deltas or estuaries (1945–2014).

Period	Cities	Population
1945–1954	22	9,850
1955–1964	37	14,842
1965–1974	60	23,421
1975–1984	72	32,694
1985–1994	105	46,134
1995–2004	153	60,919
2005–2014	174	74,374

Analysis of cities size shows that small CCAs are housing a majority of population. These CCAs amounted to 146 in 2005–2014, representing 83% of cities associated with these habitats. Its population increased from 3 million to nearly 29 million in the entire study period. Therefore, it can be said that small cities are the most abundant in deltas and estuaries. It can be interpreted as a broad city network whose growth threatens to colonize important natural areas that still exist.

The main problem of population growth is an increase of pollution. For example, Guayaquil city, in Ecuador, has grown from 250,000 inhabitants in 1950 to over 2.2 million in 2014. This population growth has taken place around the

Salado estuary, leading, on the one hand, to the disappearance of mangrove forests that used to be in the estuary and, on the other hand, to the pollution of the estuary by industries and wastewater.

3.3 CCAs and vulnerable coastal and marine ecosystems

The study of the evolution of the CCAs close to fragile ecosystems in LAC, such as mangroves and coral reefs, was made from shapefiles in vector format obtained from WCMC-UNEP (Giri *et al.* [24], UNEP-WCMC *et al.* [25]). Analysis of CCAs within a range of 100 km of mangroves and coral reefs allows obtaining cities and population that are associated with these coastal and marine ecosystems.

3.3.1 Evolution of CCAs close to coral reefs

Our results show there are 136 CCAs within 100 km of a coral reef. This means that over 52 million people live in a consolidated urban area, are close to these ecosystems, and perform their economic activities (tourism, resourcing) around them.

The ratio of population associated with coral reefs increased from 22% to 29% last seven decades. This result shows that there is not only a population growth, but also that they tend to settle close to these vulnerable ecosystems. Moreover, its characteristic distribution involves that Caribbean islands, Panama and Costa Rica have all their CCAs within 100 km of coral reefs, and these are over 50% in Venezuela and Colombia. These data show the priority in national policies regarding the management of coastal areas (Figure 1).

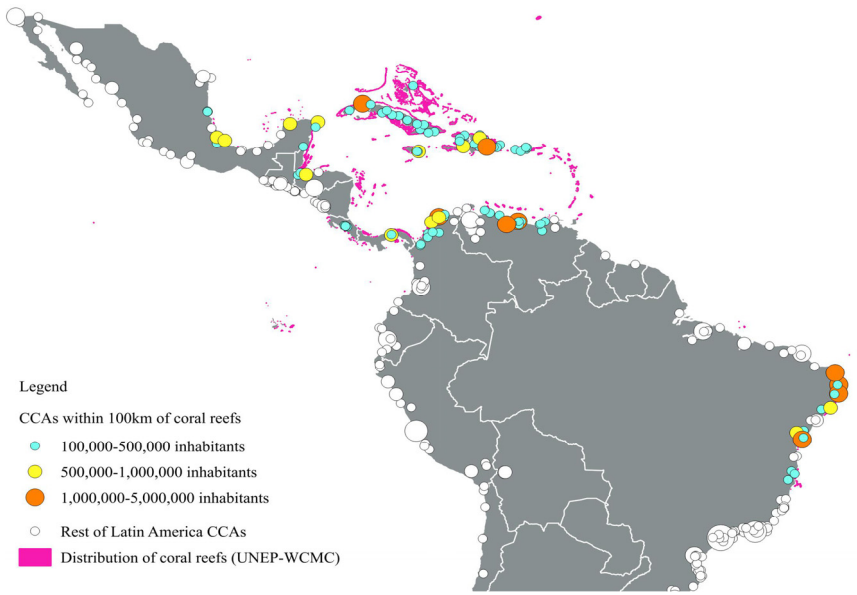

Figure 1: Latin America and the Caribbean map with CCAs associated to coral reefs.

3.3.2 Evolution of CCAs close to mangroves

The increase of cities located close to mangroves is very high. In 1945–1954 there were 26 CCAs near these ecosystems, which represented 62% of the total CCAs in LAC. In 2005–2014, there are 334 CCAs, which corresponds to 80% of cities. The high percentage of cities close to mangroves indicates settlement preferences of urban population; which has gone from 11 to 133.5 million in the whole study period. This model of urban settlement can be due to the fact that mangrove forests provide a barrier against the waves and strong winds (Giri *et al.* [24], UN-Habitat [7], Valiela *et al.* [26]). However, the main reason is because these are public spaces, where poverty is manifested as informal and unplanned occupation.

Considering the city size, 86% of the total has a population between 100,000 and 500,000 inhabitants. This implies a very solid base for future growth, and therefore it is possible that the process of occupation and degradation of these valuable ecosystems continue strongly in coming decades.

Results by country show that, except for those in the Southern Cone, all coastal LAC countries have most of its cities close to mangrove forests (Figure 2). This shows the management priorities for policy makers in coastal areas.

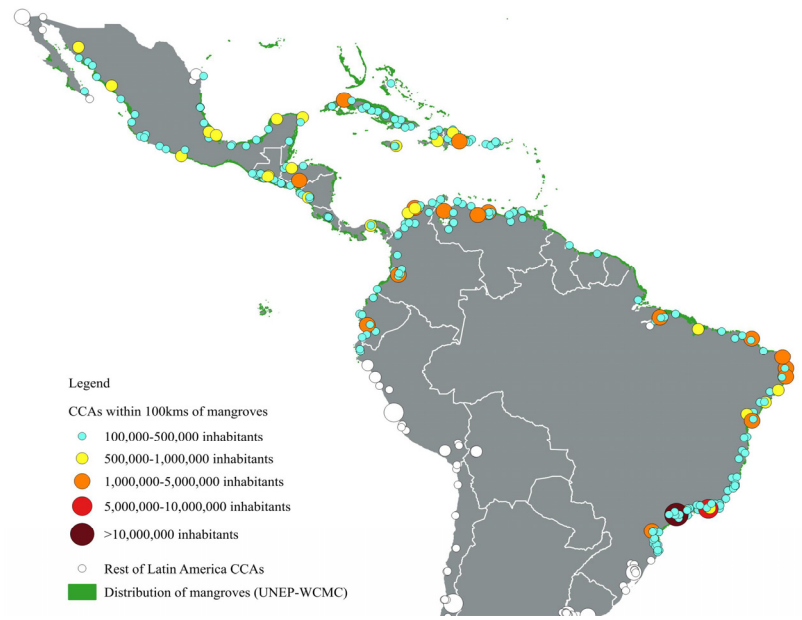

Figure 2: Latin America and the Caribbean map with CCAs associated to mangroves.

4 Conclusion

Currently, there are more than 400 CCAs in LAC, where nearly 180 million people live. The population of smaller urban settlements and urban areas must be added to these results.

The model of settlement in LAC is the result of two different processes. First, throughout history, a significant number of the population has been concentrated in coastal areas. Second, this population has growth quickly, and has created an urban habitat, occupying this area with CCAs of increasing size.

Bays have been and remain important areas of population settlement in LAC. The increase of these urban areas is mainly due to development of ports in natural refuges of bays.

The intensity of the population growth close to fragile coastal ecosystems such as mangroves and coral reefs is mainly because of development of urban infrastructures and tourism activities on them. It causes both degradation and loss of these ecosystems and, also, an impact in the economy of local people associates with them.

Therefore, integrated coastal zone management in LAC needs to be raised from an urban perspective, in which the conservation of coastal and marine ecosystems is possible, and human wellbeing is insured.

References

[1] World Bank, *Population 2013*, World Dev. Indic. Database, pp. 1–4, 2014.
[2] United Nations, *World Urbanization Prospects: The 2011 Revision. Highlights*. New York: United Nations Publications, 2012.
[3] D. Hinrichsen, *Coastal waters of the world: Trends, threat and strategies*, p. 275, 1998.
[4] L. Burke, Y. Kura, K. Kassem, C. Revenga, M. Spalding, and D. McAllister, *Analysis of global ecosystems: Coastal ecosystems,* World Resources Institute, p. 77, 2001.
[5] A. Vallega, *Fundamentals of integrated coastal management,* Academic Publishers, p. 264, 1999.
[6] L. Creel, *Ripple effects: Population and coastal regions,* Population Reference Bureau, Measure Communication, p. 8, 2003.
[7] UN-Habitat, *Estado de las Ciudades de América Latina y el Caribe 2012. Rumbo a una nueva transición urbana*, p. 194, 2012.
[8] Secretariat of the Convention on Biological Diversity, *Cities and Biodiversity Outlook*, p. 64, 2012.
[9] PNUMA, *Perspectivas del medio ambiente: América Latina y el Caribe. GEO ALC 3*, p. 380, 2010.
[10] UN-Habitat, *De la urbanización acelerada a la consolidación de los asentamientos humanos en América Latina y el Caribe: El espacio regional,* p. 99, 2000.
[11] J. Hardoy, "El proceso de urbanización en América Latina," *La Cultura en América Latina Monografías*, vol. 2, p. 35, 1974.
[12] T. Agardy, J. Alder, P. Dayton, S. Curran, A. Kitchingman, M. Wilson, A. Catenazzi, J. Restrepo, C. Birkeland, S. Blaber, S. Saifullah, G. Branch, D. Boersma, S. Nixon, P. Dugan, N. Davidson, and C. Vörösmarty, "Coastal Systems", *Ecosystems and Human Well-being: Current Status and Trends*, pp. 513–550, 2005.

[13] H. Reyes-Bonilla, *Coral reefs of the Pacific coast of Mexico,* pp. 331–349, 2003.
[14] UN-DESA, "World Population Prospects: The 2012 Revision, Highlights and Advance Tables," ESA/P/WP.228 2009, 2013.
[15] S. Angel and S. Sheppard, *The Dynamics of Global Urban Expansion*. The World Bank, p. 200, 2005.
[16] G. McGranahan and P. Marcotullio, *Urban Systems*, The Millenium Ecosystem Assessment, 27, pp. 796–825, 2004.
[17] A. Dahl, *Island Directory*, UNEP. Regional Seas Directories and Bibliographies, 35, p. 573, 1995.
[18] J. Pinto, *Urbanización, redistribución espacial de la población y transformaciones socioeconómicas en América Latina*, Serie Pobl., p. 55, 2003.
[19] A. Bárcena, "La Nueva Agenda De America Latina. Evolucion de la urbanizacion" *America Latina y el Caribe en la década de los noventa*, pp. 51–62, 2001.
[20] United Nations. Department of Economic and Social Affairs. Population Division., *World Urbanization Prospects: The 2014 Revision, Highlights*, p. 32, 2004.
[21] J. M. Barragán, *Política, gestión y litoral. Una nueva visión de la gestión integrada de áreas litorales.*Tebar, UNESCO, p. 685, 2014.
[22] A. Borsdorf, R. Hidalgo, and R. Sánchez, "A new model of urban development in Latin America: The gated communities and fenced cities in the metropolitan areas of Santiago de Chile and Valparaíso", *Cities*, vol. 24, no. 5, pp. 365–378, 2007.
[23] J. M. (coord) Barragán, *Manejo costero integrado y política pública en Iberoamérica: Un diagnóstico. Necesidad de Cambio*, p. 380, 2010.
[24] D. N. Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Masek J, "Status and distribution of mangrove forests of the world using earth observation satellite data.," *Glob. Ecol. Biogeogr.*, no. 20, pp. 154–159, 2011.
[25] UNEP-WCMC, World Fish Centre, WRI, and TNC, "Global distribution of warm-water coral reefs, compiled from multiple sources including the Millenium Coral Reef Mapping Project.," *UNEP World Conserv. Monit. Cent.*, 2010.
[26] I. Valiela, J. L. Bowen, and J. K. York, "Mangrove Forests: One of the World's Threatened Major Tropical Environments," *Bioscience*, vol. 51, no. 10, p. 807, 2001.
[27] L. D. Lacerda, J. E. Conde, C. Alarcon, R. Alvarez-Leon, P. R. Bacon, and E. Al., *Mangrove Ecosystems of Latin America and the Caribbean : a Summary*, 1993.
[28] FAO, "South America," *The world's mangroves 1985-2005*, pp. 43–48, 2007.