IMPACTS OF URBANIZATION ON COASTAL ZONES. CASE STUDY: ALTAMIRA-MADERO-TAMPICO CONJOINED AREA, TAMAULIPAS, MEXICO

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THE URBANIZATION OF COASTAL ZONES

The urban conquest of coastal zones goes back to the beginning of humankind, as a result of the consolidation of its fundamental activities, such as fishing and riparian agriculture, among others (Ducci 1995). The regions where mankind established its communities have always been associated with water, directly or indirectly, as it is one of the vital elements for the subsistence of its colonizers. Due to this vital link, human societies learned to obtain further benefits, such as the exploitation of biotic and abiotic resources, e.g., fishing and navigation, respectively, among others.

As both the needs of communities and human knowledge regarding its natural environment increased, coastal zones came to represent an excellent natural environment to establish some of the most important human cultural developments: Mayan, Egyptian, Inca, among others. Since its intuitive conception until modern times, urbanization of coastal zones has been a challenge to people, given that while coastal regions are rich in natural resources, they also represent a high risk for communities established there (health hazards, risks due to extreme weather events such as hurricanes, surges, floods, etc.).

World-wide tendencies indicate that people are moving to big cities and to coastal zones. Timmerman (1997) established that as of the year 2000, for the first time in history, more than 50% of the world's population would be living in cities, and 50% of that population would be in coastal cities, which has proven true.

As a region, the coastal zone (CZ) is a narrow strip of land that connects marine and continental ecosystems, where the river mouths represent its most characteristic biological features given the great biodiversity that they promote. In the context of contaminants transfer from continental to coastal zones, rivers are the main means of transport, in addition to atmospheric transport. In the Rio Grande (Río Bravo) basin alone (on the Mexico-USA border) over 2.6 million kg of active substances are discharged yearly and, directly or indirectly, reach the Gulf of Mexico. The main sources of pesticide waste are, in order of importance, the cultivation of sorghum, sugar cane, corn, rice and pineapple, and fumigation campaigns against malaria.

Between the Rio Grande and the Río Pánuco (that demarcate the Tamaulipas coastal zone), there is extensive use of agricultural pesticides both in volume and intensity of application (219 kg/1,000 ha on average). Most of these compounds are insecticides and, to a lesser extent, fungicides.

Petroleum exploration and intense petroleum industrial activities on the Tamaulipas marine front (especially production and transport), as well as refining and petrochemical port activities on the coast and flood plains, have caused profound ecological and social tensions in the coastal zone of this state. Mexico's main petroleum activities take place in the Gulf of Mexico. Most of its oil wells, supply monobuoys, pipelines, loading and unloading terminals, reception centers, refineries and petrochemical industries are located in its waters. The states that have the greatest number of industrial petroleum facilities and infrastructure are Veracruz, Tabasco and Campeche, and thus suffer the effects of accidental oil spills.

Mexico has over 11,000 km of coastline, distributed in 17 coastal states, 11 on the Pacific and 6 on the Gulf of Mexico, covering a total surface of 1,113,442 km^2 (56.6% of the national territory). Furthermore, it concentrates a population of 44,652,896 inhabitants (Table 13.1).

In a first approach to identify the coastal vocation, the Sea Front Coastal Index was established (I_C), which is obtained by dividing the length of the coastline by the territorial area of an associated region (multiplied by 100). The data presented in Table 13.1 shows that nationally, the states of Baja California Sur, Colima and Baja California have the greatest coastal vocation with I_C= 3.68, 2.68 and 2.22, respectively. The states with the lowest I_C are Chiapas, Michoacán, Jalisco and Tamaulipas, with values of 0.34, 0.41, 0.42 and 0.58, respectively. Baja California stands out as a state with one of the lowest percentages of natural vegetation cover with a high population density.

The density of inhabitants per km^2 in the coastal states of Mexico is, on average, 46.2 inhab/km^2. In contrast, the I_C analysis in relation to the population density shows that Baja California Sur presents the lowest population density (6 inhab/km^2) and the highest I_C value (3.68), while the state of Colima exhibits the highest population density (105 inhab/km^2) with the second highest I_C value (2.68). Jalisco, Michoacán, Tamaulipas and Veracruz exhibit the greatest coastal deficit, by supporting a larger population density with lower coastal vocation index (Table 13.1).

Using the strategies set out in the *Plan Nacional de Desarrollo 2001-2006* (National Development Plan 2001-2006) as a reference, a coastal indicator was established relative to the water-forest relationship. Table 13.2 shows the relationship between vegetation cover, jungle, bodies of water and human settlements for each of the 17 coastal states of Mexico. Nationally, the forest and jungle cover is 32.4%, a percentage that increases to 36.6% in the coastal states. Critical conditions of this coastal indicator of natural vegetation cover occur in Michoacán, Baja California, Baja California Sur, Tabasco, Tamaulipas and Veracruz (2.55%, 2.93%, 5.66%, 7.42%, 16.48% and 16.94%, respectively). The states with the highest natural vegetation cover index are Campeche, Oaxaca and Guerrero (77.8, 65.0 and 64.4%, respectively).

The establishment of a forest-jungle-water indicator shows very interesting results. Nationally this indicator shows that each km^2 of water bodies is supported by 58 km^2 of natural vegetation cover; for the coastal states this indicator raises to 73 km^2. Similarly, the extreme cases are critical: Baja California, Baja California Sur, Tabasco and Tamaulipas support each of their km^2 of water body with less than 10 km^2 of forests and jungle. On the other hand, the states of Campeche, Yucatán, Michoacán, Sonora, Quintana Roo and Oaxaca support each of their km^2 of water body with more than 100 km^2 of forests and jungles.

The states with largest spatial cover of human settlements are Jalisco, Veracruz, Tamaulipas, Sonora and Baja California, with over 550 km^2, while those with fewer human settlements are Colima, Tabasco, Campeche, Baja California Sur and Michoacán with less than 200 km^2. It is interesting to establish the loading of water, forest and jungle that is available to sustain human settlements in coastal zones. The extreme critical case is that of Baja California, with only 4 km^2 of water, forest or jungle per km^2 of human settlements, followed by Michoacán, Veracruz, Tabasco and Tamaulipas. The most favorable conditions are those of Campeche, Guerrero, Quintana Roo, Oaxaca and Chiapas, with 310, 176, 161, 142 and 131 km^2 of water, forest and jungle per km^2 of human settlements, respectively (Table 13.2).

Table 13.1. Coastal indicators of Mexico.

Coastal State	Length of Coastline[a] (km)	State Surface Area (km^2)	Population (INEGI, 2000)	Waterfront Coastal Index (Coastline/ Area)*100 (km^{-1})	Inhabitants per km^2
Pacific					
Baja California	1,555	69,921	2,487,367	2.22	36
Baja California Sur	2,705	73,475	424,041	3.68	6
Sonora	1,208	180,723	2,216,969	0.67	12
Sinaloa	640	58,328	2,536,844	1.10	43
Nayarit	300	27,621	920,185	1.09	33
Jalisco	342	80,836	6,322,002	0.42	78
Colima	139	5,191	542,627	2.68	105
Michoacán	247	59,928	3,985,667	0.41	67
Guerrero	485	64,281	3,079,649	0.75	48
Oaxaca	598	95,364	3,438,765	0.63	36
Chiapas	256	75,634	3,920,892	0.34	52
Gulf of Mexico					
Tamaulipas	458	79,384	2,753,222	0.58	35
Veracruz	745	72,815	6,908,975	1.02	95
Tabasco	184	25,267	1,891,829	0.73	75
Campeche	523	50,812	874,963	1.03	17
Yucatán	342	43,379	690,689	0.79	16
Quintana Roo	865	50,483	1,658,210	1.71	33
Totals	11,593	1,113,442	44,652,896	1.20	46.2

[a] Extension of the coast and estuarine surfaces of Mexico (INEGI 1984)

In water-forest and human settlement balance, the state of Campeche shows the most favorable environmental conditions to sustain coastal development, as opposed to the critical conditions exhibited by the states of Baja California, Tabasco, Tamaulipas and Veracruz.

WEALTH AND ENVIRONMENTAL RISK IN COASTAL ZONES

Natural resources have without doubt played a strategic role in sustaining the more than 6,000 years of coastal zone colonization by mankind. Humankind's ever clearer knowledge of its environment and technological advances has led from rudimentary exploitation to extensive and intensive exploitation of coastal resources (biotic and abiotic).

The environmental services that coastal wetlands offer are considerable and vital:

Table 13.2. Relationship between water-forest cover and human settlements by coastal state in Mexico (Palacio *et al.* 2000).

State	Territorial Surface (km^2)	Forest (km^2)	Jungle (km^2)	Forest + Jungle (km^2)	Human Settlements	Bodies of Water	Relation Forest + Jungle/Territorial Surface	Relation Forest + Jungle/Water Body	Relation Forest + Jungle +Water/Human Settlements
Mexico	1,964,382	328,510	307,005	635,515	12,459	10,997	32.35%	58	52
Pacific									
Baja California	69,921	2,050	0	2,050	560	277	2.93%	7	4
Baja Calif. Sur	73,475	782	3,374	4,156	151	398	5.66%	10	30
Sonora	180,723	19,977	32,722	52,699	600	435	29.16%	121	89
Sinaloa	58,328	8,635	20,193	28,828	492	732	49.42%	39	60
Nayarit	27,621	8,342	7,327	15,669	163	234	56.73%	67	98
Jalisco	80,836	22,527	17,684	40,211	765	1,205	49.74%	33	54
Colima	5,191	532	2,274	2,806	92	79	54.06%	36	31
Michoacán	59,928	472	1,058	1,530	188	11	2.55%	139	8
Guerrero	64,281	21,692	19,731	41,423	238	428	64.44%	97	176
Oaxaca	95,364	33,844	28,175	62,019	440	584	65.03%	106	142
Chiapas	75,634	17,711	20,316	38,027	298	926	50.28%	41	131
Gulf of Mexico									
Tamaulipas	79,384	6,046	7,038	13,084	709	1,264	16.48%	10	20
Veracruz	72,815	3,148	9,185	12,333	732	415	16.94%	30	17
Tabasco	25,267	25	1,850	1,875	126	432	7.42%	4	18
Campeche	50,812	0	39,526	39,526	128	172	77.79%	230	310
Yucatán	43,379	0	19,551	19,551	447	126	45.07%	155	44
Quintana Roo	50,483	0	31,973	31,973	200	298	63.33%	107	161
Coastal State Total	1,113,442	145,783	261,977	407,760	6,329	8,016	36.62%	73 (Mean)	82 (Mean)

biological wealth (greater biodiversity); a barrier against the effects of hurricanes and surges (reducing the risk of flooding); retention and export of sediments and nutrients; their conservation and protection help protect the coasts from global climate change (especially sea level rise).

According to Costanza *et al.* (1997) coastal wetlands can be valued at 45% of the monetary cost of the total world ecosystems (equivalent to 14.9 billion USD). This framework must be used as a reference to establish what the loss of one hectare of wetlands represents. For example, a hectare of estuaries is valued at US $22,382/year, whereas salt marshes and mangroves are valued at US $19,004/year (Costanza *et al.* 1997). According to the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO; National Commission for the Knowledge and Use of Biodiversity: www.conabio.gob.mx, July 3, 2001), there are 32,406 hectares of priority wetlands in the coastal states of Mexico. Considering the statements by Costanza *et al.* (1997) this represents an annual environmental capital of US $680 million, or approximately 7.5 billion Mexican pesos.

The overexploitation of coastal resources and the various water, air and soil contaminants, which already have global consequences, put at risk the sustainability of the holistic development of coastal zones. If this continues, for example, the rate of deforestation reported by the Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT; Secretariat of Environment and Natural Resources) in December 2001, of 600,000 ha/year, implies that some coastal states will lose an important part of their natural vegetation cover. That was the case of Campeche, Yucatán and Veracruz, which lost 100% (200,000 ha), 35% (272,000 ha) and 22% (270, 000 ha) of their forests, respectively. If this tendency continues the jungles, which cover an area of 30.8 million ha nationwide, will disappear in 58 years, while the forests, which currently total 32.9 million ha, will decrease to 26 million in 25 years and will disappear in 127 years.

The role played by the atmosphere and the ocean in the regulation of world climate is decisive. Global climate changes are modifying energy balances at a global scale, although it is very difficult to predict what are or will be their true manifestations and, moreover, their consequences. Coastal zones and their ecosystems will undoubtedly be important modulating elements in the environmental changes taking place.

The changes (increases) in the mean sea level due to ice thawing and thermal expansion of the oceans, as a consequence of global warming, will become evident in a gradual manner. Over the next 45 years the sea level could rise enough to flood coastal cities in lower zones and river deltas. It will also drastically alter international agricultural production and exchange systems, and it seems that even if we fully stopped the anthropogenic agents that are generating the global changes, these will not stop, at least in their early manifestations. The sea level is predicted to rise between 15 cm and 95 cm by the year 2100. A rise of only 15 cm would have devastating consequences in many coastal zones, which are extremely vulnerable to this physical change. It is estimated that an increase of one meter in sea level can cause land losses of 0.05% in Uruguay, 1% in Egypt, 6% in the Netherlands, 17.5% in Bangladesh, and up to 80% in Majuro Atoll of the Marshall Islands (Gallardo 1997). In the case of the coastal zone of Tamaulipas, much of the current port infrastructure would become inoperable in this scenario.

Other effects of sea level rise in coastal zones would be: substantial coastal flooding and erosion, damage to key economic sectors, risks to human health, loss of valuable coastal ecosystems such as mangrove forests and coral reefs, and the extinction of marine species.

CASE STUDY: COASTAL ZONE OF SOUTHERN TAMAULIPAS, MEXICO

The Tamaulipas coastal zone (TCZ) consists of an approximately 430 km long coastline, shaped by important coastal water bodies such as: Laguna Madre, Laguna Moreles, Laguna San Andrés, Altamira salt marsh, and lagoon system of the mouths of the Tamesí and Pánuco rivers. The coast consists mostly of sandy beaches and ancient dunes, with a very extensive and gentle continental shelf, characteristic of the central zone of the Gulf of Mexico. The continental part of the TCZ is shaped basically by low lands modeled mainly by the Rio Grande (to the north of the TCZ), the Río Soto La Marina (in the central part of the TCZ) and the Río Pánuco (to the south of the TCZ). The low lands that shape the southern portion of the TCZ are mainly influenced by the marine coastline, forming extensive coastal plains and salt marshes.

The northern part of the TCZ borders with the USA, in particular with the state of Texas – strip demarcated by the Rio Grande – and to the south it borders with the state of Veracruz – border demarcated by the Río Pánuco. The TCZ is under the jurisdiction of seven municipalities of the state of Tamaulipas that are, from north to south: Matamoros, San Fernando, Soto La Marina, Aldama, Altamira, Cuidad Madero and Tampico (the latter is on the riverside) (Fig. 13.1).

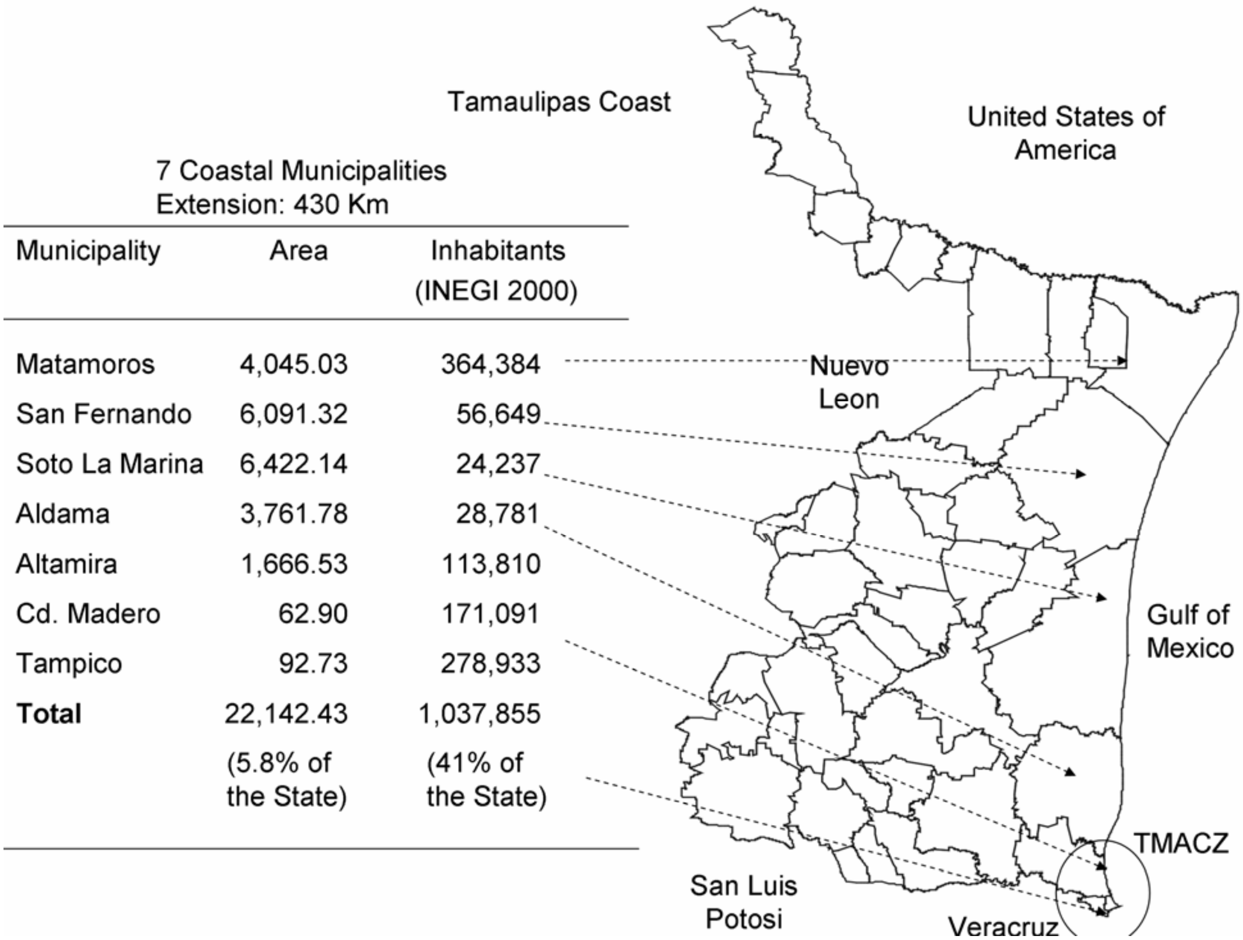
REGION OF THE TAMPICO-MADERO-ALTAMIRA CONJOINED ZONE

Currently, the second most important urban development and concentration of population in the state occurs in the south of Tamaulipas, consisting of three municipalities that give its name to the conjoined zone: Tampico, Madero and Altamira (TMACZ). According to preliminary results of the XII General Census of Population and Housing 2000, the TMACZ has 22% of the state population, equivalent to 604,291 inhabitants. The TMACZ also holds the second industrial development in the state, concentrated mainly in the municipalities of Altamira and Cuidad Madero.

The industrial and port development that has taken place during the last 15 years in the south of Tamaulipas has brought economic, urban, population, tourist and commercial growth, turning this region into a development center of national and international projection.

An important aspect in the development of the TMACZ is the commercial port of Tampico and the industrial port of Altamira, which have operated since the beginning of the century and since 1985, respectively. With no doubt, the industrial and port complex induced by the Puerto Industrial Altamira (PIA; Altamira Industrial Port), currently named Complejo Industrial Portuario Altamira (CIPA; Altamira Industrial Port Complex), has contributed the most to the development and current projection of the TMACZ.

The political panorama of the TMACZ is complex, given that the three municipalities that form it can be governed by mayors from different political parties. This has caused, for example, the deterrence of actions aimed at benefiting the social and economic development of the TMACZ. A specific case is that of the conjoined landfill, an urgent project in the region that has been in negotiation for over nine years due to the lack of agreement among the authorities of the three municipalities. The main vector of pressure and environmental deterioration in the TMACZ is, without doubt, industrial activity and associated anarchic urban development (Jiménez *et al.* 2001).



Municipality	Area	Inhabitants (INEGI 2000)
Matamoros	4,045.03	364,384
San Fernando	6,091.32	56,649
Soto La Marina	6,422.14	24,237
Aldama	3,761.78	28,781
Altamira	1,666.53	113,810
Cd. Madero	62.90	171,091
Tampico	92.73	278,933
Total	22,142.43	1,037,855
	(5.8% of the State)	(41% of the State)

Figure 13.1. Tamaulipas coastal municipalities.

Altamira is currently the municipality that suffers the most pressure and serious environmental strain in the TMACZ. This is due, among other factors, to the depletion of territorial reserves in the municipalities of Tampico (94%) and Cuidad Madero (89%) (INEGI 2000).

The municipality of Altamira had a population growth of 350% between 1980 and 2000, while Tampico and Madero only grew 10% and 37%, respectively, during the same period. Altamira holds one of the highest population growth rates in the country (5.8%), which has resulted in almost 80% of its urban settlements lacking basic public services such as potable water and drainage (INEGI 2000).

The municipality of Altamira has an area of 1,657 km^2, of which 70% is available for development (INEGI 2000). Furthermore, it has valuable natural resources for such development, like the availability of water, coastline, communications infrastructure, and an industrial and port development center of great national relevance, the Altamira Industrial Port Complex.

The industrial, manufacturing, tourist, commercial and financial economic units are the main activities in the TMACZ. The TMACZ counts with an infrastructure that favors economic and commercial development, access to tourist centers, and facilitates domestic and internationals communications. The highway network, as an element of regional integration, has enabled more than 50% of commercial traffic between Mexico and the United States to be carried out across international bridges. The conjoined area counts with federal highway No. 180, which connects the city of Tampico with the state of Veracruz to the south and with Matamoros to the north, passing through Altamira, Estación Manuel, Aldama, Soto la Marina and San Fernando. Inter-state highway No. 81 connects with Ciudad Victoria, and federal highway No. 70 with Cuidad Valles and San Luis Potosí. There is an international airport at Tampico as well as two ports, Tampico and Altamira.

This region is located in the southern part of the coastal strip, which is the most important economic region due to its extensive industrial corridor, and has commercial and services infrastructure that meets the priority needs of the corridor. This industrial, commercial and tourist development has promoted an increase in the population growth rate in recent years. It is also considered as a commercial window to the national and international hinterland, because it counts with adequate ports, one commercial and the other industrial, as well as all land and air transport services.

DISCUSSION AND CONCLUSIONS

The development indicators of Mexico's coastal zone present contrasting circumstances, some of them critical. The state of Baja California has the lowest support capacity for its coastal development, given the sustainability deficit of its water sources relative to the availability of forests. Campeche exhibits the opposite, since it has a greater capacity to support its water resources due to larger jungle cover, but unfortunately it is one of the states with high deforestation index.

Regarding the consequences of sea level rise on the coast of Tamaulipas and on Mexican coasts in general, actions can be taken to assimilate the rise in sea level, such as policies for port infrastructure adaptation and safety in view of flooding hazards. These should be priority actions for the government (as of now and for the next 50 years), to be implemented systematically in order to minimize these environmentally hazardous conditions.

The value of the environmental services provided by coastal ecosystems will have to be guaranteed through actions to control the deterioration and loss of environmental quality, and above all, in face of external factors, and synergistic and cumulative environmental impacts. Holistic management of the coastal zone, within a framework of ecological regulation and planning, can offer an excellent alternative to meet the expectations of sustainable development of the Mexican coasts. Consideration of social, cultural, legal, structural, financial, economic, and institutional action and measures can be a reference framework to solve the current environmental conflicts.

The TMACZ faces environmental problems that, in some cases (mostly garbage and sewage), have overwhelmed the response capacity of the government at all three levels (federal, state and municipal). Natural population growth added to increasing immigration as a result of economic, industrial and port development requires the creation and application of actions derived from regulatory environmental policies. This will be the only way to successfully face all the problems derived from deficient resources such as urban soil, infrastructure, housing, equipment and services in general, within a framework of environmental planning that promotes holistic and sustainable development of the region.

ACKNOWLEDGEMENTS

We would like to express our profound gratitude to L.C.C. Gabriela Hernández Mendoza, Dr. Esperanza Martínez Cano and P.I. Aarón Martínez for their help and comments in editing and reviewing this study.

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