River damming and changes in mangrove distribution

Rozane Valente Marins
Universidade Federal do Ceará

Volume 2, No. 1 *July, 2002*

GLOMIS Electronic Journal

An electronic journal dedicated to enhance public awareness on the environmental importance of mangroves

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Impacts from Land-based Activities on the Coastal Zone

Integrated Coastal Zone Management (ICZM) has minimized environmental impacts from activities installed at coastal zones. But impacts from land-based activities on the coastal zone are still poorly understood and taken into consideration in regional ICZM. In a recent report from the LOICZ-IGBP SAmBas (South American Basins) project, such impacts have been recognized as affecting the coastal zone. Among the activities listed, amming and water diversion were identified as the most significant Lacerda et al. 2001).

Damming increases sediment trapping in reservoirs. Water withdraw for human consumption, agriculture and other uses decrease the freshwater flux to the coast. Impacts caused by river damming are coastline erosion, increasing saline intrusion, nutrient depletion and in some areas, sediment accretion due to marine sand deposition in estuaries. Mangroves may be particularly affected by such impacts. The Northeastern Brazilian coast, particularly the Ceará State, witnessed rapid economic growth during the last two decades pushed by irrigated agriculture, intensive aquaculture and tourism, also leading to increasing urbanization of a formerly rural population and migration to the coast, where population density reaches 108 $inhab.km^{-2}$ (60% of the State's population (MMA, 1996). Traditional fisheries, exploitation of mangrove products and subsistence agriculture however, still support a large portion of the coastal population.

Region description

The coastline of Ceará State is characterized by coastal sandy plains with large aeolian dune fields, driven by year-round constant winds from the South East (SE) (average speed of 6.3-7.9 $m.sec^{-1}$) and small coastal lagoons (Jimenez et al., 1999). Freshwater discharge to the sea is about 200 $m^3.sec^{-1}$. High tidal amplitude (2.8 m) and small freshwater supply results in salinity intrusion inland. Tidal flood plains are covered by nearly 23,000 ha of mangroves (Herz, 1991; Lacerda, 1993). Major watershed is the Jaguaribe River (Fig. 1). The countryside is semi-arid; with annual rainfall of 500 to 700 mm, 80% of which is falling from February to May (ANEEL, 2000).

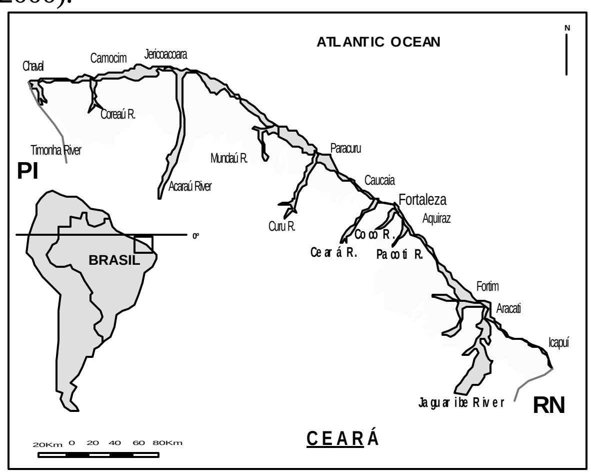

Figure 1. The coastline of Ceará State and the Jaguaribe River catchment area.

Rebouças (1999) estimated the availability of freshwater in Ceará State as 2,279 $m^3.inhab^{-1}.yr^{-1}$, being close to the lower acceptable limit of the range 2,000 to 10,000 $m^3.inhab^{-1}.yr^{-1}$ (UNDP, 1997). Water shortage triggered river damming and reservoir construction since the 19th century. Damming level of the Jaguaribe River reaches 87% and the river has been used for irrigation and urban consumption along the entire length of its course, especially for the State's capital of Fortaleza (Campos et al., 1997). With such high level of damming, the extensive mangroves of the Jaguaribe River mouth are presently showing significant changes in area, distribution and population dynamics of local species.

Environmental setting and major coastal impacts from land-based activities in the Jaguaribe Basin

The Jaguaribe Basin (Fig. 2) covers about 72,000 km^2, almost half of the State's territory and account for 70% of the total freshwater input to the adjacent Atlantic Ocean.

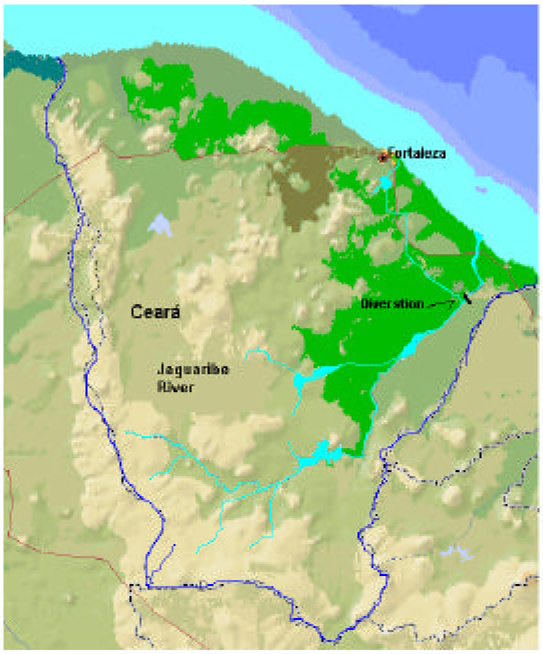

Figure 2. The Jaguaribe River in Ceará State, Northeastern Brazil

The Jaguaribe Basin is mostly under semi-arid climate (annual temperature >18ºC; annual rainfall <500 mm inland, reaching 800 to 1,000 mm at the coast). Along the basin, hundreds of small to very large dams and reservoirs were built since 1906. Small reservoirs accumulate 20-30% of the total dammed freshwater, whereas large reservoirs (less than 1% of all reservoirs) concentrate about 70%. The largest dam, the Orós, with a capacity of 1.9 x 10^9 m^3, was built in 1962, followed by the Banabiú (1.0 x 10^9 m^3) and the Pedras Brancas (0.4 x 10^9 m^3), the dams turned the river perennial, decreasing the seasonal rainy-period input of sediments and blocking freshwater flow to the sea during dry periods.

Average freshwater discharge to the Atlantic Ocean from the Jaguaribe River ranges from 60 to 130 $m^3.s^{-1}$ (ANNEL, 2000), but have varied widely (1 to 7,000 $m^3.s^{-1}$) before major damming started in the 1960's. Discharges during the 20th century have followed the building of dams. Prior to the building of the Orós Reservoir, rainy-season river flux to the Atlantic reached 200 $m^3.s^{-1}$, decreasing to 80 $m^3.s^{-1}$ by 1980. After 1996 discharge reached its present level of about 60 $m^3.s^{-1}$. With the building of the new Castanhão reservoir (4.5 x 10^9 m^3 of capacity) planned to 2002, discharge is expected to decrease to 20 $m^3.s^{-1}$ (Campos et al., 1997). Today, during the dry season, virtually no freshwater reaches the sea from the Jaguaribe River.

Sediment load to the Atlantic from the Jaguaribe River is about 60,000 $ton.yr^{-1}$ (sediment yield <0.2 $t.km^2.yr^{-1}$, Cavalcante (2000)). Marine and aeolian sand transport are dominant, reaching 600,00 and 200,000 $m^3.yr^{-1}$, respectively, triggering sedimentation processes in mangroves and coastal lagoons (Valentini, 1996; Jimenez et al.1999), Freire, 1989). Significant erosion is also occurring at the river estuary (Morais and Pinheiro, 1999).

Mangroves require sedimentation rates of about 1 $mm.yr^{-1}$ to keep pace with the general sea level rise (Ellison, 1993; Smoak and Patchineelam, 1999). Along many Ceará estuaries the supply of sediments is much less than that, particularly at the Jaguaribe River, resulting in erosion and death of mangrove trees. Erosion of mangrove mud results in high suspended matter load into the incoming tide (Fig. 3), bringing mud inland, further increasing the erosive force of tides and allowing the deposition of marine sands brought along the cost by prevailing SE trade winds. This accelerates mangrove trees destruction by high sedimentation by marine sands.(Fig. 3).

Figure 3. Sand accumulation in mangroves ecosystems, at the mouth of the Jaguaribe River, due to reduced supplies of fresh water and sediments in the estuary.

Another impact of river damming is on the mangrove crab population, a significant income for the local population. Damming allowed the development of an extended irrigated agriculture. Fresh water diversion for these agro-systems contributes to the increasing salinity observed in ground water in many coastal sites. For example, at the Pacoti River, annual salt balance showed a residual accumulation of salt of about 135,000 t (680 $t.ha^{-1}$) in the local mangroves (Freire et al., 1991). Part of it may be fluxed out to the ocean in exceptionally rainy years, but a residual build up in soil salinity and landward intrusion through ground water occurs. At the Jaguaribe River mouth, large-scale mortality of crabs was recorded in the dry season of 2000. The local crab *Ucides cordatus* develops best at salinities of about 15‰, although resisting to full seawater salinity for a period of time. A survey of water salinity along the Jaguaribe River during the rainy season of 2000, showed the lowest values between 24‰ and 29‰, whereas during the dry season of 2001 salinity varied from 38.1 to 39.4‰ within the mangroves and major creeks. Local seawater salinity is 38‰. Therefore even under rainy conditions salinity is well above the optimum reproduction range for the local crab species. Changes in fish communities have also been noted with decreasing abundance of estuarine species such as mullets (*Mugil* spp.) and robalos (*Centropomus* spp.).

Long-term impacts related to damming may also affect coastal fisheries. Coastal waters in Cearà are fairly oligotrophic, with Chl*a* concentrations ranging from 0.05 to 0.5 $mg.m^{-3}$ and primary production ranging from 0.02 to 0.2 $gC.m^{-2}.d^{-1}$. Also, most of this production depends on nutrients brought by rivers (Ekau and Knoppers, 1999). Sequestering of sediments in dams may significantly decrease this nutrient input to the sea, with a potential impact on fisheries.

Landward extension of mangroves is also affected by river damming, particularly in the estuary of the Jaguaribe River. High tidal amplitude and low river gradient make the estuary particularly sensitive to sea level rise. A general rise in sea level is suggested to occur along the Brazilian coast. Recent estimates based on tidal records of over 20 years show 0.3 to 3.6 $mm.yr^{-1}$ increase in tidal propagation into rivers, maximized by numerous dams constructed during the last decades.

Mangrove invasion on topographically higher herbaceous plains upriver are taking place since the 1980's. Saplings of *Laguncularia racemosa* are colonizing riverbanks in former pasture areas up to 30-40 km from the coast. This process is facilitated by the deposition of fine sediments on river sand and gravel beaches, derived from the erosion and transport of mangrove sediments at the river mouth.

The regional legal framework on ICZM copes with problems at the coastal zone proper, but not with controlling and minimizing impacts generated along river catchments. The Jaguaribe River damming impact is outstanding. Whereas efficient water management plans take care of water distribution among users (agriculture, towns, aquaculture, etc), they completely fail to consider the coastal ecosystems as "natural users" of the river water.

L.D. Lacerda and R.V.Marins
Intituto de Ciências do Mar, Universidade Federal do Ceará. On leave from: Dept. Geoquímica, Universidade Federal Fluminense, Niteroi, 24020-007, RJ, Brazil.
e-mail: ldrude@fortalnet.com.br

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