Research Article

The mangrove forest at the Bucatu Lagoon, Northeast Brazil: structural characterization and anthropic impacts

Rômulo Romeu Nóbrega Alves[1,*], Roberto Sassi[2] and Gindomar Gomes Santana[2]

[1]Departamento de Biologia, Universidade Estadual da Paraíba, Avenida das Baraúnas, 351, Campus Universitário, Bodocongó, 58109-753, Campina Grande, PB, Brasil.

[2]Universidade Federal da Paraíba, DSE/Núcleo de Estudos e Pesquisas dos Recursos do Mar (NEPREMAR)/CCEN, CEP 58051-900 - João Pessoa, PB, Brasil.

*Corresponding author Email: romulo_nobrega@yahoo.com.br

Abstract

We investigated the Bucatú microbasin in order to characterize the structure and composition of its surrounding mangrove area by recording the main anthropic interferences on the vegetation. This study was performed along 10 plots (1000 m^2 in total), perpendicular to the estuarine canal. Deposition and accumulation of sediments on the plants root system were evaluated using auger holes and photographs. Four plant species, *Laguncularia racemosa* (L.) Gaertn. (White Mangrove), *Rhizophora mangle* L. (Red Mangrove), *Conocarpus erectus* L.(Silver-leaved Buttonwood), and *Annona glabra* L. (Pond-apple) were recorded. The structural parameters obtained were low, and a great number of dead plants were observed, most of them of the species *L. racemosa*. Sediment deposition rates of 10-15 cm were recorded. Silting in the mangrove area and alterations of water flow in the drainage basin of the Bucatu River were the main anthropic effects observed, exerting a high negative impact on the mangrove ecosystem we investigated.

Keywords: Coastal lagoon, environmental impact, *Laguncularia racemosa, Rhizophora mangle*

Resumo

A microbacia de Bucatú foi estudada visando caracterizar a estrutura e composição do manguezal que a margeia e relacionar essas características com as interferências humanas que vem ocorrendo na área. Os estudos no manguezal foram conduzidos ao longo de 10 parcelas (1000 m^2), delimitadas perpendiculares ao canal estuarino. A deposição e o acúmulo de sedimentos sobre os sistemas radiculares das espécies de mangue foram avaliados através de tradagens e registros fotográficos. Foram registradas quatro espécies vegetais: *Laguncularia racemosa* (L.) Gaertn. (Mangue Branco), *Rhizophora mangle* L. (Mangue vermelho), *Conocarpus erectus* L. (Mangue de Botão) e *Annona glabra* L.(Panã). Os parâmetros estruturais obtidos foram baixos, sendo registrada uma elevada densidade de plantas mortas, sobretudo pertencentes à espécie *L. racemosa.* Taxas de deposição de sedimento entre 10-15 cm foram registradas no manguezal. Assoreamento na área de mangue e alterações do fluxo hídrico na bacia de drenagem do rio Bucatú são os principais impactos antrópicos que vem agindo negativamente e de forma expressiva no manguezal estudado.

Palavras-chave: Sedimentation mangrove; *Laguncularia racemosa*; Coastal lagoon; Environmental impact

Received: 17 November 2012; Accepted: 1 April 2013; Published: 24 June 2013.

Cite this paper as: Alves, R. R. N., Sassi, R. and Santana, G. G. 2013. The mangrove forest at the Bucatu Lagoon, Northeast Brazil: structural characterization and anthropic impacts. *Tropical Conservation Science* Vol. 6(2):254-267. Available online: www.tropicalconservationscience.org

Introduction

Coastal lagoons are shallow, calm bodies of water with restricted access to the sea [1]. Limited mangrove habitats occur in association with these ecosystems, making them important environments for maintaining the diversity of organisms thriving in those places or using them during their life cycles to obtain food, reproduce or as shelters against predators.

Mangrove habitats are formed by a special association of plants and animals that live in the intertidal zone of low tropical coasts, along estuaries, river deltas, inland brackish waters, lakes and lagoons and their associated estuaries, which are among the most productive areas of our planet [2, 3]. These environments work as an integrated system, in which the vegetation is mainly responsible for the productive dynamics of tropical estuaries and adjacent areas.

Substantial reductions have been reported recently in mangrove areas worldwide [4], due mainly to anthropic activities [3]. Information on the structure of mangrove areas is greatly needed in order to comprehend the processes of succession, primary production and the reaction of mangrove habitats to stresses caused by natural processes and humans [5].

It is noteworthy that most of the studied mangrove areas are associated with large estuaries, mainly the ones with apparent economic and social importance. On the other hand, the mangrove habitats of micro-estuaries have been a neglected research area. Sand bars generally block the lagoonal coastal systems, obstructing the efficient drainage of surrounding mangrove areas that are only flooded during high tides. Consequently, such ecosystems have a more compacted soil, often covered by a dense layer of litter. Some tree and/or bush plants, not normally found in mangrove habitats, thrive in those areas [6].

In Brazil, microestuaries occur in several northeastern states, many of them with well-developed mangrove forests that have experienced varying degrees of anthropic impacts [6]. The structural characterization of mangrove areas is a valuable tool to estimate the ecosystem’s response to environmental conditions caused by alterations of local habitats. In the State of Paraíba there are several small lagoons, forming natural scenery that attracts tourists and people during their leisure time. Those environments have been impacted by varied sources and degrees of human interferences. Here we characterize the mangrove habitat associated with the lagoon system of the Bucatú river, State of Paraíba, with respect to its structure and flora. We also examine the main human interferences in the entire area and their likely effects on the mangrove habitat structure.

Methods

Characterization of the area

The microbasin of the Bucatu River is *ca.* 856.2 ha, located on the southern Paraíba coast, in the municipality of Conde, *ca.* 17 km from João Pessoa, the capital of Paraíba., The basin's geographic coordinates are between 7º18'19.85" and 7º19'27.37"S, and between 34º47'47.14" and 34º48'46.67"W (Figures 1 and 2). It is bordered on the north and west by the Maceió de (lagoon of) Tabatinga, on the south by the microbasin of Mucatu River, on the east by the Atlantic Ocean. The microbasin of the Bucatu River, in geological terms lies predominantly on the Plio-Pleistocene sediments of the 'Formação Barreiras'. The area is geomorphologically subdivided into three well-defined dominions: the Low Coastal Plains, Fluvio-marine plain, and Coastal Plain. The source of the Bucatu River is located at *ca.* 90 m above the sea level. The edges of the deforested slopes, on the left riverside of its upper course, have been slightly eroded by intense runoff, consisting of a sandy-clayey material [7].

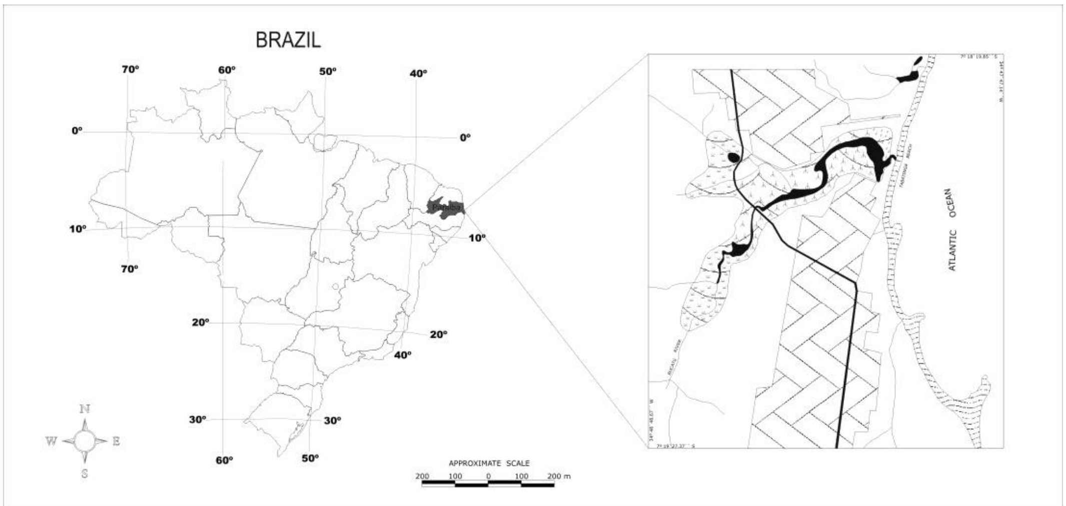

Fig. 1. Map with localization of the study area.

The methods we used are as follows. The structural characterization of the vegetation at the microbasin of the Bucatu River was performed using the method described by Schaffer-Novelli and Cintrón [8]. Sampling in the mangrove habitat was carried out using ten plots 10 x 10 m, perpendicular to the estuarine canal, delimited with nylon ropes. The first three plots were located close to the river mouth and the others situated further upstream.

All alive and dead plants in each plot were identified and their diameter at breast height (DBH) was measured to within 1 cm by using a calliper made up of a plastic 50-cm rule and wood. Individuals smaller than 1.30 m had their diameter measured at soil surface instead of DBH, though we have maintained the DBH denomination for practical purposes [9]. The tree heights were measured with telescoping aluminum tubes of known length. A tape measure was used for measuring the stilt-roots.

From the measurements of the plants carried out in each plot, we calculated the density of alive and dead individuals of each species, mean DBH, basal area of alive and dead individuals, and their mean height. With respect to characterization of structural abundance [10] we estimated: the absolute density (AD, ind/ha), specific relative density (RD, %), specific absolute frequency (AF, %), absolute total frequency (ATF, %), specific relative frequency (RF, %), specific basal area (BA, m^2/ha), specific relative basal area (Rba, %), and specific importance value index (IVI, %). The data obtained were statistically analyzed using the computer program 'Excel 9.0' and 'Statistica 4.0'. The distributions concerning the heights and diameters of sampled plants in the plots were analyzed through frequency histograms.

All plants sampled from the mangrove habitats and their margins were pressed at the locale they were collected and then were oven-dried in the laboratory at 50^{o}C for 72 hours. They were subsequently identified and the dried specimens were housed in the Herbarium Professor Lauro Pires Xavier (JPB/DSE/CCEN/UFPB).

The deposition and accumulation of sediments on the root system of mangrove plant species were evaluated with auger holes and photographs. A chi-square test (χ^2, 5% significance) was applied to determine the proportion of plant species and their state (alive and dead individuals).

The anthropic interferences recorded in the present study were based mainly on field observations, photographic documentation, and soil sampling with augers.

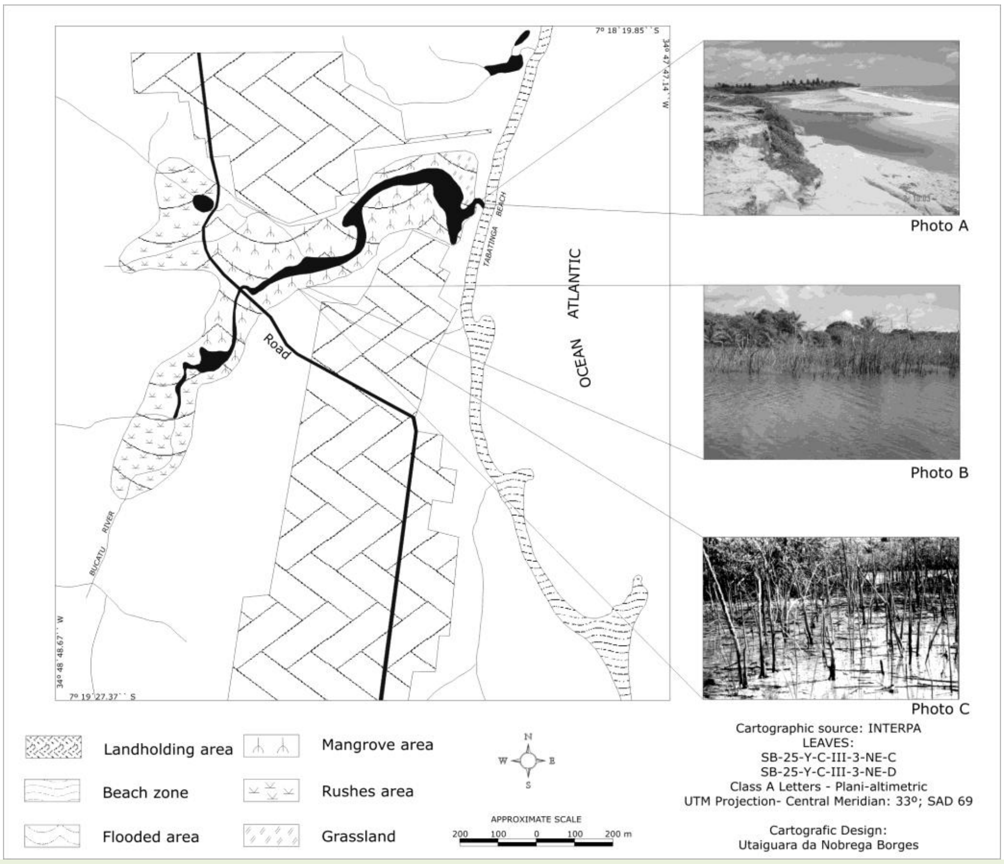

Fig. 2. Study area, with details of the Bucatu river mouth (Photo A), and parts of the dead mangrove habitat: flooded (Photo B) and covered by silt (Photo by Rômulo Alves).

Results

In the 10 plots analyzed, 517 specimens of plants were recorded, belonging to four distinct species: *Laguncularia racemosa* (L.) Gaertn. (Mangue Branco), *Rhizophora mangle* L. (Mangue vermelho)*, Conocarpus erectus* L. (Mangue de Botão) e *Annona glabra* L. (Panã) The most abundant species was *L. racemosa*, followed by *R. mangle*. The species *C. erectus* and *A. glabra* occurred only in two plots. Despite the notable abundance of *L. racemosa*, followed by *R. mangle*, in the mangrove ecosystem at Bucatu Lagoon, they had similar densities when considering just the alive individuals. The total absolute density showed high numbers of alive and dead plants, 1290 and 3880 individuals/ha, respectively (Table 1).

Table 1. Density of alive and dead individuals and basal area (m^2/ha) per class of DBH (cm) in the plots of the study area in the mangrove habitat at Bucatu Lagoon, State of Paraíba.

Plot	Basal area (m^2/ha)				Density **			
	≤ 2.5	**> 2.5**	**>10**	**Total**	**≤ 2.5**	**> 2.5**	**>10**	**Total**
1	0.055	0.239	0.113	0.407	46	5	1	52
2	0.001	0.143	0.153	0.297	1	7	1	9
3	0.029	0.400	0.132	0.561	12	22	1	35
4	0.003	0.102	-	0.105	1	6	-	7
		(0.019*)		(0.019*)	2*			2*
5	0.006	0.078	-	0.084	2	7	-	9
6	0.012	0.081	-	0.093	3	7	-	10
7	0.087	0.047	-	0.134	3 (8*)	4	-	7
		(0.098*)		0.098*				8*
8	0.325*	0.183*	-	0.508*	121*	26*	-	147*
9	0.206*	-	-	0.206*	117*	-	-	117*
10	0.148*	0.063*	-	0.211*	105*	09*	-	114*
Total	Alive 0.193	1.090	0,398	1.681	68	58	3	129
	Dead 0.679*	0.363*	-	1.042*	353*	35*	-	388*
Total general	0.872	1.453	0.398	2.723	421	93	3	517

* Dead plants. Density: plots (indiv/0.01 ha), total (indiv/0.1 ha).

The distribution of individuals according to DBH showed a general predominance of tree trunks with ≤2.5 cm diameter (Figure 3). Among the alive plants, the classes of specimens with DBH >2.5 cm and >10 cm comprised most of the total basal area of the study area, 1.681 m^2/ha (Table 1). Such distribution of individuals per DBH class indicates that most alive individuals (n = 129) are concentrated in the class 0.5 – 1 cm, though they also had a distribution up to the DBH class >10 cm, but in small proportions. Among the 338 dead plants, the individuals had a maximum 3 cm DBH, with a larger concentration of classes smaller than 2.5 cm. In the three upstreams plots there were only dead plants, most of them belonging to the diameter class ≤2.5 cm, the greatest portion of the dead basal area, totalling 1.042 m^2/ha. The basal area of dead plants was 3.5 times larger than the basal area of alive plants in the diameter class ≤2.5

cm (Table 1). Dead specimens of *L. racemosa* had the most expressive basal area (Table 2) and relative density in percentage, in the plots numbers 7 to 10 (Table 4).

Table 2. Basal area (m^2/ha), and density per species and DBH, in the plots of the study area in the mangrove habitat at Bucatu Lagoon, State of Paraíba.

		Species							
		L. racemosa		***R. mangle***		***C. erectus***		***A. glabra***	
Plot	DBH (cm)	Basal area	Dens.	Basal area	Dens.	Basal area	Dens.	Basal area	Dens.
P1	≤ 2.5	0.046	43	0.009	3	-	-	-	-
	>2.5	0.239	5	-	-	-	-	-	-
	>10	0.13	1	-	-	-	-	-	-
P2	≤ 2.5	0.001	1	-	-	-	-		-
	>2.5	0.070	2	0.014	2	0.052	2	0.007	1
	>10	0.153	1	-	-	-	-		-
P3	≤ 2.5	0.003	2	0.020	8	0.003	1	0.003	1
	>2.5	0.014	1	0.153	8	0.207	12	0.026	1
	>10	-	-	-	-	0.132	1	-	-
P4	≤ 2.5	-	-	0.003	1	-	-	-	-
	>2.5	0.012	1	0.090	5	-	-	-	-
				0.019*	2*				
	>10	-	-	-	-	-	-	-	-
P5	≤ 2.5	-	-	0.006	2	-	-	-	-
	>2.5	-	-	0.078	7	-	-	-	-
	>10	-	-	-	-	-	-	-	-
P6	≤ 2.5	0.004	1	0.008	2	-	-	-	-
	>2.5	-	-	0.081	7	-	-	-	-
	>10	-	-	-	-	-	-	-	-
P7	≤ 2.5	0.085	2	0.002	2	-	-	-	-
	>2.5	0.098*	8*	0.047	3	-	-	-	-
	>10	-	-	-	-	-	-	-	-
P8	≤ 2.5	0.325*	121*	-	-	-	-	-	-
	>2.5	0.183*	26*	-	-	-	-	-	-
	>10	-	-	-	-	-	-	-	-
P9	≤ 2.5	0.206*	117*	-	-	-	-	-	-
	>2.5	-	-	-	-	-	-	-	-
	>10	-	-	-	-	-	-	-	-
P10	≤ 2.5	0.148*	105*	-	-	-	-	-	-
	>2.5	0.063*	9*	-	-	-	-	-	-
	>10	-	-	-	-	-	-	-	-
Total	≤ 2.5	0.139	49	0.048	18	0.003	1	0.003	1
		0.679*	343*						
	>2.5	0.335	9	0.463	32	0.259	14	0.033	2
		0.344*	43*	0.019*	2*				
	>10	0.266	2	-	-	0.132	1	-	-

* Dead plants

The mean tree height in the plots was up to 3.5 m (Table 3), presenting a maximum 5 m and minimum 0.7 m in height. In figure 4 the distribution of individuals is shown by classes of tree height. The height class 1.0 – 1.5 m included the largest number of alive individuals, whereas the classes 2.0 – 2.5 m and 2.5 – 3.0 m contained the largest number of dead individuals, mainly of *L. racemosa* specimens. The chi-square test between the alive or dead plant condition and the species, showed that there is a significant association among the variables

(χ^2 = 222.2; df = 1; p <0.01), emphasizing that 86% of *L. racemosa* individuals were dead. The other plant species had a 3% value of dead individuals (Table 5).

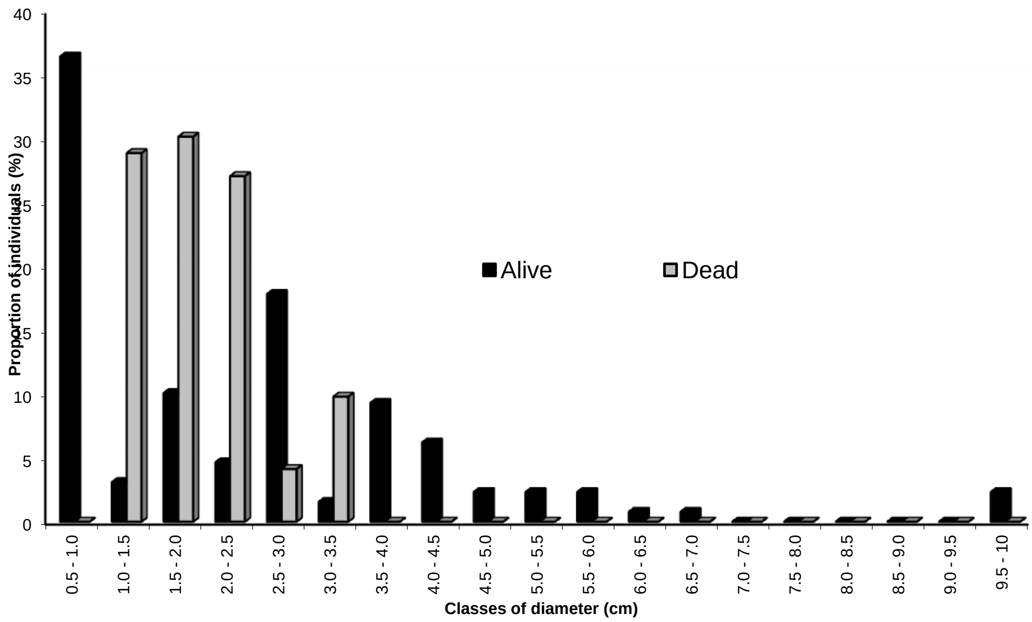

Fig. 3. Distribution of number of individuals (alive and dead) per class of diameter, in intervals of 0.5 cm (closed at left and open at right), in the plots of the study area in the mangrove habitat at Bucatu lagoon, State of Paraíba.

The high density of *L. racemosa* with a DBH <2.5 cm shown in Table 2, suggests that the study area was in a regenerative process, which had apparently been gradually interrupted, as evidenced by the large number of dead plants we recorded.

In the surveyed area we observed an intense deposition of sediment on the upper parts of the local mangrove habitat, where occurred a large concentration of alive and dead specimens of *L. racemosa*. Evaluation of auger-holes showed sediment deposition of 10-15 cm. In the surveyed area the gradual sedimentation accretion on pneumatophores appeared to be killing those plants (Figures 5 and 6A-C). In addition, the obstruction of the river mouth reduced local drainage, reducing the removal rate of the sediment by the ebb and flow of the tides and rendering the environment unsuitabe for plant growth and survival.

Discussion

The low diversity of species recorded in the study area was expected, considering that the usual number of species recorded in northeastern mangrove ecosystems has varied from three to four, including those species found in the Bucatu mangrove area, deemed as a low floristic diversity [6]. It is also not surprising that the species *L. racemosa* and *R. mangle* were the most abundant in the study area. Sassi [7] reported both species as the most frequent in other mangrove ecosystems associated with lagoon systems in the State of Paraíba. Coutinho [11] and Soares [12], who studied the Paraíba microbasins of Camurupim and Jacarapé, respectively, reported the predominance of *R. mangle*. Alves and Sassi [6] reported the predominance of *L. racemosa* in a strongly impacted mangrove habitat at Intermares, in the municipality of Cabedelo, near João Pessoa.

Table 3. Mean height and mean DBH of alive and dead plants in the plots of the study area in the mangrove habitat at Bucatu Lagoon, State of Paraíba.

Plots	Mean height (m)		Mean DBH (cm)	
	Alive	Dead	Alive	Dead
1	1.31	-	3.16	-
2	2.86	-	6.48	-
3	3.02	-	4.52	-
4	3.17	-	4.37	3.48
5	3.04	-	3.45	-
6	2.80	-	3.44	-
7	2.20	1.65	4.94	3.95
8	-	2.13	-	2. 10
9	-	2. 50	-	1.50
10	-	2.21	-	1.53

The variability in the composition and structural development of mangrove ecosystems associated with lagoons seems to be strongly influenced by anthropic tensions. This situation was recorded in the study area, where anthropic impacts have influenced the phytosociological parameters of the local plant species, especially in relation to the composition of the species, with a predominance of *L. racemosa*. Soares [9] pointed out that mangrove habitats dominated by small-sized specimens of *L. racemosa* are typical of disturbed environments in regenerative process. Soares and Tognella [13] also stated that the dominance of *L. racemosa*, in terms of basal area and density of individuals, characterized the ecological succession and regenerative process of mangrove habitats at the canal of Bertioga, State of São Paulo. Smith III [14] reported that in mangrove ecosystems with greater frequency of disturbances, species of Rhizophoraceae are less represented than species of other families, like *Laguncularia* spp. Alves and Sassi [6] reported that in the mangrove habitat at Intermares, near João Pessoa, *L. racemosa* seemed to be more resilient to cuts, with a better reaction to this impact than other plant species. Thom [15] emphasized that *L. racemosa* is more tolerant of changes in habitat conditions. However, the higher resilience of *L. racemosa* seemed to be related to the kind of impact the mangrove habitat is being subjected to, since alterations in the hydrological flux leading to persistent floods and/or sedimentation accretion in that environment probably affected *L. racemosa* more than other species.

The excessive mortality of plants we observed likely resulted from the pronounced accumulation of sediments in the flood plain of the mangrove ecosystem, as well as from alterations of water flow powered by sand imported from the mouth of the Bucatu river and from construction of the asphalt paving road crossing that lagoon. Most of the sediment came from erosion of nearby slopes caused by deforestation, collection of sand for construction, and subsistence agriculture. Accumulation of sediments was observed at other mangrove forests, causing the death of mangrove plants [16-18]. According to several studies [19-21], sudden high sedimentation events during the rainy season, caused by the increase of sediment load downstream and towards the coast, may cover prop roots of mangrove trees, seriously impairing their respiration and causing widespread death of plants. Terrados *et al.* [22] suggested that import of sediment increases the mortality rate of mangrove seedlings, *Rhizophora apiculata*, by reducing the oxygen supply to their hypocotyl and root system, and reducing their linear growth rate by affecting the carbon balance. The reduced supply of oxygen to the roots may also reduce their tolerance to phytotoxins from anaerobic sediments [23, 24]. Hatton and Couto [25] reported that movement of sand in mangrove areas on the island of Mozambique caused high mortality of *Ceriops tagal*, shifts in composition of species, and the disappearance of crustaceans and molluscs.

Table 4. Phytosociological parameters of *Rhizophora mangle* (Rm), *Laguncularia racemosa* (Lr), *Annona glabra* (Ag), *Conocarpus erectus* (Ce), and of dead plants (Dp) in the plots of the study area in the mangrove habitat at Bucatu Lagoon, State of Paraíba.

Plot	**Relative density (%)**					**Relative basal area (%)**					**IVI*(%)**				
	Rm	Lr	Ag	Ce	Dp**	Rm	Lr	Ag	Ce	Dp**	Rm	Lr	Ag	Ce	Dp**
1	6	94	-	-	-	2	98	-	-	-	29	71	-	-	-
2	32	18	27	23	-	44	44	2	10	-	37	28	18	17	-
3	46	8	6	40	-	31	3	5	61	-	43	21	9	27	-
4	67	11	-	-	22	75	10	-	-	15	53	22	-	-	25
5	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
6	90	10	-	-	-	96	4	-	-	-	73	27	-	-	-
7	33	14	-	-	53	22	36	-	-	42	36	24	-	-	40
8	-	-	-	-	100	-	-	-	-	100	-	-	-	-	100
9	-	-	-	-	100	-	-	-	-	100	-	-	-	-	100
10	-	-	-	-	100	-	-	-	-	100	-	-	-	-	100

* Importance value index ** Dead plants

In the Bucatu lagoon, the high number of dead individuals of *L. racemosa* was certainly caused by anthropic disturbances, especially as a direct consequence of continual floods and silting up of mangrove areas, which may become a serious obstacle to respiration of their quite small roots, the pneumatophores (Figures. 5 and 6A-C). These roots are more easily covered by sediment and/or submerged than the prop roots of *R. mangle*. The ability of mangrove species to cope with root burial of several centimetres a year probably varies among species as a function of root architecture [16]. According to Cintrón *et al.* [26], the segment of a root with the largest number of lenticels demarcates approximately the fluctuation zone of prevailing water levels in the ecosystem. The covering of those surfaces by changes in water level obstructs the air to the roots and may cause the death of trees. Souza and Sampaio [27], studying a mangrove ecosystem at Suape, State of Pernambuco, found the greatest number of dead plants in flooded or silted areas, particularly areas with selective coppicing.

The values of mangrove habitat structure obtained from Bucatu were generally lower than the values obtained from other mangrove areas of the coast of Paraíba. Coutinho [11], at Jacarapé Lagoon, recorded trees of 15 m height and basal area of 11.9 m^2/ha; Soares [12], at Camurupim Lagoon, recorded basal area of 21.1 m^2/ha; and Alves and Sassi [6], at the microbasin of Intermares, found mean tree heights of 7.6 m and basal area of 14.08 m^2/ha in a mangrove ecosystem strongly impacted by human occupation. All these values are much greater than the values we recorded at Bucatu. Jimenez *et al.* [28] stated that the reduced structural development of mangrove ecosystems might be due to anthropic actions that do not allow the vegetation to reach its structural maturity.

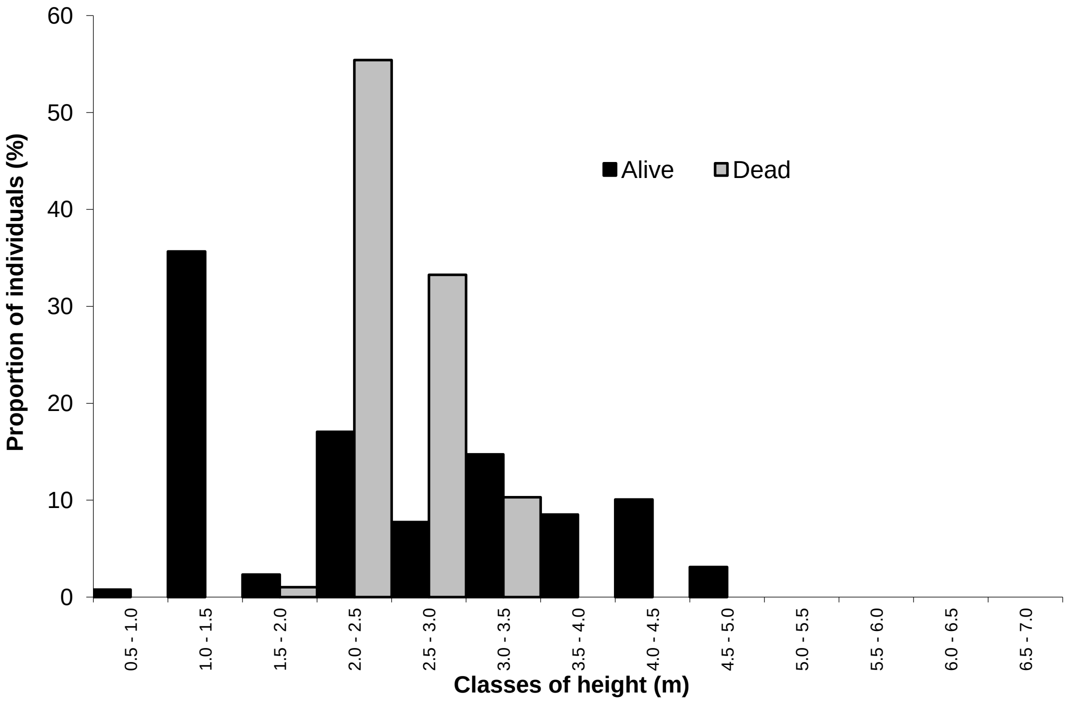

Fig 4. Distribution of number of individuals (alive and dead) per class of height at intervals of 0.5 m (closed at left and open at right), in the plots of the study area in the mangrove habitat at Bucatu lagoon, State of Paraíba.

Implications for conservation

In Brazil, microestuaries occur in different states of the Northeast region, where many of them exhibit well-developed mangrove forests. These environments have endured anthropic impacts differing in origin and degree [6]. Although these environments have adapted under conditions of high temperatures, anaerobic substrates and fluctuations in salinity, there are certain situations, natural as well as human-induced, to which they are extremely vulnerable [5]. Discussion about the preservation of these environments has intensified in recent years, because it has become evident that these areas are of great importance for maintaining the productivity and biodiversity of marine and coastal ecosystems.

Table 5. Contingency table between alive and dead individuals of plant species in the plots of the study area in the mangrove habitat at Bucatu Lagoon, State of Paraíba.

Species	Condition		Total
	Alive	Dead	
L. racemosa	63 (14%)	383 (86%)	446
Other species	69 (97%)	2 (3%)	71
Total	132	385	517

The coastal lagoons are generally located in or near urban areas, where they are readily accessible to people. This intensifies human occupation around these ecosystems. The pressure from anthropic activities has led to various modifications in the structure of the mangroves associated with these environments. The anthropic stressors differ in origin and degree and can act directly at the local level, such as the cutting down of mangrove trees, accumulation of garbage, and human invasion. At the extra-local level are modifications outside the area of the hydrographic area of the rivers that empty into the lagoons but also affect these ecosystems, such as the contamination of waters by domestic sewage and the decrease in river flow due to the diversion of river courses.

Among the principal impacts on mangrove forests associated with coastal lagoons of Paraíba are deforestation and human occupation along the mangrove area, where their effects on mangrove forests are immediate. An example is the lagoon at Intermares, located in the Municipality of Cabedelo, where a marked deforesting of the mangrove swamp areas was recorded by Alves and Sassi [6], with as much as 1576.2 cut trees/0.1 ha. Associated with deforestation, urban expansion has further aggravated the degradation of the vegetation. Logging takes place without any concern for forest regeneration, besides breaking environmental laws declaring the mangrove swamps as permanent preservation areas. Due to urban expansion, the adjacent mangrove areas rapidly lose their functions and turn into foci for insect breeding and clandestine garbage dumping.

Fig. 5. Flooding and silting in the mangrove of Bucatu lagoon, State of Paraíba. Individuals of *L. racemosa* dead (in the center). Photo by Rômulo Alves.

The impacts along the river basins that form the lagoonal systems deserve to be pointed out. The diversion of river courses, channeling, and road construction modify the water flow to the interior of the lagoons, directly affecting their associated ecosystems. Carmo [29] notes that alterations in river courses, channeling, drainage, sewage, or other factors that interfere with normal water flow can cause modifications in sedimentation or in the water level, structurally altering the forest or even killing the trees. All of these stressors were recorded in the surveyed area and in other lagoonal coastal systems of Paraíba State. Unfortunately, the lack of supervision or punishment of the violators has made increasing degradation of the environment even easier.

Another factor that needs to be emphasized is that many human traditional communities living close to estuarine areas are directly dependent on resources from the mangrove swamps. In recent years, with the recognition of the ecological and social importance of estuarine environments, studies have intensified in these areas, but the majority have been carried out in large estuaries, mainly those that show evident economic or social importance [30-42], but the coastal lagoons and microbasins along the Brazilian coast, especially in poorer areas, are still very poorly studied.

Despite growing degradation, mangrove-associated fauna can still be found occasionally (small monkeys, alligators, several birds), including animals protected by law such as marine turtles, which come to the beaches of this region to lay their eggs. It should be noted that the lack of inspection and failure to prosecute offenders have facilitated the growing degradation of the environment in question. Therefore, it is of urgent and fundamental importance to establish programs to maintain this ecosystem's integrity.

Acknowledgements

We are grateful to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support, process no. 524.154/96, and for providing a research fellowship to the first and second authors. Dr. Breno Grisi and Dr. A. Leyva helped with the English translation and editing of the manuscript. The first and second authors would like to thank CNPq for providing a research fellowship.

References

[1] Suguio, K. 1992. *Dicionário de Geologia Marinha*. Ed. Bisordi, LTDA, São Paulo.

[2] Vannucci, M. 2001. What is so special about mangroves? *Brazilian Journal of Biology* 61:599-603.

[3] Walters, B. B., Rönnbäck, P., Kovacs, J. M., Crona, B., Hussain, S. A., Badola, R., Primavera, J. H., Barbier, E. and Dahdouh-Guebas, F. 2008. Ethnobiology, socio-economics and management of mangrove forests: A review. *Aquatic Botany* 89:220-236.

[4] French, P. 1997. *Coastal and estuarine management*. Routledge, London.

[5] Odum, W. E. and Johannes, R. E. 1975. The Response of Mangroves to Man-Induced Environmental Stress. In: *Tropical Marine Pollution*. Wood, E. J. F. and Johannes, R. E. (Eds.), pp.52-62. Elsevier (Oceanography Series).

[6] Alves, R. R. N. and Sassi, R. 2003. Phytosociological Characteristics and Anthropogenic Impacts on The Mangrove of Intermares Coastal Lagoon, Northeastern Brazil. *Tropical Oceanography* 31:135-147.

[7] Sassi, R. 1997. *Estudo Integrado das Lagunas Costeiras do Estado da Paraíba*. Report. Universidade Federal da Paraíba, Núcleo de Estudos e Pesquisas de Recursos do Mar, 111p + anexos.

[8] Schaffer-Novelli, Y. and Cintrón, G. 1986. *Guia para estudos de áreas de manguezal: estrutura, função e flora*. Caribbean Ecological Research, São Paulo.

[9] Soares, M. L. G. 1999. Estrutura vegetal e grau de perturbação dos manguezais da Lagoa da Tijuca, Rio de Janeiro, RJ, Brasil. *Revista Brasileira de Biologia* 59:503-515.

[10] Rodal, M. J. N., Sampaio, E. V. S. B. and Figueiredo, M. A. 1992. *Manual sobre métodos de estudo florístico e fitossociológico - ecossistema caatinga*. Sociedade Botânica do Brasil, Brasília.

[11] Coutinho, S. M. V. 1999. *Impactos ambientais nas microbacias do litoral sul do Estado da Paraíba: ênfase nos aspectos sócio-ambientais e características estruturais do mangue na laguna de Camurupim*. Thesis. Universidade Federal da Paraíba, João Pessoa.

[12] Soares, D. M. B. 2000. *Considerações ecológicas do manguezal da laguna de Jacarapé, João Pessoa, PB, e as interferências antrópicas na sua área de influência*. Thesis. Universidade Federal da Paraíba, João Pessoa.

[13] Soares, M. L. G. and Tognella, M. M. P. 1994. *Diagnóstico ambiental dos manguezais próximos ao empreendimento Marina Guarujá, Guarujá, São Paulo*. Report.

[14] Smith III, T. J. 1992. Forest structure. In: *Coastal and estuarine studies. Tropical mangrove ecosystems*. Robertson, A. I. and Alongi, D. M. (Eds.), pp.101-136. American Geophysical Union Washington, D.C.

[15] Thom, B. G. 1967. Mangrove ecology and deltaic geomorphology: Tabasco, Mexico. *The Journal of Ecology* 55:301-343.

[16] Ellison, J. C. 1999. Impacts of sediment burial on mangroves. *Marine Pollution Bulletin* 37:420-426.

[17] Craighead, F. C. and Gilbert, V. C. 1962. *The effects of Hurricane Donna on the vegetation of southern Florida*. Quarterly Journal of the Florida Academy of Sciences.

[18] Lee, S. K., Tan, W. H. and Havanond, S. 1996. Regeneration and colonisation of mangrove on clay-filled reclaimed land in Singapore. *Hydrobiologia* 319:23-35.

[19] Milliman, J. D. and Meade, R. H. 1983. World-wide delivery of river sediment to the oceans. *The Journal of Geology* 91:1-21.

[20] Ellison, A. M. and Farnsworth, E. J. 1993. Seedling survivorship, growth, and response to disturbance in Belizean mangal. *American Journal of Botany* 80:1137-1145.

[21] Thampanya, U., Vermaat, J. E. and Terrados, J. 2002. The effect of increasing sediment accretion on the seedlings of three common Thai mangrove species. *Aquatic Botany* 74:315-325.

[22] Terrados, J., Thampanya, U., Srichai, N., Kheowvongsri, P., Geertz-Hansen, O., Boromthanarath, S., Panapitukkul, N. and Duarte, C. M. 1997. The Effect of Increased Sediment Accretion on the Survival and Growth of Rhizophora apiculata Seedlings. *Estuarine, Coastal and Shelf Science* 45:697-701.

[23] McKee, K. L. 1993. Soil Physicochemical Patterns and Mangrove Species Distribution--Reciprocal Effects? *Journal of Ecology* 81:477-487.

[24] Youssef, T. and Saenger, P. 1996. Anatomical adaptive strategies to flooding and rhizosphere oxidation in mangrove seedlings. *Australian Journal of Botany* 44:297-313.

[25] Hatton, J. C. and Couto, A. L. 1992. The effect of coastline changes on mangrove community structure, Portuguese Island, Mozambique. *Hydrobiologia* 247:49-57.

[26] Cintrón, G., Lugo, A. E., Pool, D. J. and Morris, G. 1978. Mangroves of arid environments in Puerto Rico and adjacent islands. *Biotropica* 10:110-121.

[27] Souza, M. M. A. and Sampaio, E. V. S. B. 2001. Variação temporal da estrutura dos bosques de mangue de Suape-PE após a construção do porto. *Acta Botanica Brasilica* 15:1-12.

[28] Jimenez, J. A., Lugo, A. E. and Cintron, G. 1985. Tree mortality in mangrove forests. *Biotropica* 17:177-185.

[29] Carmo, T. M. S. 1987. *Os manguezais da Baía Norte de Vitória, Espírito Santo*. ACIESP.

[30] Alves, R. R. N. and Nishida, A. K. 2002. A ecdise do caranguejo-uçá, Ucides cordatus L. (DECAPODA, BRACHYURA) na visão dos caranguejeiros. *Interciencia* 27:110-117.

[31] Nordi, N., Nishida, A. K. and Alves, R. R. N. 2009. Effectiveness of Two Gathering Techniques for Ucides cordatus in Northeast Brazil: Implications for the Sustainability of Mangrove Ecosystems. *Human Ecology* 37:121-127.

[32] Alves, R. R. N., Nishida, A. and Hernandez, M. 2005. Environmental perception of gatherers of the crab 'caranguejo-uca' (Ucides cordatus, Decapoda, Brachyura) affecting their collection attitudes. *Journal of Ethnobiology and Ethnomedicine* 1:10.

[33] Nishida, A. K., Nordi, N. and Alves, R. R. N. 2006. Mollusc Gathering in Northeast Brazil: An Ethnoecological Approach. *Human Ecology* 34:133-145.

[34] Nishida, A. K., Nordi, N. and Alves, R. R. N. 2006. Molluscs production associated to lunar-tide cycle: a case study in Paraíba State under ethnoecology viewpoint. *Journal of Ethnobiology and Ethnomedicine* 2:6.

[35] Alves, R. R. N. and Nishida, A. K. 2003. Aspectos socioeconômicos e percepção ambiental dos catadores de caranguejo-uçá *Ucides cordatus cordatus* (L. 1763) (Decapoda, Brachyura) do estuário do Rio Mamanguape, Nordeste do Brasil. *Interciencia* 28:36-43.
[36] Nishida, A. K., Nordi, N. and Alves, R. R. N. 2006. The lunar-tide cycle viewed by crustacean and mollusc gatherers in the State of Paraíba, Northeast Brazil and their influence in collection attitudes. *Journal of Ethnobiology and Ethnomedicine* 2:1-12.
[37] Firmo, A. M. S., Tognella, M. M. P., Silva, S. R., Barboza, R. R. D. and Alves, R. R. N. 2012. Capture and commercialization of blue land crabs ("guaiamum") Cardisoma guanhumi (Lattreille, 1825) along the coast of Bahia State, Brazil: an ethnoecological approach. *Journal of Ethnobiology and Ethnomedicine* 8:12.
[38] Alves, R. R. N. 2012. Relationships between fauna and people and the role of ethnozoology in animal conservation. *Ethnobiology And Conservation* 1:1-69.
[39] Rocha, M. S. P., Mourão, J. S., Souto, W. M. S., Barboza, R. R. D. and Alves, R. R. N. 2008. Uso dos recursos pesqueiros no Estuário do Rio Mamanguape, Estado da Paraíba, Brasil. *Interciencia* 33:903-909.
[40] Nascimento, D. M., Ferreira, E. N., Bezerra, D. M., Rocha, P. D., Alves, R. R. N. and Mourão, J. S. 2012. Capture techniques' use of Caranguejo-uçá crabs (Ucides cordatus) in Paraíba state (northeastern Brazil) and its socio-environmental implications. *Anais da Academia Brasileira de Ciências* 84:1051-1064.
[41] Firmo, A. M. S., Tognella, M. M. P., Có, W. L. O., Barboza, R. R. D. and Alves, R. R. N. 2011. Perceptions of environmental changes and Lethargic crab disease among crab harvesters in a Brazilian coastal community. *Journal of Ethnobiology and Ethnomedicine* 7.
[42] Rosa, I. L., Alves, R. R. N., Bonifacio, K., Mourão, J. S., Osorio, F., Oliveira, T. P. R. and Nottingham, M. 2005. Fishers' knowledge and seahorse conservation in Brazil. *Journal of Ethnobiology and Ethnomedicine* 1:1-12.