RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Biogeography and ecology of the mangroves ecosystem from the semi-arid coast of the Northeast Brazil[1]

Edson Vicente da Silva [*], Francisco Davy Braz Rabelo [**], Luiz Antonio Cestaro [***]

[*] Departamento de Geografia, Universidade Federal do Ceará, cacauceara@gmail.com
[**] Centro de Estudos Superiores de Tefé, Universidade do Estado do Amazonas, davyrabelo@yahoo.com.br
[***] Departamento de Geografia, CCHLA, Universidade Federal do Rio Grande do Norte , lacestaro@gmail.com

DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

[1]With funding by Project CAPES PGPSE Proc.s 88887.123947/2016-00 and 88881-195790/2018-01 named Sistemas Ambientais Costeiros e Ocupação Econômica do Nordeste (Environmental systems and economic occupation of the Northeast).

Abstract

The northern coast of Brazil presents a section where the semi-arid climate determines particular characteristics to the estuaries and mangroves. The objective of this work was to segment the mangroves of this section and describe the distribution of the species of flora and fauna in the ecosystem, according to the different environmental compartments, and enumerating the main environmental services carried out by the mangroves in the region. The study area extends from the estuary of the Cardoso and Camurupim rivers in Luís Correia in Piauí (41° 28' long W) to the Cabo de Calcanhar in Touros in Rio Grande do Norte (35° 29' 22" long W), in an approximately 790 km extension. Most of the area is under a slightly wetter climate, As, with a longer annual wet period, while a driest climate, BSh, controls from Areia Branca (RN) to Pedra Grande (RN). Five sectors of coast were individualized and delimited according to the similarity of theirs estuaries and mangroves. Four associations of plant species were identified, whose distribution is associated with the mangrove internally dominant environmental characteristics. The most frequent animal species are presented according to the habitats identified in relation to the frequency of tidal floods. At the end, the ecosystem functions and services identified for local mangroves are listed. The semi-arid climate exerts a strong influence on local mangroves, both in the development of plant species and in the internal distribution of plant and animal associations.
Keywords: hypersaline estuaries, mangrove ecology, Northeast Brazil mangroves, ecosystem functions, ecosystem services.

Resumo

O litoral setentrional do Brasil apresenta um trecho onde o clima semiárido determina características particulares aos estuários e aos manguezais locais. O objetivo deste trabalho foi setorizar os manguezais e descrever a distribuição das espécies da flora e da fauna no ecossistema, de acordo com os diferentes compartimentos ambientais e enumerando os principais serviços ambientais exercidos pelos manguezais nesse trecho do litoral. A área de estudo de estende do estuário dos rios Cardoso e Camurupim em Luís Correia no Piauí (41°28' long S) até o Cabo de

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Calcanhar em Touros no Rio Grande do Norte (35°29' 22" long S), numa extensão de aproximadamente 790 km. A maior parte da área está sob um clima um pouco mais úmido, As, com um período úmido anual mais longo, enquanto o clima mais seco, BSh, se estende desde Areia Branca (RN) até Pedra Grande (RN). Foram individualizados e delimitados cinco setores onde os estuários e manguezais são mais semelhantes entre si. Nos manguezais foram identificadas quatro associações de espécies vegetais, cuja distribuição está associada às características ambientais dominantes. São apresentadas as espécies da fauna mais comuns de acordo com a frequência de inundação pelas marés. Ao final são elencados as funções e os serviços ecossistêmicos identificados para os manguezais locais. O clima semiárido exerce influência acentuada sobre os manguezais locais, seja no desenvolvimento das espécies de mangue, seja na distribuição interna das associações vegetais e animais.

Palavras chaves: estuários hipersalinos, ecologia de manguezais, manguezais do nordeste do Brasil, funções ecossistêmicas, serviços ecossistêmicos.

I. INTRODUÇÃO

The mangroves are tropical and subtropical ecosystems situated at the interface between marine, fluvial, terrestrial and atmospheric systems, possessing amphibian properties due to tide frequency and climatic and fluvial steady state (ICMBIO, 2018). Located on the costal strips between low and high tides with higher concentration in estuary zones and low fluvial courses of tropical 123 countries, the mangroves occupy around 150,000 km², with larger areas (51,049 km²) and diverse flora species in the southeast of Asia, followed by South America (23,883 km²) (SPALDING et al., 2010). In Brazil, occurring from the Oiapoque (AP) unto Laguna (SC), the mangroves stretch for 13,989.13 km², of which 6,958.43 km² (49.74%) are in the Northeast region (HERZ, 1991; LEÃO et al., 2018).

The processes derived from the dynamic deposition of sediments, of fluvial water flows, tides and costal drifts, beyond the salinity dynamic, over that the climate is predominant, are those that exert larger influence on the genesis and the development of mangroves (LACERDA, 2002; SINGH e ODAKI, 2004). These estuarine ecosystems possess great ecological and social economic relevance, providing an important quantity of services for the human society (EWEL et al., 1998; VANNUCCI, 2002; GUEDES et al., 2017).

A greater part of the Brazilian septentrional coast is under the domain of semi-arid climates (IBGE, 2010; 2002). In such environments, where the evapotranspiration exceeds the precipitation during most part of the year, the estuaries tend to be positive, also called hypersalines (SAVENIJE & PAGÈS, 1992; LARGIER, 2010; RAMOS e SILVA et al., 2010). The organisms that inhabit the estuaries are strongly influenced by salinity, determining communities with composition and structures strictly associated with salinity patterns (DUKE et al.,

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

1998; MATTHIJS et al, 1999; JOSHI & GHOSE, 2003; MEDEIROS et al., 2010). In the Brazilian semi-arid estuaries, therefore, mangroves have fauna and flora communities with characteristics associated with hypersalinity (RAMOS E SILVA et al., 2010; SERPE et al., 2010; COSTA et al., 2014) that, probably, differentiate them from the mangroves where the presence of freshwater is greater.

Thus, the objectives of this study are to put in groups or sectors, according its similarity, the existing mangroves throughout the hypersaline estuaries of the semi-arid coast of the Northeast of the Brazil, to indicate the species of fauna and flora presents according to the different compartments of the ecosystem and to list the principal environmental functions and services exercised by the mangroves of these estuaries.

II. MATERIAL AND METHODS

Study area

The object of study involves the ensemble of mangroves existing in an extension of approximately 790 km of the Brazilian northern coast, from de estuaries of the rivers Cardoso and Camurupim in Luís Correia in Piauí (41° 28' W) up to the Cabo de Calcanhar in Touros in Rio Grande do Norte (35° 29' 22" W). This stretch of the coast encompasses part of the coastal compartment defined and delimited by Muche & Nicolodi (2008) as the Brazilian North Semi-arid Coast and the entire South Semi-arid Coast. According to Maia et al. (2006), the study area is part of the ecoregion Brazilian Northeast Semi-arid Coast.

Two climate types dominate the study area, according to the Köppen-Geiger climate classification (KOTTEK et al., 2006; ALVARES et al., 2013): Climate of Equatorial Savannah with dry summer (As) and the Climate Arid of Steppe (BSh). Both with elevated temperatures throughout the year and with monthly averages rarely descending below 24°C. The driest climate (BSh) extends from Areia Branca (RN) to Pedra Grande (RN) for approximately 150 km of coastline, with annual precipitation totals, on average, below 700 mm and a raining period (monthly precipitation averages above 100 mm) from two to three months a year (FICK & HIJMANS, 2017). A larger extension of the study area, nonetheless, is under the domain of a slightly less dry climate (As), with annual precipitation totals, on average, between 850 mm and 1,200 mm, and a longer annual humid period, lasting four to five months. These climatic conditions reflect in the capture of surface, as well as underground, fresh water by rivers and estuarine plains. Thus, in the climatically drier portion of the study area, the rivers are intermittent and, in the more humid areas, the tendency is for rivers fed by fresh water for a longer period, remaining perennial in exceptionally rainy years. The negative balance between annual precipitation and

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

evapotranspiration associated with little few fresh water entry determine the higher than normal salt content in water, soil and sediment inside the local estuaries (RAMOS E SILVA et al., 2010; COSTA et al., 2014).

Procedures

A field survey was carried out in most estuaries and mangroves present in the study area, using as a strategy direct observation, survey of materials and interviews with residents and users of the mangroves with more in-depth local knowledge. The identification of flora and fauna species was done through the consultation of literature, sites, databases and taxonomy experts.

Databases such as Reflora (http://reflora.jbrj.gov.br), specieslink (www.splink.org.br), Planeta Invertebrados (www. planetainvertebrados.com.br), sealifebase (www.sealifebase.ca), FishBase (https://www.fishbase.se), WoRMS – World Register of Marine Species (www.marine species.org), Avibase (https://avibase.bsc-eoc.org/avibase.jsp), and táxeus (https://taxeus.com.br) were consulted the verify the valid scientific name and the common name, in English, of the species. The common names, in Portuguese, are those used by the local people. Information on the presence, characteristics, habitat and uses of the species of the mangroves, in diverse places in the study area, were obtained from the literature, observations and interviews with local people. The phytoecological associations were identified from the observations.

The distribution of fauna in the mangroves was recorded according to the level of reach of the tidal waters, where the species were observed in the field survey and indicated to be present by the local people. The interviews followed the technique used by Silva (1987). Three ranges, or habitats layers, of fauna distribution in the mangroves were considered: low, medium and high. The low coastal level corresponds to the muddy soil and the areas frequently reached by tides, where the more frequent and abundant species are euryhalines and, therefore, can be shared with the marine environment. The middle coastal level corresponds to environments established by the strip between soil surface and the superior limit of the aerial and props roots of the trees, being reached by higher tides. The high coastal level corresponds to the peripheral environments of the mangrove, rarely affected by the tides, and where the presence of species does not depend directly on the water salinity.

The ecosystem services were identified from information obtained in interviews with local residents and in the literature, and classified according to HEINES-YOUNG and POTSCHIN (2013).

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

III. RESULTS AND DISCUSSION

3.1. The distribution of mangroves of the Brazilian northeast semi-arid coast

The main areas of mangroves on the coastal stretch in question were divided into five sectors: Mangroves of Piauí, Mangroves of western Ceará, Mangroves of the Metropolitan Region of Fortaleza, Mangroves of eastern Ceará and Mangroves of northern Rio Grande do Norte (Figure 1).

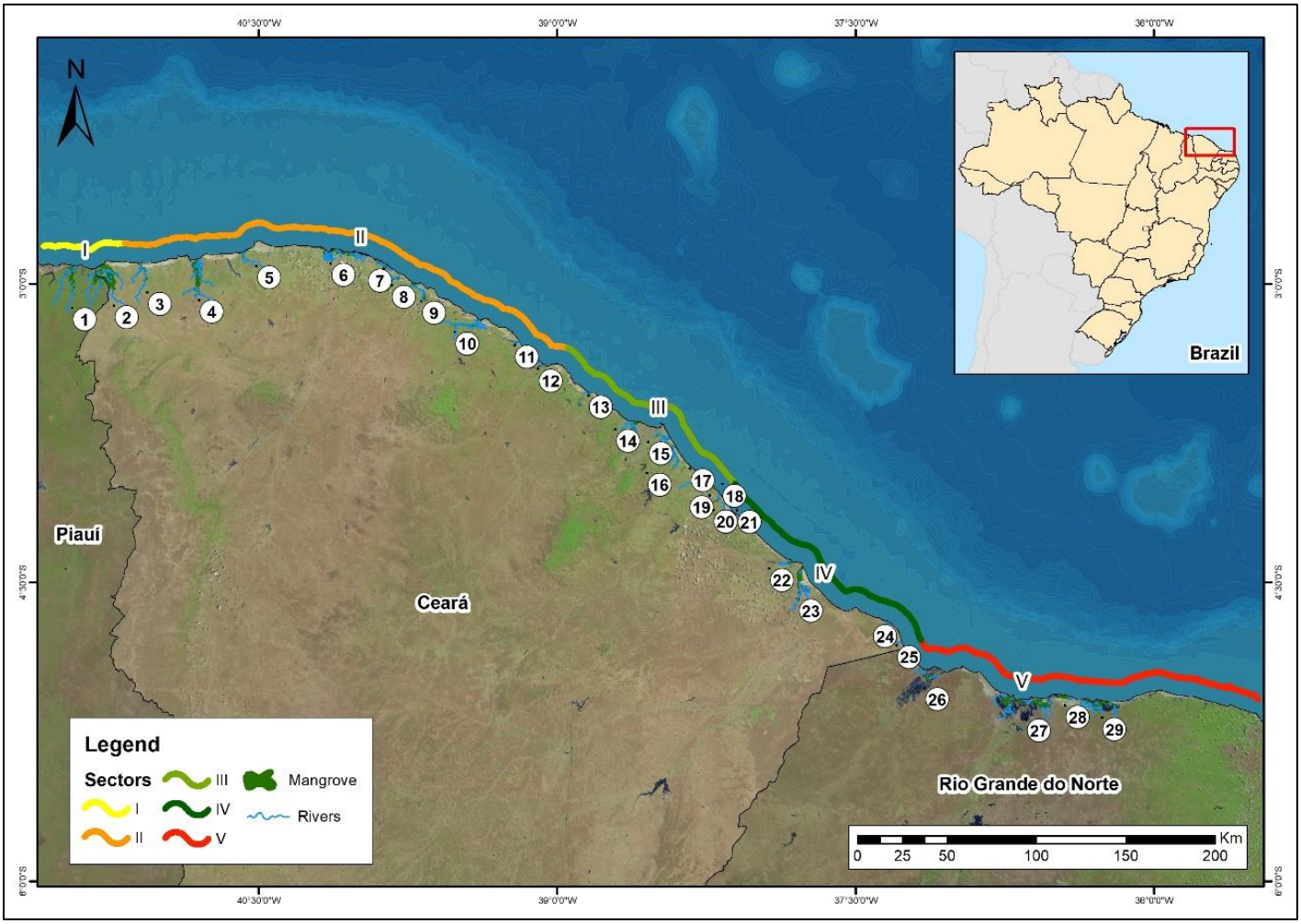

Figure 1. Sectors of the Brazilian northeast semi-arid coast and related estuaries/mangroves (The numbers inner the circles represents the mangrove areas identified in Table 1).

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Table 1. Sectors of mangroves in the semi-arid coast of northeastern Brazil and their mains estuaries and mangroves (See their localizations in Figure 1).

Sectors (790 km long)	Main areas of mangroves
I – Piauí Mangroves (30 km long)	1 - Cardoso / Camurupim estuary
	2 - Ubatuba / Timonha estuary
	3 - Remédios
II – Western Ceará Mangroves	4 - Rio Coreaú estuary
(270 km long)	5 - Rio Guriú / Mangue Seco
	6 - Rio Acaraú
	7 - Rio Zumbi estuary
	8 - Rio Aracati Mirim estuary
	9 - Rio Acacatiaçu estuary
	10 - Rio Mundaú estuary
	11 - Lagamar do Sal
	12 - Rio Curú estuary
III – Mangroves of the Metropolitan	13 - Guaribas estuary
Region of Fortaleza	14 - Ceará estuary
(130 km long)	15 - Cocó estuary
	16 - Pacoti estuary
	17 - Iguape
	18 - Marisco / Barro Preto
	19 - Batoque
	20 - Malcozinhado / Águas belas estuary
IV – Eastern Ceará Mangroves	21 - Barra Nova / Choró estuary
(140 km long)	22 - Pirangi estuary
	23 - Jaguaribe estuary
	24 - Barra Grande
V – Mangroves of northern Rio Grande	25 - Arrombado
do Norte	26 - Apodi / Mossoró estuary
(220 km long)	27 - Piranhas / Açu estuary
	28 - Barreiras / Diogo Lopes
	29 - Guamaré / Galinhos

The Piauí Mangroves (Sector I) occur on a stretch of coastline of approximately 30 km and are under the influence of largest pluviometric volumes and the estuaries make up large sedimentary deposits with consolidated island environments. The surrounding involve tabular surfaces associated with the Barreiras Geological Formation. There are no dune formations in the area.

The estuaries and mangroves of the Setor II (Western Ceará Mangroves), in a stretch approximately 270 km long, are characterized by the more intense geomorphogenic dynamics due to the predominance of dune fields in their surroundings. Coastal arrows formation and temporary closure of estuarine bars are common in this sector.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

The Sector III, 130 km long, involving the Mangroves of the Metropolitan Region of Fortaleza, presents small rivers supplied mainly by water contributions of orographic precipitation. The surroundings of estuaries presents dunes and coastal tableland environments.

The Eastern Ceará Mangroves (Sector IV), in a stretch approximately 140 km long, are associated to estuaries subjected to the indirect effects of irregular pluviometry that supplies the rivers that drain the Sertaneja Depression. The drainage, therefore, presents a marked seasonal behavior and dune fields and cliffs of the Barreiras Group form the surroundings.

The Mangroves of northern Rio Grande do Norte, the Sector V, 220 km long, form low forests in hypersaline estuaries, were the geomorphological dynamic are high. Here, estuaries were, before the advent of dams, subject to relatively high inflows of fresh water and sediment during the short and irregular rainy season.

Vegetation, flora and its characteristics

In Brazil the words "manguezal" and "mangue" do not have the same meaning. While the former is used to designate the ecosystem and its vegetation, the last term designates the plant species present in the mangrove forest (Schaefer-Novelli, 2018).

The mangrove vegetation is halophilic and classified as Manguezal Sempre Verde Paludoso Marinho (Mangrove Evergreen Swampy Marine Vegetation) by Fernandes (1998) and as Formação Pioneira Arbórea com Influência Fluviomarinha (Pioneer Arboreal Formation with Estuarine Influence) by IBGE (2012).

Distributed around the tropical estuaries of the world, the mangrove flora are low diversified. In the study area, it is associated to Phytogeographic Neotropical Kingdom, Atlantic Provence, Coastal Subprovence, Mangrove or Swampy Sector, according to Fernandes (1998, p. 251), and is composed of three families, four genera and five tree species: Rhizophoraceae (*Rhizophora mangle*), Acanthaceae (*Avicennia germinans*, *A. schaueriana*) and Combretaceae (*Laguncularia racemosa* and *Conocarpus erectus*). Besides the mangrove feature, in the estuaries are identified too the salt flat (apicum and salgado, in Portuguese), which is a flat place, very salty and slightly higher than around. In this habitat, vegetation is scarce and composed of essentially halophilic herbaceous species (Schaefer-Novelli, 2018).

Rhizophora mangle, whose common names are Red mangrove, mangue-sapateiro, mangue-vermelho and mangue-verdadeiro in Portuguese, is a tree species of wide geographical distribution, which reaches heights of up to 17 meters in the study area, occupying channel banks in soils with a high percentage of silt and clay. It

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

has a good adaptation to conditions of lower relative salinity and its leaves are covered with wax and tannin, which slows the process of decomposition and integration of the organic matter to the soil.

R. mangle hold a system of stilt roots, for a better fixation of the trees in the muddy soil, and presents lenticels (lenticular opening) for oxygen assimilation. The specie exhibits a physiological system that allows salt water to be filtered through the absorption of salts by the roots. In terms of reproduction, it is a viviparous species, once its fruit will only detach from the tree when it reaches a level of development like a seedling, already germinated. The propagules possess an elevated floating capacity and ability of remaining a long time in the salt water, supporting high levels of salinity. The system of the propagule dispersion depends on the intensity and the duration of the water flows in the mangroves. The best place for seedlings fixation are always under the treetops close to the rhizophores of the own species. The wood is used in the construction of rooftops, as well as provide wood and coal for domestic use. As for the trunk bark are applied in infusions in the cure of dysentery and hemorrhaging, also serving as a dye for clothes and fishing equipment.

Laguncularia racemosa, whose common names are White mangrove, mangue-branco, mangue-manso and mangue-rajadinho, is a tree species reaching heights of up to 15 meters and occupies areas of more recent sedimentation. Its leaves present a faster decomposition in the aquatic environment, and microorganisms at the base of food chain quickly digest them. Coating the base of the trunk of the trees are lenticels to facilitate the exchange of gases with the atmosphere. Possess a root system not very deep, which presents respiratory roots (pneumatophores). The leaves have salt excretory glands in the blade and nectaries in the petiole, whose function is to attract ants, which protect the plant from herbivorous insects.

L. racemosa is a semi viviparous species, once its seeds germinate with contact with water, which is also its means of dispersion. After fallen, the fruit can remain floating during up to a month and, due to its reduced size, it reaches wide dispersion areas, following the direction of the water flows. In stress conditions, the species can sprout on the trunk and branches. This species provides wood for navigational equipment (mast for raft, for instance), and for lumber for rooftop, fence and coal. It is the regionally most explored species among the mangrove tree species, which can cause high environmental damage to the mangrove ecosystems, mainly because it is the dominant specie on the flooded margins of the estuarine plains.

Avicennia germinans and *Avicennia schaueriana*, whose common names are Black mangrove, mangue-preto, mangue-siriuba and mangue-canoé, are two tree species very similar, with little morphological differentiations on the leaves and flowers. Its average height is 18 meters, and its leaves have a lighter green

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

color than the other local species. In the study area, *A. germinans* is more abundant than *A. schaueriana*. Both species has the highest tolerance to adverse physical and climatic conditions, occurring mainly where the soils are more salty and sandy. These species stand out for the large amount of pneupatophores and, like *L. racemosa*, have excretory salt glands in the leaves. In addition, like the others mangue tree species, *A. racemosa* e A. schaueriana are semi viviparous and present hydrochory, with seedlings that can float supported by cotyledons forb along many weeks. Like L. racemosa, under stress conditions black mangrove can also sprout on branches and trunk. These species have their trunk used for masts and for others vessels parts that require a prolonged contact with marine waters. Also offer wood for the building of houses, fences and coal.

Conocarpus erectus (Buttonwood, button mangrove, mangue-de-botão or ratinho-ratinho) is a shrub of large to medium stature (5 meters to 8 meters in height), that develops in more external surfaces and peripheral of estuarine plain, where sandy soils are predominant. This species do not present vivipary characteristics, and the seeds dispersion occurs by gravity, wind or animals. The species has high budding capacity in trunks and branches, and can occupy dune fields and lake margins in interdune plains. Buttonwood possess a heavy and compact wood, used in internal and external parts of vessels, serving as well as stake for fences, rafters and fuel.

Some flora species are considered facultative in the mangrove, like the shrub *Dalbergia ecastaphyllum* (Coin-vine or cipó-bugi), that occupy the sandy borders of estuarine plains, *Acrostichum aureum* (Mangle fern or samambaia-do-mangue,) and *Typha domingensis* (Southern cattail, tabuba or taboa), herbaceous plants that appear in the contact of mangroves with environments less salinized or near a freshwater source.

Phytoecological associations of mangroves

The mangroves in the study area are composed of four main phytoecological associations: Mgl (*L. racemosa*, *A. germinans*, *A. shaueriana and C. erectus*), Mgc (*C. erectus*, *L. racemosa*, *A. germinans* and *A. schaueriana*), Mgr (*R. mangle*, *A. germinans*, *A. shaueriana* and *C. erectus*) and Mga (*A. germinans*, *A. shaueriana* and *R. mangle*). Studies performed by Silva (1987) demonstrated that the formation of these phytoecological associations occurred as consequence of structure and formation of the soil/sediment, variations of freshwater contents and marine water flows in the inner part of the mangrove. The association Mgl, where *L. racemosa* is the more frequent species, forms the mangroves of estuaries flootplains with greater flow of freshwater. There the shrub *D. ecastaphyllum* is recurrent in the periphery of the mangrove better preserved. In degraded areas, in mangrove borders and in surfaces of recent sediment accumulation the frequence of *L. racemosa* is greater.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

In the sectors where the mangrove association Mgc occurs, with *C. erectus* as predominant, is noticed a more striking presence of sandy soil surrounding the nuclear surfaces of the mangrove. The presence of *C. erectus* is an indicator of the dune advance over the edge of the mangroves. In these associations, species from other communities, such *Byrsonima* spp (murici) and *D. ecastaphyllum*, occur in areas where sandy sedimentation caused by the wind predominates.

The third association, Mgr, has *R. mangle* as a dominant species, found in environments with better conservation state and near the margins of estuary channels. Swampy species, such *A. aureum* and *T. domingensis*, are present upstream of the mangroves with permanent supply of fresh water.

The Mga association has as dominant species *A. germinans* and *A. schaueriana* and occurs in the sectors with elevated estuary salinity, or even occupying almost all the estuary, such is the case of the River Apodi-Mossoro, in the sector 5 (Costa et. al. 2014).

Mangrove edges, degraded mangrove surfaces, recently sedimented mangroves and salt flats are partially occupied by halophytic herbaceous vegetation. The main species are graminoids and or herbaceous, with emphasis for: ***Ruellia paniculata*** (Acanthaceae), *Blutaparon portulacoides* (Amaranthaceae), ***Sesuvium portulacastrum*** **(Aizoaceae),** *Euploca polyphylla* (Boraginaceae), *Cyperus* spp. (Cyperaceae), *Euphorbia sp.* (Euphorbiaceae), *Aeschynomene evenia*, *Chamaecrista diphylla*, *Crotalaria retusa*, *Desmodium triflorum*, *Indigofera microcarpa* and *Stylosantes* sp. (Fabaceae), *Schultesia guianensis* (Gentianaceae), *Mesosphaerum suaveolens* (Lamiaceae), *Sida ciliaris* (Malvaceae), *Paspalum vaginatum* and *Panicum* sp. (Poaceae), *Borreria verticillata*, *Portulaca oleracea* (Portulacaceae), *Diodia* sp. and *Richardia scabra* (Rubiaceae), *Waltheria* sp. (Sterculiaceae) and *Xyris* sp. (Xyridaceae).

Diversity of the fauna and habitats

The mangrove fauna of the area of study is included in the Biogeographical Neotropical Region, Tupi Provence, Oceanic Sector and Mangrove Districts, according to Vasconcelos Sobrinho (1971). Some of the local fauna species possess a larger capacity of territorial displacement also occupying areas of other neighboring ecosystems, still having a faunistic distribution differentiated by the distinct microhabitats of the mangroves. Factors such as water and soil salinity regime, types of substrate and presence of habitat suitable to the species tolerance limit are conditioning factors in the distribution of fauna components.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

In the local mangroves it is possible to find marine and fresh waters, being the euryhalines the species that possess a larger potential of spatial distribution. In the periods of higher rainfall, an increase of freshwater fauna takes place, while in the drought period, when the salt water dominates the estuaries, the presence of marine fauna is amplified. The mangrove fauna is relatively much more diverse than its flora. For a better understanding of the diversity, distribution and interactions of the main faunal components of the mangrove ecosystem in question, a description of the habitats and their most prominent species will be made below, following the groups of mollusks, crustaceans, fish, reptiles, birds and mammals.

Overall, the molluscs locate with higher frequency in the proximities of the marine mouth of the mangroves. The species may be buried in the substrate or on the surface. Among the species of more density, *Tagelus plebeius* (Stout tagelus or picholeta) and *Anomalocardia brasiliana* (West Indian pointed venus or búzio) are highlighted, and are captured for complementary feeding by local people. Other species explored as food or for the production of handcraft are *Neritina virginea* (Virgin nerite or búzio), *Crassostrea rhizophorae* (Mangrove cupped opyster or ostra), *Donax striatus* (Striate donax or intã) and *Phacoides pectinatus* (Thick lucine or rapacoco).

Tagelus plebeius remains in the inside the substrate and at depths greater than one meter. It is a filter species, feeding on planktons and presents external fecundation. *Anomalocardia brasiliana* spreads through the depths and margins of the channels of the estuarine plain, burying itself temporarily and superficially, also feeds on planktons and possess external fecundation.

Neritina virginea is found in the surfaces of the mangrove edges or under tree roots of the mangrove. It is herbivore and has external fecundation. Other species of molluscs that occupy the surface of the substrate are *Macoma constricta* (Constricted macona), *Phacoides pectinatus* and *Donax striatus* (Striate donax).

All the crustaceans identified in the mangrove are of great importance in the faunal composition and ecological physiology of this ecosystem, not only due to the abundance and participation in the food chain, but also due to the other ecological functions they perform. According to environment distribution, some differentiated groups can be identified.

One group includes the swimcrabs of the Portunidae family (*Callinectes* spp) and the shrimps of Penaeidae and Palaemonidae families. The species of this group develop in the aquatic environment, are marine migrant euryhalines and can spend most of its life in the mangrove, going up through the channels reaching fresh water. The families of crabs Ucididae, Gecarcinidae, Grapisidae and Ocypodidae occupy amphibian

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

environments, in the sediment lane under the influence of fluctuations in the level of rivers and tides. The species *Macrobrachium carcinus* (Bigclaw river shrimp or camarão pitú) and *Macrobrachium acanthurus* (Cinnamon river shrimp or camarão-canela) are crustaceans stenohalines and cannot support a significant increase in water salinity, limiting their distribution to mangrove areas where there is less salt water influence.

Occupying mangrove channels, are the swimcrabs *Callinectes affinis*, *C. danae* and *C. bocurti*. These species have a large tolerance for oscillations in water salinity. The fiddler crabs, locally known as ciciés and caranguejos-violinistas, occupy the substrate, roots and treetops of the mangroves. *Leptuca leptodactyla* (Marbled fiddle crab), *Uca rapax* (Mudflat fiddler), *Uca maracoani* (Brazilian fiddler crab), *Leptuca leptodactyla* (Marbled fiddler) and *Leptuca thayeri* (Atlantic mangrove fiddler crab) are the species with greatest abundance in the substrate of the floodplain edges. These crabs have reduced size, with dimensions between two and four centimeters of shell.

Still found in the muddy substrate, are the medium port crabs (5 cm to 8 cm) such as *Euritium limosum* (Broadback mud crab or mão-no-olho) and *Sesarma rectum* (mochila or aratu). *Ucides cordatus* (Mangrove crab or caranguejo-uçá,) makes its hideout inside the substrate and in surfaces where a denser vegetation is predominant, while *Goneopsis cruentata* (Red mangrove-root crab or aratu-vermelho) resides in branches and tree trunks of the mangrove, since it feeds on its leaves. At the edge of muddy estuarine plains, where the substrate is sandy and the shrub *Conocarpus erectus* is frequent, occurs *Cardisoma guanhumi* (blue crab or guaiamum).

In the waters of the mangrove ecosystem of the study area, 39 species of fish of common occurrence, distributed in 26 families, were identified. The main species are *Ablenes hians* (Flat needlefish or zambaia), *Achirus* sp. (Sole or solha-redonda), *Anisotremus virginicus* (Porkfish or salema), *Archosargus probatocephalus* (Sheepshead or sargo), *Atherinella brasiliensis* (Brazilian silversides or varapau), *Bagre bagre* (Coco sea catfish or bagre), *Bathygobius* sp. (moré or papa-terra), *Batrachoides surinamensis* (Pacuma toadfish or pacamon), *Caranx* sp. (xaréu), *Centropomus ensiferus* (Swordspine snook or camurim), *Citharichthys spilopterus* (Bay whiff or solha-comprida), *Cynoscion sp.* (Weakfish or pescada), *Diapterus* sp. (carapeba), *Diplectrum radiale* (Pond perch or jacundá), *Elops saurus* (Ladyfish or ubarana), *Eucinostomus* sp. (carapicu or mojarra), *Genyatremus luteus* (Torroto grunt or golosa), *Haemulon melanurum* (Cottonwick grunt or tapuruna-preta), *Haemulon plumierii* (White grunt or biquara), *Haemulon* sp. (tapuruna-branca), *Lutjanus apodus* (Schoolmaster snapper or caranha), *Lycengraulis* sp. (Arenque or anchova), *Megalops atlanticus* (tarpon or camurupim), *Menticirrhus*

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

americanus (Southern kingcroaker or judeu), *Micropogonias furnieri* (Whitemouth croaker or cururuca), *Mugil curema* (White mullet or saúna ou tainha), *Mugil incilis* (Parassi mullet or tamantarana), *Mugil liza* (Lebranche mullet, coípe or tainha), *Myrophis punctatus* (Speckled worm-eel or muriongo), *Oligoplites* sp. (Leatherjacket or tibiro), *Opisthonema oglinum* (Atlantic thread herring or sardinha-bandeira), *Poecilia vivipara* (garú), *Selene setapinnis* (Atlantic moonfish or peixe-galo), *Sphoeroides testudineus* (Checkered puffer or baiacu), *Sphyraena guachancho* (Guachanche barracuda or bicuda), *Synodus foetens* (Inshore lizardfish or peixe-lagarto), *Tachysurus* sp. (Catfish or bagre,), and *Trachycorystes* sp. (Catfish or cangati).

Among the reptiles, is remarkable the presence of apredator, the snake *Boa constrictor* (jiboia), that uses the mangrove as a refuge and for capturing prey such as birds and small mammals.

The ornithofauna is quite diverse since the mangroves share species with others close environments like dunes, beach, lagoons and terrestrial ecossystems. As characteristic species of the mangroves are markable *Aramides mangle* (Little Wood-Rail or saracura-do-mangue), *Conirostrum bicolor* (Bicolored Conebill or sibite-do-mangue) and *Pardirallus nigricans* (Blackish Rail or saracura-preta), while other birds, like *Calidris minutilla* (Least Sandpiper or maçariquinho,), are migratory species. Some species have habits predominantly aquatic, like *Aramides mangle* e *Dendrocygna autumnalis* (Black-bellied Whistling-Duck or marreca-cabocla), and others have arboreal habits like the *Conirostrum bicolor*, *Elaenia spectabilis* (Large Elaenia or cucurutado), *Turdus leucomelas* (Pale-breasted Thrush or sabiá-branca).

The mammal with the most significant presence in the mangrove ecosystem, acting as a predator of molluscs and crustaceans, is *Procyon cancrivorus* (crab-eating Raccoon, guaxinim or mão-pelada,). Other species of mammals, above all rodents, move towards the mangroves temporarily, manly to quench their thirst in areas and moments where there is fresh water.

Zonal distribution of the fauna in the mangroves

In the lower habitats layer of the estuary, the dominant species are euryhalines, which also live on the marine coast. The molluscs more commons are *Neritina virginea*, *Tagelus plebeius* e *Anomalocardia brasiliana*. As for crustaceans, the predominant ones are the shrimp *Penaeus schmittii* and the swimcrabs *Callinectes affinis*, *C. danae* e *C. bocurte*. The most common fishes in this zone are *Achirus* sp., *Bagre bagre*, *Centropomus ensiferus*, *Citharichthys spilopterus*, *Cynoscion* sp. *Diapterus* sp., *Elops saurus*, *Eucinostomus* sp., *Lycengraulis* sp,

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Megalops atlanticus, *Mugil curema*, *Opisthonema oglinum*, *Sphoeroides testudineus*, *Sphyraena guachancho*, and *Tachysurus* sp.

In the medium habitats layer, are present the mollusc *Neritina virginea* and the crustaceans, each one with specific environments. *Uca maracoani* prefers substrates of little consistency and close to water (channels), *Leptuca thayeri* occurs in soils that are more consistent. *Uca rapax* prefers sand and mud, and *Leptuca lepdactyla*, occur in sandy substrates with little clay. Mid-sized crabs like *Panopeus* sp., *Euritium* limosum and *Sesarma rectum* are bound to clay shadowy by the mangrove vegetation, just as *Ucides cordatus*. In more internal channels, where the penetration of sea water is less frequent, inhabit *Macrobrachium* carcinus and *Macrobrachium acanthurus*. In the areas more distants from the sea, with lower salt levels, ichthyofauna is represented by *Hoplias* sp. (Trahira or traíra), *Crecicichla* sp. (jacundá), *Leporinus* sp. (piau) and others fishes deriving from the fluvial ecosystem.

In the upper habitats layer, formed manly by trunks and branches of trees and rarely reached by tides, are found crabs *Goneopsis cruentata*, that possess arboreal habits, and *Cardisoma* guanhum, that occupy the external strip of the mangrove, in the sandy substrate. The species of birds more frequent on this level are *Eleania spectubilis* (*Large eleania* and cucurutado), *Conirostrum bicolor*, *Turdus leucomelas* and *Coereba flaveola* (Bananaquit or sibite).

The biological activity of the fauna is very important for the transportation and the exchange of matter and energy from the mangrove with neighboring ecosystems. Its participation as primary, secondary or tertiary consumers is fundamental for the functionality of the food chain and the maintenance of the ecological balance of the mangrove.

The zoocoenosis of the mangrove is fairly active and diversified, where some species are characteristics and totally adapted to the environment. It participates directly in the energetic and material flows of the mangrove ecosystem, and some species play the role of exporters of the biomass to others peripheral ecosystems, such as the marine fishes that develop in the mangroves, returning in its adult or juvenile phase to the ocean.

Birds that migrate or constantly move to other peripheral ecosystems benefit from the animal biomass in the mangroves. Thus, the fauna in the mangroves holds an ecological importance that affects neighboring ecosystems, mainly through predators that have a wider distribution area.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Crabs play an important role in the mangrove, revolving mud, remobilizing nutrients, facilitating the circulation of water and aerating the soil by opening holes. The mangrove fauna, like any other component of this ecosystem, is essential for the maintenance of its functions, especially regarding biological productivity.

Dynamics, use and occupation of the mangroves

The mangrove ecosystem, together with salt flats (apicum and salgado), for occupying the estuarine plains, is subject to the intensity of matter and energy flows typical of coastal environments.

Climatic conditions, through rainfall and wind, offer fresh water inputs during the raining season and more intense sea breezes in the drier months, determining different dynamics throughout the year.

In the raining season, from December/January to April/May, sediments and nutrients are exported from mangrove ecosystem to the sea, offering greater fertility to the coastal marine waters. During the dry period, the sea breezes accelerate the processes of sandy sedimentation inside the mangroves by means of the advancement of dunes, beach and post beach sands.

Oscillations in the flow of marine water occur daily (two high tides and two low tides) and weekly by dead tides (periods of crescent and waning moons) and by living tides (periods of full and new moons). The former causing the least penetration of marine water, while the latter the largest. The tides directly and strongly influence the intensity of depositional or erosive processes, as well as the dispersion of seeds, seedlings and eury and stenohaline animals.

The formation of sediment banks by the water flow is accompanied by the dispersion of seeds, with *Laguncularia racemosa* being the one with the greatest dispersion capacity on the banks and channels of fluviomarine plains. *Rhizophora mangle* seedlings flow with the highest and with the lowest tides, settling exactly where there is a greater concentration of trees of the same species. The propagules of *Avicennia germinans* and *A. shaueriana* have dispersion concentrated in the nuclear areas of the mangroves, while *Conocarpus erectus* is dispersed by anemochory or zoochory.

The intensity of the flows of matter and energy in the mangroves implies morphodynamic instability that is only attenuated by the biostabilizing effect of vegetation (TRICART, 1977, RODRIGUEZ & SILVA 2018). Due to human actions, not only inside the mangroves, but also on the surrounding ecosystems, there is an intensification in the dynamics of the mangroves, sometimes slowing sometimes accelerating the processes of morphogenesis and biostabilization in the estuarines plains.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Human pressure occurs mainly through actions developed from the edges of mangroves and their drainage channels. In the study area, the anthropic actions that cause the fragmentation of mangrove vegetation and its progressive spatial reduction are mainly deforestation (production of charcoal, removal of firewood and wood), fires, construction of structures for the production of salt, and shrimp farms. Also noteworthy are the advances in coconut cultivation and other agricultural crops, as well as the construction of residences, urbanization and road structures.

The knowledge of the mangrove biogeography and ecology is essential for establishing strategies to manage the natural resources of the mangroves and measures for their preservation and recovery.

Ecosystem Services

From the observation of the mangrove ecosystem in the study area and related literature (HEINES-YOUNG, POTSCHIN, 2013; COSTA, 2017; GUEDES et al., 2017), it was possible to identify and numerate a considerable group of ecosystem functions and services provided directly and/or indirectly.

The most notably functions and services offered by local mangrove ecosystem are (i) geomorphological stabilization, (ii) conservation of water resources of surface (iii) water and soil fertilization and (iv) function as habitat and biological production.

Regarding the functions of geomorphological stabilization (biostabilization) that the mangrove exercise, the following can be highlighted:

- Fixation of unstable soils, contributing to the reduction of erosion on the banks of channels and on the estuaries.
- Replenishment of fluvial sediments in estuarine plains.
- Conservation of the balance of geomorphological processes of the neighboring coastal ecosystems, from the weathering mechanism and easing the action of sediment wind transports; and
- Contribution in the maintenance of the coastal line, due to biostabilization exerted by the vegetation.

The conservation effect of surface water resources exercised by the mangroves implies:

- Microclimatic mitigation by interference of vegetation in the evaporation rates of superficial waters;

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

- Regulation of water quality due to the assimilation of nutrients and other chemical substances and the deposition of particles in the soil of estuarine plain;
- Decreased silting of the water runoff channels and protection of vegetated margins; and
- Retention of the advance of marine waters upstream.

The fertilization of water and soil in the mangrove occurs due to the high speed of recycling, transformation and conservation of nutrients, including aid to the marine system. Regarding the importance of fertilization capacity, the following actions are mentioned:

- Nutrients enrichment in the mangrove, marine and fluvial ecosystems, through water inputs that suspend or dilute organic waste, nitrate and phosphate, and
- Exportation of organic matter to the sea, favoring the development of the food chain with basis on phytoplankton that elevates the productivity and the biomass as a whole.

The ichthyofauna stands out, both in terms of diversity and ecological niches, when mangrove is observed in terms of habitat and biological production. Among the properties that contribute to biological productivity of the local mangroves are:

- Elevated primary productivity through the mangrove vegetation, algae and phytoplankton;
- Development of a complex food chain, constituted by diversified and abundant animal species;
- Supply of substrate to benthic, excavators and nektonic species, like molluscs, crustaceans and fishes;
- Habitat for diverse bird species, as local residents as migratory;
- Temporary habitat for diverse species resident in others ecosystems like dunes, beaches, rivers and sea.

In relation to the socio-economic importance, the mangrove constitutes a great and inexhaustible source of natural resources, utilized directly by the local communities. Among its functions and services to society, are:

- Decrease in the advance of mobile dunes over the cultivated areas in water courses subjected to economic exploitation;
- Source of wood and vegetable biomass used for making utensils, for buildings and as domestic fuel.
- Availability of animal resources that are exploited through activities such as fishing and shellfish (mollusks and crustaceans);
- Area of reproduction of marine fishes of great economic value;

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

- Enriching the beauty of the coastal landscape that favours tourist exploration; and
- Location of nautical loading and unloading port structures.

IV. CONCLUSIONS

The environment of the semi-arid coast of Northeast Brazil is very dynamic. This is due to the marine currents and the intense winds, both acting predominantly from east to west. This dynamic is even more intense in local estuaries due to the particular distribution of precipitations. The intense and concentrated rainfall lead to abundant sediments and fresh water transport during the rainy season toward the estuaries. The intensive erosive and depositional processes therefore directly influence the morphological arrangement of estuaries, with immediate effects on the dynamics of the mangrove itself and, consequently, on the composition of species associations and their spatial distribution. These conditions allowed to identify five mangrove sectors in the study area. Also associated with the climate, the prevailing semi-arid conditions in the region cause prolonged periods of scarcity and even null intake of fresh water and, consequently, hypersalinization of the estuaries. High salt concentrations in the soil and/or in the water displace most species from their ecological optimum. The mangrove trees, for instance, are relatively small when compared to estuaries where fresh water intake is higher. The mangroves on the semi-arid coast of Brazil have particular characteristics, and therefore are somewhat different from those located under a climate whose rainfall is better distributed throughout the year.

V. REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; GERD, S. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Meteorological Societies of Austria, Germany and Switzerland, v. 22, n. 6, p. 711-728. 2013. Available at: 10.1127/0941-2948/2013/0507. Accessed: 12 August 2015.

COSTA, D. F. Serviços ecossistêmicos prestados pelos manguezais do Rio Grande do Norte (nordeste do Brasil). In: **XVII Simpósio Brasileiro de Geografia Física Aplicada e I Congresso Nacional de Geografia Física**, 2017, Campinas. Os desafios da Geografia Física na fronteira do conhecimento. Campinas: Instituto de Geociências - UNICAMP, 2017. p. 1127-1136. Available at: 10.20396/sbgfa.v1i2017.2025. Accessed: 12 November 2018.

COSTA, D. F.; ROCHA, R. M.; CESTARO, L. A. Análise fitoecológica e zonação de manguezal em estuário hipersalino. **Mercator**, Fortaleza, v. 13, n. 1, p. 119-126, 2014. Available at: 10.4215/RM2014.1301.0009. Accessed: 12 August 2015.

DUKE, N. C.; BALL, M. C.; ELLISON, J. C. Factors influencing biodiversity and distributional grandients in mangroves. **Global Ecology and Biogeography Letters**, Willey, v. 7, n. 1, p. 27-47, 1998.

EWEL, K. C.; TWILLEY, R. R.; ONG, J. E. Different kinds of mangrove forests provide different goods and services. **Global Ecology and Biogeography Letter**, Willey, v. 7, n. 1, p. 83-94, 1998.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

FERNANDES, A. **Fitogeografia Brasileira**. Fortaleza: Multigraf, 1998.

FICK, S. E.; HIJMANS, R. J. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. **International Journal of Climatology**, Royal Meteorological Society, v. 37, p. 4302-4315, 2017.

GUEDES, D. R. C.; BATISTA, I. S.; CESTARO, L. A.; COSTA, D. F. S. Serviços ecossistêmicos de provisão do manguezal da Reserva de Desenvolvimento Sustentável Estadual Ponta do Tubarão (Macau-RN). In: **XVII Simpósio Brasileiro de Geografia Física Aplicada e I Congresso Nacional de Geografia Física**, 2017, Campinas. Os desafios da Geografia Física na fronteira do conhecimento. Campinas: Instituto de Geociências - UNICAMP, 2017. p. 1341-1351. Available at: 10.20396/sbgfa.v1i2017.2569. Accessed: 12 November 2018.

HEINES-YOUNG, R.; POTSCHIN, M. Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012. EEA Framework Contract n° EEA/IEA/09/003, 2013. Available in: www.cices.eu. Accessed: 15 September 2015.

HERZ, R. **Manguezais do Brasil**. São Paulo: USP-Instituto Oceanográfico. 1991.

IBGE - Instituto Brasileiro de Geografia e Estatística. **Mapa de Clima do Brasil**. Escala 1:5.000.000 Rio de Janeiro: IBGE - Diretoria de Geociências. 2002. Available in: https://www.ibge.gov.br/geociencias-novoportal/informacoes-ambientais/ Accessed: 12 August 2015.

_____. **Atlas Nacional do Brasil Milton Santos**. Rio de Janeiro: IBGE, 2010.

_____. **Manual Técnico da Vegetação Brasileira**. 2. ed. Rio de Janeiro: IBGE-CDDI, 2012 (sér. Manuais Técnicos, n. 1).

ICMBIO - Instituto Chico Mendes de Conservação da Biodiversidade. **Atlas dos manguezais do Brasil**. Brasília: ICMBio, 2018.

JOSHI, H.; GHOSE, M. Forest structure and species distribution along soil salinity and pH gradient in mangrove swamps of the Sundarbans. **Tropical Ecology**, v. 44, n. 2, p. 197-206, 2003.

KOTTEK, M.; GRIESER, J.; BECK, C.; RUDOLF, B.; RUBEL, F. World map of the Köppen-Geiger climate classification updated. **Meteorologische Zeitschrift**, v. 15, n. 3, p. 259-263, 2006.

LACERDA, L. D. (ed.) **Mangrove Ecosystems: Function and Management**. Heidelberg: Springer Verlag, 2002.

LARGIER, J. Low-inflow estuaries: hypersaline, inverse, and thermal scenarios. In: VALLE-LEVINGSON, A. (ed.) **Contemporary issues in estuarine physics**. New York: Cambridge University Press, 2010. chap. 9, p. 247-272.

LEÃO, A.; PRATES, A. P. L.; FUMI, M. Manguezal e as unidades de conservação. In: ICMBIO – Instituto Chico Mendes de Conservação da Biodiversidade. **Atlas dos manguezais do Brasil**, 2018. chap. 4, p. 57 a 72.

MAIA, L. P.; LACERDA, L.D.; MONTEIRO, L. H. U.; SOUZA, G. M. E. **Atlas dos Manguezais do Nordeste; Avaliação das Áreas de Manguezal dos Estados do Piauí, Ceará, Rio Grande do Norte, Paraíba e Pernambuco**. Fortaleza: Superintendência Estadual do Meio Ambiente, 2006.

MATTHIJS, S.; TACK, J.; SPEYBROECK, D.; KOEDAM, N. Mangrove species zonation and soil redox state, sulphide concentration and salinity in Gazi Bay (Kenya), a preliminary study. **Mangrove and Salt Marshes**, Springer, v. 3, p. 243-249, 1999.

MEDEIROS, A. M. A.; BARBOSA, J. E. L.; MEDEIROS, P. R.; ROCHA, R. M.; SILVA, L. F. Salinity and freshwater discharge determine rotifer distribution at the Mossoró River Estuary (Semi-arid Region of Brazil). **Brazilian**

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.8, n.2, p. XX – XX, 11/2020
DOI: http://dx.doi.org/10.5380/raega.v49i0.65811

Journal of Biology, Associação da Revista Brasileira de Biologia, v. 70, n. 3, p. 551-557, 2010.

MUEHE, D.; NICOLODI, J. Geomorfologia. In: ZAMBONI, A.; NICOLODI, J. L. (Org.). **Macrodiagnóstico da Zona Costeira e Marinha do Brasil**. Brasília: Ministério do Meio Ambiente, 2008. chap. 2, p. 23-41.

RAMOS e SILVA, C. A.; MIRANDA, L. B. de; DÁVALOS, P. B.; SILVA, M. P. da. Hydrochemistry in tropical hypersaline and positive estuaries. **Pan-American Journal of Aquatic Sciences**, v. 5, n.3, p. 432-443, 2010. Available at: https://panamjas.org/ Accessed: 12 August 2015.

RODRIGUEZ, J. M. M.; SILVA, E. V. **Planejamento e gestão ambiental: subsídios da geoecologia das paisagens e da teoria geossistêmica**. 3. ed. Fortaleza: Edições UFC. 2018. 370 p.

SAVENIJE, H. H. G.; PAGÈS, J. Hypersalinity: a dramatic change in the hydrology of Sahelian estuaries. **Journal of Hydrology**, Elsevier, v. 135, p. 157-174, 1992.

SCHAEFFER-NOVELLI, Y. Mangue e manguezal. In: ICMBIO – Instituto Chico Mendes de Conservação da Biodiversidade. **Atlas dos manguezais do Brasil**. Brasília: Instituto Chico Mendes de Conservação da Biodiversidade, 2018. chap. 1, p. 15-20.

SERPE, F. R.; ADLOFF, C. T.; CRISPIM, M. C.; DE MEDEIROS-ROCHA, R. Comunidade zooplanctônica em um estuário hipersalino no Nordeste brasileiro. **Revista Brasileira de Engenharia de Pesca**, São Luís (MA), v. 5, n. 3, p. 51-73, 2010.

SILVA, E. V. **Modelo de aprovechamiento y preservación de los manglares de marisco y barro prieto – Aquiraz – Ceará/Brasil**. 1987. Masters dissertation. (Master degree in Planificación Rural en Función del Medio Ambiente) - Instituto Agronómico Mediterráneo de Zaragoza, Zaragoza.

SINGH, V. P. e ODAKI, K. **Mangrove Ecosystem: Structure and Function**. Jodhpur: Scientific Publishers, 2004.

SPALDING, M.; KAINUMA, M.; COLLINS, L. **World Atlas of Mangroves**. Londres, UK: Earthscan, 2010.

TRICART, J. **Ecodinâmica**. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística, 1977.

VANNUCCI, M. **Os manguezais e nós: uma síntese de preocupações**. São Paulo: EDUSP, 2002.

VASCONCELOS-SOBRINHO, J. **As regiões naturais do Nordeste, o meio e a civilização**. Recife: Conselho de Desenvolvimento de Pernambuco, 1971.