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Área de concentração: Ecologia

ESTRUTURA E SERAPILHEIRA EM UM MANGUEZAL DE ILHÉUS, BAHIA, BRASIL

LORENA LACERDA SANTOS

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Dissertação apresentada ao Programa de Pós-Graduação em Sistemas Aquáticos Tropicais da Universidade Estadual de Santa Cruz, para a obtenção do título de Mestre em Sistemas Aquáticos Tropicais

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Orientadora: Erminda da Conceição Guerreiro Couto
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Exemplos de carinho e dedicação:
À minha família

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ESTRUTURA E SERAPILHEIRA EM UM MANGUEZAL DE ILHÉUS, BAHIA, BRASIL

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RESUMO

Os manguezais são definidos como ecossistemas costeiros de baixa energia, localizados na zona banhada entre marés, em regiões tropicais e subtropicais. Dentre as fontes de matéria orgânica encontrada no manguezal, a serapilheira destaca-se como um importante fornecedor de carbono, contribuindo a partir da queda da estrutura das plantas (flor, propágulos e folhas) sobre o sedimento. A serapilheira pode ser usada como medida de produtividade dos manguezais e permite compreender a influência da biomassa vegetal sobre a alimentação dos animais e o fluxo de nutrientes. Assim, os objetivos deste estudo foram: caracterizar a estrutura do manguezal, estimar a produção de serapilheira, verificando a contribuição de cada espécie e itens em períodos seco e chuvoso e avaliar efeitos de fatores abióticos na produção de serapilheira. Após prévia caracterização fitossociológica dos bosques do manguezal, foram instalados cestos coletores ao longo de nove parcelas, orientados perpendicularmente ao rio, para estimar a produção de serapilheira. O conteúdo dos coletores foi recolhido quinzenalmente e a identificação e quantificação de cada item foram analisadas em laboratório. Amostras do sedimento em cada parcela foram coletadas para obtenção do teor de matéria orgânica Dean (1974) e granulometria (Suguio, 1973). As parcelas foram descritas e agrupadas em grupos semelhantes após Analise de Cluster. Para a serapilheira, a participação de cada item e espécies nas parcelas foi descrita e a variação temporal foi avaliada com o teste não paramétrico de Kruskall-Wallis. As diferenças encontradas na produção foram relacionadas às características estruturais dos bosques, bem como a fatores abióticos.

A dominância, densidade e granulometria foram os fatores mais importantes no agrupamento das parcelas. As parcelas mais semelhantes foram 1 e 4 e 6 e 9. Entretanto, a serapilheira não apresentou este mesmo padrão. *R. mangle* foi a espécie com maior contribuição em todos as parcelas e períodos, seguido por *A. schaueriana* e *L. racemosa*. As folhas foram o principal item na serapilheira, ocorrendo continuamente ao longo meses para todas as espécies. *R. mangle* apresentou produção contínua de flores e propágulos ao longo do tempo, e as parcelas que mais contribuíram para sua produção foram as que possuíam maior densidade desta espécie. Os picos de produção de itens foram mais marcados, entre setembro e dezembro para *A. schaueriana*. *L. racemosa* teve pouca contribuição durante todo o estudo e flores somente foram observadas em dezembro e janeiro. As espécies pareceram responder com investimento reprodutivo e renovação de folhas à chegada do verão, onde houve os maiores valores de produção. A temperatura e umidade relativa do ar pareceram ser os fatores mais importantes na determinação da fenologia das espécies.

Palavras-chaves: bosques semelhantes, produção de serapilheira, variação temporal.

STRUCTURE AND LITTERFALL IN MANGROVE ON ILHÉUS , BAHIA, BRAZIL

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ABSTRACT

Mangroves are coastal ecosystems of low energy, located in the intertidal zone in tropical and subtropical regions. The organic matter found in mangrove is from a variety of sources. Litterfall is an important supplier of carbon, contributing by fall of plants components (flower, propagules and leaves) on the sediment. Litterfall can be used as a measure of productivity of mangroves and it allows understanding the influence of plant biomass on animal nutrition and the flux of nutrients. The objectives of this study were: to characterize the structure of the mangrove; estimate litterfall production, verify the contribution of species and items during dry and wet periods and assess effects of abiotic factors on litterfall production. After preliminary fitossociological characterization of mangrove forests, litter traps were installed along nine plots to estimate the production of litter. The contents of the traps were collected fortnightly and the identification and quantification of each item were analyzed in the laboratory. Sediment samples were collected in each stand to obtain organic matter content according to Dean (1974) and granulometry (Suguio, 1973). The plots were described and grouped considering similarities after cluster analysis. For litterfall, the participation of each item and species in the plots was described and temporal variation was assessed by nonparametric test of Kruskall-Wallis. The differences in production and organic matter were related to the structural characteristics of forests, as well as abiotic factors.

The dominance, density and granulometry were the most distinctive factors of plots group. Similarities were found in plots 1-4 and 6-9. However, the pattern of litter production did not present the same trend. *R. mangle* was the species with the highest contribution in all the plots and periods, followed by *A. schaueriana* and *L. racemosa*. Leaves were the main item in the litter, occurring continuously throughout months for all species. *R. mangle* showed continuous production of flowers and propagules over time, and the plots that contributed most to it were plots that had highest density of this species. The peak production of most items was marked, between September and December to *A. schaueriana*. *L. racemosa* had little contribution throughout the study and flowers were observed only in December and January. The species seemed to respond with reproductive investment and renewal of leaves to arrival of summer, which were found the highest values of production. The temperature and relative humidity appeared to be the most important factors in determining the phenology of species.

Keywords: similar forests, litter production, temporal variation.

SUMARY

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1. INTRODUCTION

Mangroves are common ecosystems of tropical and subtropical coastal areas. The ecologic and economic importance of mangroves have been widely recognized mainly due to their role in coastline protection, as shelter for several marine species, as an important system for recycling of organic matter and nutrients, besides of being useful to human activities (Lugo & Snedaker, 1974; Odum & Heald, 1975; Laegdsgaard & Johnson, 2001 ; Röonback, 1999; Kristensen et al., 2008).

Litterfall production reflects the fall of vegetative and reproductive structures of mangrove plants caused by intrinsic and mechanic actions (Brown, 1984). Although litterfall represents only 30% of net canopy production (Kristensen et al., 2008), it represents an indirect measure usually applied to ecological studies to measure forest production and to estimate phenology periods, considering temporal scales and the equilibrium in losses and gains of vegetal air biomass (Woodroffe, 1988; Coulter et al., 2001).

Carbon from mangrove litterfall might be consumed by herbivores, stored in substrate, remineralized through decomposition or exported to adjacent systems, where the last three are the predominant pathways (Duarte & Cébrian, 1996). Although there are other carbon and nutrient sources easier and faster to be processed and assimilated than mangrove litter (Wafar et al., 1997; Bouillon, 2003; France, 1998; Loneregan et al., 1997, Kristensen et al., 2008), their contribution plays an important role since it makes nutrients available to recycling and to feeding organisms that cannot reach the canopy (Wafar et al. 1997; Dittmar et al., 2006).

It is difficult to accomplish comparative studies of litterfall production and nutrient flux in mangroves due to structural, topographic, morphologic and environmental differences in each region in the world (Wafar et al., 1997). In Brazil, about 13,400km^2 of shoreline is covered by mangroves (Spalding, 1997). Schaeffer–Novelli et al. (1990) classified it in physiographical units, according to structural characteristics and environmental conditions. Mangroves of north and southeast regions have been better studied than northeast ones (Maia et. al., 2005). In this context, this study is a first overview on the litter production in a mangrove of Bahia (Northeast, Brazil) providing subsidies for studies of their participation in the balance and mass flux in the estuary. Our aims were: (i) characterize the structure of mangrove, verify similarities between areas (ii) estimate spatial and temporal variation in litterfall production by litter components and species during dry and wet periods (iii) assess possible effects of abiotic factors in production of items and species.

2. STUDY AREA

The Cachoeira river basin (4,600km^2), is located in one of the most developed regions of south Bahia. Due this high population and no sewage treatment, Cachoeira river receives a large load of industrial and domestic effluents from twelve cities. In the Cachoeira estuary, 248ha are covered by mangroves (Fig. 1) (Martins, 2008). According to Köppen classification, the weather in Ilhéus is Af, so it presents low water deficit, it is megatermic, i.e precipitation is higher than evaporation and it has well-distributed rain all over the year. The annual average temperature is 24ºC, ranging from 17 – 30,5ºC (Nacif et. al. 2004)

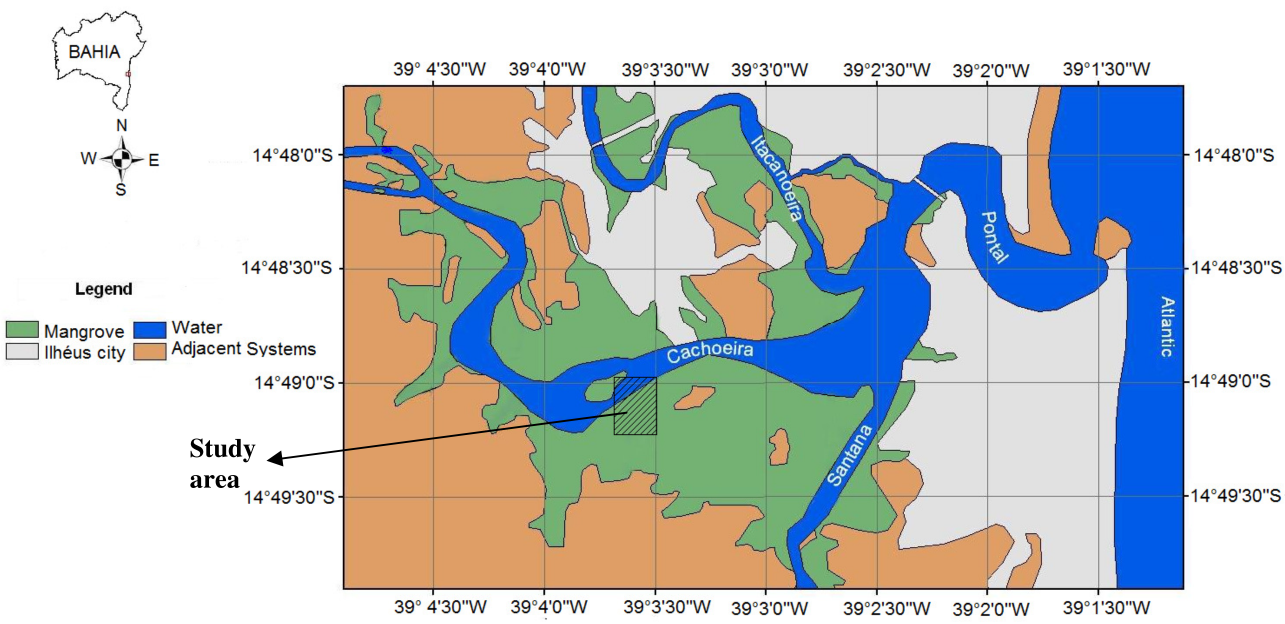

Figure 1. Mangrove area along Cachoeira estuary (Adapted from Martins, 2008)

Mangrove species composition and its structural patterns vary along inner, mid and outer estuary (Martins, 2008) and the dominant species are *Rhizophora mangle*, *Avicennia schaueriana* and *Laguncularia racemosa*.

The mangrove forest at the study site can be classified as riverine forest (Lugo & Snedaker, 1974). The forest extends up to 1km landwards. The portion of the study area next to the river bank (14º49'00"S/ 39º03'36"W) is situated about 0.9m above mean sea level. Within a distance of 100m from the main river channel, the ground level rises smoothly to 1.0m above mean sea level. In 300m distance from the main channel, ramifications of two second-order tidal channels form a dense network of tidal creeks. The tidal flooding is semidiurnal, with a tidal amplitude of up to 3.2m.

3. MATERIAL AND METHODS

Vegetation structure

The study site was chosen after evaluation of a larger area along the Cachoeira river by means of preliminary recordings of forest structure via the point-centered quarter method (Citrón & Schaeffer-Novelli, 1986). Within the study area, nine square plots of 100m^2 each were established at arbitrary positions within the study area, with a minimum distance of 50 m from each other and from the channel border (Fig. 2).

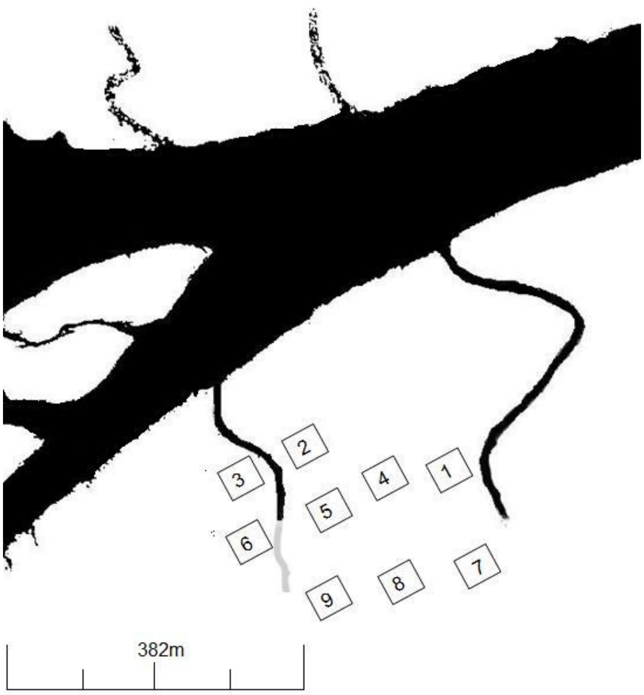

Figure2. The plots established in mangrove.

Within the single plots took measures of height and diameter at breast height (DBH) of all trees with DBH≥10cm. Based on these data, we calculated frequency, density and dominance of single species (Cítron & Schaeffer-Novelli, 1986).

Sediment analysis

Sediment samples were collected from the surface within each plot (3 replicates). We estimated organic matter content via ignition loss (550ºC for 1 hour; (Dean, 1974) and granulometry by screening, according to Suguio (1973).

Similarities among plots in terms of vegetation structure, organic matter content and sediment granulometry were analyzed by Cluster Analysis.

Litterfall

In each of the nine plots, five litter traps (0,25m^2 surface) were placed in regular distances, suspended above the highest high water level. Samples were collected twice a month, from June 2008 to January 2009. In the laboratory, litterfall was separated into litter components (leaves, flowers and fruits, including propagule) of each species (Brown, 1984) and each item was dried in a oven until reaching constant weight (at 60±/5ºC, for 72h) and subsequently weighed. The distribution of litterfall along the plots was described and temporal variation (dry and wet) was compared by Kruskall-Wallis test and Dunn method.

Differences found in temporal variation were associated to structural features and abiotic factors collected from climate databases CPTEC/INPE (temperature, precipitation and air humidity) by descriptive statistics.

4. RESULTS

Vegetal structure and plot characterization

The point-centered-quarter method provided a view of variation in species dominance and height of trees across the mangrove. *A. schaueriana* and *R. mangle* were the mixed forest predominant, while small spots of *R. mangle* and *L. racemosa* occurred mainly in border areas (Fig. 3).

Figure 3. Profile of mangrove. Blue squares are water channels; black and white squares represent 10m of distance between dots.

The mangrove showed a high degree of development, due to the high basal area and low density. The highest values in number and dominance (basal area) were observed in *R. mangle* (*Rm*), followed by *A. schaueriana* (*As*) and *L. racemosa* (*Lr*) (Table 1).

Table 1. Structural features of species along plots in Cachoeira estuary

Plot	Sp	Nº	Density (%)	Basal Area (%)	Height (m)
1	*Rm*	5	50	74.07	11.2±1.48
	As	1	10	1.79	-
	Lr	4	40	24.13	8.38±2.49
2	*Rm*	6	54.54	93.83	14.4±1.56
	As	5	45.45	6.17	7.2±2.94
3	*Rm*	7	87.5	96.84	16.3±1.14
	As	1	12.5	3.16	-
4	*Rm*	6	75	84.8	11.83±0.4
	As	1	12.5	9	-
	Lr	1	12.5	6.2	-
5	*Rm*	5	83.33	97.51	20.7±0.97
	As	1	16.66	2.49	-
6	*Rm*	4	50	74.65	17±3.82
	As	4	50	25.35	10.63±6.81
7	*Rm*	5	71.42	43.48	15±3.6
	As	2	28.57	56.52	17.25±1.76
8	*Rm*	3	50	72.21	16.67±4.93
	As	3	50	27.78	12.17±4.07
9	*Rm*	2	40	66.06	17.75±1.06
	As	3	60	33.94	11.5±4.76

Sediment was predominantly composed of sand (>60%) and silt/clay (from 3% to 24%). Plots 1 and 4 showed highest fraction of gravel while another plots had similar values of fractions.

Organic matter among plots ranged from 6.9% to 18.4% (Fig.4).

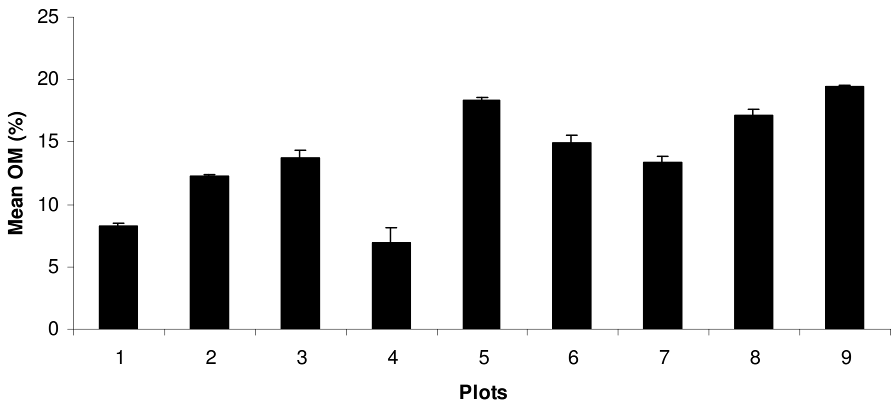

Figure 4. Organic matter in plots sediment.

The highest average values were found in plots 5 (18.3%±0.27) and 9 (19.46%±0.04) which have a considerable fraction of fine grains; the lowest values were to plots 1 (8.2%±0.34) and 4 (6.95%±1.15) associated to a high fraction of coarse grains.

Based on these features, the Cluster Analysis discriminates plots in two large groups: Group **A** – 7 and Group **B** – 1, 2, 3, 4, 5, 6, 8 and 9 (Fig. 5). *L. racemosa* was not considered a good indicator in this analysis because it was found only in two plots.

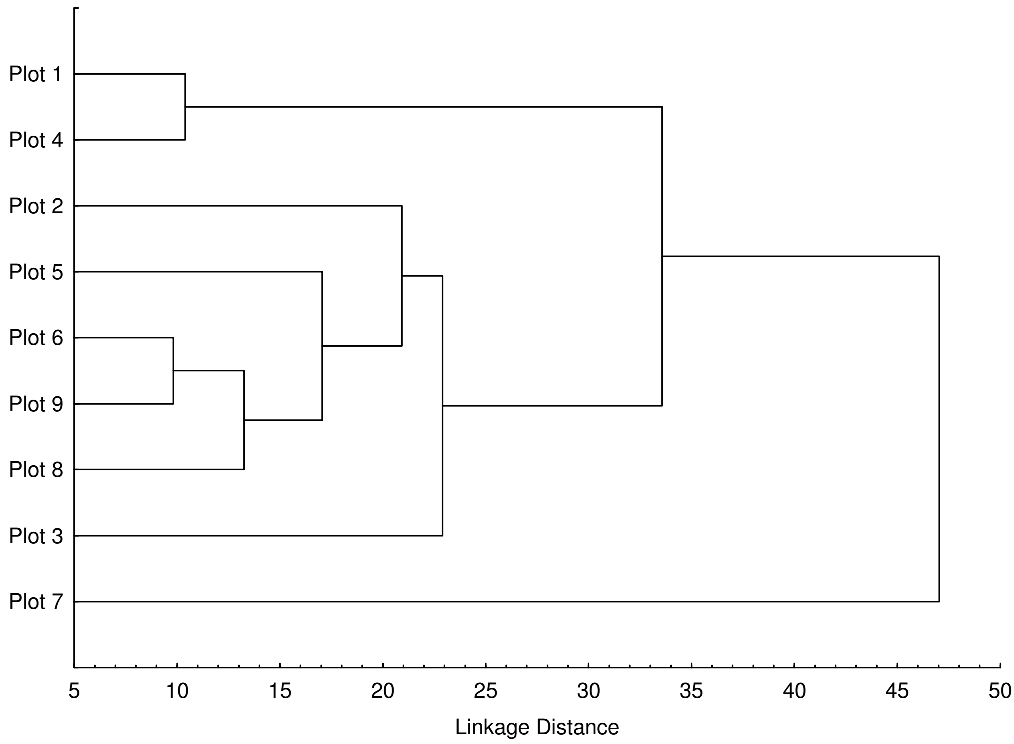

Figure 5. Cluster analysis among plots (WPGA, Euclidian distances).

The cluster analysis suggested that composing Group **A**, plot 7 was separated mainly by dominance of *A. schaueriana*. In contrast, Group **B** has the other plots joined in different distances due to little differences features.

Plots 6 and 9 were similar due to its proportions of sediment fractions, height of both species and *A. schaueriana* dominance. Higher *R. mangle* dominance, height of trees and a little higher proportion of gravel in sediments were common characteristics observed to plot 2, and 5, but plot 2 was distant from plot 5 due to have more gravel and less organic matter on sediment. Plot 3 joined more distantly because it showed distinguishable characteristics as higher proportion of silt/clay and low organic matter.

Abiotic factors

Among the variables selected, only precipitation presented distinct periods. The values were lower between Sep 4 and Oct 27 (from 6 to 9 fortnights, respectively) and the highest occurred during the beginning of summer (Table 2).

Table 2: Environmental variables during the study.

	Mean Temperature (ºC)	Mean Air humidity (%)	Mean Precipitation (mm)
Jun/26 - Jul/8	20.68	95.8	3.88
Jul/9 - Jul/23	19.91	95.18	2.99
Jul/24 – Ago/7	19.16	94.34	5.2
8/Ago – 21/Ago	19.58	94.81	2.8
22/Ago – 3/Sep	20.26	93.74	3.91
4/Sep – 25/Sep	20.91	91.63	0.54
26/Sep – 10/ Oct	21.08	91.69	0.21
11/Oct – 26/Oct	21.89	92.85	1.8
27/Oct – 11/Nov	22.29	89.27	3.26
12/Nov – 27/Nov	23.82	86.28	15.04
28/Nov – 11/Dec	23.17	92.33	7.28
12/Dec – 25/Dec	23.38	95.56	9.46
26/Dec – 11/Jan	23.31	94.46	11

Temperature averages were around 19°C during the winter with small variation, but from October until summer, the temperature starts to increase, reaching values of 23°C. Constrasting with precipitation, air humidity had lower values from September to November.

Litterfall

Spatial variation of litterfall

Vegetation structure was an important factor that influenced spatial distribution. Some items showed differences along plots, such as *A. schaueriana* leaves and flowers, and *R. mangle* flowers and propagules (Figure 6).

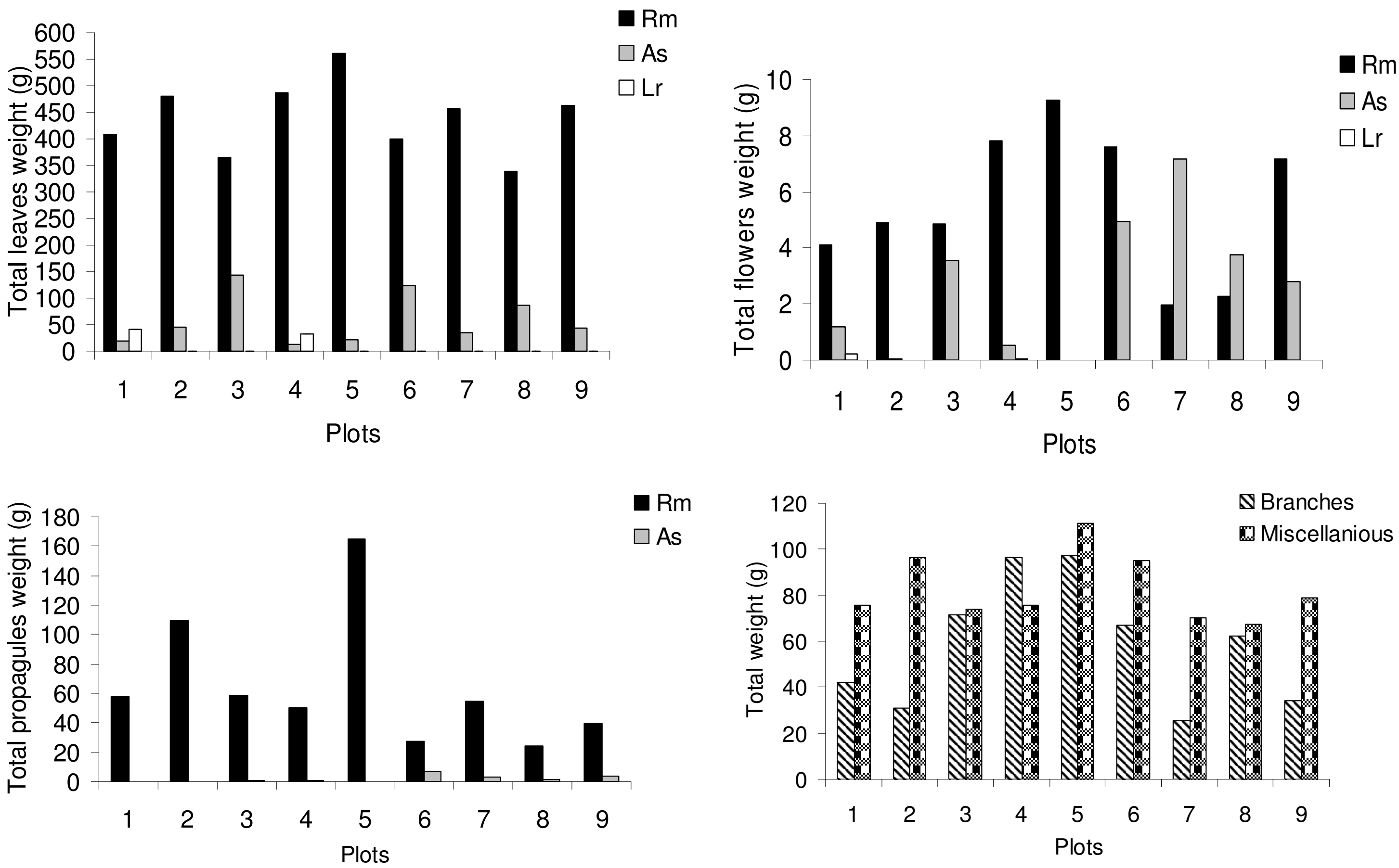

Figure 6. Total weight of items and species through plots. Rm – ***Rhizophora mangle*****; As –** ***Avicennia schaueriana*****; Lr –** ***Lagungularia racemosa*****.**

The leaves were the item that most contributed in all plots. Plot 5 showed higher values compared to plots 1, 3, 6 and 8 for *R. mangle*. Inversely, plots 3, 6 and 8 had higher values for *A. schaueriana*. Not every contribution presented a direct relation with vegetation structure. As an example, plots 2 and 7 also showed values of basal area and density similar to the plots 3, 6 and 8, and they were not expressive on *A. schaueriana* litter production. *L. racemosa* had little production on all items, due to its low density., since it was found only in plots 1 and 4 (see table 1).

R mangle showed flowers and propagules weight with different distribution along plots due to effects of density and maturity of trees in each plot. However, this effect of density in litterfall contribution was observed in major intensity to *A. schaueriana*. Trees of *A. schaueriana* were more frequent in plots 3, 6, 7 and 8 which present the highest production values of flowers and seedlings, while plots 2 and 5, did not register these items. Flowers of *L. racemosa* had small participation, not excceding 0.12g in plot 4. Propagules of this species were not registered during this study.

There were not expressive differences in wood among plots, only plots 2, 7 and 9 showed minor contribution. Miscellanious was homogeneous in plots and it was composed mainly by plant fragments (stipules of *R. mangle* and wood) and remains of animals.

Temporal variation

The daily average of total litterfall dry matter was 2.6 g m^{-2} per day and leaves were responsible to more than 60% of litterfall. Litterfall had a strong variance and significant differences production of items along fortnights ($p<0,05$). The highest variance was registered to *R. mangle* leaves (15.8), followed by its propagules (7.71). To the other items, variance was lower than 2.

Leaves, flowers and propagules of *R. mangle* were found in all months, but showed the higher contribution in January and December. In contrast, *A. schaueriana* did not present this trend, showing peaks of contribution mainly to reproductive items in October and November (Fig.7).

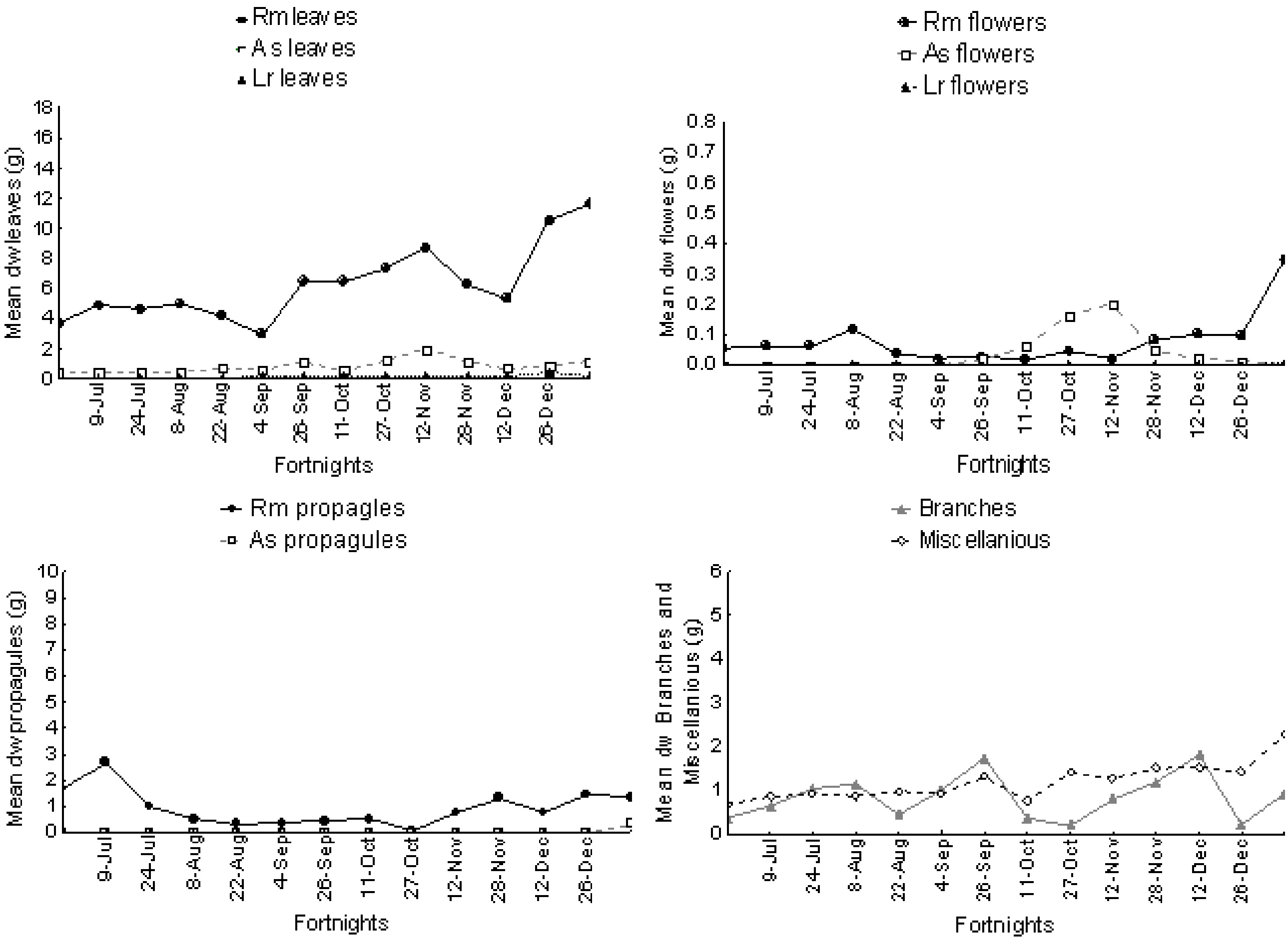

Figure 7. Mean of dry weight (dw) of items along fortnights (n=630).

In general, differences in litterfall tended to be found among the three abiotic patterns identified: June to September, September to November and November to January.

Leaves of *R. mangle* presented higher values in the rainy season (Dec 26 and Jan 12). Thus, *R. mangle* had a small peak during winter and another peak, higher, from end of December until January, which correspond to the transition spring to summer.

R. mangle flowers weight presented significant differences with lowest contribution to litterfall on October, and the highest, found August and January. After November, the flower production smoothly increases until January, the month significantly higher ($p<0.05$). Most of flowers concentration was around 0.7g, i.e. on average, around eleven flower were recorded by period (each flower weight about 0.06g), in exception of peak periods. Propagules occurred throughout the months, without significant differences ($p=0.25$), but it was more intensive in during winter, in June and July.

The item of second largest contribution to litterfall was *A. schaueriana* leaves which had two peaks of leaves fall. The first was in September, and the other one, markedly from end of October until end of November. The initial values were significantly different from peaks (from September until November). Flowers of *A. schaueriana* followed the same pattern of leaves (peak between October and November), but they did not occurred in other moment of year, except on these months. After flower production, propagules start to appear only in December.

The leaves of *L. racemosa* had small participation on litterfall along fortnights. Due to this fact, no significant differences in items along time were observed ($p=0.99$). It starts to increase in November, reaching maximum values of 8.05g in December. The flowers of *L. racemosa* began to contribute to the litter from the end of December, only in plot 4. Flowers are not visible in graphs because they occurred only twice: Sep 26 (0.04g) and Jan 12 (0.21g). Propagules were not registered during this study.

The contribution of wood was higher in August, September and December. Differences were significant only between highest and lowest values (September to October and December to October). Miscellaneous did not present significant differences among plots ($p<0.05$). Due to be composed by *R. mangle* stipules, miscellaneous followed it patterns about crescent values along periods, with peak in summer beginning.

Environmental conditions x Litterfall

Among other variables, only rainfall, air humidity and temperature were used to this study, for promote complete data to analysis and for it showed a considerable variation that justify being used to assess seasonality (Fig. 8).

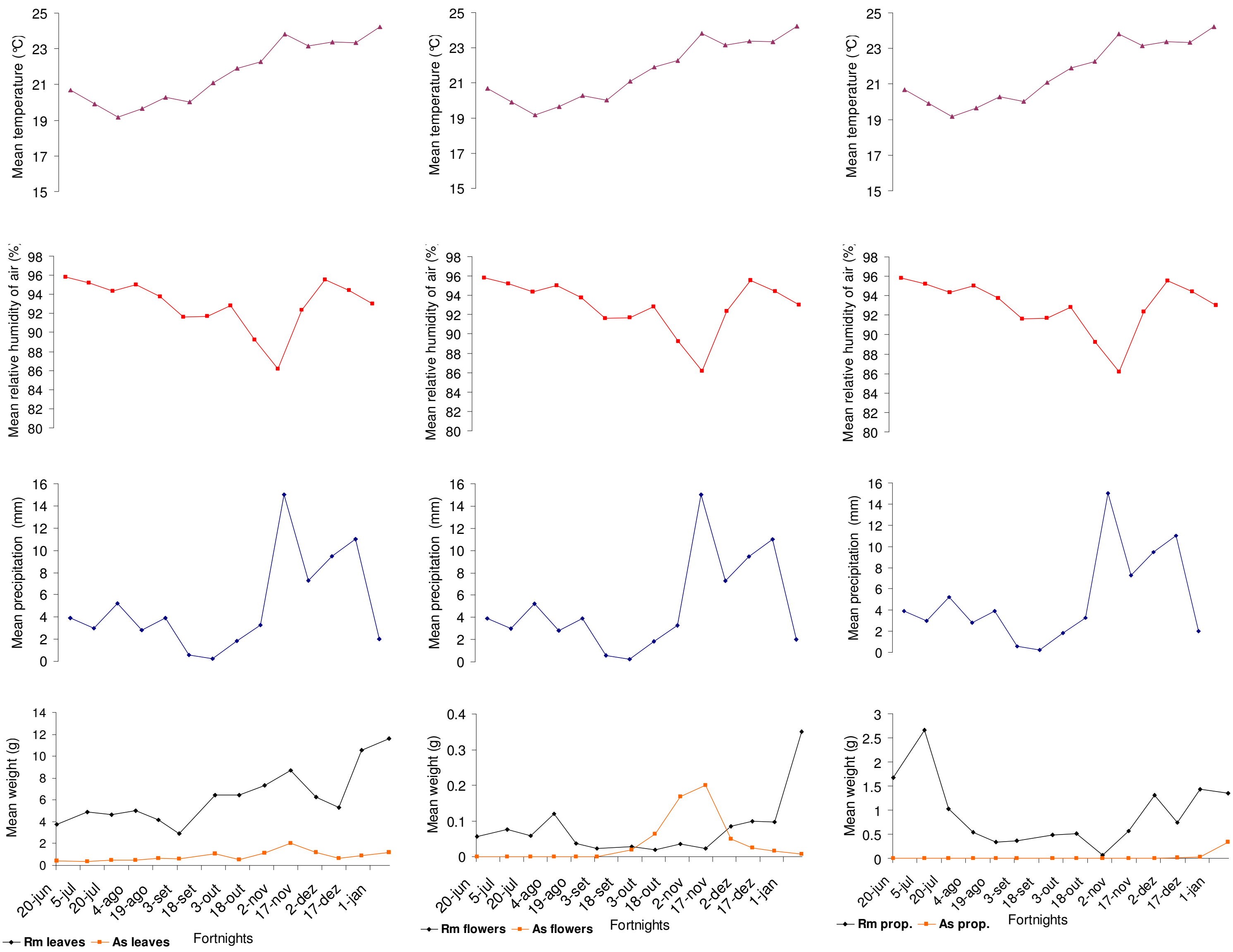

Figure 8. Abiotic factors and litterfall along fortnights.

Great amount of litterfall was provided by *R. mangle* and *A. schaueriana* thus, this species were related in the graphic above. *A. schaueriana* items seems to be more influenced by abiotic factors than *R. mangle*, considering its peaks in periods of alteration of abiotic factors (e.g October to December).

5. DISCUSSION

Vegetal structure and plot characterization

The forests are a combination of young and mature trees, it can be checked by the variation of the heights and basal areas (Table 1). The lower heights were observed in the plots 1, 2 and 4, while the subsequent plots showed higher ones, i.e. it has better development.

Considering spatial view (see Fig.2), the plots which are located nearly to the major water channel (1 and 4) were composed by a high fraction of gravel (28.53% and 25.29%, respectively). It may be a result of high tides and high discharge periods of Cachoeira. River which occurs usually during wet season (Bahia, 2001). Thus, the gravel is carried out by the water during high discharges, and when it reduces, the gravel is deposited near channel edges (Suguio, 1973). On the other hand, plots near to the other water channel which has lower flux of water (2, 3 and 5) have not gravel in a significant fraction.

Differences in sediment composition may influence species occupation, since it is responds to retention of high or low nutrients and organic matter. Mangrove species can develop under a variety of sediment conditions (Jimenez, 1985) but in this study, *L. racemosa* tended to occur only in areas with a major fraction of sand and gravel in sediments (plots 1 and 4).

The mangrove structural characteristics of each plot may influence the litterfall production. It was expected that the dominant species would show a great contribution to the amount of litterfall. However, despite of these structural similarities among plots, the litterfall did not responded exactly to the same pattern of resemblance, probably due to influence of other agents, such as tidal flooding and biotic action.

Spatial variation of litterfall

The major contribution of a species to litterfall seems to be positively related to the density of this species in the plot. In contrast to results of Mackey and Smail (1995), who found no significant effects of density and age of trees in litterfall, in this study, vegetation structure had important role to spatial variation of litterfall. As an example of it, in general, plots with predominance of *R. mangle* (e.g 2 and 5) had few *A. schaueriana* litterfall and vice versa. Despite of plot 3 show dominance of *R. mangle*, it is surrounded by *A. schaueriana* trees, and as a consequence, it showed expressive contribution from this species.

Indeed, the seasonality has been recognized as an important factor to determine variations of leaves fall. Moreover, in spite of phenological responses to seasonality, the study of items in each plot revealed that litter presented different responses to time in each plot. For example, the plots 2, 4, 5, 6 and 9 showed increase in leaves of *R. mangle* values from beginning of spring, but at plots 1, 3, 7 and 8, changes were not registered.

Our results display that spatial variation of items distribution can occur even in small areas, responding to specific features at each site as discussed by Fernandes (1999). In this study, although each plot has some differences as shown by cluster analysis, it can be observed that items of litterfall did not have the same behavior expected along plots. Considering the small area used to analyze spatial variation, the litterfall may be responding more strongly to the temporal variation in specific periods, causing peaks in the plots where trees were present or nearby it.

Temporal variation of litterfall

The daily average litterfall dry matter was 2.6 g m^{-2} per day, similar to values cited by Twilley et. al. (1986) for mixed mangroves of Florida (2.25g to 4.08g $m^{-2}d^{-1}$) and to brazilian mangroves at different latitudes (from 2.69g $m^{-2}d^{-1}$ until 4.19g $m^{-2}d^{1}$) (Sessegolo, 1997; Mehlig, 2001; Bernini, 2007). Total litterfall per day is variable over the years and could be different even in sites with similar environmental conditions (Fernandes et. al., 2007). Additionally, in most studies the peaks of litterfall were found in wet season and most of litterfall dry matter was provided by leaves (Lugo & Snedaker, 1974; Twilley et al., 1986; Mehlig, 2001; Fernandes, 2007; Sessegolo, 1997;

Fernandes, 1999). We found 60% of leaves composing litterfall and it was provided mainly from *R. mangle*, the dominant species.

The main item responsible for the most of the organic matter production were leaves, followed by propagules. For all items, *R. mangle* were dominant in contribution, due to higher weight of the leaves and abscission occurrence along all periods. Litterfall analysis is not the best method to estimate phenological periods (Fernandes et. al., 2005), but even during a short period of study, it was observed some patterns of phenology similar to other studies.

R. mangle items occurred throughout periods following the increasing of temperature before the summer, reaching the higher peak between December and January. The same pattern of *R. mangle* was observed in other studies in neotropical mangroves areas (e.g. Fernandes, 1999; Mehlig, 2001; Mehlig, 2006; Menezes, 2008).

Mehlig (2006) pointed out that low salinity regime and solar radiation could influence *R. mangle* phenological patterns. According to him, a small rise in solar radiation and precipitation during the summer could be responsible to promote new leaves formation. At Cachoeira estuary, high values of precipitation occurs during summer and it is often associated with increasing of river discharge. Thus, it could reduce the salinity of mangrove sediment and, as a consequence, the litterfall would increase before of new leaves formation.

Only propagules of *R. mangle* did not show a specific pattern of occurrence. It was found high values of propagules during winter and summer; however, it was not an evidence of investment on fruiting in these periods, because propagules contributed with a high proportion of weight in relation to total litterfall even if only one propagule has fallen. According to Mehlig (2001) it is difficult to identify the specific factors that control flower abscission and propagule production.

The remarkable seasonality of *A. schaueriana* items in this study was not observed in other studies with *Avicennia* spp. which found litterfall items along all year (Fernandes, 1999; Lopez-Portillo & Ezcurra 1985; Sessegolo, 1997). Flowering and fruiting were sequential, flowers were produced from the end of spring until summer beginning and after that, propagules were registered in December. Similarly, May (1999) found flowering peaks of *Avicennia* sp. from September until November. On the other hand Twilley (1986) found to its genus, peaks during Autumn.

The highest production of *Avicennia marina*, according to Mackey & Smail (1995) is found in wet season. However, in this study, the litterfall of *A. schaueriana* seemed to be associated to low precipitation values (October to November) which preceded wet season. According to Duke (1990), salt excretion is not efficient in new leaves of it species, so, the leaf fall preceding December may be a good strategy to production of new leaves during wet season.

The production of *A. schaueriana* did not reach values as higher as the ones recorded for *R. mangle*, even when *R. mangle* was found in smaller amounts. This fact is due to intrinsic characteristics of each species, since there is less investment in the structural composition of the leaves of *A. schaueriana* and, therefore they have lower individual biomass than those of *R. mangle* within the same area (Cannicini et al., 2008).

L. racemosa had small contribution to litterfall production in this mangrove and it could be a result of low density of this species and the fact of this study did not follow an annual cycle. Nevertheless, even following two years, Twilley (1986) found small contribution of this species. Fernandes (1999), Menezes et al. (2008) and Fernandes et al., (2005) registered litterfall items along all year, in contrast with our study, where flowers of *L. racemosa* were registered only in December and January, suggesting that reproductive investment starts during rainy season as well as found by Menezes et al. (2008) and Fernandes et al. (2005).

Although branches and miscellaneous material had peaks throughout months, it is difficult attribute these peaks to specific conditions through periods. In general, it is related that miscellaneous and branches have disordered pattern (Fernandes et al., 2007; May, 1999). Most branches were found in plots near to *L. racemosa* trees. We assumed that as *L. racemosa* has less resistant timber, it suffered with mechanical action, resulting in an increased shedding of branches of this species.

It was found remarkable peaks of some items; however, production tends to be flexible according to changes in environmental conditions, varying over the years (Fernandes, 1999; Fernandes et al., 2007). Menezes et al. (2008) related several peaks observed to the same species, in different months, attributing it to specific conditions predominant in mangrove at some moment are also responsible for variation in litterfall.

Rainfall, air humidity, salinity, temperature, solar radiation and wind speed have been used in multivariate analysis as the main important abiotic factors that could influence litterfall production (Arreola-Lizárraga, 2004; Mehlig, 2001; Fernandes, 1999). Cachoeira estuary is located in a region of hot and humid weather where it has been reported that there are no defined dry season (Schaeffer-Novelli et al., 1990;

Bahia, 2001), so some variables could be not interesting to compare with litterfall variations.

In this study, precipitation and temperature demonstrated remarkable changes along winter to summer. In order to compare litterfall among periods, fortnights 6 to 9 (September to November) were considered as dry season, where precipitation and air humidity values were lowest. Winter and summer had similar values to precipitation, but high means were found near to summer (from Nov/12 until Jan/12 fortnights), and it was considered as wet season. Other variables such as wind speed and solar radiation were not used in this study because they had homogeneous distribution, and consequently, they were not considered good indicators of possible effects of seasonality to litterfall.

Species trended to flowering or fruiting near or during the summer, then, the smoothly increasing of temperature and air humidity oscillation from winter until summer may explain better litterfall patterns. In fact, the same variables were cited as important factors by Mehlig (2001), Fernandes (1999) and Arreola-Lizárraga (2004).

Although some abiotic factors may explain part of variability on litterfall along time, there are biotic factors affecting directly and indirectly structure and litterfall production in mangroves, such as herbivory (Cannicini et al., 2008; Lee, 1999; Fernandes, 1999; Fernandes et al., 2007). Moreover, in each mangrove specific conditions may change the importance of different variables to production. Integrated studies are necessaries to determine the real role of each factor influencing mangrove production along years.

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