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Salinity and Flooding Frequency as Determinant of Mangrove Forest Structure in Babitonga Bay, Santa Catarina State, Southern Brazil

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ABSTRACT

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This work aimed to evaluate the effects of salinity and flooding frequency on structure of mangrove forests in Babitonga Bay, State of Santa Catarina (southern Brazil). Eight sites were selected along a salinity gradient. Into each site, 100m2 plots were positioned along the flooding frequency gradient, 50m from each other, from water edge to landwards. All the trees into the plot was identified and measured to estimate structural parameters of the forest. Data were compared using cluster and canonical correspondence analyses. *Laguncularia racemosa* was dominant in oligohaline plots with high flooding frequencies, which showed lower densities and higher diameters and biomass. Euhaline and mesohaline plots with high flooding frequencies were clustered due to lower total densities, high diameter and tree height and high *Avicennia schaueriana* biomass. Low flooding frequencies plots presented high tree densities and low biomass, and were separated in two clusters: euhaline and mesohaline forests. In euhaline forests with low flooding frequencies *L. racemosa* was the dominant species, with higher densities and biomass. In mesohaline forests with low flooding frequencies *Rhizophora mangle* was largely dominant in density, but biomass was very similar among species. In Babitonga Bay, mangrove structure is primarily related to flooding frequencies, but it is also dependent on salinity.

ADDITIONAL INDEX WORDS: *Laguncularia racemosa; Avicennia schaueriana; Rhizophora mangle.*

INTRODUCTION

Mangrove forests occur along Brazilian coast from 4°30'N to 28°30'S, presenting about 7 species of typical trees (KJERFVE and LACERDA, 1993). Despite this low diversity, strong changes in forest structure are known along the latitudinal gradients (SCHAEFFER-NOVELLI *et al*., 1990). Structural changes have also been reported worldwide at local level, as a consequence of local environmental factors. The search for the distributional patterns of mangrove species and for the mechanisms that rule these patterns are challenges since the first studies on mangrove forests (DAVIS, 1940; MACNAE, 1968; LUGO and SNEDAKER, 1974; CHAPMAN, 1976; CINTRON and SCHAEFFER-NOVELLI, 1985 and others). In some mangrove forests, the species seems to occupy discrete zones along the tidal flooding gradient (DAVIS, 1940; MACNAE, 1968; SMITH, 1992; DUKE *et al.*, 1998), and these patterns have been attributed to differences among species in tolerance levels for environmental factors, dispersion processes, competition and herbivory (MCKEE, 1993, 1995; ELLISON and FARNSWORTH, 1993, 1997; FARNSWORTH and ELLISON, 1997; BALL, 1998). But many different patterns of zonation for species have been observed worldwide, without significant repetition (BUNT, 1996, 1999; BUNT and STIEGLITZ, 1999; ELLISON and FARNSWORTH, 2001). According to TOMLINSON (1986) this variability of species zonation patterns could be consequence of the very large tolerance levels of mangrove species to factors as pH, nutrients availability, Eh, sulfites and others.

Despite the difficulties in establish typical zones for each species (or group of species), the structural variability of mangrove forests is largely known, even in monospecific or low diversity mangrove forests (LUGO and SNEDAKER, 1974; LUGO *et al*., 1988), and these structural differences affect all the ecosystem processes (CINTRON and SCHAEFFER-NOVELLI, 1983; TWILLEY *et al.*, 1986; DAY JR. *et al.*, 1987, 1996; LUGO *et al*., 1988; ROBERTSON 1991; FLORES-VERDUGO *et al*., 1992; CHEN and TWILLEY, 1998; RIVERA-MONROY *et al.*, 1998). Considering that, the first approach to evaluate the ecosystem function could be the evaluation of how the major environmental gradients rule the mangrove forest structure. To accomplish that, we aimed in this work to evaluate the effects of salinity and flooding frequency on structure of mangrove forests in Babitonga Bay, State of Santa Catarina (southern Brazil).

MATERIAL AND METHODS

Study Site

Babitonga Bay (26°08' to 26°28'S and 48°28' to 48°50'W) is located in the State of Santa Catarina (Figure 1), near to southern

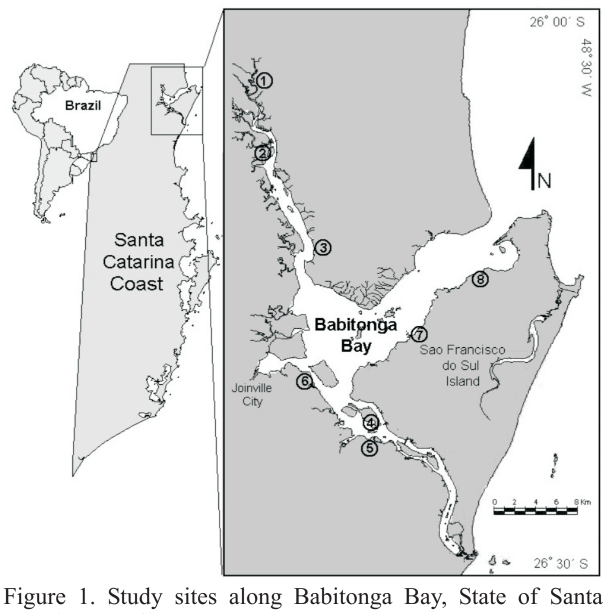

Figure 1. Study sites along Babitonga Bay, State of Santa Catarina, Brazil.

limit of mangroves in Brazil (28^{o}S). The bay area is about 167 Km^2, presenting 60 Km^2 of well-preserved mangrove forests (IBAMA, 1998), where there are the occurrence of the trees *Rhizophora mangle, Avicennia schaueriana* and *Laguncularia racemosa*. There are also the occurrence of *Spartina alterniflora, Spartina densiflora, Scirpus spp, Crinun sp.* and others hebaceous plants, and seaweeds (*Bostrychia, Caloglossa, Cladophoropsis, Rhizoclonium* and others).

Tides are mixed, mainly semidiurnal with tidal range about 1.2m. Mean temperature ranges from 15^{o}C in winter to 26^{o}C in summer. Annual rainfall is about 2600 mm year-1, ranging from 100 mm $month^{-1}$ in the winter to 400 mm month-1 in the summer (mean data from 1977 to 1994). Mean salinity ranges horizontally from 0 upstream to 35 seaward.

Eight sites were selected along the salinity gradient. At each site, 100 m^2 (10 X 10 m) plots were placed along a transect from the mangrove water edge to dry land edge, distant 50 m from each other. Number of plots into each site depended on the mangrove forest wide, comprising 37 plots at all. At site 2 the mangrove forest was too extensive, with very soft bottom and many tidal channels. At this site it was not possible to place plots near to dry land. Two numbers named the plots: first representing the site and second representing position from the water edge (Examples: plot 45 was located at site 4, and it was the closest to dry land at this site, the number five along the transect. The plot 41, also at site 4, was the closest to the water edge).

Data Sampling and Analysis

Mangrove forest structure was determinate between March and May 1997. Within the plots each tree was identified and tree heights were measured. The DBH (diameter at breast-height) was measured for trees higher than 1.3m (adults), but not for trees with 1.3m high or lower (saplings). These data were used to estimate absolute and relative density, average tree height (adults), absolute and relative basal area and biomass. Allometric equations used to estimate biomass (g dry weight m^{-2} or ton dry weight ha^{-1}) was based on data from CINTRON and SCHAEFFER-NOVELLI, (1985).

The maximum height of seaweed belt in all trees of each plot was measured and used as an indicator of mean high water level. Tidal level was recorded along the day in some plots and compared with predicted tidal height and seaweed belt height. These records were used to calculate the flooding frequency, as the number of days (%) in a 1-year period, in which tides reached each plot soil surface.

Soil salinity was measured in triplicates into each plot during the structure measurements in autumn (March to May 1997) and also in sites 1, 3, 4 and 8 in summer (January 1998). Additionally, salinity was synoptically measured from site 1 to site 6 in dry season (july/1997), to compare with annual mean data from IBAMA (1998).

The structural data for each species into each plot (tree density, sapling density, mean diameter, height, biomass, number of trunks per tree) were standardized to perform statistical analyses. The plots were grouped using Cluster Analysis (UPGA and the indexes 1-r Pearson and Bray Curtis) and Canonical Correspondence Analysis (CCA). The averaged values for structural characteristics were estimated for major clusters formed.

RESULTS

The sites upstream, sites 1 and 2, with salinity lower than 18, were classified as oligohaline (Table 1). Sites 3, 4, 5, and 6, with salinities ranging from 15 to 25, were classified as mesohaline. Sites 7 and 8, where mean salinities were about 30, were classified as euhaline. There were no significant differences in soil salinity among plots into the same site or between salinity into the plot and water column salinity ($p>0.2$). Flooding frequencies ranged from 100% in the water edge plots, to 50% in some the landward plots.

The three mangrove species, *Laguncularia racemosa*, *Rhizophora mangle* and *Avicennia schaueriana* occurred at all sites along the bay, but absolute and relative densities presented high variability into and among sites. Into each site there was a tendency of increase in densities and of decrease in tree height, mean diameters and tree biomass, when flooding frequencies decreased. There was also a tendency of decrease in relative density of *L. racemosa* and increase of *R. mangle* in lower flooding frequencies. Seedlings and saplings densities presented a positive relation with adults' densities, especially for *R. mangle*.

Tree height and average diameter of trees were larger for *A. schaueriana* and smaller for *R. mangle.*

As Cluster Analysis using Bray Curtis and using 1-r Pearson indexes resulted in very similar clusters, the last one were chosen to the comparisons. The plots of mangrove forests were joined into four major clusters (Figure 2A). Clusters 1 and 2 joined all the plots with lower flooding frequencies. Cluster 1 joined the euhaline plots intermediate to landward, where L. racemosa presented the highest absolute and relative densities (Figure 2B) and also high relative biomass (Figure 2C), with averaged salinity of 30.3± 4.6 and averaged flooding frequency of 76.4± 8.7 % (Figure 3). Cluster 2 joined the mesohaline plots intermediate to landward. These plots presented very high values of *R. mangle* relative and absolute densities (Figure 2B) and also high relative biomass, in comparison to other plots (Figure 2C). This cluster presented salinity of 24.5±3.4 and flooding frequency of 74.2 ± 8.1 % (Figure 3). Cluster 3 joined all euhaline and mesohaline plots close to the water edge (Figure 2A). These plots presented low values of *A. schaueriana* absolute density (Figure 2B) and higher values of biomass (Figure 2C). Averaged salinity for Cluster 3 was 28.8 ± 3.7 (Figure 3A) and flooding frequency was 94.3 ± 7.2% (Figure 3B). Cluster 4 joined the oligohaline plots (Figure 2A), where densities were very low (Figure 2B) and biomasses were very high (Figure 2C). In these plots *L. racemosa* was the dominant species and *R. mangle* and *A. schaueriana* presented very low densities and biomasses (Figures 2B and 2C). Averaged salinity of Cluster 4 was 12.1 ± 8.7 (Figure 3A) and flooding frequency was about 94.4 ±7.7% (Figure 3B).

A comparison of tree diameter, tree height, density and biomass averaged for each cluster are shown in Figure 4. The differences among clusters were clearly related with the differences of flooding frequencies (differences of first two clusters from the last two) and salinity (differences of clusters 1 from cluster 2 and of cluster 3 from cluster 4; Figures 3 and 4).

Tree height and mean diameter (DBH) presented a positive correlation with flooding frequencies for all mangrove species (Figure 4). *L. racemosa* was the species with broadest distribution along the bay, always comprising more than 20% of relative density and of biomass values at the plots (Figures 2B, 2C and 4). Its higher structural development occurred in high flooding frequencies and low salinities. *R. mangle* presented the lower tree height and diameter, and its higher values of density and biomass occurred at the landward plots, especially in those at mesohaline areas. *A. schaueriana* always showed very low densities, but in the plots close to water edge, were flooding

Table 1. *Salinity at the sites in Babitonga Bay. Autumn and summer DATA were sampled into the site. Winter data are from sinoptical sampling of water column and annual mean data are from IBAMA (1998).*

Site	Autumn	Winter	Summer	Annual Mean	Category
1	3	5	0	-	Oligohaline
2	18	15	-	-	Oligohaline
3	23	25	9	15.5 5.9	Mesohaline
4	28	-	20	25.2 1.9	Mesohaline
5	27	-	-	25.2 1.9	Mesohaline
6	28	29	-	22.7 2.8	Mesohaline
7	32	-	-	30.3 1.6	Euhaline
8	33	-	27	30.3 1.6	Euhaline

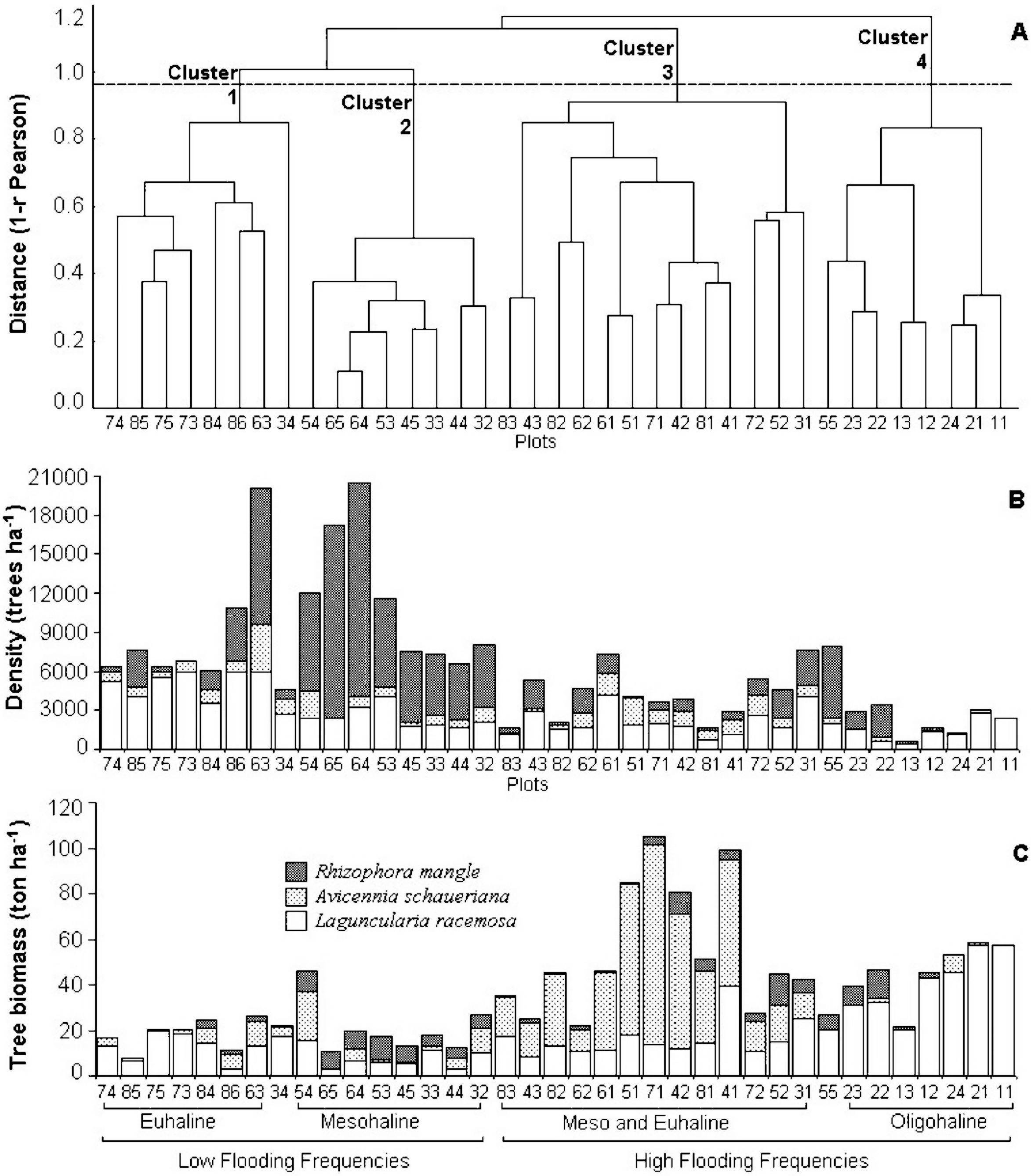

Figure 2.(A): Clustering of mangrove forest plots, according to dissimilarity (1-r Pearson); (B) Density of each species into each plot (trees ha^{-1}); (C) Biomass of each species into each plot (ton ha^{-1}).

frequencies were high, this species presented very high biomasses, once it presented large trunk diameters and also the tallest trees (Figure 4).

The influence of salinity and flooding frequency on mangrove forests structure were also identified in Canonical Correspondence Analysis, where first three axes extracted explained about 60% of data variance. Salinity showed a correlation of -0.94 with first axis. Flooding frequency showed a correlation of 0.56 with first axis and of -0.83 with second axis (Figure 5).

DISCUSSIONS

Despite the occurrence of the three species, *L. racemosa, R. mangle* and *A. schaueriana*, in all areas of Babitonga Bay, structural aspects of the mangrove forests largely varied, together with the variability of flooding frequencies and salinity. The influence of flooding frequencies on the forest structure was very clear, given that much more variability occurred into the site (plots landward against plots close to water edge), than among sites. Nevertheless, salinity was also an important factor, influencing the forest structure along the bay, especially in landward plots.

The clustering of all high frequency flooding mesohaline and euhaline forests could be a consequence of the decrease of some stressing factors caused by washing due to high flooding frequencies into these plots. We can also hypothesize that, if flooding frequency reduces the soil stressful factors, the importance of other factors could increase its effects on forest structure, as herbivory, competition, propagules dispersion.

The oligohaline mangrove forests, as well as the water edge forests of euhaline and mesohaline areas could be classified as riverine forests, according to structural classification proposed by LUGO and SNEDAKER (1974). These forests are usually well

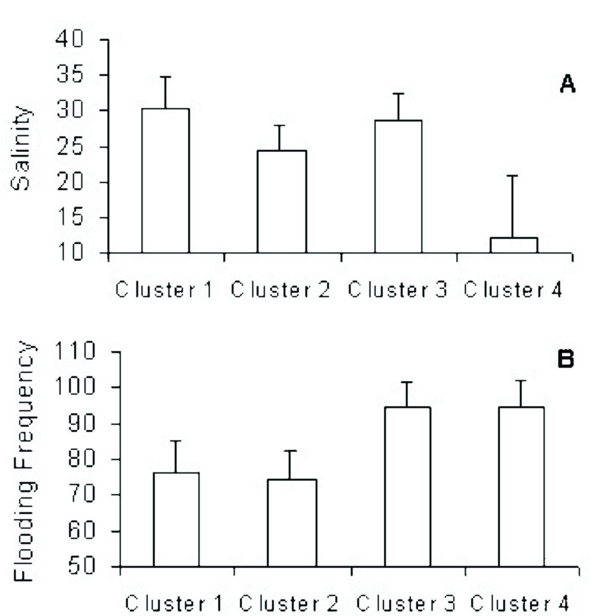

Figure 3. Averaged (A) Salinities and (B) Flooding frequencies for the plots into each cluster from Cluster Analysis.

developed and mainly dominated by *R. mangle* in Florida (Lugo and Snedaker, 1974), Caribbean (Cintron *et al.*, 1985) and also in Northern and Northeastern Brazil (Schaeffer-Novelli *et al.*, 1990). This patter was not observed in Babitonga Bay, where *R. mangle* rarely showed high densities in forests close to the water edge. It is possible that these low densities of *R. mangle* in the fringe could be related to its sensitivity to low temperatures, considering that Babitonga Bay (26° 28'S) is quite close to southern limit of this species in Brazil (27° 53'S, Schaeffer-Novelli *et al.*, 1990). The tree on the forests edge receive more directly the cold winds during the winter, which could be more stressful to *R. mangle* than to other species, increasing its susceptibility to other environmental factors, as flooding frequencies, salinity and other edaphic factors, as well as biotic interactions, as herbivory and competition (especially as seedlings and saplings). *Rhizophora* is usually reported as most flooding tolerant than other two species, but showed very high densities and biomass in lower flooding frequencies, a point to be explained, but could be related to its high tolerance to low nutrients availability in comparison with *Avicennia* and *Laguncularia*, as reported by Sherman *et al.* (2000).

The mangrove forests landward could be classified as basin forests, according to structural classification proposed by Lugo and Snedaker (1974), which are usually dominated by Avicennia and Laguncularia, presenting lower tree height and biomass, as well as lower productivity (Cintron and Schaeffer-Novelli, 1985; Twilley *et al.*, 1986; Day Jr. *et al.*, 1987, 1996; Smith, 1992). The structural differences among from riverine and fringe to basin mangrove forests are usually assumed as consequence of high salinity and sulfites in soil water, due to low flooding frequency (Davis, 1940; Chapman, 1976; Lugo and Snedaker, 1974; Cintron and Schaeffer-Novelli, 1985 and others). Salinity seems to limit mangrove structure in values about 40 and 65, and the increase of salinity occurs due to topographic depressions, where water is retained (Lugo *et al.*, 1988; Day Jr. *et al.*, 1996; Chen and Twilley, 1999). In Babitonga Bay such high values of salinity were never observed during the study, even in the periods of the year when rainfall were low. There are always hydric surplus during all year, especially in summer. These mangroves are also surrounding by mountains, which carry the runoff and wash the mangrove forest floor, reducing the salinity. So, the differences of mangrove structure from landward forests to water edge forests cannot be assumed as a consequence of salinity, but to

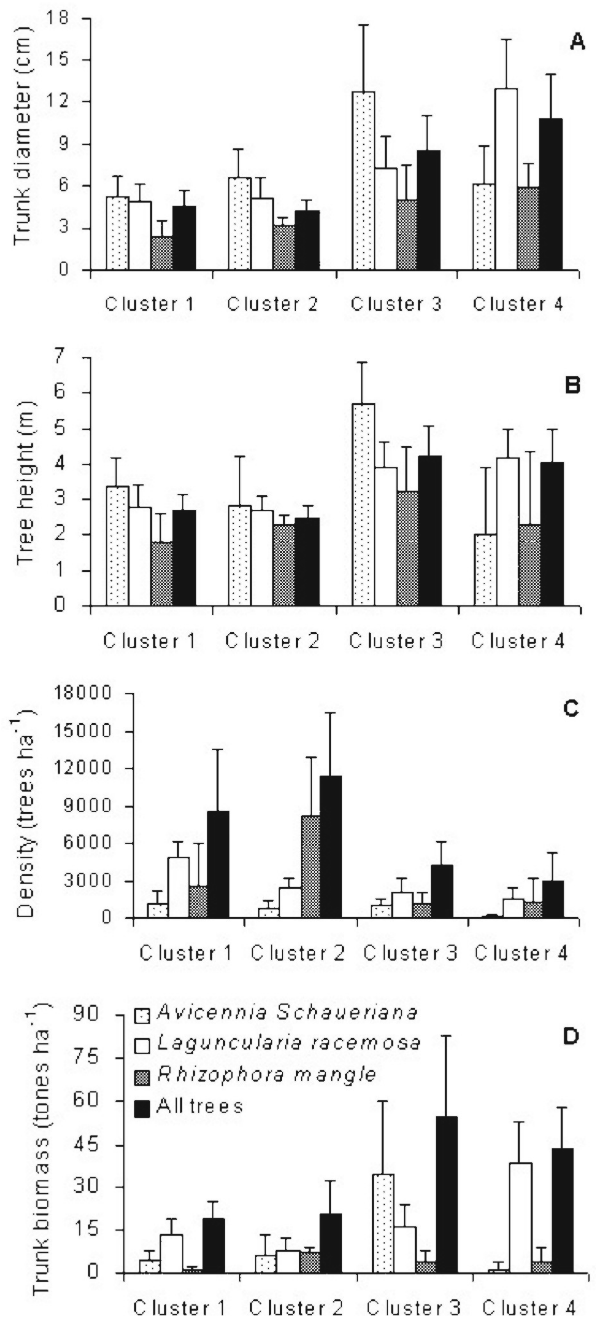

Figure 4. Averaged data of plots into each cluster: (A) Mean diameter (DBH) of trees (cm); (B) Tree height (m); (C): Adults density (trees ha^{-1}); (D) Tree biomass (tones ha^{-1}).

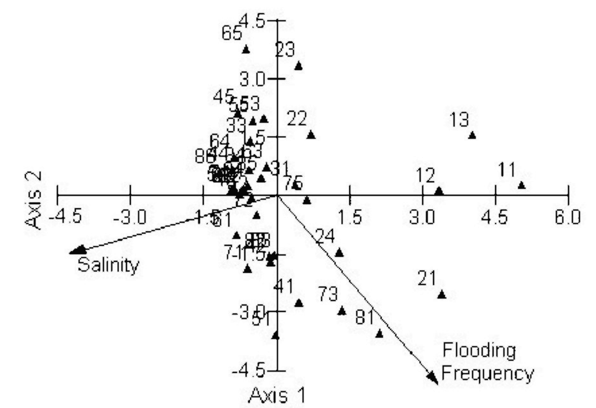

Figure 5. Distribution of the plots along the two main axes extracted by Canonical Correspondence Analysis, and the environmental constrains, salinity and flooding frequencies.

another factors related to low flooding frequencies.

Differences in the structure of mangrove forests are usually assumed as differences in maturity stages of the forests (CINTRON and SCHAEFFER-NOVELLI, 1983, 1985). The high values of biomass and low density of adult and seedlings, like those observed in oligohaline forests and also in water edge forests of euhaline and mesohaline areas of Babitonga Bay area fitted to typical mature forests. The high density of adults and seedlings and the low tree biomass observed in landward forests of euhaline and mesohaline areas of Babitonga Bay fitted to expected younger forests. Despite this, we believe there were no important differences in maturity stages among the plots, but those structural differences could be consequences of environmental factors related to flooding frequency and freshwater input, similarly to observed by CHEN and TWILLEY (1999) and by SHERMAN *et al.* (1998), which reported strong influence of edaphic factors (mainly soil nutrients availability) on mangrove structure.

As a general pattern, in Babitonga Bay flooding frequency is more important than salinity to determine mangrove forest structure, probably due modifications of soil characteristics by different tidal washing. Which characteristics are those, how they vary with flooding frequency, and how they determine structural patterns of mangrove forests in Babitonga Bay are matters which need to be investigate in a future work.

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LITERATURE CITED

BALL, M.C., 1998. Mangrove species richness in relation to salinity and waterlogging: a case study along Adelaide River Floodplain, Northern Australia.Global Ecol. Biogeogr. Letts., 7:73-82.

BUNT, J. S. & STIEGLISTZ, T., 1999. Indicators of mangrove zonality: the Normanby River, N.E. Australia. Mangroves and Salt Marshes, 3:177-184.

BUNT, J. S., 1996. Mangrove zonation: an examination of data from seventeen riverine estuaries in tropical Australia. Ann. Bot., 78:333-341.

BUNT, J. S., 1999. Overlap in mangrove species zonal patterns: some methods of analysis. Mangroves and Salt Marshes, 3:155-164.

CHAPMAN, V. J., 1976. Mangrove Vegetation. J. Cramer, West Germany, 447p.

CHEN, R. & R. R. TWILLEY., 1998. A gap dynamic model of mangrove forest development along gradients of soil salinity and nutrient resources. Journal of Ecology, 86:37-52.

CHEN, R. & R. R. TWILLEY., 1999. Patterns of mangrove forest structure associated with soil nutrient dynamics along the Shark River estuary. Estuaries, 22:1027-1042.

CINTRON, G. & SCHAEFFER-NOVELLI, Y., 1983. Introduccion a la Ecologia del Manglar. Montevideo, Uruguay, ROSTLAC - UNESCO. 109 p.

CINTRON, G. & SCHAEFFER-NOVELLI, Y., 1985. Caracteristicas y desarrollo estructural de los manglares de Norte y Sur America. Ciencia Interamericana 24(1-4): 4-15.

CINTRON, G.; LUGO, A. E. & MARTINEZ, R., 1985. Structural and functional properties of mangrove forests. In: DARCY, W.G. & CORREA, A. (ed). The Botany and Natural history of Panama, Missouri Botanical Garden, Saint Louis, Missouri. Pp.53-66.

DAVIS, J.H. Jr., 1940. The ecology and geologic role of mangroves in Florida. Papaers from Tortugas Laboratory, no 32. Carnegie Institute of Washington Publications, 517:303-412.

DAY JR., J. W.; CONNER, W.; LEY-LOU, F.; DAY, R. H. & MACHADO, A. N., 1987. The productivity and composition of mangrove forests, Laguna de Terminos, Mexico. Aquatic Botany, 27:267-284.

DAY JR., J. W.; CORONADO-MOLINA, C.; VERA-HERRERA, F.; TWILLEY, R. R.; RIVERA-MONROY, V. H.; ALVAREZ-GUILLEN, H.; DAY, R. & CONNER, W., 1996. A 7 year record of above-ground net primary production in a southeastern Mexican mangrove forest. Aquatic Botany, 55: 39-60

DUKE, N.C.; BALL, M.C. & ELLISON, J.C., 1998. Factors influencing biodiversity and distributional gradients in mangroves. Global Ecol.Biogeogr.Letts. 7:27-47.

ELLISON, A. M. & FARNSWORTH, E. J., 1993. Sedling survivorship, growth and response to disturbance in Belizean mangal. American Journal of Botany, 80:1137-1145.

ELLISON, A. M. & FARNSWORTH, E. J., 1997. Simulated sea level change alters anatomy, physiology, growth, and reproduction of red mangrove (Rhizophora mangle L.). Oecologia, 112: 435-446.

ELLISON, A. M. & FARNSWORTH, E. J., 2001. Mangrove communities. In: BERTNESS, M. D.; GAINES, S. & HAY, M. E. (eds). Marine Community Ecology. Sinauer Press, Sunderland, Massachusetts, USA. Pp. 423-442

FARNSWORTH, E. J. & ELLISON, A. M., 1997. Global patterns of pre-dispersal propagule predation in mangrove forests. Biotropica, 29: 318-330.

FLORES-VERDUGO, F. J.; GONZALEZ-FARIA, F.; ZAMORANO, D. S. & RAMIREZ-GARCIA, P., 1992. Mangrove ecosystems of the pacifc coast of Mexico: distribution, structure, litterfall and detritus dynamics. In: SEELIGER, U. (Ed.) Coastal Plant Communities of Latin America. San Diego, Academic Press. Pp. 269-288.

IBAMA, 1998. Proteção e controle de ecossistemas costeiros: manguezal da Baía de Babitonga., 146 p.

KJERFVE, B. & LACERDA, L.D., 1993. Mangroves of Brazil. In: LACERDA, L.D. (Ed.). Conservation and sustainable utilization of mangrove forests in Latin America and Africa regions. ITTO/ISME PD 114/90(F), p. 245-272.

LUGO, A. E. & SNEDAKER, S. C., 1974. The ecology of mangroves. Ann. Rev. Ecol. Syst. 5:39-64.

LUGO, A. E.; BROWN, S. & BRINSON, M. M., 1988. Forested wetlands in freshwater and saltwater environments. Limnology and Oceanography, 33(4/2):894-901.

MACNAE, W. 1968. A general account of the fauna and flora of mangrove swamps and forests in the indo-West Pacific region. Adv. Mar. Biol. 6:73-270.

MCKEE, K.L., 1993. Soil physicochemical patterns and mangrove species distribution reciprocal effects? Journal of Ecology, 81:477-488.

MCKEE, K.L., 1995. Seedling recruitment patterns in a Belizean mangrove forest: effects of establishment ability and physico-chemical factors. Oecologia, 101:448-460.

RIVERA-MONROY, V. H.; MADDEN, C. J.; DAY, JR., J. W.; TWILLEY, R. R.; VERA-HERRERA, R. & ALVAREZ-GUILLEN, H., 1998. Seasonal coupling of a tropical mangrove forest and an estuarine water column: enhancement of aquatic primary productivity. Hydrobiologia 379:41-53.

ROBERTSON, A. I., 1991. Plant-animal interactions and the structure and function of mangrove forest ecosystems. Australian Journal of Ecology, 16:433-443.

SCHAEFFER-NOVELLI, Y.; CINTRON, G.; ADAIME, R. R. & CAMARGO, T. M. 1990. Variability of mangrove ecosystems along the Brazilian Coast. Estuaries, 13: 204-218.

SHERMAN, R. E.; FAHEY, T. J. & BATTLES, J. J., 2000. Small-scale disturbance and regeneration dynamics in a neotropical mangrove forest. Journal of Ecology, 88:165-178

SHERMAN, R. E.; FAHEY, T. J. & HOWARTH, R. W., 1998. Soil-plant interactions in a neotropical mangrove forest: iron, phosphorus and sulfur dynamics. Oecologia, 115:553-563.

SMITH, T. J. III., 1992. Forest structure. In: Robertson, A.I. & Alongi, D.M. (Eds). Tropical Mangrove Ecosystems. American Geophysical Union, Washington, D.C. pp.101-136.

TOMLINSON, P. B., 1986. The Botany of Mangroves. Cambridge University press, Cambridge. 413p.

TWILLEY, R. R.; LUGO, A. E. & PATTERSON-ZUCCA, C., 1986. Litter production and turnover in basin mangrove forests in southwest Florida. Ecology, 67:670-683.