LITTER PRODUCTION OF *Rhizophora Mangle* AT BACALAR CHICO, SOUTHERN QUINTANA ROO, MEXICO

PRODUCCIÓN DE HOJARASCA DE *Rhizophora Mangle* EN BACALAR CHICO, AL SUR DE QUINTANA ROO, MÉXICO

Alberto de Jesús Navarrete (alberto@ecosur-qroo.mx.) [1]
José Juan Oliva Rivera [2]

El Colegio de la Frontera Sur-Unidad Chetumal [1, 2]
Chetumal, Quintana Roo, México.

Artículo recibido: 28 de noviembre de 2001
Artículo aceptado: 19 de septiembre de 2002

ABSTRACT

In order to know the litter fall of the red mangove, *Rhizophora mangle*, samples were collected from July 1996 to July 1997 in the channel of Bacalar Chico in southern of Quintana Roo state. Litter was collected bimonthly in duplicate baskets at five sites. Four mangrove species were present in the study area, but *R. mangle* dominated widely. Leaf production comprised 99.8% of total litter fall biomass, being the highest in July and September 1996 (0.27 g·dry wt·m^{-2}·day^{-1} and 0.28 g·dry wt·m^{-2}·day^{-1} respectively). Although, the flowers and the fruits represented less of 1% of total litter production, it was clear that the reproductive season was coincident with the highest values of temperature and precipitation, both occurring in September. Mangrove in Quintana Roo produced a total litter fall of 2.61 t dry wt $ha^{-1}year^{-1}$. Mangroves of Quintana Roo must be protected and used with conservation criteria.

Key words: coastal zone, litter fall, *Rhizophora mangle*, Quintana Roo, Mexico.

RESUMEN

Para conocer la producción de hojarasca del mangle rojo, *Rhizophora mangle*, se recolectaron muestras de julio 1996 a julio 1997 en el Canal de Bacalar Chico al sur de Quintana Roo. La hojarasca se recolectó cada dos meses utilizando canastas por duplicado en cinco sitios. Cuatro especies de manglar estuvieron presentes, pero *R. mangle* mostró una amplia dominancia. La producción de hojas correspondió al 99.8% de la biomasa total, siendo la máxima en julio y septiembre de 1996 (0.27 g·peso seco libre de cenizas·m^{-2}·day^{-1} y 0.28 g· peso seco libre de cenizas·m^{-2}·day^{-1} respectivamente). A pesar de que las flores y frutos representaron menos del 1% de la producción total, fue notorio que la estación reproductiva coincidió con los valores más altos de temperatura y precipitación, que se presentaron en septiembre. Los manglares de Quintana Roo produjeron una biomasa de hojarasca de 2.61 t peso seco libre de cenizas $ha^{-1}year^{-1}$. Los manglares de Quintana Roo deben ser protegidos y usados con criterios de conservación.

Palabras clave: zona costera, producción de hojarasca, *Rhizophora mangle,* Quintana Roo, México.

INTRODUCTION

Mangroves and salt marshes are considered among the most productive ecosystems of the world (Chapman, 1977). Mangroves are important producers of organic matter in tropical systems and their influence extends beyond the coastal line, reaching coral reef areas (Fleming *et al*., 1990). Mangrove litter fall contributes, via detritus, to the food chains in the benthic coastal systems (Odum and Heald 1972; Snedaker, 1978).

The biological and ecological aspects of mangroves have been studied worldwide (Lugo and Snedaker, 1974; Boto *et al*., 1984; Hutchings and Saenger, 1985; Twilley *et al*., 1986; Odum and McIvor, 1990; Twilley, 1995; Cox and Allen, 1999). In the Caribbean region, the studies of Lugo and Bayle (1992), Twilley *et al*. (1992), Garrity *et al*. (1994) stand out. Most researchers deal with patterns of primary productivity, nutrient cycle and detrital export in riverine mangroves, whereas fringe and scrub mangrove have been studied to a lesser extent (Twilley *et al*., 1992; Alongi *et al*., 1992; Lee, 1995). Recently, Ellison and Farnsworth (1996) discussed the anthropogenic and natural disturbance of Caribbean's mangroves, but they do not include information from Mexico.

The first work related to mangrove productivity in Mexico was accomplished in Campeche by Rico-Gray (1982). López Portillo (1982) determined litter fall in relation to salinity, dissolved oxygen and flooding level, whereas López-Portillo and Ezcurra (1985), determined the litter fall of *Avicennia germinans* during an annual cycle; both studies were carried out at the Mecoacan lagoon in Tabasco. At Terminos lagoon in Campeche, several investigations related to structure and production of mangroves have been carried out (Day *et al*., 1987; Rivera-Monroy *et al*., 1995). Flores-Verdugo *et al*. (1987) studied litter fall in a coastal lagoon at the Mexican Pacific.

In the Yucatan Peninsula, mangroves have been studied as part of more general vegetation studies (Rico-Gray, 1982; Olmsted and Duran, 1990; Trejo-Torres *et al*., 1993) or as studies on the effects of hurricanes (Whigham, *et al*., 1991). There are very few specific studies on mangroves in the Yucatan peninsula (Trejo, 1986; Trujeque, 1990; Granados-Sánchez *et al*., 1998; Domínguez *et al*., 1998). This is unfortunate since mangroves constitute a conspicuous community in the Yucatan peninsula, where particular characteristics occur: no river flows and a dominance of calcareous sediments. These characteristics give to the Yucatan peninsula mangroves a different structure and dynamics at the Gulf of Mexico and the Pacific Ocean mangrove communities.

Nowadays, mangroves at the southern of Quintana Roo coast are in a good conservation shape. However, there is no information on structure or mangrove production. Despite, they are threatened due to the Costa Maya tourist development. The goal of this study was to describe fringe mangrove from the southern part of Quintana Roo, and to provide quantitative information on *Rhizophora mangle* litter fall production.

MATERIALS AND METHODS

Study area. - Bacalar Chico is a set of shallow channels, located at the south of Xcalak, in the international borderline with Belize. These channels communicate the Chetumal Bay with the Caribbean Sea. Swamps and mangroves surround the area. Salinity in this area varies from 21 to 37 PSU.

The dry season extends from March to June, while the rainy season from July to October. The cold season is characterized by strong northerly winds ("nortes"), and goes from November to February. According to meteorological data from Comisión Nacional del Agua in Chetumal, the mean temperature during the sample period was 27.49 ± 4.98 °C, whereas mean precipitation was 4.45 ± 8.20 mm. The highest precipitation was recorded in September (11.15 ± 16.76 mm) (CNA, 1997).

Samples were collected bimonthly from the southern coast of Quintana Roo, from July 1996 to July 1997 at five sites (Fig. 1). No samples were taken in March and May 1997 because of logistics problems. The first site (E1) was located in the Chetumal Bay (18° 12' 31" N, 87° 52' 28" W) corresponding to a dwarf mangrove patch. The next two sites (E2, E3) were located at the San Juan channel in the international borderline with Belize (18° 11' 14" N, 87° 51' 37" W and 18° 10' 57" N, 87°51' 21" W). The last two sites (E4 and E5) were located at the Mexican Caribbean Sea (18° 14' 11" N, 87°50' 22" W and 18°11' 11" N, 87° 50' 53" W) (Fig. 1).

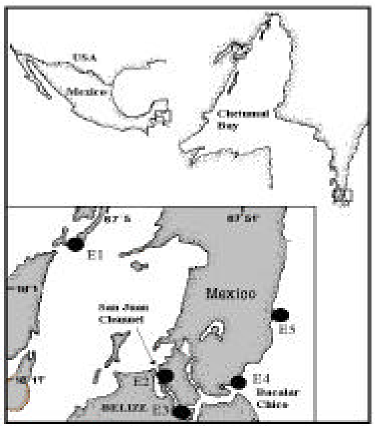

Figura 1. Study area showing the five study sites in the Chetumal Bay, Mexico.

At each site, a 200 m line transect was established from the coastline to inland. Ten points separated by 20 m between them were established. In each point, trees were counted, and identified within a ten-meter diameter and the estimated height.

Two 0.10 m^2 baskets, made of chicken wire 0.05 cm mesh size were installed at each site, exclusively in the *R. mangle* zone. Baskets were tied to the tree trunks at a height of 1.5 m to prevent losses by flooding. In the laboratory, the collected material was separated into the following fractions: leaves, flowers, fruits, and stalks, and dried at 70 °C for 72 hours. Each component was weighted separately using an analytic balance (0.0001 g). Litter fall biomass was expressed as g·dry wt·m^{-2}·day^{-1} (Brown, 1984).

Temperature (°C) and dissolved oxygen (mg/l) were recorded in the surface of adjacent water of each site, using an oxygen meter (YSI Model 58). Salinity (PSU) was measured with a temperature-conductivity meter (OHAUS Model 50).

Friedman's analysis of variance by ranks was applied to determine significant differences between the litter fall components: leaves, flowers, fruits and stalks ($p < 0.05$); site and period sample were considered as blocks, using Statgraphics 4.0 computer software.

RESULTS

Site E1 corresponded to a small islet, (5 m in diameter) where *R. mangle* and *Avicennia germinans* were the occurring mangroves, with a maximum height of 3.0 m for *R. mangle*.

E2 and E3 *R. mangle* were dominant at sites, extending 40 m away from the coastal margin, with trees as high as 7 m. From there onwards, *A. germinans* and *Laguncularia racemosa* were present reaching 8 to 15 m in height. At Bacalar Chico channel (E4) the four mangrove species reported for the region were found, *R. mangle* dominated the border and extended 70 m towards inland, a ribbon of mixed mangrove followed later, composed of *R. mangle*, *A. germinans*, *L. racemosa*. *Conocarpus erectus* was located at the end of the 200 m transect. The taller trees were *L. racemosa* (7 m), while the other components had heights between 5 and 6 m. In E5, trees of the four species were found with heights ranging from 5 to 7 m. Like in the other sites, *R. mangle* was the dominant species. Tree densities at each site were: E1, 0.004 ind/ 0.1 Ha; E2, 212 ind/ 0.1 Ha; E3, 188 ind/ 0.1 Ha; E4, 104 ind/0.1 Ha and E5, 197 ind/ 0.1 Ha. This information and other related to mangrove structure characteristics will be published soon (de Jesús-Navarrete and Oliva-Rivera, in prep).

The leaf litter biomass ranged from 0.077 g·dry wt·m^{-2}·day^{-1} to 0.408 g·dry wt·m^{-2}·day^{-1} during the sampling period.

The site E2 had a leaf productivity of 0.383 g·dry wt·m^{-2}·day^{-1} in July 1996 and 0.408 g·dry wt·m^{-2}·day^{-1} in September. E5 had 0.289 g·dry wt·m^{-2}·day^{-1} in July and 0.384 g·dry wt·m^{-2}·day^{-1} in September 1996. (Fig. 2a).

Friedman's test showed statistical significant differences in the leaf litter fall between sites and months, $(?^2)_{0.05, 5, 5} = 11.68$.

Stalks represented an intermediate supplier of litter biomass between all components. Higher production was registered at E4 in September 1996 (0.17

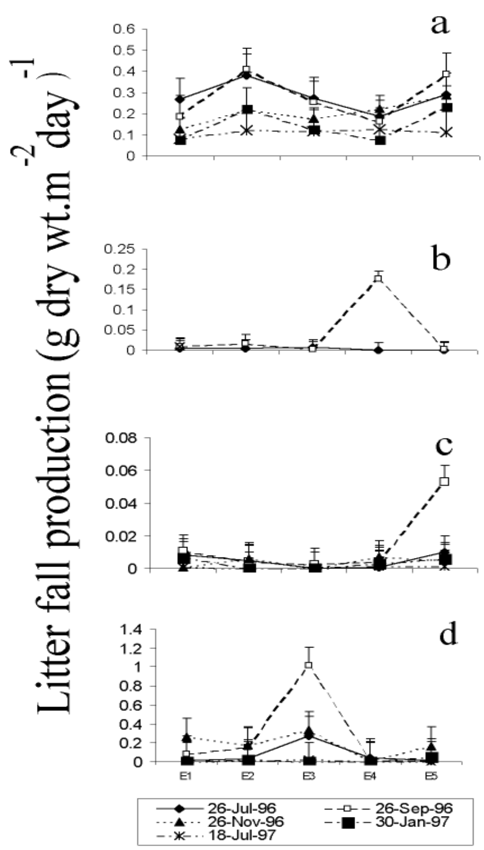

Figura 2. Litter production by component of mangroves at southern Quintana Roo. a) Leaves, b) Stalks c) Flowers d) Fruits. Notice differences on scale.

g·dry wt·m^{-2}·day^{-1}) whereas lower production corresponded to E5 (0.0015 g·dry wt·m^{-2}·day^{-1}). In November 1996 and July 1997 there was no stalk litter fall production (Fig. 2b). No significant differences were found between sites nor between months.

Flower production ranged from 0.0006 g·dry wt·m^{-2}·day^{-1}. to 0.053 g·dry wt·m^{-2}·day^{-1}. The highest flower production occurred at E5 in September, whereas the lowest production occurred in November 1996 (Fig. 2c). There were no significant differences in flower production between sites nor between months.

Fruit litter fall biomass ranged from 0.0023 g·dry wt·m^{-2}·day^{-1} at site E1 in July 1997 to 1.01 g·dry wt·m^{-2}·day^{-1} in September 1996 at site E3 (Fig. 2d). There were significant differences between months in fruit litter fall biomass $(?^2)_{0.05, 5, 5}$ = 10.22, but not between sites.

The total annual litter fall was 2.61 t dry wt.ha^{-1}, and 99.83% corresponding to leaf production (Table 1).

The lowest water temperature was registered in January (26.5 °C), while highest temperatures were measured in July and September 1996 (31.7 and 31.1 °C, respectively). Salinity at sites E2 to E5 varied from 31.2 to 36.4 PSU, with lowest values in

Table 1. Contribution of major mangrove components to total litter fall for predominantly mono-specific stands (-) no data.

Percent of total litter fall						
Predominant specie	**Location**	**Total Litter fall (t ha^{-1}yr^{-1})**	**Leaves (%)**	**Reproductive material (%)**	**Other (%)**	**Source**
Avicennia spp.	Australia	8.00- 10.00	-	-	-	Clough 1992
Avicennia marina	New Zealand	8.10	69.4	12.3	18.3	Woodroffe *et al*., 1988
Rhizophora apiculata	Australia	11.15	53.9	22.5	23.6	Bunt 1982
Rhizophora mangle	Florida,	16.30	-	-	-	Saenger and Snedaker, 1993.
Rhizophora mangle	Venezuela	21.00	-	-	-	Wiebe *et al*. 1997.
Rhizophora mangle	Hawaii	25.20	51.9	44.8	3.3	Cox and Allen, 1999
Rhizophora mangle	Mexico	11.00	-	-	-	Espinoza *et al*., 1981
Rhizophora mangle	Mexico	12.63	59.30	-	-	Rico-Gray and Lot, 1983.
Avicennia germinans	Mexico	6.14	83	8	9	López-Portillo and Ezcurra, 1985
Laguncularia racemosa	Mexico	11.00	89.09	-	-	Flores Verdugo *et al*. 1987.
Rhizophora mangle	Mexico	12.52	70.28	-	-	Day *et al*., 1987
Rhizophora mangle	Mexico	2.61	99.83	0.15	0.01	This study

November and January. At site E1, salinity ranged from 21.6 PSU to 28.0 PSU, whereas E2 there was 44.5 PSU, the rest of the salinity values were 38.2 at E3, 43.8 at E4 and 38.5 at E5. The lowest concentration of dissolved oxygen was registered in November 1996 (2.9 mg·l^{-1}), whilst the highest value was found in January 1997 (7.5 mg·l^{-1}) (Table 2).

Table 2. Temperature (°C), salinity (PSU), and dissolved oxygen, (mgl^{-1}) of the adjacent water of five mangrove stands at southern Quintana Roo, Mexico.

	E1			E2			E3			E4			E5		
	T	**Sal**	**DO**	**T**	**Sal**	**DO**	**T**	**Sal**	**DO**	**T**	**Sal**	**DO**	**T**	**Sal**	**DO**
Jul 1996	31.7	28.0	7.4	28.1	36.4	4.0	28.0	36.5	5.1	27.5	35.3	5.3	27.2	37.3	4.1
Sep 1996	31.1	28.0	7.3	32.6	36.5	6.3	31.0	--	5.7	29.5	--	4.3	29.5	--	5.2
Nov 1996	28.3	23.9	7.5	27.5	31.2	2.9	27.6	32.9	4.5	26.5	32.4	--	27.9	35.5	5.9
Jan 1997	26.5	21.6	7.5	26.9	32.2	--	26.3	31.3	--	25.8	33.6	--	25.7	34.2	--
Jul 1997	29.4	22.6	--	28.4	--	5.2	28.0	--	5.5	30.0	--	--	28.7	--	6.7

DISCUSSION

The mangroves of Quintana Roo are similar to other Caribbean areas, with only four species, mixed stands, and a dominance of *R. mangle*. In oligotrophic low salinity environments, it is common to find poorly developed stands (Pool *et al*., 1977; Twilley *et al*., 1992; Chen and Twilley, 1999). Probably, this is the case at the site E1, where salinity was 28 PSU and sediments were apparently reduced, given the existence of an intense H_2S smell, which probably affected the height of trees (Lugo and Snedaker, 1974).

At all sampling sites, *mangle* was the dominant species, but an increase in the number of species from site E2 to site E5 was evident. Mixed stands exhibited heights over 7m with a good development. These data are coincident with the observations of Ellison and Farnswhorth (1996), who reported heights lower than 10m for *R. mangle* trees at Wee Wee Cays in Belize.

In general, *R. mangle* dominates neotropical mangrove forests, in stems density, net primary productivity and litter export from mangal (Hutchings and Saenger, 1985; Tomlinson, 1986; Saenger and Snedaker, 1993). This litter exportation is possible because *R. mangle* adjusts their leaf morphology, photosynthetic rate, plant structure and nutrient uptake to changing resource variability (Tomlinson, 1986; Feller, 1995; Ball, 1996; Farnsworth and Ellison, 1996). This adaptability is reflected by the presence of tall trees and forest in riverine and dwarf scrub towards inland areas (Lugo and Snedaker, 1974; Lugo, 1980; Feller, 1995). However, there is no available information on fringe mangroves like Quintana Roo's systems, which depend on variations on low tide amplitude, sediment type and nutrient supply for their growth.

The litter fall found in Quintana Roo (2.61 t dry wt.ha^{-1} yr^{-1}) was lower to other values reported for other sites (Table 1), however the data from July 1997 must be taken with caution, because litter was collected after five months in the environment. A production from 8.0 to 10.00 t dry wt.ha^{-1} year^{-1} has been reported for the mangroves of Australia (Clough, 1992). Litter fall rates greater than 20, or even 15 t ha^{-1} yr^{-1} have been reported for very few stands (Bunt, 1982). The highest litter fall rate that has been reported for *R. mangle* is 25.2 t ha^{-1} yr^{-1} in Hawaii (Cox and Allen, 1999), followed by 16.3 t ha^{-1}yr^{-1} for a mangrove stand from the southwest Florida (Saenger and Snedaker, 1993). Weibe et al. (1997) described preliminary results for various locations in the Caribbean, listed a site from Venezuela producing 21 t ha^{-1} yr^{-1} (Table 1). Litter production seems to vary with latitude, with a low production at high latitudes (Wiebe *et al*., 1997).

The presence of a channel system in the study area (Fig. 1) with a very low kinetic energy, besides low tide amplitude that diminish the litter exportation and therefore causing a high nutrient concentration in adjacent water, could be a factor that encouraged a high mangrove production in this area.

The litter fall production found was lower than other data collected in Mexico. Espinoza *et al*. (1981) found a litter production of 11.00 t ha^{-1} yr^{-1} in Baja California Sur at the northern limit of *R. mangle* distribution. Flores-Verdugo *et al*. (1987) reported a production of 11.00 t ha^{-1} yr^{-1} of *L. racemosa* for a coastal lagoon from the Mexican Pacific coast, 89% corresponding to leaves. In the region of Gulf of Mexico, Rico-Gray and Lot (1983) reported a litter production of 12.63 t ha^{-1} yr^{-1} in a fringe *R. mangle* association at Veracruz. López-Portillo and Ezcurra (1985) registered 6.14 t ha^{-1} yr^{-1} of *A. germinans* in Tabasco, and Day *et al*. (1987) found a production of 12.52 t ha^{-1} yr^{-1} at Terminos Lagoon in Campeche (Table 1).

As in the whole Caribbean region in Quintana Roo, the minimum litter production occurred in winter and the highest in summer (July-September). In Belize, the highest production was reported from August to October and it was related to temperature (Wiebe *et al*., 1997). However, the maximum litter production has been attributed to factors like water stress during hot, dry periods (Gill and Tomlinson, 1971; Lugo and Snedaker, 1974) increased precipitation (Pool *et al*., 1977) and wind (Sasekumar and Loi, 1983). Other evidence indicates that litter fall production might be related to tree height or other aspect of stand structure. Woodroffe *et al*. (1988) found that litter fall of *A. marina* tress exceeding 10 m in height was about 8 t ha^{-1} yr^{-1}, while production from smaller tress could be considerably less than 3 t ha^{-1} yr^{-1}. Other authors consider that there is no correlation between litter production and mangrove forest structure (Flores-Verdugo *et al*., 1987).

Even though the flower and fruit production was very low, it is clear that the reproductive season corresponds to an increase on temperature and precipitation, occurring from July to September. Flowers were conspicuous at trees since May, but its collection in baskets was low, (<1%), probably as an effect of sample size. The reproductive season also was coincident with the presence of rain, probably as a strategy for seeds dispersion.

Mangroves at southern Quintana Roo are in a good conservation state and with high litter production. They must be protected and used under conservation criteria. Further research on nutrient content, sediment dynamic and water dynamics will help us to understand the distribution of trees in calcareous sediments of this area.

ACKNOWLEDGEMENTS

To A. Medina, M. Domínguez, N. Quintero and W. Hadad for their support on the data collection; to B. Schmook and J. Espinoza Avalos for their comments and to two anonymous reviewers who improved the manuscript.

LITERATURE CITED

ALONGI, D.M., K. G. BOTO and A. I. ROBERTSON. 1992. Nitrogen and phosphorous cycle's pp. 251-292. In: Robertson, A. I and D. M. Alongi (Eds).Tropical Mangrove Ecosystems, American Geophysical Union, Washington, D.C.

BALL, M. C. 1996. Canopy structure and dynamics: integration of growth process in tropical pioneer trees pp. 619-658. In: Mulkey, S. S., R. L. Chazdon and P. P. Smith (Eds), Tropical Forest Plant Ecophysiology. Chapman and Hall, New York.

BUNT, J. S. 1982. Studies of mangrove litter fall in tropical Australia. pp. 223-238. In: Clough, B. F. (Ed),Mangrove Ecosystems in Australia: Structure Function and Management. Australian National University Press, Canberra, Australia.

BOTO, K.G., J.S. BUNT and J.T. WELLINGTON. 1984. Variations in mangrove productivity in Northern Australia and Papua New Guinea. Estuarine, Coastal and Shelf Science 19: 321-329.

Brown, M. S. 1984. Mangrove leaf litter production and dynamics pp. 231-238. In: Snedaker, S.C. and J. G. Snedaker (Eds). The Mangrove Ecosystem: Research Methods. UNESCO, Paris.

CLOUGH, B. F. 1992. Primary productivity and growth of mangrove forest, pp. 225-249. In: Robertson, A. I. and D. M. Alongi. (Eds). Tropical Mangrove Ecosystems. American Geophysical Union Coastal and Estuarine Series, Volume 41, Washington, D. C.

CNA, 1997. Comisión Nacional del Agua, datos meteorológicos diarios, Estación Chetumal, Q, Roo. México.

CHAPMAN, V. J. 1977. Introduction. pp 1-29. In: Chapman, V. J,. (Ed). Ecosystems of the World 1. Wet Coastal Ecosystems. Elsevier, New York. 428 pp.

Chen, R., R. and R. Twilley. 1999. Patterns of mangrove forest structure and soil nutrient dynamics along the Shark river estuary Florida. Estuaries. 22: 955-970.

COX, E. F. and J. A. ALLEN. 1999. Stand structure and productivity of the introduced *Rhizophora mangle* in Hawaii. Estuaries 22: 276-284.

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

DOMINGUEZ, C. A., L. E. EGUIARTE, J. NÚÑEZ-FARFAN and R. DIRZO.1998. Flower morphometry of *Rhizophora mangle* (Rhizophoraceae): Geographical variations in Mexican populations. American Journal of Botany 85: 637-643.

ELLISON, A. M. and E. J. FARNSWORTH. 1996. Anthropogenic disturbance of Caribbean mangrove ecosystems: past impacts, present trends and future predictions. Biotropica 28: 549-565.

ESPINOSA, M., P. SÁNCHEZ, and E. MUÑOZ. 1981. Valor energético de los detritos y algunos aspectos de la productividad y degradación de *Rhizophora mangle* en tres zonas de manglar de la bahía de la Paz, Baja California Sur. Annual Laboratory Report, pp. 137-139.

FARNSWORTH, E. J. and A. M. ELLISON. 1996. Sun-shade adaptability of the red mangrove, *Rhizophora mangle* (Rhizophoraceae): changes through ontogeny at several levels of biological organization. American Journal of Botany 83: 1131-1143

FELLER, I. C. 1995. Effects of nutrient enrichment on growth and herbivory of dwarf red mangrove (*Rhizophora mangle*). Ecological Monographs 65: 477-506.

FLEMING, M., G. LIN and L.S.L. STERNBERG. 1990. Influence of mangrove detritus in an estuarine ecosystem. Bulletin of Marine Science. 47: 663-669.

FLORES-VERDUGO, F., J. W. DAY and R. B. DUEÑAS, 1987. Structure, litter fall, decomposition and detritus dynamic of mangroves in a Mexican coastal lagoon with an ephemeral inlet. Marine Ecology Progress Series 35: 83-90.

GARRITY, S. D., S. C. LEVINGS and K. A. BURNS. 1994. The Galeta Oil Spill I. Long-term effects on the Physical structure of the mangrove fringe. Estuarine, Coastal and Shelf Science 38: 327-348.

GILL, A.M. and P.B. TOMLINSON.1971. Studies on the growth of red mangrove (*Rhizophora mangle* L.) 2. Growth and differentiation of aerial roots. Biotropica 3: 63-77.

GRANADOS-SÁNCHEZ, D., G. LÓPEZ-RÍOS, F. DE J. MARTÍNEZ, and J. MARTÍNEZ-CASTILLO. 1998. Los manglares de Quintana Roo, Revista Chapingo, IV: 253-265 .

HUTCHINGS P. A, and P. SAENGER. 1985. Ecology of mangroves, University of Queensland press, St. Lucie.

LEE, S. Y. 1995, Mangrove outwelling: A review. Hydrobiologia 295: 203-212.

LÓPEZ-PORTILLO, J. 1982. Ecología de manglares y de otras comunidades de halófitas en la laguna de Mecoacán, Tabasco. Tesis Profesional. Facultad de Ciencias, UNAM 160 pp.

LÓPEZ-PORTILLO, J. and E. ESCURRA. 1985. Litter fall of *Avicennia germinans* L. in a one-year cycle in a mudflat at the Laguna de Mecoacan, Tabasco, Mexico. Biotropica 17: 186-190.

LUGO, A. and B. BAYLE. (Eds). 1992. Wetlands management in the Caribbean and role of forestry and wetlands in the economy. Institute of Tropical Forestry, Río Piedras, Puerto Rico.

LUGO, A. 1980. Mangrove ecosystem: successional or steady state? Biotropica 12 (supplement): 65-72.

LUGO , A. E. and S. C. SNEDAKER. 1974. The ecology of mangroves. Annual Review of Ecology and Systematic 5: 39-64.

ODUM, W. E. and C. C. MCIVOR. 1990. Mangroves pp. 517-548., In: Myers, R. L. y J.J. Ewel (Eds). Ecosystems of Florida, University of Central Florida Press. USA.

ODUM, W. E. and E. J. HEALD, 1972. Trophic analyses of an estuarine mangrove community. Bulletin of Marine Science 22: 671-738.

OLMSTED, I. and R. DURÁN. 1990. Vegetación de Sian Kaán. Pp 1-12. In: Navarro, D. and J. Robinson. (Eds). Diversidad Biológica en la Reserva de la Biosfera de Sian Ka´an. Quintana Roo, México. Centro de Investigaciones de Quintana Roo, Chetumal, 350 pp.

POOL, D. J., S. C. SNEDAKER and A. E. LUGO. 1977. Structure of mangrove forest in Florida, Puerto Rico, Mexico and Costa Rica. Biotropica 9: 195-212.

RICO-GRAY, V. 1982. Estudio de la vegetación de la zona costera inundable del noroeste del estado de Campeche, México: Los Petenes. Biótica 7:171-188.

RICO-GRAY, V. and A. H. LOT. 1983. Producción de hojarasca del manglar de la Laguna de la Mancha, Veracruz, México. Biótica 3: 295-301.

RIVERA-MONROY, V.H. , J.W. DAY, R. TWILLEY, F. VERA-HERRERA and C. CORONADO-MOLINA. 1995. Flux of nitrogen and sediments in a fringe mangrove forest in Terminos Lagoon, Mexico. Estuarine, Coastal and Shelf Science 40: 139-160.

SAENGER, P. and S. C. SNEDAKER. 1993. Pantropical trends is mangrove above-ground biomass and litter fall. Oecologia 96: 293-299.

SASEKUMAR, A. and J. J. LOI. 1983. Litter production in three mangrove forest zones in the Malay Peninsula. Aquatic Botany 17: 283-290.

SNEDAKER, S. C. 1978. Mangroves their value and perpetuation. Natural Resources 14:6-13.

TREJO, J. A. 1986. Estudio de la vegetación de la zona costera inundable perteneciente a los bordes de la laguna de Celestún, Yuc. Rep. Serv. Soc. UAM-I, México D.F. 30 pp.

TREJO-TORRES, J. C. , R. DURÁN and I. OLMSTED, 1993. Manglares de la Península de Yucatán. pp 660-672. In: Salazar-Vallejo, S. y E. González. (Eds) Biodiversidad Marina y Costera de México. CONABIO/CIQROO, México. 865 pp.

TRUJEQUE, C. C. 1990. Estudio de la composición de hojarasca de dos especies de manglar: *Avicennia germinans* y *Rhizophora mangle*, en el estero de Celestún Yucatán, México. Tes. Lic. Fac. Química, UADY, Mérida, 81 pp.

TOMLINSON, P. B. 1986. The Botany of Mangroves. Cambridge University Press, Cambridge.

TWILLEY, R. R. 1995. Properties of mangrove ecosystem related to the energy signature of coastal environments, pp. 43-62 In: Hall, C. (Ed). Maximum Power. University of Colorado Press, Boulder, Colorado.

TWILLEY, R. R., R. CHEN and T. HARGIS. 1992. Carbon sinks in mangroves and their implications to carbon budget of tropical ecosystems. Water, Air and Soil Pollution. 64: 265-288.

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

WIEBE, W., D. T. GERACE, L. FLOWERS, L. JHONSON, C. WARD, B. OXONFORD, C. PARKER, J. TECHIRKY, S. R. SMITH, J. ELLISON, D. DE MAYER, P. BUSH, J. GARZON-FERREIRA, J. NIVIA, L.P.J. J. POR, J. A. NEGELKERKEN, F. X. GERALDES, J. RAMIREZ, J. HERRERA-SILVEIRA, R.O. SÁNCHEZ-ARGUELLES, J.R. GARCIA, G. ALLENG. K. BONAIR, R. LAYDOO, R. VARELA, E. KLEIN, D. BONE, D. PEREZ and D. LINTON. 1997. Structure and productivity of mangrove forest in a Greater Caribbean Region. Proceedings of the 8th International Coral Reefs Symposium 1: 669-672.

WHIGHAM, D. F., I. OLMSTED, E. C. CANO and M. E. HARMON. 1991. The impact of hurricane Gilbert on trees, litter fall and woody debris in a dry tropical forest in the northeastern Yucatan Peninsula. Biotropica 23: 434-441.

WOODDROFFE, C. D., K. N. BARDSLEY, P. J. WARD and J. R. HANDLEY. 1988. Production of mangrove litter in a macrotidal embayment, Darwin Harbor, N. T., Australia. Estuarine, Coastal and Shelf Science 26 :581-598.