Leaf Litter Decomposition and Changes in Leaf C:N Ratio in the Mangals of Negombo Lagoon

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Abstract

The objective of the study was to characterize the mangrove areas in Negombo lagoon, as sources of detritus for the coastal foodwebs. Senescent *Rhizophora mucronata* leaves in 2 mm mesh bags placed in the innermost areas of a mangal in an island, lost weight faster (7-14 days) than those that were placed in the water-front areas, which took 14 - 28 days to lose 50% of the initial weight. On the contrary, litter in the 13 mm mesh bags, lost half its weight within 3 days at water-front, 7-14 days at the middle area and 35-42 days in the innermost site. In the dry season, decomposition was slower and more than 46 days were taken for 50% weight loss. *R. mucronata* leaf litter placed in the tanks filled with lagoon water took the longest time (41 days) for decomposition, further substantiating the effect of tides, soil moisture as well as the macro- and micro- organisms on the process. Carbon represented 42% and 29% of the dry weight of senescent leaves of *R. mucronata* in the wet and dry seasons respectively. During 96 days of decomposition, about 75% of this carbon was lost and about 25% transformed to particulate organic matter. An increase in the nitrogen content and a decrease in the carbon content were observed during the first 56 days of decomposition, indicating the nitrogen mobilization due to the microbial action. The remarkable decrease after 56 days may be due to the very low rainfall, thus low moisture content during this period. The nitrogen contribution to the ecosystem upto 56 days of the wet season was calculated to be 1.76×10^{-2} t/ha. The total increase of N in the wet season however is as twice as that in the dry season. The average C:N ratio of *R. mucronata* changed with decomposition from 199.7 : 1 to 69.98:1 in the dry season and from 60.97:1 to 16.06:1 in the wet season. The dietary requirement of protein for most animals is 16.5% of the dry weight of diet, which corresponds to a C:N intake of about 17:1. The detritus produced, particularly during the wet season therefore, is of immense importance to the foodwebs in these coastal waters.

Introduction

Decomposition of plant litter is the primary mechanism by which organic matter and nutrients are returned to the forest soils. Unlike in the ocean waters where phytoplankton are the key primary producers, the primary food source for aquatic intertidal mangrove dwelling organisms comes from vascular plant detritus, mostly from mangrove leaves (Odum 1970). The breakdown of mangrove leaves is brought about by the activities of micro-organisms such as fungi, bacteria and protozoa (Odum 1970; Mathias 1974).

Twilley et al. (1986) hypothesized that various rates of aquatic plant decomposition would be directly related to the initial structural integrity (as indicated by C:N ratio) of the respective autotroph.

The present study was focussed on the decomposition of *Rhizophora mucronata* leaf litter which comprises 55% (personal observations) of the total litter produced in the managed mangals of Negombo lagoon. Its objectives were to characterize the managed mangals of Negombo lagoon as a source of detritus to this aquatic system and to provide a basis for more intensive future analysis of the detritus based foodwebs in these waters.

Materials and Methods

Study Area

Negombo lagoon is an estuarine ecosystem with an extent of 3502 ha under water, located in Attanagalu oya basin which covers an area of 932.4 km^2 (Survey Department 1966). Mangroves cover 350 ha of inter-tidal land around the lagoon (Samarakoon & Van Zon 1991). The study site was located at Munnakkare, an island situated at the northern part of the lagoon. This is a cultivated mangrove stand, mainly with *Rhizophora mucronata* (the dominant species) and *Lumnitzera racemosa*.

Methods

Litter Decomposition

Nylon mesh bags of 4 mm and 13 mm mesh sizes were used for the study of litter decomposition, in order to investigate the effect of direct grazing of litter by macrofauna. Fifty grams (fresh weight) of air dried senescent leaves of *R. mucronata* were placed in 50 cm x 50 cm nylon mesh bags.

Values for daily litter decomposition rate (k) were obtained, using the regression equation between $\log_e W_t$ (W_t = dry weight remaining at time t) and t_t (time interval).

$$\text{Log}_e W_t = A + kt_t$$

Thirty bags were placed in each of the three locations, i.e., in the water-front zone (10 m from the shoreline), in more inland areas (30 m and 50 m from the shoreline), along the *R. mucronata* dominating zone of Munnakkare. Bags were retrieved in triplicate from these sites after 1, 3, 5, 7, 14 days and henceforth every fortnight for three months. Sediments accumulated in the bags and on the leaf material were removed by gently rinsing them in running tap water and the dry weights were obtained after drying at 70^{0}C to constant weight. Two trials were carried out during rainy and dry seasons in 1990.

Effect of lagoon environmental conditions such as tides, micro- and macrofauna on decomposition was determined by placing *R. mucronata* leaves in 4 mm mesh bags in two large fibreglass tanks filled with lagoon water. Water in tanks was changed twice a week.

C:N Ratio

Changes of C:N ratio during the decomposition were studies in both the seasons. The leaves retrieved from bags with different mesh sizes were pooled for the analysis for carbon and nitrogen. Carbon content of decomposing leaves were determined using Walkley & Black (1934) method and total nitrogen content by Kjeldhal method.

Results

Rate of Litter Decomposition/ Dry Matter Loss

Percentage dry weight of *R. mucronata* leaf litter remained over time, during the decomposition at Munnakkare, in wet and dry seasons as well as in tanks in the laboratory are presented graphically in Figs 1, 2 and 3 respectively.

As the initial number of litter bags used for the experiment were insufficient to extend the experiment beyond 60 days, decomposition rates could not be obtained until the decomposition of litter is completed during the dry season.

Time taken for 50% weight loss of litter placed in 4 mm and 13 mm mesh bags in the three localities and in the tank are presented in Table 1.

Daily litter decomposition rates in the wet and dry seasons are shown in Table 2. During the dry season, daily litter decomposition rate (g/day) of *R. mucronata* leaves in 4 mm mesh bags were higher than that in 13 mm mesh bags in the water-front , while it was slightly lower in 4 mm mesh bags than in 13 mm mesh bags in other two zones. During the wet spell, high leaf litter decomposition rates were observed in the 4 mm mesh bags in the water-front and mid zones and in 13 mm mesh bags in the inland locality.

During the dry season, rates of litter decomposition in the 4 mm mesh bags in the water-front were the highest, followed by the mid and inland localities. The decomposition rates of litter in 13 mm mesh bags, in the middle zone however, were greater than those in the water-front zone.

The highest average litter decomposition rate was observed in the wet season and it was found to be 7 times greater than that during the dry spell and about 1.7 times faster than the tank experiment. Hence the decomposition rate of leaves in tank experiment was approximately 4 times faster than the average decomposition rates of leaves in the field experiment in the dry season. Nevertheless, the average decomposition rates of leaves in the wet season is about 1.5 times greater than the decomposition rate of leaves in the tanks.

Carbon Content during Decomposition

Variation of percentage carbon and nitrogen during the two study periods (dry and wet) are presented in Figs 4 and 5 respectively. Initial carbon percentage of the senescent yellow leaves of *R. mucronata*, was 43 while initial percentage nitrogen content was 1.02. *R. mucronata* leaves exibited relatively uniform change in dry matter loss and percentage of carbon in each locality and season. In the wet season, leaves lost carbon rapidly and steadily, while in the dry spell, the leaves showed an initial rapid loss of carbon content which subsequently slowed down (Figs 4 and 5). Loss of carbon in wet season was greater than that in the dry season.

Nitrogen Content During Decomposition

When considered the whole decomposition period, percent nitrogen in the wet season showed a rather erratic change. During the first 56 days of decomposition however, a gradual increase in percentage nitrogen was observed in all three localities, while a marked reduction was shown in nitrogen content subsequently, in the wet season.

The relative increase in nitrogen contents during the wet season were 91%, 95% and 90% at the water-front, mid zone and inland locality respectively. In the dry spell, relative increase of nitrogen in these three localities were 30%, 47.5% and 38% respectively (Fig. 4). Hence the net nitrogen immobilization in the wet season was as twice as that in the dry

(a)

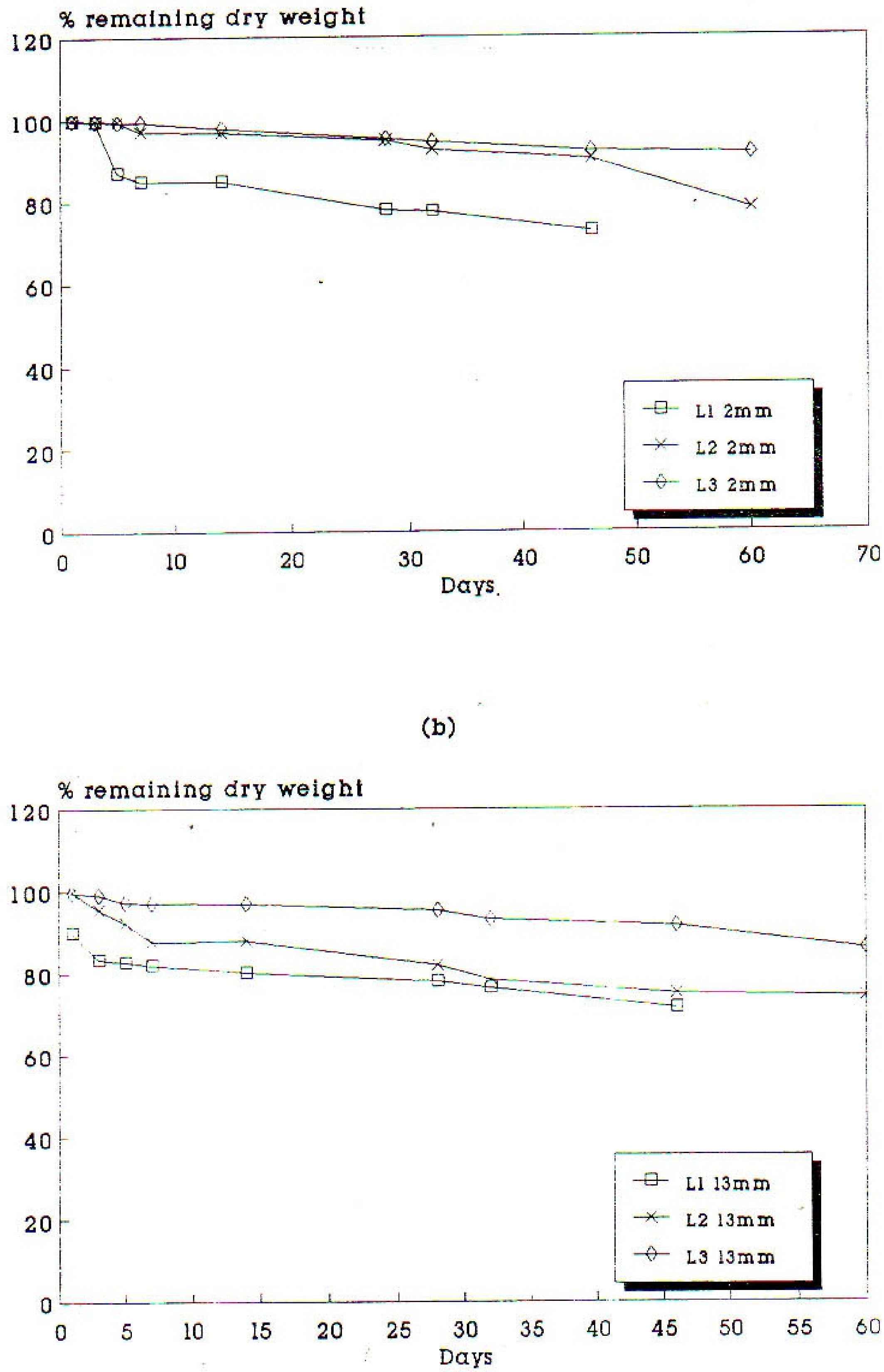

Fig. 1. Percentage dry weight of *Rhizophora mucronata* leaf litter remaining over time in (a) 2 mm mesh size (b) 13 mm mesh bags during the dry season (L1 - waterfront; L2 - middle zone; L3 - innermost area).

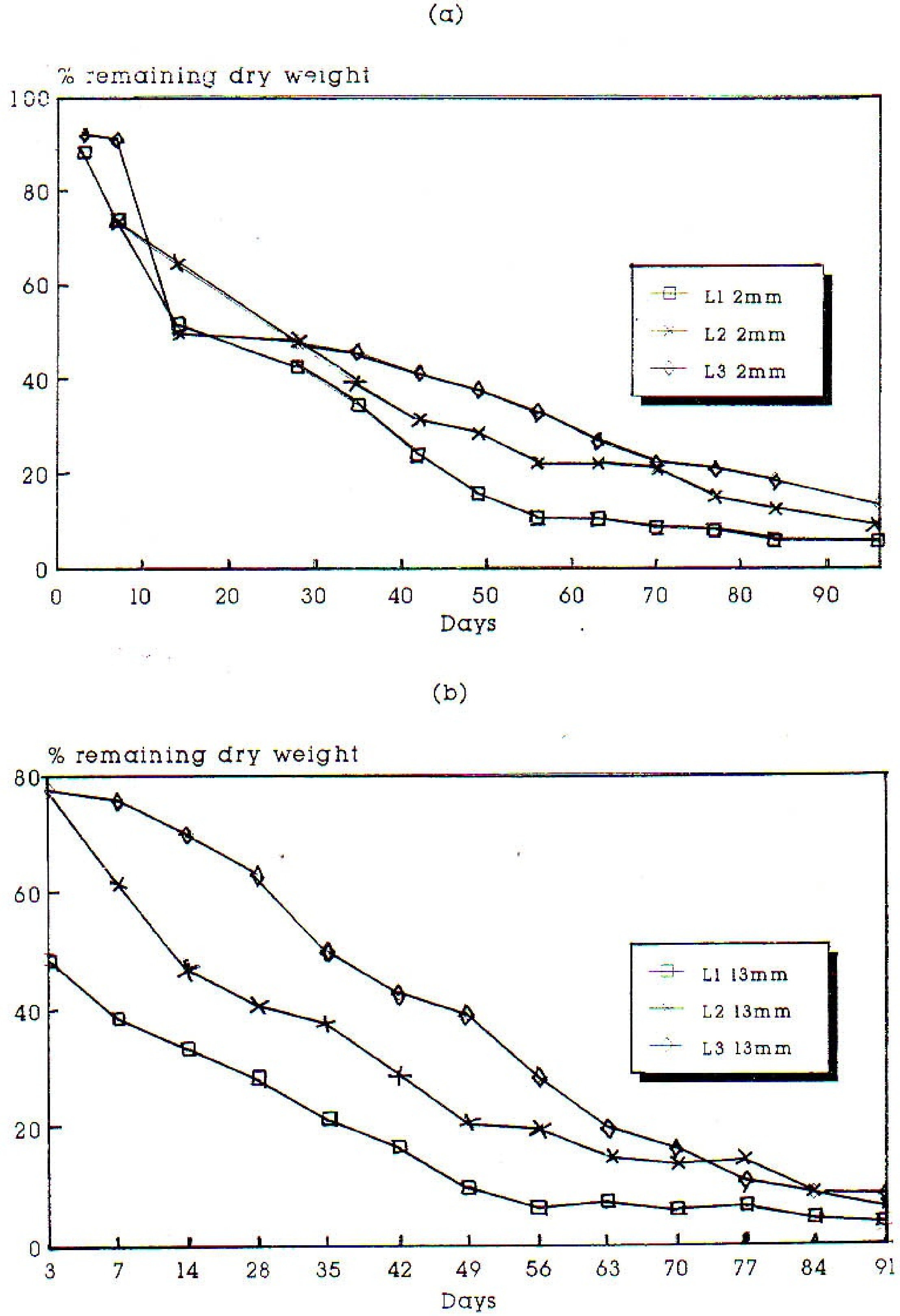

Fig. 2. Percentage dry weight of *Rhizophora mucronata* leaf litter remaining over time in (a) 2 mm mesh size (b) 13 mm mesh bags during the wet season (L1 - waterfront; L2 - middle zone; L3 - innermost area).

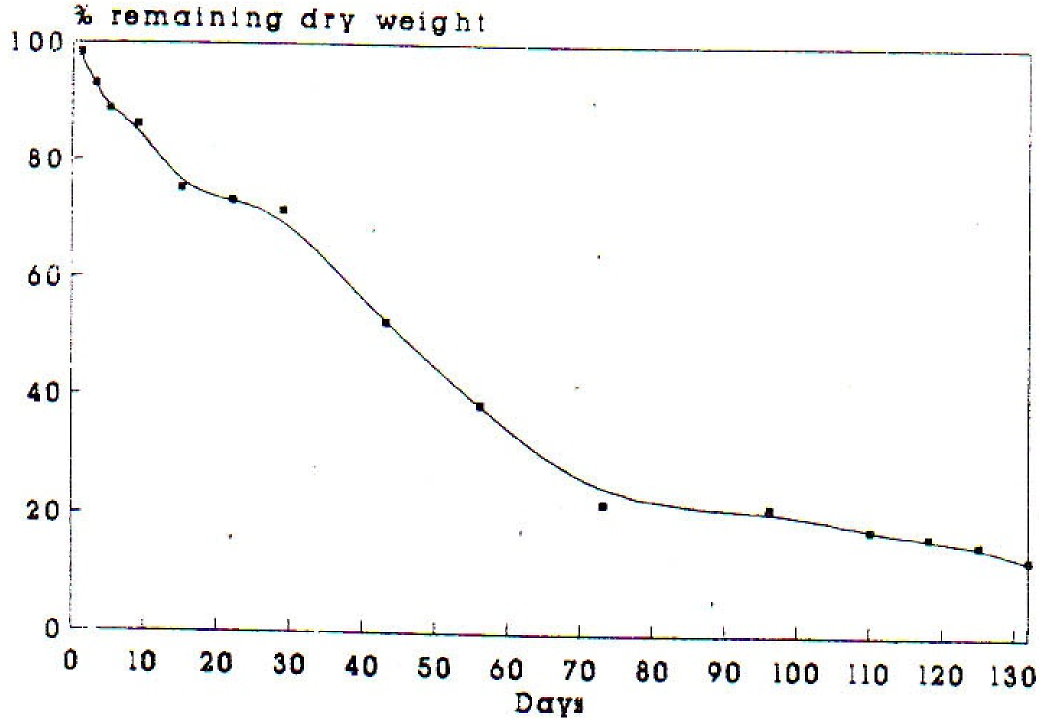

Fig. 3. Percentage dry weight of *Rhizophora mucronata* leaf litter remaining over time in the tank experiment.

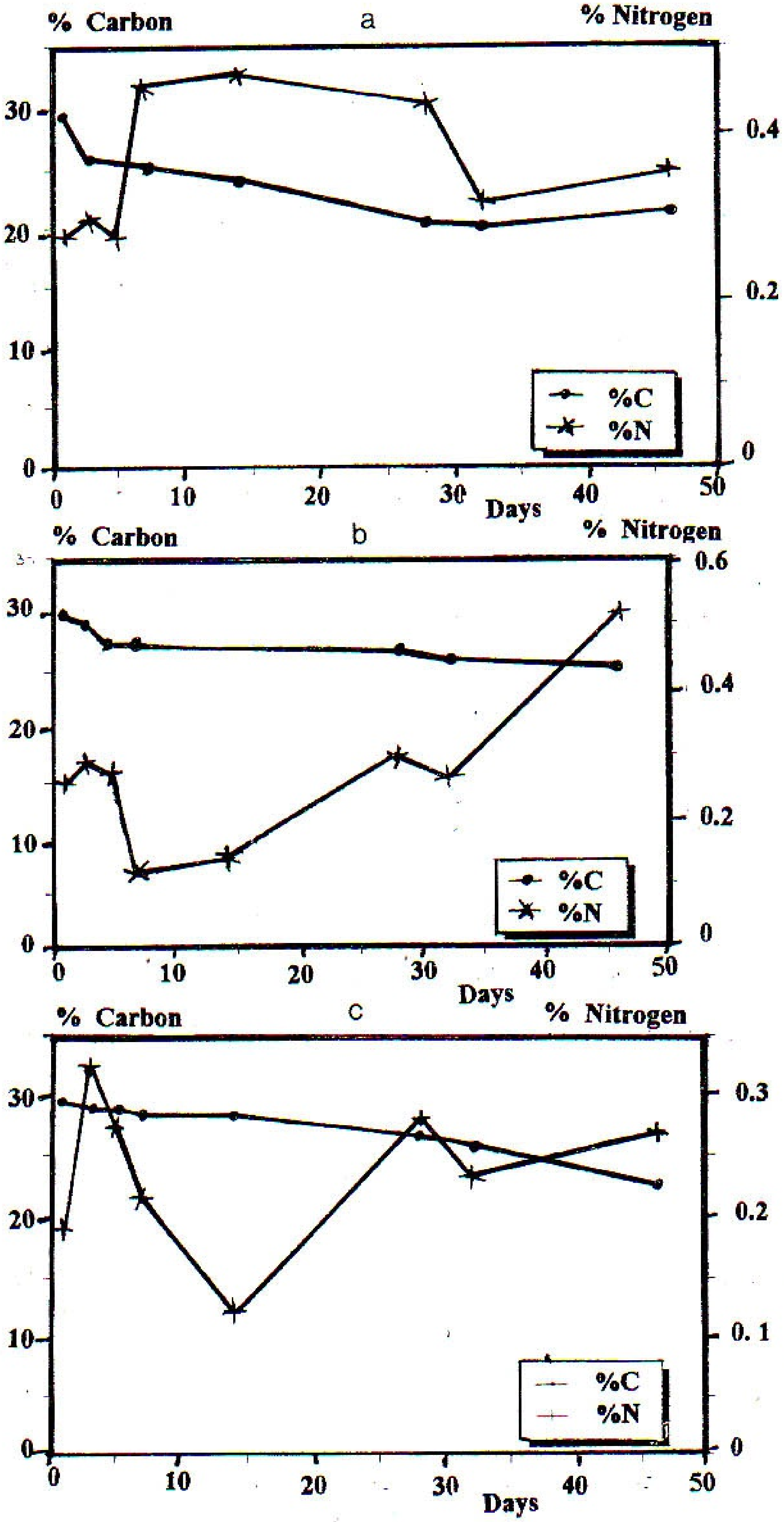

Fig. 4. Variation of percentage carbon and nitrogen during decomposition in the dry season (a) waterfront area; (b) mid-mangrove area; (c) innermost area.

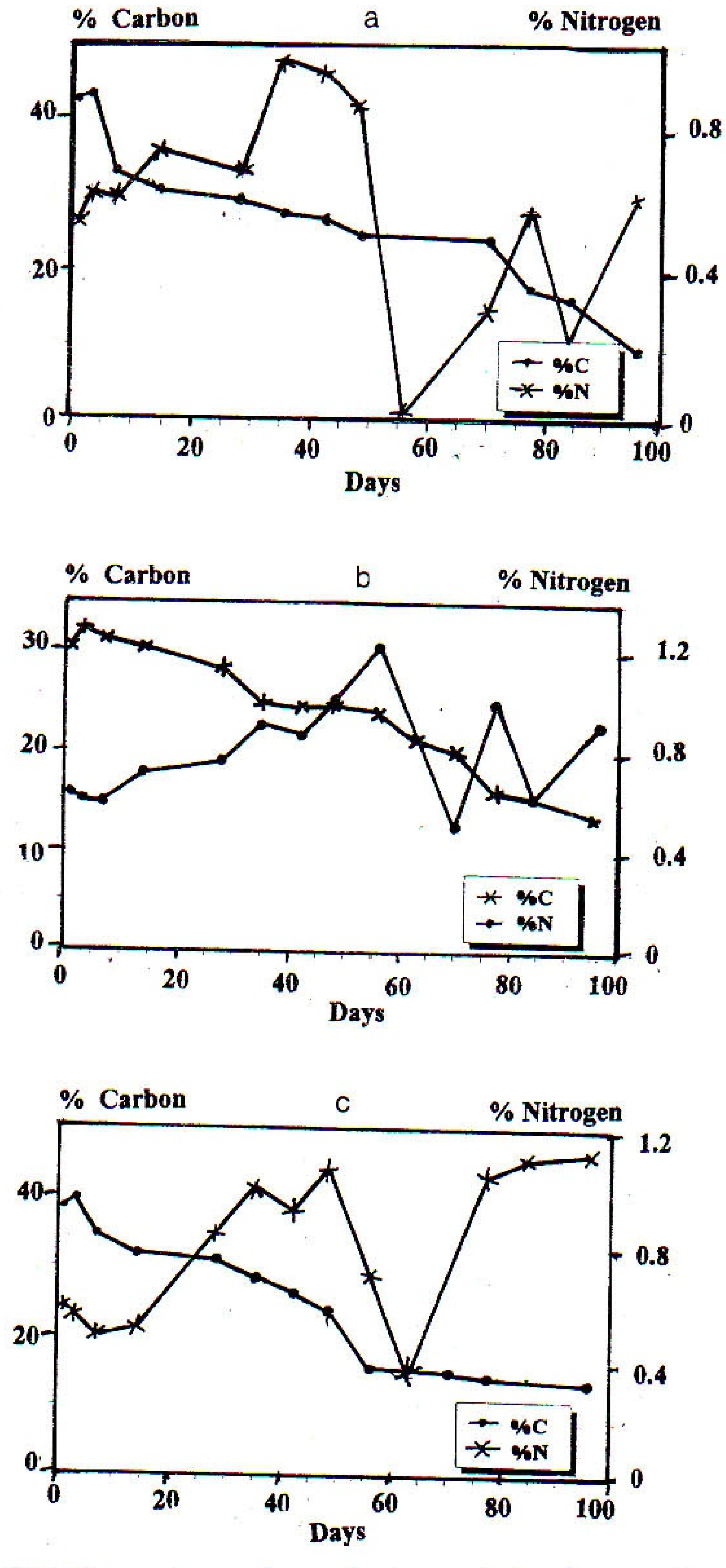

Fig. 5. Variation of percentage carbon and nitrogen during decomposition in the wet season (a) waterfront area; (b) mid-mangrove area; (c) innermost area.

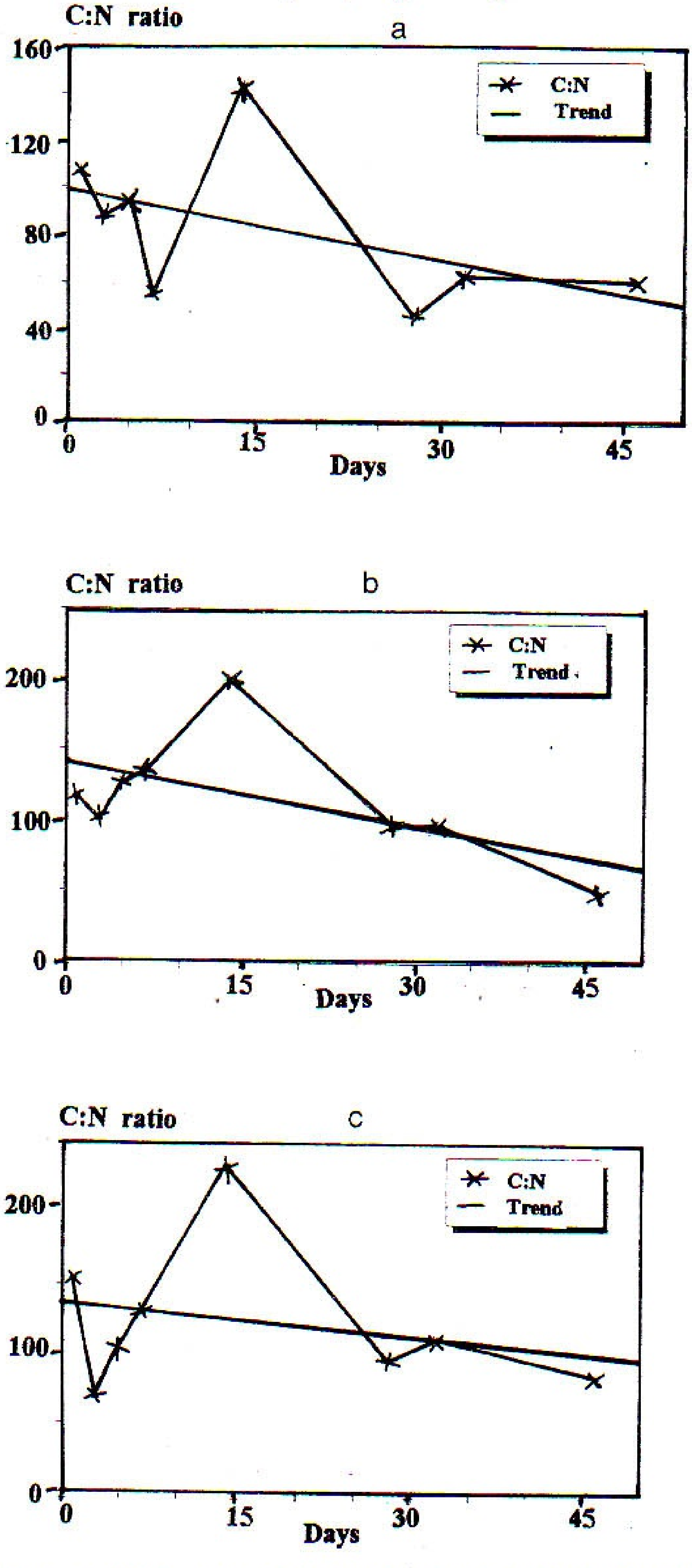

Fig. 6. Variation of C:N ratio and the trend in the dry season (a) waterfront; (b) middle zone; (c) innermost area.

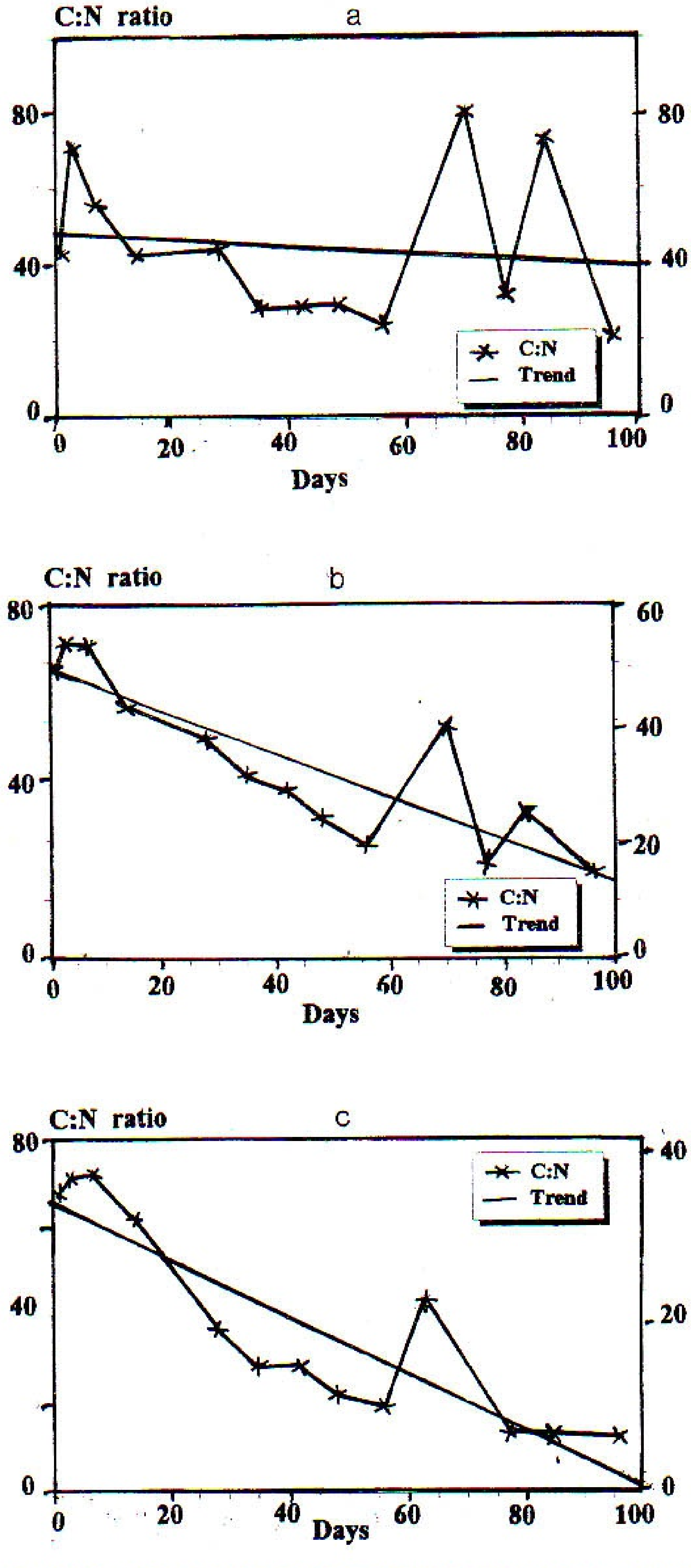

Fig. 7. Variation of C:N ratio and the trend in the wet season (a) waterfront; (b) middle zone; (c) innermost area.

season. In both the seasons, nitrogen contents increased in the leaf litter on the forest floor (except after 56 days in the wet spell) while carbon content decreased.

C:N Ratio During Decomposition

Variation of C:N throughout the decomposition in dry and wet seasons are graphically represented in Figs 6 and 7 respectively.

Discussion

Higher leaf litter decomposition observed in the wet season may be associated with the higher respiration rates of associated microbes (Twilley et al. 1986) or may be attributed to the increased occurrence of detritivores such as amphipods and mud crabs, which depend on mangrove detritus. Consumption of leaf litter by crabs has been reported previously for other mangrove communities (Leh & Sasekumar 1985). It is assumed that the primary effect of the crabs is to aid the mechanical breakdown of fallen leaves, so that the decomposition takes place rapidly (Darnell 1967).

The effect of such macrofauna on the leaf litter breakdown is apparent in the results of the present study. Increased abundance of macrofauna such as gastropods and crabs, on the mangal floor during the wet season, may have partly contributed to faster weight loss in 13 mm mesh bags (50% weight loss in 3 days) than in the 4 mm mesh bags, which took 14 - 28 days to show a 50% weight loss of the litter they contained. Among other factors, tidal water movements and boat-washing to which these water-front areas are subjected to, may have hasten the loss of litter.

Although the initial weight loss in the 13 mm mesh bagged leaves were higher in the water-front areas during the wet season, it was revealed that the overall decomposition rate of the litter in 4 mm mesh bags was the highest. Furthermore, decomposition rate in 4 mm mesh bags in the innermost area of the mangal was greater than that of the 13 mm mesh bags. This may be due to efficient retention of moisture among and underneath the litter in 4 mm mesh bags that would have facilitated profuse microbial growth, even during the relatively dry periods. A positive correlation has been reported between the decomposition rate and soil moisture content (Mathias 1974). Higher litter decomposition rates during the wet season may thus be attributed to the increased microbial populations that occur in/on substratum (both soil and litter) as a result of its greater moisture content.

R. mucronata leaf litter placed in the tanks filled with lagoon water took the longest time (41 days) for the decomposition up to 50% weight loss. This observation indicates the relative contribution of physical environmental factors on the decomposition process. The low rate of decomposition in the tanks may be due to enhanced anaerobic conditions prevailing in the tank environment as well as the limited presence of the soil micro- and macro-organisms responsible for litter decomposition. Unlike in the tank-situation, tides transport the detritus produced in the mangals to the lagoon and near-shore waters, thus causing greater weight loss during relatively a short span.

Among the basic changes that take place during decomposition of many terrestrial and aquatic leaves, is a reduction in carbon content and an increase in the nitrogen content, as a result of the decomposition of cellulosic substrates and the infiltration of fungal mycelia (Fell & Master 1980). The rate of decomposition of various aquatic plants may vary, depending on the initial structural integrity, as indicated by C:N ratios (Twilley et al. 1986). It has been reported that carbon can constitute upto 45% of dry senescent mangrove leaves and about half this carbon can be leached out while the other half becomes particulate detritus (Fell & Master 1980). Carbon represents 40.29% and 29.58% of the dry weight of senescent *R. mucronata* leaves from mangals of Negombo lagoon, in the wet and dry seasons respectively. During 96 days of decomposition in the wet season, about 75% of this carbon was lost, may be due to leaching and microbial respiration and about 25% remained as particulate organic matter or detritus. The average annual *R. mucronata* senescent leaf fall at the site was 410.0 g m^{-2} yr^{-1} (4 mt ha^{-1} yr^{-1}) (personal observations) and hence the organic matter released to the aquatic system through leaching and microbial respiration is 307.5 g m^{-2} yr^{-1} (3 mt ha^{-1} yr^{-1}), while 102.5 g C m^{-2} yr^{-1} (1 mt ha^{-1} yr^{-1}) is retained as detritus within the mangal. In the dry season however, 22% of the carbon (0.9 mt ha^{-1} yr^{-1}) was lost during 46 days of decomposition, and the remaining 78% may have been accumulated in the forest floor as partially decomposed detritus, of which the decomposition may complete in the following wet season.

The initial nitrogen content in the *R. mucronata* leaf litter (0.588 to 0.625) increased up to 0.791- 1.221, while the carbon content decreased from 40.29 to 19.68 during the first 56 days of decomposition, indicating the nitrogen mobilization due to microbial action. The remarkable decrease of percentage nitrogen after 56 days may have resulted by the very low rainfall received during this period, which might have led to poor microbial growth due to low moisture content in soil. The nitrogen contribution up to 56 days of the wet season therefore, would be 1.76×10^{-2} t ha^{-1}. The total increase of N in wet season however, is as twice as that in the dry season. Similar trends of nitrogen immobilization have been recorded during decomposition of *R. mangale* leaf litter (Fell & Master 1980; Fell et al. 1980).

Nitrogen enrichment during decomposition in the dry season was lower than that of the wet season and this may be due to the reduced presence of microbial communities in the dry season. The structure of the microbial communities will vary not only with substrate and its moisture content, but also with variables such as season, water temperature, salinity, dissolved oxygen content and degree of decomposition of the leaf. The rapidly colonizing fungi are the potential agents of nitrogen immobilization and thus the weight loss and change in carbon content has been observed to be greater in the presence of fungi (Fell et al. 1984).

In addition, leaves with high contents of unavailable carbon for fungi may also show low rates of decomposition, thus nitrogen immobilization. Hence the low nitrogen immobilization in the dry season may perhaps be due to higher fibre content and low amounts of available carbon compounds.

Nutritive enrichment of *R. mangale* leaf litter has been reported to be a result of loss of carbon and increase of final nitrogen. The C:N has changed from 120:1 in senescent leaves to 43:1 in partially decomposed leaves (Fell & Master 1980). In the present study, the average C:N of *R. mucronata* at Munnakkare has ranged from 124.71 in senescent leaves to 64.98 in partially decomposed leaves during the dry season and from 51.89 in senescent leaves to 16.03 in decomposed leaves during the wet season.

The dietary requirement of protein for most animals is 16.5% of the dry weight of diet, which corresponds to a C:N intake about 17:1. In general, food with a C:N above 17:1 is considered protein deficient (Russel-Hunter 1970). Hence, the particulate matter (detritus) produced from mangals at Munnakkare, particularly in the wet season, are of immense importance in catering to the dietary requirement of the detritivores in these coastal waters.

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