



Aquatic Resource and Environmental Studies of the Straits of Malacca:  
*Managing the Straits through Science and Technology*

## ***Bruguiera parviflora* Leaf Litter Loss at Kuala Selangor Mangrove Forest, Malaysia**

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### **Abstract**

The mangrove, *Bruguiera parviflora* leaf litter loss was studied in the mangrove forest at Kuala Selangor Nature Park, Malaysia. *Bruguiera parviflora* constitutes about 80% of the growing stock at the study area. The study involves assessing and comparing leaf litter loss due to feeding plus mechanical breakdown and microbial degradation during dry and wet months by using two exposure methods; leaf litter on string and leaf litter in bag respectively. All leaves on strings disappeared after 60 and 20 days during dry and wet months respectively. Higher grazing evidences were observed for leaves on string during the initial 10 to 30 days and 10 to 15 days of the dry and wet months respectively. Leaf litter on strings and in bags showed physical changes during the period of exposures. Leaf litter in bags showed physical changes in structure from 60 and 15 days during dry and wet months respectively. These changes and burial of leaves were accelerated in wet months compared to dry months. Leaves in bags exhibited 63% and 60% dry weight loss at 150 and 30 days during dry and wet months respectively. Comparatively a higher rate of leaf litter loss in bags occurred in the initial period of dry and wet months followed by lower rates thereafter. However, a relatively higher decomposition rate was observed during the wet months. Comparatively a lower rate of leaf litter loss due to feeding plus mechanical breakdown was observed during the initial 5 days of dry and wet months. Comparison between the exposure methods, the overall pattern of leaf litter loss indicated a relatively higher percentage of leaves loss; ranged 52.61%-69.33% was attributed to feeding plus mechanical breakdown by crabs, *Sesarma versicolor* while the contribution due to microbial activities ranged 30.67%- 47.39%. In addition this study showed leaf litter loss due to feeding plus mechanical breakdown by crabs was not influence by the wet or dry months. As reflected by leaf litter loss, microbial degradation was influenced by the wet and dry months. The detail aspect on *Bruguiera parviflora* leaf

litter loss in an undisturbed mangrove forest and the factors affecting the disappearance are discussed in this paper.

## 1. Introduction

Mangroves are productive ecosystems and have a high rate of primary production. The primary productivity of mangroves seems to vary with the geographical locations and with the tidal amplitudes (Twilley *et al.*, 1986; Woodroffe *et al.*, 1988). Mangrove ecosystems export high amount of organic matter to support variety of living organisms (Odum and Heald, 1975; Ong, 1995). This is the result of high leaf production, leaves fall and rapid breakdown of detritus (Aksornkoae, 1993). Bunt *et al.* (1979) reported that litter fall is about 30-60% of the total primary production and has significant importance on detrital based food webs in the coastal environment and coastal fisheries (Odum and Heald, 1975; Ong *et al.*, 1984; Lee, 1995). The amount of organic matter export to the aquatic ecosystem from the mangroves depends on the litter decomposition rates while decomposition rates depend on the degree and frequency of tidal inundation, climatic and edaphic factors and presence or absence of litter consuming fauna within the mangrove forest (Reice *et al.*, 1984; Valiela *et al.*, 1985; Twilley *et al.*, 1986; Robertson, 1988; Chale, 1993). In general the dynamics of litter breakdown not only vary with species but also geographically (Ashton *et al.*, 1999) and affected by leaf chemical composition like nutrients and lignin content (Tam *et al.*, 1998). Significant amount of nutrients and organic matter are released during the process of mangrove litter decomposition and has an important role in internal nutrient cycling (Steink *et al.*, 1993; Lu and Lin, 1990), tree productivity and mangrove related food chain (Ashton *et al.*, 1999). The present study aims to compare the rate of leaf litter degradation and litter loss of *Bruguiera parviflora* attributed to factors that are inherent in the studied mangrove forest.

## 2. Materials and methods

### 2.1 Description of the study area

The study area is 100 ha mangrove forest (3° 20' N Latitude and 101° 14' E Longitude) of Kuala Selangor Nature Park. This mangrove forest is totally protected since 1987 and categorized under Watson's (1928) tidal inundation class 4 characterized by tidal height ranges from 13 to 15 feet and inundated by water for 2 to 20 times per month. Species of mangroves in the family of *Avicenniaceae*, *Rhizophoraceae*, *Sonneratiaceae* and *Euphorbiaceae* are found in this forest. *Bruguiera parviflora* is the dominant species that contributes about 80% of the growing stock.

### 2.2 Leaf litter degradation experiments

Bulk samples of yellowish freshly fallen leaves were collected from the litter layer. Collected leaf samples were sorted into three size classes as 10 to 15, 15 to 20 and 20 to 30 cm<sup>2</sup> respectively. Each sample contained a total of six leaves (two leaves from every classes) and the fresh, converted oven-dry weight and leaves areas ranged from 2.79-4.38 g, 1.2-1.88 g and 100-128 cm<sup>2</sup> respectively. 110 sets of leaves in nylon bags and 110 sets of leaf on string were prepared and coded. For the estimation of leaf litter loss due to feeding plus mechanical breakdown each set of samples were sewn

onto monofilament nylon string through the lamina adjoining the mid-rib so that leaves were not overlapped. However, for estimating microbial degradation each set of sample was placed in 300 x 150 mm nylon bag with 1 mm<sup>2</sup> mesh size. To prevent the leaves from folding and clumping they were laid flatly and sewn and placed in the bag. One hundred litter bags and one hundred strings were placed in the field at a same time and ten bags and strings were brought back to the laboratory for calculating conversion factor for fresh to oven-dry weight at 105°C to constant weight. Bags and strings were tied with flaged pegs so that they flat on the sediment. Experiments were initiated during dry month (July) and wet month (November) in 2002. Field experiments in July 2002 were carried for five months but in November 2002 for one month. Ten bags and strings were collected every five days interval for the initial month and each of ten bags and strings were collected monthly for the subsequent four months period. The collected leaf litter samples were gently washed and all sediments and dirt particles were then removed by using a soft brush with running tap water followed by final rinsing in distilled water. Each sample was than oven-dried at 105°C to constant weight and weighted. The loss in dry weight of the samples was calculated from the original converted oven-dry weight. The percentage of losses in initial dry mass in bags and strings was determined. The amount of leaf litter loss due to feeding plus mechanical breakdown was estimated based on the difference between mean dry weight loss of leaves on strings and men dry weight loss of leaves litter in bags. The rate of degradation was calculated from the percentage of wet loss divided by respective days of collection. The different rates of litter degradation and leaf litter losses were transformed to arcsin and compared by one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test ( $p < 0.05$ ) by using SAS (6.12). The rate of leaf litter degradation and loss due to feeding plus mechanical breakdown in different time periods of dry and wet months were compared by Hierarchical cluster analysis by using SPSS (11.0) statistical package.

### 3. Observation and Discussion

#### 3.1 Observation on progressive changes of the leaf litter

Field observation of progressive changes of the leaf litter at different sampling periods is presented in Table 1. Comparatively faster changes in leaf litter were observed during the wet month. Leaf litter on strings showed physical changes in colour from 10 days during the initial period dry and wet months. The higher grazing evidence was observed from 10 to 30 days and 10 to 15 days during the initial period of dry and wet months respectively. Crabs (*Sesarma versicolor*) not only grazed the freshly fallen leaves but also the aged leaves. Leaves on strings, being freely suspended showed little evidence of sediment settlement and resuspension. Leaves in bags showed physical changes in colour from 10 days during the initial period of dry and wet months. Leaves in bag showed physical changes in structure from 60 and 15 days during dry and wet months respectively. There were some evidences of leaf grazing inside the bag by crabs. Partial burial of bags started from 20 and 5 days during dry and wet months respectively (Table 1).

Table 1. Observations on progressive changes of the leaf litter

| Days       | Leaf on strings                                                                                                                                                                      | Days      | Leaf in bags                                                                                                                                                                                    |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dry months |                                                                                                                                                                                      |           |                                                                                                                                                                                                 |
| 5          | Leaves remained yellowish and intact on strings. Some leaves were grazed along the margin. Leaves were dragged into crab holes                                                       | 5 to 15   | Leaves remained yellowish in colour. Leaves surface covered with black spots. Some litterbags have holes and the crabs grazed inside leaves                                                     |
| 10 to 15   | Leaves turned to light brown in colour. Leaves were grazed up to the mid rib. Some leaves disappeared and some dragged into crab holes                                               | 20 to 30  | Leaves turned to brown and veins were visible with small round shaped. Leaves inside the bags partially covered by thin sediment layers                                                         |
| 20 to 30   | Leaves turned to brown and heavily grazed and small parts were attached with strings. Some leaves disappeared and thin layers of sediment smothered the leaves surface               | 60        | Leaves turned to dark brown and soft. Leaves veins were cleared with more surface areas. Leaves were partially covered by thick sediment layers                                                 |
| 60         | All leaves were lost                                                                                                                                                                 | 90 to 150 | Leaves remained dark brown and became very soft and fragile. Leaves areas were lost along the margin. Leaves remained partially covered by thick sediment layers                                |
| Wet months |                                                                                                                                                                                      |           |                                                                                                                                                                                                 |
| 5          | Leaves remained yellowish and intact on strings. Some leaves were grazed along the margin. Leaves were dragged into crab holes. Thin layers of sediment smothered the leaves surface | 5         | Leaves remained yellowish and leaves surface covered with black spots. Some bags have holes and the crabs grazed inside leaves. Leaves partially covered by thin sediment layers                |
| 10         | Leaves turned to brown and grazed up to the mid rib. Some leaves disappeared and some dragged into crab holes. Thin layers of sediment smothered the leaves surface                  | 10        | Leaves turned to light brown and became soft and veins cleared in round shaped areas. Some bags have holes and the crabs grazed inside leaves. Leaves partially covered by thin sediment layers |
| 15         | Leaves turned to dark brown and heavily grazed. Small parts of leaves were attached with strings. Thin layers of sediment smothered the leaves surface                               | 15 to 20  | Leaves turned to brown and became soft and fragile. Leaves areas were lost long the margin up to the mid rib. Leaves were partially covered by thick sediment layers                            |
| 20         | All leaves were lost                                                                                                                                                                 | 25 to 30  | Leaves turned to dark brown and fragmented into bigger pieces. Leaves remained partially covered by thick sediment layers                                                                       |

### 3.2 Leaf litter loss and rate of degradation

The conversion equation and  $R^2$  values of fresh weight to oven-dry weight and relationship between fresh weight and leaf area is presented in Table 1. Comparatively higher percentage of dry weight loss occurred in bags and strings during the wet month. In bags, 63% and 60% of the dry weight loss was observed for 150 and 30 days during dry and wet months respectively. All leaves on strings disappeared from 60 and 20 days during dry and wet months (Fig. 1). Comparatively a higher rate of leaf litter degradation was observed during the wet month. Relatively a higher rate of leaf litter degradation in bags occurred in 10 days and 5 days during the initial period of dry and wet months respectively followed by lower rates thereafter (Fig. 2). Comparatively lower rate of leaf litter loss on strings were observed in 5 days and relatively higher rates was observed in 10 days during the initial period of dry and wet months (Fig. 3). The rates of microbial degradation in relation to days and seasons were compared and grouped in to different clusters as Group 1: Having similar degradation rates at different collection periods during dry months and Group 2: Having similar degradation rates at different collection periods during wet months (Fig. 4). While, litter loss on strings were grouped into different clusters as Group 1: Having similar rates during 20, 25, 30, 60 days of dry months and 5 days of wet month, Group 2: Having similar rates during 10, 15, 20 days of wet month and 15 days of dry months (Fig. 5). Robertson (1988) reported that initial rapid loss of leaf litter (*Rhizophora stylosa*, *Avicennia marina* and *Ceriops tagal*) mass both in subtidal and submerged condition is the result of rapid leaching of dissolved organic matter, including organic carbon, nitrogen and tannins. Van der Valk and Attiwill (1984) reported that 13% reduction in weight caused by leaching losses after 3 days when *Avicennia marina* leaf litter were submerged in seawater. The percentage of mass loss of mangrove leaf litter due to leaching varies according to species, sites and exposure condition. The remaining leaf biomass, particularly organic matter is decomposed more slowly and highly dependent on the action of bacteria and fungal communities (Robertson *et al.*, 1992). Steinke and Ward (1987) reported that leaf litter degradation rates vary with *Avicennia marina* and *Bruguiera gymnorhiza* in different exposure condition (continuous submergence, exposed only at low spring tides and inundated only at high spring) and seasons (cool and warm). *Avicennia marina* leaf litter showed higher degradation rates than *Bruguiera gymnorhiza*. Constantly submerged leaves degraded at a faster rate than those exposed for longer time and the degradation rates were consistently lower in the cool season. Higher rates of *Rhizophora apiculata* leaf litter degradation in a Malaysia mangrove was reported during heavy rainfall (Japar Sidik, 1989). Lu and Lin (1990) have shown higher rates of leaf litter (*Avicennia marina* and *Kandelia candel*) degradation during the summer at Fujian, China. Comparative results of leaf litter degradation with different mangrove species at various geographical locations is presented in Table 2. Different mangrove species and even the same species showed different leaf litter degradation rates in relation to geographical locations and seasons. Thus, the rate of mangrove leaf litter degradation is specific for species, sites and exposure conditions.

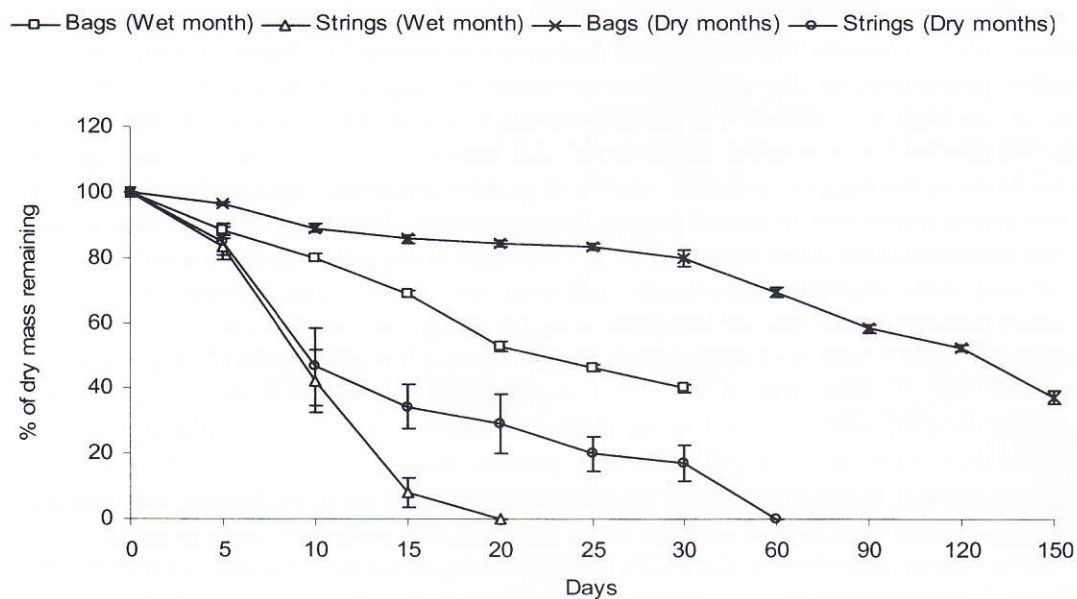


Fig. 1. Mean percentage of dry mass remaining at different time interval during dry and wet months

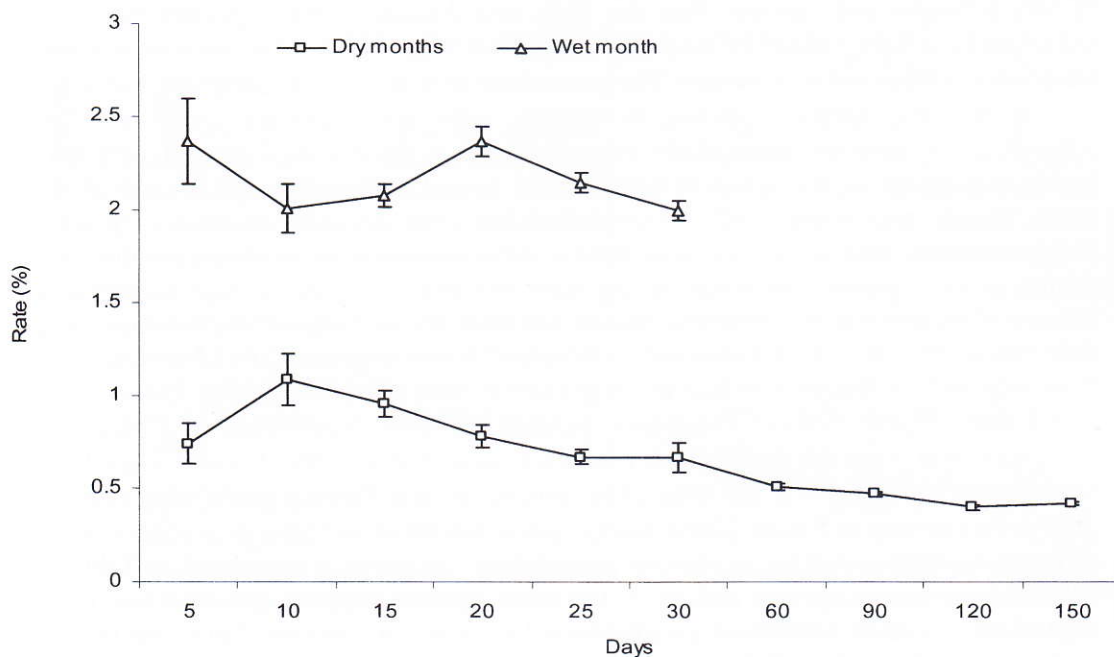


Fig. 2. Degradation rates of leaf litter in bags during dry and wet months

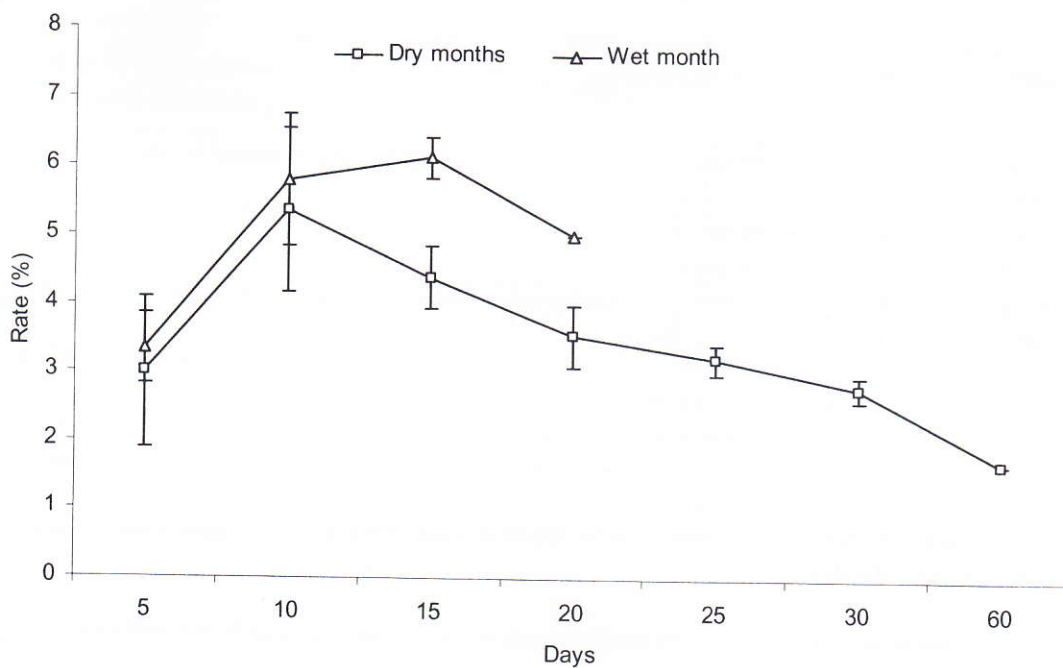


Fig. 3. Degradation rates of leaf litter on strings during dry and wet months

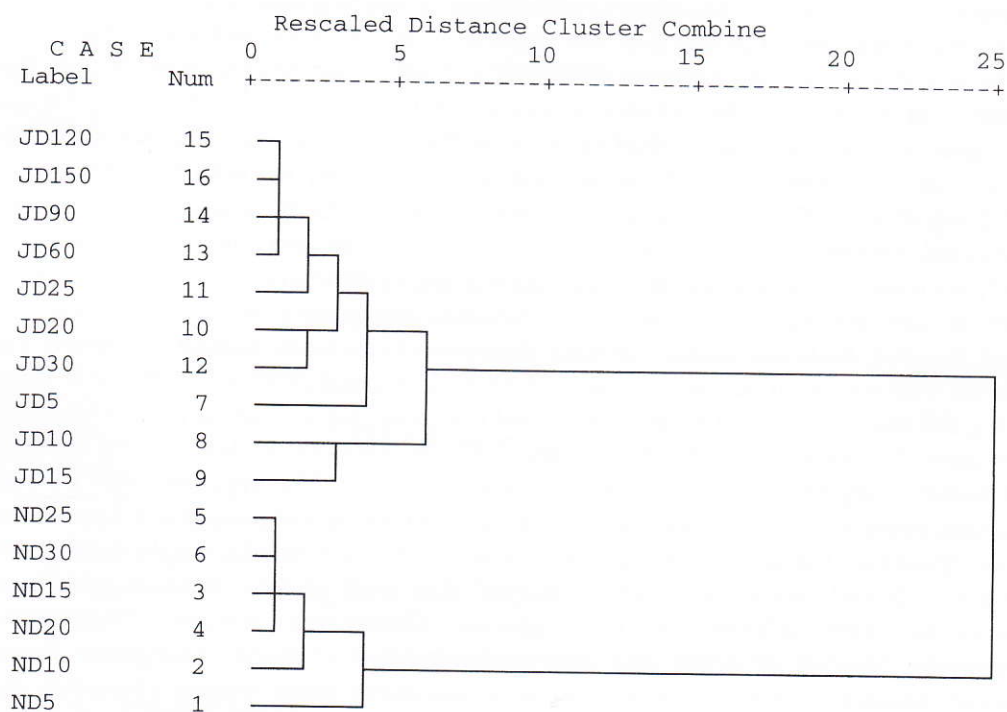


Fig. 4. Rates of leaves litter degradation in bag experiment during dry and wet months

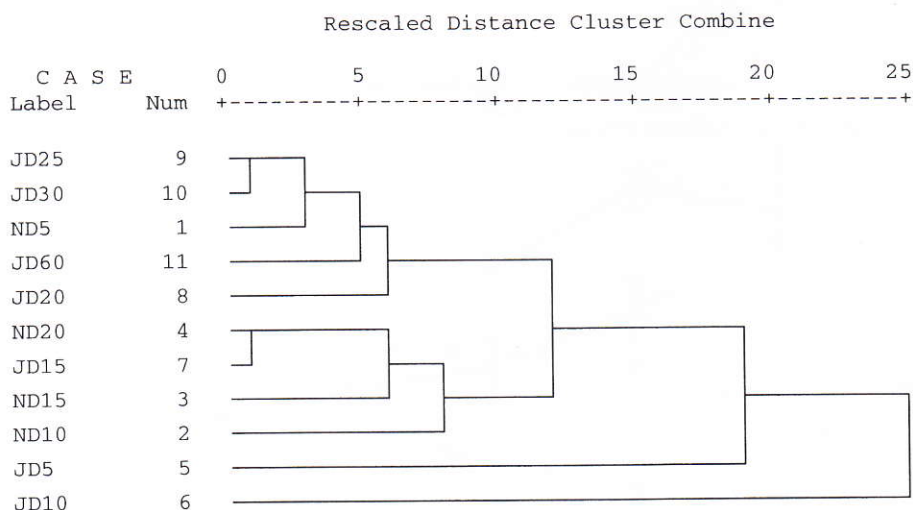


Fig. 5. Rate of leaves litter loss due to feeding plus mechanical breakdown during dry and wet months

### 3.3 The contribution of macro-feeders and micro-organisms to leaf litter degradation

The contribution of macro-feeders and micro-organisms to leaf litter degradation is presented in Table 3. The percentage of dry weight loss due to feeding plus mechanical breakdown by crabs was relatively lower (11.31%-4.83%) for 5 days but comparatively similar (55.18%-52.61%) percentage of wet loss was observed for 20 days during the initial period of dry and wet months. Leaf litter were grazed mechanically and broken down by crabs (*Sesarma versicolor*) and amounted 52.61% to 69.33% but the contribution of microbial degradation amounted 30.67% to 47.39% (Table 3 and Figure 1). In general, leaf litter loss by feeding plus mechanical breakdown was not influence by the season but the microbial degradation was affected by the season. Cundell *et al* (1979) reported that readily leachable carbohydrate and tannins were lost from the submersed *Rhizophora mangal* leaf litter by 14 to 28 days and microbial population slowly increase on the leaf surface and degradating of structural material. Japar Sidik (1989) studies the leaf litter (*Rhizophora apiculata*) degradation at Matang Mangrove Forest Reserve, Malaysia under different Watson's (1928) tidal inundation classes. He reported that microbial degradation was 22.8% to 58.6% and 26.9% to 76.7% for 90 days during dry and wet months respectively. Leaf litter loss due to feeding plus mechanical breakdown by crabs was 12.6% to 49% and 7.3% to 29.8% for 90 days during dry and wet months respectively. Van der Valk and Attiwill (1984) reported that 61% of *Avicennia maria* leaf litter as lost due to feeding plus mechanical breakdown by crabs at Westernport Bay Mangrove forest, Australia with 1.5 to 2.3 m tidal height during wet months. Leh and Sasekumar (1985) reported that food of five common species of Sesarminae crabs (*Chiromantes onychophorum*, *Chiromantes eumolpe*, *Clistocoeloma merguiensis*, *Sesarma versicolor* and *Sesarmoides kraussi*) at Kapar Mangrove Forest Reserve, Malaysia consisted of 83% to 97% mangrove plant matter. However, the contribution of macro-feeders and micro-organisms to mangrove leaf litter degradation is specific for species, sites, exposure conditions and abundance of micro and macro-organisms.

Table 2. Comparison of leaf litter loss and degradation rate with different mangrove species in different places

| Geographical location and seasons                                                                                                                                                                                                      | Species                                                                                                                         | Leaf litter loss                                     |                                                      | References               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|--------------------------|
|                                                                                                                                                                                                                                        |                                                                                                                                 | % of litter loss                                     | Days                                                 |                          |
| Kuala Selangor, Malaysia<br><br>(Dry months)<br>Litter bags<br>Litter on strings<br>(Wet month)<br>Litter bags<br>Litter on strings                                                                                                    | <i>Bruguiera parviflora</i>                                                                                                     | <br><br>63<br>100<br><br>60<br>100                   | <br><br>150<br>60<br><br>30<br>20                    | The present study        |
| Matang Mangrove forest, Malaysia<br>(Wet month)<br>Litter bags<br>Cleared areas<br>Virgin Jungle Reserve<br>Cleared areas<br>Virgin Jungle Reserve<br>Cleared areas<br>Virgin Jungle Reserve<br>Cleared areas<br>Virgin Jungle Reserve | <i>Bruguiera parviflora</i><br><br><i>Rhizophora apiculata</i><br><br><i>Rhizophora mucronata</i><br><br><i>Sonneratia alba</i> | <br><br>35<br>53<br>50<br>58<br>33<br>68<br>85<br>93 | <br><br>56<br>56<br>56<br>56<br>56<br>56<br>56<br>56 |                          |
| Shenzhen, China<br>(Summer)<br>Litter bags                                                                                                                                                                                             | <i>Aegiceras corniculatum</i><br><i>Kandelia candel</i>                                                                         | 68<br>88                                             | 70<br>42                                             |                          |
| Matang Mangrove forest, Malaysia<br>Litter on strings<br>Litter bags                                                                                                                                                                   | <i>Rhizophora apiculata</i>                                                                                                     | 94-98<br>80                                          | 180<br>180                                           |                          |
| Queensland, Australia<br>(Summer)<br>Litter bags                                                                                                                                                                                       | <i>Rhyziphora stylosa</i><br><i>Avicennia marina</i><br><i>Ceriops tagal</i>                                                    | 50<br>50<br>50                                       | 39<br>10<br>27                                       |                          |
| Matang Mangrove forest, Malaysia<br>Litter on string                                                                                                                                                                                   | <i>Rhizophora</i> spp.<br><i>Bruguiera</i> spp.                                                                                 | 75-90<br>80                                          | 20<br>20                                             | Ong <i>et al.</i> (1980) |

Table 3. The contribution of macro-feeders and micro-organisms to leaf litter degradation

| Dry months |                                       |                                     |                                                             |
|------------|---------------------------------------|-------------------------------------|-------------------------------------------------------------|
| Days       | Mean percentage of wet loss on string | Mean percentage of wet loss in bags | Percentage of wet loss by feeding plus mechanical breakdown |
| 5          | 15.02±5.48                            | 3.72±0.57                           | 11.31                                                       |
| 10         | 53.53±11.85                           | 10.92±1.41                          | 42.61                                                       |
| 15         | 65.69±6.82                            | 14.38±1.02                          | 51.31                                                       |
| 20         | 70.76±8.91                            | 15.58±1.11                          | 55.18                                                       |
| 25         | 80.03±5.34                            | 16.69±1.08                          | 63.34                                                       |
| 30         | 82.99±5.69                            | 20.17±2.47                          | 62.82                                                       |
| 60         | 100                                   | 30.67±1.41                          | 69.33                                                       |
| Wet month  |                                       |                                     |                                                             |
| 5          | 16.7±2.6                              | 11.87±1.16                          | 4.83                                                        |
| 10         | 57.96±9.46                            | 20.1±1.32                           | 37.86                                                       |
| 15         | 91.98±4.45                            | 31.2±0.9                            | 60.78                                                       |
| 20         | 100                                   | 47.39±1.61                          | 52.61                                                       |

#### 4. Conclusion

Significant amount of nutrients are released into the mangrove ecosystems during the process of litter degradation. The released nutrients could support the tree productivity and mangrove food webs. Lower rates of litter decomposition may have implication for internal nutrient cycling and functioning of the mangrove ecosystem. The rates of microbial leaf litter degradation influence by seasons. Leaf litter loss due to feeding plus mechanical breakdown by macro-feeders was not influenced by seasons. Crabs not only grazed the freshly fallen leaves but also the aged leaves. Freely suspending leaf litter on strings showed little evidence of sediment settlement and resuspension. The local environmental factors and abundance of micro and macro-organisms influence the mangrove litter degradation. Thus, the rate of mangrove leaf litter degradation is specific for species, site and exposure condition specific.

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