THE STUDY ON MANGROVE LITTERS AS A SOURCE OF NUTRIENTS FOR BLANAKAN MANGROVE POND, SUBANG, WEST JAVA

Joni Haryadi*)#, Adi Basukriadi), and Muhadiono***)**

*) Center for Aquaculture Research and Development
**) Faculty of Mathematic and Natural Science, University of Indonesia
***) Faculty of Mathematic and Natural Science, University of Bogor

(Received January 9th, 2013; Accepted April 12th, 2013)

ABSTRACT

Mangrove litters as a source of nutrients for sylvofishery pond (TS), sedimented pond (TT), and conservation pond (TP) was studied at Blanakan mangrove pond during April until June 2008. The variables of study were litter production, litter decomposition, and dissolved nutrients (ammonium, nitrite, nitrate, and phosphate). The obtained data were analyzed using F test and continued using Least Significant Different (LSD). The results showed that litter production at TS, TT, and TP were 19.55±4.34 ton/ha/year, 15.90±1.98 ton/ha/year, and 21.67±1.89 ton/ha/year respectively. The decomposition rate at TS, TT, and TP was 0.051±0.038, 0.051±0.018, and 0.081±0.041, respectively. Mangrove litters were potentially as a source of dissolved nutrients at Blanakan mangrove pond. Increasing both litter production and decomposition rate could increase ammonium, nitrite, and phosphate. Therefore, mangrove litters were play role for determined the fertility at Blanakan mangrove pond.

KEYWORDS: **mangrove litters, nutrients, Blanakan mangrove pond**

INTRODUCTION

Leave mangroves give a lot benefit for organisms. Five percentage of leaves production are consumed by herbivore groups such as Lepidoptera larvae, whereas 95% into water column as detritus (Robertson, 1991). Litter production is an important component of mangrove ecosystems. They are the component of net primary productivity (Bunt *et al.*, 1979), the guideline of canopy dynamic (Clarke, 1994), component at nutrients cycle (Mokolensang & Tokuyama, 1998) and as indicator for ecosystem fertility (Kathiseran & Bingham, 2001).

The estimates of the annual global litter fall from mangroves range from 130 to 1870 g/m^2 (Kathiseran & Bingham, 2001). Litter production are varying significantly from habitat to habitat depend largely on local conditions, species composition, and productivity of the individual mangroves. Litter production of Avicennia marina at Blanakan mangrove pond rare be studied, though the study of litter fall still required to complete the information of litter production (Budiman & Suhardjo, 1992).

The mangrove litters which fall into water column will be decomposed. Litter decomposition involved three processes: fragmentation by a biotic factors, leaching, and decomposition by microbial activities (Holmer & Olsen, 2002). The decomposition of litters contributes to the production of dissolved organic matter (DOM) and the recycling of nutrients both in the mangroves and in adjacent habitats. After decomposition, several nutrients

Corresponding author. Center for Aquaculture Research and Development, Jl. Ragunan 20, Pasar Minggu, South Jakarta 12540, Indonesia. Phone: +62 21 780 5052
E-mail: joniharyadi73@gmail.com

such as nitrogen and phosphor will be transported to estuarine and ocean ecosystems (Holmer & Olsen, 2002). The both organic detritus and nutrients could potentially enrich the coastal sea and, ultimately, support fishery resources. The contribution of mangroves could be particularly important in clear tropical waters where nutrient concentrations are normally low (Kathiseran & Bingham, 2001). The aims of this research were to know mangrove litters as a source of nutrients for Blanakan mangrove pond.

MATERIALS AND METHODS

This research was conducted in Blanakan mangrove pond from March-June 2008 at four stations: sylvofishery pond (TS), sedimented pond (TT), and conservation pond (TP).

Observation of litter production was begun with putting litter trap which made of plastic bag size of 1 m x 1 m on dominant mangrove species. Each mangrove put in four litter traps with encircle tree position. These litter traps function as litter lodging. In every two weeks, litter took out from lodging and measured to determine the weight of litters.

Observation of litter decomposition was begun with enter 30 g leaves litter into litter bag. Four litter bags were placed on the water column at each sampling area. All litter bags were bounded at mangal roots. Litter bag samples were collected every 15 days. The litters were rinsed and air-dried. These litter samples were dried at 80°C for about 48 h to constant weight. Weight loss was the difference between the initial weight of the incubated leaves sample and that of the sample after each time interval. Analysis of C, N, and P was conducted in Indonesian Soil Research Institute, Bogor. Decomposition rate was measured using equation by Subkhan (1991).

$$\ln X_t = \ln X_o - kt$$

where:

X_t = weight of litter after each time interval
X_o = initial weight of litter
k = decomposition rate
t = time interval

Water samples were collected at 11.00 to 13.00 and entered into sample bottle. The sample bottles were kept at ice box. Analysis of dissolved nutrients (ammonium, nitrite, nitrate, and phosphate) was conducted at Freshwater Fisheries Laboratory, Subang.

RESULTS AND DISCUSSION

Litter production at each sampling site can be seen at Figure 1. Different locations showed no significant different (P>0,05) on the litter production.

Litter production at TS, TT, and TP was 19.553±4.337 ton/ha/year, 15.893±1.976 ton/ha/year, and 21.670±1.889 ton/ha/year, respectively. Litter production can be classified into three categories: (1) high, if the litter production greater than 10 ton/ha/year, (2) moderate, if the litter production between 5 ton/ha/year to 10 ton/ha/year, and (3) low, if the litter production less than 5 ton/ha/year (Kusmana, 1995). According to these categories, litter production at TT, TS, and TP was high.

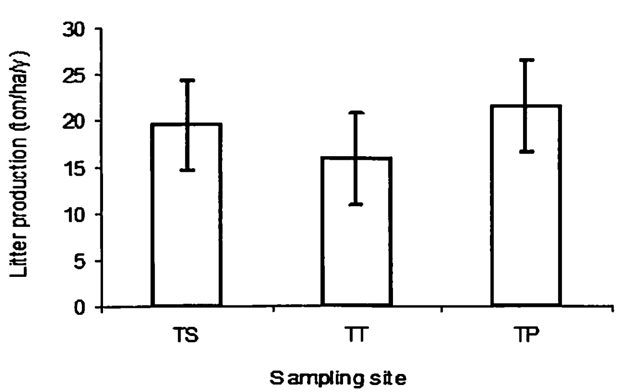


Figure 1. Litter production at each sampling site

Litter production at TP was the highest of the other sampling sites. Perhaps, these matters were related with the age of mangrove at these locations. The mangrove at TP was the oldest of the other sampling sites, followed by TS and TT. Older mangrove have a lot owning leaves turn yellow and easy to fall when blown by wind, so litter production at old plant was higher than young plant (Ong *et al.*, 1982). These statements were supported by Nga (2004) that litter production of *Rhizophora apiculata* which have age 11 year was higher than *Rhizophora apiculata* which have age 7 year.

The other factor that influence on the litter production was the tall of mangrove (Woodroffe, 1985). Mangrove at TP was the tallest of the other sampling sites, followed by TS and TT. Higher plant was more blown by wind than shorter plant. Therefore, litter production at TP was the highest of the other sampling sites. These results were supported by Ellison & Simmonds (2003), that annual litter production of *Avicennia marina* which have tall 3.85 m was 1,077 g/m^2, while *A. marina* which have tall 2.47 m was 659 g/m^2.

Freshwater regulation also determined litter production. TP is near from the river, so the regulation of freshwater at this location was good. Input of freshwater increased nutrients, so it's support mangrove regenerations by let fall the leaves (Wafar *et al.*, 1997). Perhaps, this matter was cause of litter production at TP was the highest of the other sampling sites.

Litter production was influenced by tidal activities (Kusmana *et al.*, 1994). Mangrove forests which influenced by high tide produced more litters (Twilley *et al.*, 1986). During high tide, nutrients were accumulated at mangrove forests and influence litter production (Odum, 1980). Woodroffe *et al.* (1988) showed that litter production of *Ceriops* sp. at tidal flat was 745 g/m^2/year, while at hinterland was 686 g/m^2/year.

Litter production was influenced by light intensity. Photosynthesis was faster and more excellent, if the light intensity was high. These conditions caused the plant more active to leaves regeneration (Moriya *et al.*, 1988). These statements were supported by Alrasjid (1986) that during dry season, old leaves were competitive with young leaves to get sunshine. In generally, old leaves were in below young leaves and less to get sunshine. These conditions caused the old leaves will be dry and fall because failing to photosynthesis.

Litter production was influenced by latitude. Goulter & Allaway (1979) suggested that to the south, litter production progressively decrease. These statements were supported by Wiebe *et al.* (1997) [23] that litter production at tropics was higher than sub-tropics. Light intensity at tropics was higher than subtropics so their photosynthesis was more optimal. Therefore, litter production at Blanakan mangrove pond was higher than Northland, New Zealand which have 6.2 ton/ha (May, 1999). Litter production at Blanakan mangrove pond was an important component in mangrove ecosystems food chain because as source of detritus. Therefore, decomposition rate of litter was studied by researchers (Keiluhu, 2000; Mahasneh, 2001; Mfilinge *et al.*, 2002; Nur, 2002; Anandan & Sridhar, 2004; Nga, 2004) because these process linked raw materials to readily substances which is used by aquatic organisms (Mason, 1976). Weight of litter at Blanakan mangrove pond can be seen at Figure 2.

Based on the Figure 2, weight of litter at TS decrease 39.65% after place on the water column for during 10 weeks, while at TT decrease 40.17%. Litter at TP was placed on water column only for 6 weeks because it's caused location permit. After placed on the water column for 6 weeks, weight of litter at TP decrease 38.5%. Reduction of weight of litter at Blanakan mangrove pond was slower than the reports from Goulter & Allaway (1979) that weight of leaves litter of *Avicennia marina* decrease 50% after placed on the water column for 8 weeks. Other statement showed that weight of leaves litter of *A. marina* decrease 50% after placed on the water column for 11 days (Robertson, 1988).

Reduction of weight of litter at each sampling site was related with the decomposition rate of litter. Decomposition rate at each sampling site can be seen at Figure 3. The difference of locations showed no significant different ($P>0.05$) on the decomposition rate.

Decomposition rate at TS, TT, and TP was 0.051 ± 0.038, 0.051 ± 0.018, and 0.081 ± 0.041, respectively. Decomposition rate can be classified into three categories: (1) high, if the decomposition rate is greater than 0.8, (2) moderate, if the decomposition between 0.5 to 0.8, and (3) low, if the decomposition rate

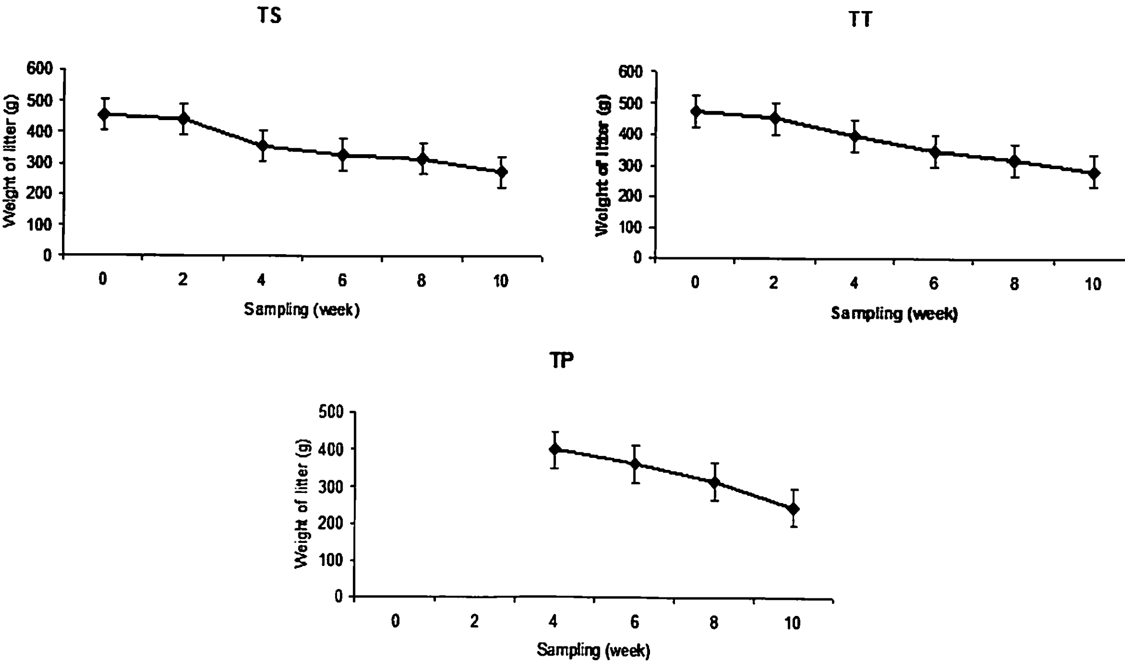


Figure 2. Weight of litter after placed on water column for 10 weeks

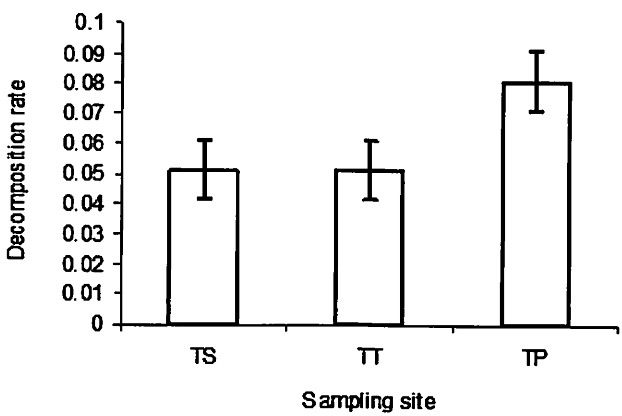


Figure 3. Decomposition rate at each sampling site

is less than 0,5 (Kusmana, 1995). According to these categories, decomposition rate at TS, TT, and TP was low.

Decomposition rate was influenced by several factors such as temperature (Ashton *et al.*, 1999), salinity (Nga, 2004), tide (Robertson *et al.*, 1992), freshwater regulation (Dick & Osunkoya, 2000), dissolved oxygen (Mfilinge *et al.*, 2002), litter characteristics (Middleton & McKee, 2001), litter nutrients (Melillio *et al.*, 1984), macrofauna (McKee & Faulkner, 2000), and microbe (Rajendran & Kathiseran, 2007). Therefore, temperature, salinity, and DO at each sampling site were recorded (Table 1).

Decomposition rate at TP was higher than TT. Perhaps, this matter was related with salinity at each sampling site, as was reported by Nga & Roijackers (2002). Salinity at TP was lower than TT. High salinity will be decrease

Table 1. Temperature, salinity, and DO at each sampling site

Parameters	TS	TT	TP
Temperature	30.84±1.3	30.71±0.74	30.84±0.96
Salinity	8.63±2.23[a]	26±1.6[b]	10.63±2.39[a]
DO	7.93±1.79[a]	2.73±0.8[b]	7.23±1.53[a]

microbial abundance, so the litter decomposition at this location was slower (Snedaker, 1978; Hyde, 1992). These statements were supported by Nga (2004) that the decomposition rate of *Rhizophora apiculata* at salinity 5 ppt was higher than salinity 15 ppt, 25 ppt, and 35 ppt.

Decomposition rate was influenced by DO. Based on Table 1 can be seen that DO at TS and TP was higher than TT. Litter decomposition was faster at aerob conditions, so decomposition rate at TP was higher than TT. These results were supported by Nga (2004) that litter of *Rhizophora apiculata* which placed on water column during 90 days at salinity 5 ppt and aerated showed decomposition rate was 0.008/day to 0.01/day, while at without aerated showed decomposition rate was 0.004/day to 0.006/day.

Several studies showed that decomposition rate was related with water temperature (Mackey & Smail, 1996). Perhaps, increasing water temperature could increase the microbial populations so the litter decomposition was faster (Steinke & Charles, 1986). But, if the water temperature was very high can be inhibiting microbial populations, so the litter decomposition was slower. Ashton *et al.* (1999) showed that the litter of *Soneratia* sp. was decomposed until 90% at placed on the water column during 56 day and temperature 29,07°C, while at temperature 31,6°C was 80%.

Perhaps, litter decomposition at TP was influenced by abundance of macrofauna. Decomposition of mangrove litter was accelerated by the feeding activities of macrofauna (Ashton *et al.*, 1999). The macrofauna may process large volumes of the litter and increased the litter surface, so the litter decomposition was faster and more optimal. Middleton & McKee (2001) showed that the feeding activities of macrofauna increased the litter decomposition until 1%/day.

Odum (1980) reported that decomposition rate was influenced by tide activities. The tide activities caused the litter was fragmented so increased the litter decomposition (Ashton *et al.*, 1999) Twilley *et al.* (1986) reported that the litter decomposition of *Rhizophora mangle* and *Avicennia germinans* at inundation for 190 folds were faster than at inundation for 127 folds.

TP is in near rivers, so the freshwater regulation at these locations was better. The freshwater regulation input nutrients to the mangrove areas for support microbial growth so the litter decomposition was faster (Dick & Osunkoya, 2000). Therefore, the decomposition rate at TP was the fastest of the other sampling sites. These results were supported by Flores-Verdugo *et al.* (1987) that the decomposition rate at riverine was faster than at dwarf.

The litter decomposition was conducted by microbial activities (Pritchett, 1979). Fungi were the first and primary microbial that decompose a litter, followed by bacterial groups (Rajendran, 1997). Raghukumar *et al.* (2004) showed that the litter decomposition by fungi was begun by fungi that producing cellulose at day-0 until day-21 followed by fungi that producing xylanase at day-28 until day-60 and fungi that producing pectinase, amylase, and protease. Mahasneh (2001) reported that the bacterial that dominant in decomposition of *Avicennia marina* were amylolitic bacteria, followed by proteolytic bacteria, cellulolytic bacteria, and lipolytic bacteria.

Some characteristics of leaf such as morphology, anatomy and chemistry resulted the decomposition rate were different (Steinke, Naidoo, & Charles, 1983). Decomposition of *Avicennia* sp. leaves was faster because thinner and less of tannin contents (Kristensen *et al.*, 1995). Poovachiranon & Chansang (1982) showed that the *A. marina* leaves that placed on the water column during 4 weeks were decomposed until 50%, while *R. apiculata* leaves were decomposed until 32%. The different components at same plant will result different decomposition rates. Valk & Attiwill

(1984) reported that at A. *marina*, the leaves decomposition was faster than the roots decomposition.

The decomposed litters containing several nutrients such as carbon, nitrogen, and phosphor (Table 2). The difference of locations showed no significant different (P>0.05) on the litter nutrients.

Litter carbon at TS, TT, and TP was 39.95±1.76%, 44.14±3.71%, and 35.31±6.69% respectively. Litter nitrogen at TS, TT, and TP was 0.83±0.39%, 1.05±0.19%, and 0.97±0.13% respectively. Litter phosphor at TS, TT, and TP was 0.04±0.005%, 0.06±0.008%, and 0.10±0.10% respectively. In generally, increasing decomposition rate could increase litter nutrients. These results were supported by Pereira *et al.* (2007) that the litter nutrients were influenced by decomposition rate of litter.

Litter nutrients will be dissolved into water column and can be used as an indicator for the fertility of mangrove ecosystems (Wepener, 2007). Dissolved nutrients at each sampling site can be seen at Table 3. Different locations showed no significant different (P>0.05) on the both nitrite and nitrate, but showed significant effect (P<0.05) on the both ammonium and phosphate.

Ammonium at TB, TS, TT, and TP was 0.0077±0.0034 mg/L, 0.0193±0.0068 mg/L, 0.0075±0.0046 mg/L, and 0.6247±0.5902 mg/L, respectively. Nitrite at TB, TS, TT, and TP was 0.0109±0.0152 mg/L, 0.0143±0.0078 mg/L, 0.0138±0.0048 mg/L, and 0.0289±0.0386 mg/L, respectively. Nitrate at TB, TS, TT, and TP was 0.0841±0.0843 mg/L, 0.1040±0.1167 mg/L, 0.0150±0.0074 mg/L, and 0.0417±0.0427 mg/L, respectively. Phosphate at TB, TS, TT, and TP was 0.0097±0.0105 mg/L, 0.0115±0.0039 mg/L, 0.0297±0.0093 mg/L, and 0.1816±0.1728 mg/L, respectively.

Based on the Figure 4 can be known that increasing litter production could increase the both dissolved inorganic nitrogen and dissolved inorganic phosphor. These facts showed that the mangrove litters were potentially as a source of dissolved nutrients for Blanakan pond. These matters can be understood because the mangrove litters at Blanakan pond containing several nutrients, as listed at Table 2. The same case was reported by Woitchik *et al.* (1997) that the litter decomposition of the both *Rhizophora mucronata* Lamarck leaves and *Ceriops tagal* (Perr) C.B. Rob leaves increased nitrogen contents at east African mangrove areas.

Input their nutrients caused status of ammonium at TB, TS, and TT was normal, but at TP was higher than maximum value was 0.05 mg/L. These matters were caused by litter production at TP was very high so input nutrients to this location more than other sampling sites. But, nitrite at TB, TS, TT, and TP was normal and less than maximum value was 0.5 mg/L (Mintardjo *et al.*, 1985).

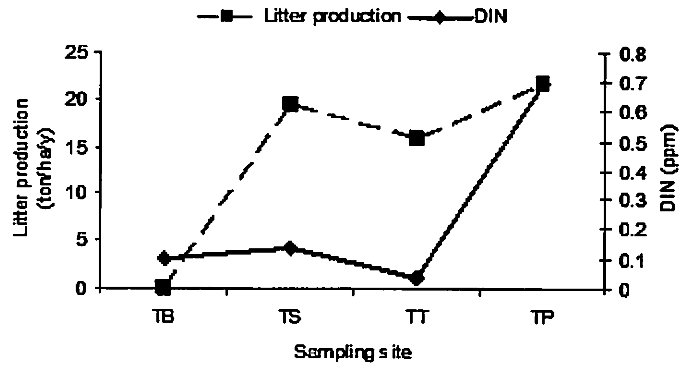
Based on the phosphate concentration, the fertility of pond can be classified into three categories: (1) low, if the phosphate less than

Table 2. Litter nutrients at each sampling site

Nutrient	TS	TT	TP
C (%)	39.95±1.76	44.14±3.71	35.31±6.69
N (%)	0.83±0.39	1.05±0.19	0.97±0.13
P (%)	0.04±0.005	0.06±0.008	0.10±0.10

Table 3. Dissolved nutrients (mg/L) at each sampling site

Nutrient	TB	TS	TT	TP
Ammonium	0.0077±0.0034[a]	0.0193±0.0068[a]	0.0075±0.0046[a]	0.6247±0.5902[b]
Nitrite	0.0109±0.0152	0.0143±0.0078	0.0138±0.0048	0.0289±0.0386
Nitrate	0.0841±0.0843	0.1040±0.1167	0.0150±0.0074	0.0417±0.0427
Phosphate	0.0097±0.0105[a]	0.0115±0.0039[a]	0.0297±0.0093[a]	0.1816±0.1728[b]



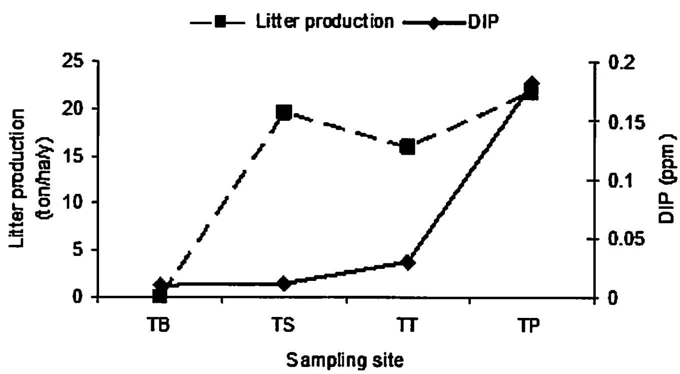


Figure 4. Relationship of litter production between dissolved nutrients

0.020 mg/L, (2) moderate, if the phosphate between 0.021 mg/L to 0.050 mg/L, and (3) high, if the phosphate greater than 0.050 mg/L (Liaw, 1969). According to these categories, the fertility at the both TB and TS was low, while at TT was moderate and at TP was high. The difference of fertility at each sampling site showed that litter production was important role to supply nutrients. At the sampling site that higher litter production, the fertility at this location was high. Therefore, the fertility at TP was the highest of the other sampling sites.

CONCLUSION

Mangrove litters were potentially as a source of dissolved nutrients at Blanakan pond. Increasing both litter production and decomposition rate could increase ammonium, nitrite, and phosphate. Therefore, mangrove litters were play role for determined the fertility at Blanakan mangrove pond.

REFERENCES

Alrasjid, H. 1986. Jalur hijau untuk pengelolaan hutan mangrove Pamanukan, Jawa Barat. *Bulletin Penelitian Hutan*, 475: 29-65.

Anandan, K. & Sridhar, K.R. 2004. Diversity of filamentous fungi on decomposing leaf and woody litter of mangrove forests in the southwest coast of India. *Current Science* Mason C.F. 1976. Decomposition. Department of The Environmental. Oxford, 243 pp.

Ashton, E.C., Hogarth, P.J., & Ormond, R. 1999. Breakdown of mangrove leaf litter in a managed mangrove forest in Peninsular Malaysia. *Hydrobiologia*, 413: 77-88.

Budiman, A. & Suhardjo. 1992. Penelitian mengenai hutan mangrove di Indonesia: pendayagunaan dan konservasi. *In* Hutomo, M. & Soemodihardjo, S. (Eds.) *Prosiding Lokakarya Nasional Penyusunan Program Penelitian Biologi Kelautan dan*

Proses Dinamika Pesisir. Semarang, 24-28 Agustus 1992. p. 34-71.

Bunt, J.S., Boto, K.G., & Boto, G. 1979. A survey method for estimating potential levels of mangrove forest primary productivity. *Marine Biology*, 52: 123-128.

Chale, F.M.M. 1993. Degradation of mangrove leaf litter under aerobic conditions. *Hydrobiologia*, 257(3): 177-183.

Clarke, P.J. 1994. Baseline studies of temperate mangrove growth and reproduction, demographic, and litter fall measures of leafing and flowering. *Australian Journal of Botany*, 42: 37-48.

Dick, T.M. & Osunkoya, O.O. 2000. Influence of tidal retriction floodgates on decomposition of mangrove litter. *Aquatic Botany*, 68: 273-280.

Ellison, J.C. & Simmonds, S. 2003. Structure and productivity of inland mangrove stands at Lake MacLeod, Western Australia. *Journal of the Royal Society of Western Australia*, 86: 25-30.

Flores-Verdugo, F.J., Day, J.W., & Briseno-Duenas, R. 1987. Structure, litter fall, decomposition, and detritus dynamics of mangroves in a Mexican coastal lagoon with an ephemeral inlet. *Marine Ecology*, 35: 83-90.

Goulter, P.F.E. & Allaway, W.G. 1979. Litterfall and decomposition in a mangrove stand, *Avicennia marina* (Forsk) Vierh. *In* Middle Harbour Sydney. *Australian Marine and Freshwater Research*, 30: 541-546.

Holmer, M. & Olsen, A.B. 2002. Role of decomposition of mangrove and seagrass detritus in sediment carbon and nitrogen cycling in tropical mangrove forest. *Marine Ecology Progress Series*, 230: 87-101.

Hyde, K.D. 1992. Intertindal mangrove fungi from the west coast of Mexico, including one new genus and two new species. *Mycological Research*, 96: 25-30.

Kathiseran, K. & Bingham, B.L. 2001. Biology of mangrove and mangrove ecosytems. *Marine Biology*, 40: 81-251.

Keiluhu, H.J. 2000. *Pola produksi dan laju dekomposisi daun **Rhizophora mucronata** di Hutan Taman Wisata Teluk Yotefa Kotamadya Jayapura-Papua*. Tesis. Program Studi Biologi, Program Pascasarjana, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Indonesia, Depok, 77 pp.

Kristensen, E., Holmer, M., Banta, G.T., Jensen, M.H., & Hansen, K. 1995. Carbon, nitrogen, and sulphur cycling in sediments of the AO NAM BOR mangrove forest, Phuket, Thailand: A review. *Phuket Marine Biologial Centre Research Bulletin*, 60: 37-64.

Kusmana, C. 1995. Teknik pengambilan contoh data biofisik sumber daya vegetasi wilayah pesisir. Laboratorium Ekologi Hutan. Institut Pertanian Bogor. Bogor.

Liaw, W.K. 1969. Chemical and Biological Studies or Fish Ponds and Reservoirs in Taiwan. Reprinted from Chinese. American Joint Commision on Rural Reconstruction. *Fisheries Series*, 7: 43.

Mackey, A.P. & Smail, G. 1996. The decomposition of mangrove litter in a subtropical mangrove forest. *Hydrobiologia*, 332: 93-98.

Mahasneh, A.M. 2001. Bacterial decomposition of *Avicennia marina* leaf litter from Al-khor (Qatar-Arabian Gulf). *Journal of Biological Sciences*, 1(8): 717-719.

May J. D. 1999. Spatial variation in litter production by the mangrove *Avicennia marina* var. *australasica* in Rangaunu Harbour, Northland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33: 163-172.

McKee, K.L. & Faulkner, P.L. 2000. Mangrove peat analysis and reconstruction of vegetation history at the Pelican Cays, Belize. *Atoll Research Bulletin*, 468: 45-58.

Melillio, J.M., Naiman, R.J., Aber, J.D., & Linkins, A.E. 1984. Factors controlling mass loss and nitrogen dynamics of plant litter decaying in Northern Streams. *Bulletin of Marine Science*, 35(3): 341-356.

Mfilinge, P.L., Atta, N., & Tsuchiya, M. 2002. Nutrient dynamics and leaf litter decomposition in a subtropical mangrove forest at Oura Bay, Okinawa, Japan. *Trees*, 16: 172-180.

Middleton, B.A. & McKee, K.L. 2001. Degradation of mangrove tissues and implications for peat formation in Belizean island forests. *Journal of Ecology*, 89: 818-828.

Mintardjo, K., Sunaryanto, A., Utaminingsih, & Hermiyaningsih. 1985. Persyaratan Tanah dan Air. *In* Anonim. 1985. Pedoman Budidaya Tambak Ditjen Perikanan, Departemen Pertanian. Jakarta.

Mokolensang, J.F. & Tokuyama, A. 1998. Litter production of mangrove forests at the Gesashi River. *Bull. Coll. Sci., Univ. Ryukyus*, 65: 73-79.

Moriya, H., Komoyama, A., & Prawiroatmodjo, S. 1988. Specific characteristics of leaf dyanamics. *In* Ogino, K. & Chihara, M. (Eds.). Biological System of Mangrove. A Report of East Indonesian Mangrove Expedition 1986. Echine University, Tokyo, p. 123-136.

Nga, B.T. & Roijackers, R. 2002. Decomposition of *Rhizophora apiculata* leaves in a mangrove-shrimp system at the Thanh Phu state farm, Ben Tre province, Vietnam. *Selected papers of the Workshop on Integrated Management of Coastal Resources in the Mekong Delta.* Vietnam, p. 95-100.

Nga, B.T. 2004. Post-larvae of the Shrimp *Penaeus monodon* and their Interaction with *Rhizophora apiculata*. Thesis. Wageningen University. Wageningen.

Nur, S.H. 2002. *Pemanfaatan ekosistem hutan mangrove secara lestari untuk tambak tumpangsari di Kabupaten Indramayu, Jawa Barat.* Disertasi. Program Pascasarjana, Institut Pertanian Bogor. Bogor, 249 pp.

Odum, E.P. 1980. The status of three ecosystem level hypothese regarding salt marsh estuarine: tidal subsidy, outwelling and detritus based foodchains. *In* Kennedy, V.S. (Ed.). Estuarine Perspective. Academic Press. New York, p. 485-495.

Ong, J.E., Gong, W.K., & Wong, C.H. 1982. Productivity and nutrient status of litter in a managed mangrove forest in Malaysia. *Biotrop Special Publications*, 17: 32-41.

Pereira, P., Cacador, I.., Vale, C., Caetano, M., & Costa, A.L. 2007. Decomposition of belowground litter and metal dynamics in salt marshes (Tagus Estuary, Portugal). *Science of The Total Environmental*, 380(1-3): 93-101.

Poovachiranon, S. & Chansang, H. 1982. Structure of Ao Yao mangrove forest and its contribution to the coastal ecosystem. *Biotrop Special Publications*, 17: 101-112.

Pritchett, W.L. 1979. Properties and Management of Forest Soils. John Wiley & Sons, Inc. New York, 92 pp.

Raghukumar, S., Sharma, S., Raghukumar, C., Sathe Pathak, V., & Chandramohan, D. 2004. Thrauschytrid and fungal component of marine detritus: laboratory studies on decomposition of leaves of the mangrove *Rhizophora apiculata* Blume. *Journal of Experimental Biology and Ecology*, 183(1): 113-131.

Rajendran, N. 1997. *Studies on mangrove-associated prawn seed resources of the Pichavaram, Southeast of India.* Ph.D. Thesis. Annamalai University, India, 131 pp.

Rajendran, N. & Kathiseran, K. 2007. Microbial flora associated with submerged mangrove leaf litter in India. *International Journal of Tropical Biology*, 55(2): 393-400.

Robertson, A.I. 1988. Decomposition of mangrove leaf litter in tropical Australia. *Journal of Experimental Marine Biology and Ecology*, 166: 235-247.

Robertson, A.I. 1991. Plant-animal interactions and the structure and the function of mangrove forest ecosystem. *Australian Journal of Ecology*, 16: 433.

Robertson, A.I., Alongi, D.M., & Boto, K.G. 1992. Food chain and carbon fluxes. *In* Robertson, A.I., Alongi, D.M. (Eds.) Tropical mangrove ecosystems. Washington D.C. *American Geophysical Union*, p. 293-326.

Snedaker, S.C. 1978. Mangrove: their value and perpetuation. *Nature and Resources*, 14: 6-13.

Steinke, T.D., Naidoo, G., & Charles, L.M. 1983. Degradation of mangrove leaf and stem tissues in situ in Mgeni estuary, South Australia. *In* Teas, H.J. (Ed.) Biology and Ecology of Mangroves. Dr. W. Junk Publisher. Lancaster, p. 141-149.

Steinke, T.D & Charles, L.M. 1986. In vitro rates of decomposition of leaves of the mangrove *Bruguiera gymnorrhiza* as affected by temperature and salinity. *South African Journal of Botany*, 52: 39-42.

Subkhan. 1991. *Produksi dan Penguraian Serasah Mangrove di Sungai Talidenden Besar, HPH PT. Bina Lestari, Riau.* Skripsi. Jurusan Manajemen Hutan, Fakultas Kehutanan, Institut Pertanian Bogor. Bogor.

Twilley, R.T., Lugo, A.E., & Zucca, P. 1986. Litter production and turnover in Basin Mangrove Forest in Southwest Florida. *Ecology*, 67(3): 670-683.

Valk, van der.A.G., & Attiwill, P.M. 1984. Decomposition of leaf and root litter of *Avicennia marina* at Westernport Bay, Victoria Australia. *Aquatic Botany*, 18:

205-221.

Wafar, S., Untawale, A.G., & Wafar, M. 1997. Litter fall and energy flux in a mangrove ecosystem. *Estuarine, Coastal and Shelf Science*, 44: 111-124.

Wepener, V. 2007. Carbon, nitrogen dan phosphorus fluxes in four sub-tropical estuaries of northern KwaZulu-Natal: case studies in the application of a mass balance approach. *Water SA*, 33(2): 203-214.

Wiebe, W., Gerace, D.T., Flowers, L., Jhonson, L., Ward, C., Oxonford, B., Parker, C., Techirky, J., Smith, S.R., Ellison, J., De Mayer, D., Bush, P., Garzo-Ferreira, J., Nivia, J., Por, L.P.J., Negelkerken, J.A., Geraldes, F.X., Ramirez, J., Herrera-Silviera, J., Sanchez-Arguelles, R.O., Garcia, J.R., Alleng, G., Bonair, K., Laydoo, R., Varela, R., Klein, E., Bone, D., Perez, D., & Linton, D. 1997. Structure and productivity of mangrove forest in a Greater Caribbean Region. *Proceedings of the 8th International Coral Reefs Symposium*, 1: 669-672.

Woitchik, A.F., Ohowo, B., Kazungu, J.M., Rao, R.G., Goeyens, L., & Dehairs, F. 1997. Nitrogen enrichment during decomposition of mangrove leaf litter in an east African coastal lagoon (Kenya): relative importance of biological nitrogen fixation. *Biogeochemistry*, 39: 15-35.

Woodroffe, C.D. 1985. Studies of a mangrove basin, Tuff Crater, New Zealand: mangrove biomass and production of detritus. *Estuarine, Coastal and Shelf Science*, 20(3): 265-280.

Woodroffe, C.D., Bardsley, K.N., Ward, P.J., & Hanley, J.R. 1988. Production of mangrove litter in a macrotidal embayment, Darwin-Harbour, N.T. Australia. *Estuarine, Coastal and Shelf Science*, 26(6): 581-590.