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LITTER FALL AND DECOMPOSITION OF MANGROVE SPECIES *AVICENNIA MARINA* IN SURABAYA EAST COAST, INDONESIA

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Abstract

The mangrove ecosystem is supported by leaf litter production and decomposition that accompanied the release of nutrients in system and adjacent coastal water. The release of nutrients in the form of nitrogen and phosphorus have an important role to enrich the nutritional content and is beneficial for marine organisms. In present study litter production, rate of leaf decomposition and release of nutrient (nitrogen and phosphorus) in mangrove habitat at Surabaya East Coast, Java, Indonesia were studied. The result showed total mangrove litter production (dry weight) ranged between around 2.15 to 3.28 g/m2/day. Among them leaf litter was the major contributor (76.26% –78.53%) followed by branches (9.43-13.27%), and reproductive parts (8.20–14, 31%). Mangrove forests in Surabaya East Coast are the result of reforestation with an area of approximately 345.6 ha which potentialy contribute nitrogen and phosphorus (109.43 to 173.549 kg/ha/ year) and (5.467 to 8.12 kg/h/year), respectively. Variations in litter decomposition indicate fluctuations input of nutrients that are important for mangrove ecosystems.

Key word: Aquatic nutrition, Ecosystem, Mangrove litter, Nutrient value.

Introduction

Release of organic matter from litter is an important functions of mangrove forests that can support the stability of the food webs in coastal ecosystems. Mangrove production is primarily in the form of litter fall which ultimately decompose and release nutrients in water. This high productivity is directly related with detritus based food chain . Decomposition is an important process to analyze the function of an ecosystem. Decomposition of mangrove litter, especially leaf litter, contributes major contributions in nutrients regeneration entering in thesediment and surrounding waters. Only small parts of decaying leaves have been directly consumed by herbivores or detritus feeder organisms.

According to Kristiningrum *et al*., (2019); Kathiresan & Bingham (2001) and Nybakken (1993), the highly productive estuarine ecosystems is supported by mangrove forest because of degradation process of litter and efficient nutrients recycling in mangrove habitat and it is also an agreement with others study (Bosire *et al*., 2005; Dewiyanti, 2010). Estimation of productivity in mangrove ecosystems is not so easy, however, estimation of litter production has been widely used method because this is one of the important components of productivity, especially contributes in nutrients recyclingin the system (Morrisey *et al*., 2007; Nagelkerken *et al*., 2008; Reef *et al*., 2010 and Alongi, 2018). Therefore, method to estimate the litter production and decomposition becomes important tool for assessing overall ecosystem productivity (Kamruzzaman *et al*., 2019).

Hemati *et al*., (2017) showed that decomposition and litter production is used as the primary pathway to enrich nutrients into the ecosystem, but it differs from location to location in the world (Kamruzzaman *et al*., 2019 and Rafael *et al*., 2018) and seasons also (Kathiresan & Bingham, 2001). For example in Malaysia, production and litter fall occur throughout the year but falling maximum in the rainy season (Hemati *et al*., 2107). Through the decomposition process, the nutrients in the form of phosphorus and nitrogenous compouds (ammonia, nitrate and nitrite) are released into estuary and open sea ecosystems. The time of release of organic substances from the mangrove ecosystem also depends on the level of mangrove decomposition which depends on the level and frequency of mangrove species, oxygen availability, tidal flooding, temperature and also availability of fauna involved in decomposition (Nga *et al*., 2004; Rahman & Tsukamoto, 2013; Numbere & Camilo, 2017 and Alongi 2018).

The overall objective of this research is to find out: 1) mangrove leaf litter production; 2) rate of mangrove leaf litter decomposition; and 3) its contribution to nutrients cycling in the mangrove ecosystem of Surabaya East Coast. Therefore, this research is expected to contribute the information related to mangrove litter production and the value of decomposition which produces essential nutrients for estuary life.

Materials and Methods

Study area: This research was conducted in the Surabaya coastal area, Java, Indonesia to collect vegetation data and substrate samples. The research area was dominated by a large number of small trees showing a typical diamete density distribution. There were 7 species trees of mangroves (*Avicennia marina*, *Avicennia alba*, *Sonneratia alba*, *Rhizophora stylosa*, *R. apiculate*, *R. mucronata*, and *Xylocarpus molucensis*) and dominated by *Avicennia marina* (Susanto *et al*., 2018) The datas were collected from 3 transects area (Fig. 1).

Transect A: (7°15'39.23''S 112°49'34.59''T) - (7°15'28.05''S 112°49'41.53''T)
Transect B: (7°15'28.06''S 112°49'12.95''T) - (7°15'11.83''S 112°49'21.17''T)
Transect C: (7°15'12.05''S 112°48'57.07''T) - (7°14'59.60''S 112°49'02.35''T)

Fig. 1. Sampling area of vegetation analysis (A, B, and C lines represented the transect). Courtesy: Google.com

Litter fall measurement: The most common method used to measure litter production in the mangrove ecosystem is using litter-trap (Sukardjo, 2010). Litter collected from leaves, fruit, flowers and twigs falling from vegetation in the research location. Litter productivity measurements were carried out with a litter-trap measuring 1 × 1 m. In each plot lay 5 litter-traps systematically at each treatment under the canopy of mangrove stands of the type *Avicennia marina*. This equipments were tied with branches of the trees in the *A. marina* zones up to 2 m above the forest floor. This height setting was intended to prevent the equipments from getting wet during high tide time (Tam *et al*., 1998). The instruments were placed 10 m apart from each other. Litter collection time was carried out at 14-day intervals sequentially (14, 28, 42 and 56 days period). This collecting period were conducted for two months for dry season and rainy season. The collected litter components were then collected into a special plastic bag and labeled, brought to the research room, cleaned and every part was separated (leaves, twigs, fruit and flowers) and dried in a drying oven for 48 hours at 80° C until the weight was constant (Ellis & Bell, 2004; Kristiningrum *et al*., 2019). To calculate dry weight of the litter, it was wrapped in aluminium foil at a temperature of 100^{o}C for 3 days (Woodroffe, 1985; Ellis & Bell, 2004).

The dried litter was then weighed with a weigher which had an accuracy of 0.05 g. Analysis of litter production is done using the following equation:

$$Xj = \sum_{j=1}^{n} \frac{Xi}{n} (g/m^2)$$

notes: Xj = the average of litter production per replication at a certain time period; Xi = litter production for each repetition for a certain period of time (i = 1, 2, 3,.., n), n = number of litter trap observations.

Decomposition: The decomposition rate of litter fall of mangrove leaves was calculated to determine the rate at which nutrients (N and P) were released from litter in mangrove ecosystem (Pannier, 1984). To determine the rate of litter degradation, litter-bag (15 x 15 x 25 cm) having mangrove litter was placed on the floor in mangrove forest for 80 days.

Decomposition rate measurement was conducted by collecting litter fall material from Avicennia marina by using a bag at study sites. The criteria of leaves used were senescent yellow either easily hand picked from the trees or freshly fallen at surrounding area (Siska *et al*., 2016; Gallagher *et al*., 2014). Collected leaves were air dried for 24 hours, and then taking about 28 g of leaf were placed in a 15 x 15 x 25 cm plastic bag (total 64 bags) with a mesh size of 1 mm2 (Pandey *et al*., 2007; Gallagher *et al*., 2014). The bag was securely fastened to the pneumatophore and placed on sediment surface. All bag samples were taken from each location at 14, 28, 42, 56 and 80 days, respectively gently cleaned before to remove other material and sediment attached on it. The detritus samples were oven dried at 100oC for 72 hours till constant mass was obtained. The final result of dry mass was recorded according to Ellis & Bell, (2004).

Decomposition of organic matter was expressed as litter dry weight ratio remaining in the form of function exponential Wt = Wo x e-kt, calculated to determine composition rate (k) where Wt was residual dry weight after time t, Wo was the initial dry weight, k was the rate decomposition (per day), and t was the incubation time (days). While the content of N and P was the proportion weight of N and P in the remaining samples with the initial sample. Data obtained were analyzed to determine the relationship pattern between the rate of degradation of organic matter, N and P as a function from incubation time.

All litters were air-dried to a constant weight and six sub-samples (about 12.00 g per sub-sample) from each kind

of litter were analyzed for initial N and P concentrations. N concentration was determined by the semimicro-Kjeldahl digestion method followed by the detection of ammonium with a Wescan ammonia analyzer, while total P concentration was analyzed colorimetrically after acidified ammonium persulfate digestion.

The release of nutrients ($g.g^{-1}.day^{-1}$) was calculated as follows: NUTRIENTt (release) = (DW_o * $NUTRIENT_o$) - (DW_1 * $NUTRIENT_1$); where DW_o is dry weight initial leaf litter, DW_1 is the remaining dry weight on time t day. $NUTRIENT_o$ is the initial nutrient content, and NUTRIENTt is the residual nutrient content on t day, and t incubation time (days).

Result and Discussion

Litter production: The total production of *Avicennia marina* litter (dry weight) ranges between 4.15 g/m^2/day to 2.63 g/m^2/day with average value of 3.45 g/m^2/day. Total litter production the highest was at transect A which was equal to 4.15 g/m^2/day and followed by transect C at 3.58 g/m^2/day and transect B of 2.63 g/m^2/day.

Leaf litter was the major contributor (76.26% – 78.53%) of total litter production within an average value of 77.41% followed by branches (ranged between 9.43-13.27%; average 10.82%), reproductive parts (flower and fruits) ranged from 8.20–14.31% with an average of 11.77%. On transect A where the oldest plant age was between 12-22 years, the production of reproductive organs was the maximum that was equal to 8.20%, while at transect B (age plants 9-11) was at 12.81% and transect C (age plants 5–8) at 14.31% (Table 1).

Total litter production for each transect was different due to age of plants and density. This total litter production was smaller than that with total production of mangrove litter in Cilacap (2.36–4.50 g/m^2/day) (Affandi, 1996) and in Irian Jaya (Bintuni) as big as 3.04 g/m^2/day (Taberima *et al*., 2014). This condition was caused by existing mangroves in Cilacap & Bintuni (Central Java) are growing mangroves naturally so the type of plant and its density washigher compared to existing mangroves in Nguling, Pasuruan (East Java) which is the result of reforestation. However, the total production of mangrove litter from this study ie 2.23-3.33 g/m^2/day was greater when compared with the results of the study of Soenardjo (1999) in Kaliuntu, Rembang (Center of Java) which was also a reforestation forest with total production of mangrove litter ranged from 1.93-2.84 g/m^2/day. A comparison of total production of mangrove litter, *Avicennia marina*, from this study with the total production of mangrove litter from different locations is gilven in Table 2.

Litter decomposition: There was no difference in average of litter dry weight (%) lost from litter bags in 80 days at all three transect. At the beginning of the experiment (after 10 days) the leaf litter was lost by 37.39%, then increased as the time elapsed 46.69% (20th day) and 64.67%, (30^{th} days) 75.95% (40th day), 91.37% (60^{th} day) 93.87% (70^{th} day) and 95.92% (80^{th} day). This result is almost similiar as the results of a study conducted by Soenardjo (1999) in the Kaliuntu mangrove forest in Rembang, Central Java, which also uses the amount of dry weight of 10 grams of litter per bag.

The high degradation at the initial stage is thought to be related to the leaching of soluble inorganic and organic materials and is also supported by the presence of microorganisms that play a role in degradation process. According to Affandi & Ni'matuzahroh (2000) the macro organisms such as insect (4 species with an abundance of 32.61%), crustaceae (12 species with an abundance of 31.62%), mollusca (16 species with an abundance of 19.03%), polychaeta (25 species with an abundance of 16.69%) and myriapoda (1 type with an abundance of 0.05%). Farooqui *et al*., (2014) found in the mangrove ecosystem that in addition to microorganisms i.e., fungi also participate in the early stages of decomposition process and play a very important role in the loss of organic and inorganic materials. According to Affandi *et al*., (2001) 30 strains represented by 7 genera, each Penicillium (4 strains), Aspergillus (10 strains), Gliocladium (2 strains), Gonatobotryum (1 strain), Paeocilomyces (2 strains), Syncephalastrum (1 strain) and Trichoderma (10 strains) involved in degradation process of mangrove in the North Coast region of Surabaya. Fell & Master (1980) in Affandi (1996) reported that 50% of carbon is lost from Rhizophora leaf litter within 6–15 weeks and reduced to sugar and tannin in 14 and 24 days, respectively.

Table 1. Production of total mangrove leaf Litter (g/m^2/day) and percentage of litter components.

Transect	Leaves		Branches		Reproduction organ		Total	
	gr/m^2/day	%	gr/m^2/day	%	gr/m^2/day	%	gr/m^2/day	Ton/ha/year
A	3.28	78.53	0.48	13.27	0.39	8.20	4.15	12.97
B	2.15	77.44	0.27	9.75	0.21	12.81	2,63	9.17
C	2.87	76.26	0.39	9.43	0.32	14.31	3.58	11.56
Average	2.76	77.41	0.38	10,82	0.33	11.77	3.45	11.23

Table 2. Total production of mangrove litter from *Avicennia marina* in various locations.

Location	Species	Production (g/m^2/day)	References
Maputo Bay, Mozambique	*Avicennia marina*	37.86 ± 18.49	Fernando & Bandiera, 2009
Whangamata Harbour, North Island, New Zealand	*Avicennia marina*	53,8 ± 74	Gallagher *et al*., 2014
Uzi-Nyeke, The Zanzibar	*Avicennia marina*	0.56 ± 0.03	Mchenga & Ali, 2017
Northern Coast of Aceh Besar, Indonesia	*Avicennia marina*	0,70 ± 2,14	Dewiyanti *et al*., 2019
Surabaya East Coast, Indonesia	*Avicennia marina*	2,339 ± 3,39	This research

The half-life (t50) at locations 0–25 m ranged between 25–31 days (average 27 days), while at locations 25–50 m it reached between 18–20 days (average 19 days). This result is in agreement with the results of Bosire *et al*., (2005) who reported earlier for *Rhizophora mucronata*, i.e., t50 in the rainy season recorded on the 26th day, but the decomposition rate was greater at 0.19 times. This was because that the less number of decomposer organisms were present in mangrove (Bosire *et al*., 2005).

The maximum value (0.0819 per day) of litter decomposition rate was observed on the 50th day and minimum after 20 and 66 days at both (0-25m and 25-50m) location (Fig. 2). The results of this study indicate that the decomposition rate at locations 0–25 m and 25–50 m from the coastline has no difference. This can be caused by the duration of standing water between stations.

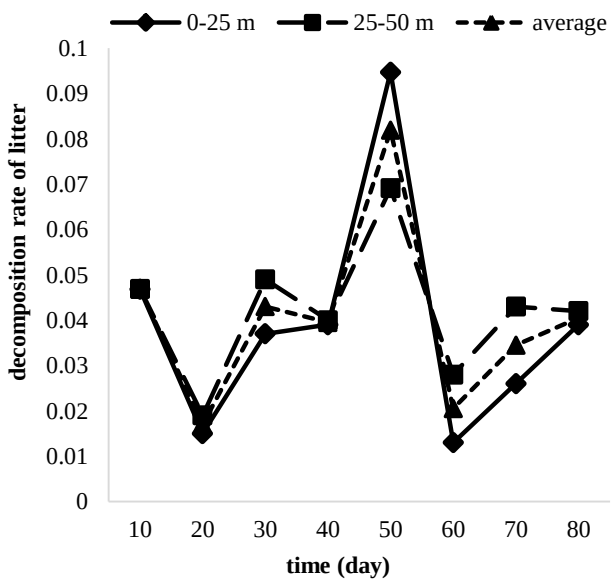

Fig. 2. Rate of litter decomposition in leaf decomposition.

The increase in decomposition rate on the 50th day of observation in this study might be due to the presence of decomposer animals. In the bag of litter decomposers (macrofauna (amphipoda, decapoda and polychaeta) found at the initial stage which subsequently increased as decomposition proceeded. It is suspected that the dominant group of animals found plays significant role in accelerating the process of decomposition (Dewiyanti *et al*., 2019).

Mangrove contributions to nutrients: Results showed that the concentration of phosphors and nitrogen in decomposing leaf litter during decomposition period increased rapidly until the 50th day and then slowed down and tended to be stable after more than 80 days (Fig. 2).

Using data on leaf litter production of 1.78 to 2.53 g/m2/day or an average of 2.18 g/m2/day, the total amount of nutrients released by Avicennia marina, i.e. nitrogen ranged from 0.0355 to 0, 0506 g/m2/day. Whereas phosphorus ranges from 0.0018 to 0.0025 g/m2/day (Table 3).

Mangrove forests in Surabaya East Coast are the result of reforestation with an area of approximately 345.6 ha. Contribution of nitrogen and Phosphorus was about 109.43 to 173.549 kg/ha/ year (6.39 to 9.54 tons/year) and 5.467 to 8.12 kg/ha/year (0.34 to 0.41 tons/year), respectively.

The important stage in the process of nutrient recycling was indicated by result of mangrove litter decomposition. These decomposition also can supply the organic substance into the estuarine food web, and play an important function in the stability of the various matter surounding such as quantities balance of oxygen, estuary substrate, and the activity of estuary organisms (Lugo & Snedaker, 1974). Organic substance that result from litter decomposition entering mangrove food web is produced autochthonously (Kristensen *et al*., 2008, Huzham *et al*., 2010).

Mangrove productivity via litter fall and decomposition in the coastal areas of Indonesia has an important function in supporting the balance of life, especially in the estuary area. Therefore, its existence must be maintained and preserved so that the nutritional needs of coastal waters can be fulfilled forever.

Table 3. N and P (as nutrient) released from leaf litter of *Avicennia marina*.

Component	Nutrient released (g/g/day)	Nutrients are released in the forest Avicennia (g/m2/day)			Average
		Transect 1	Transect 2	Transect 3	
Nitrogen (N)	0,02	0,0446	0,0506	0,0355	0,0436
Phosphor (P)	0,001	0,0022	0,0025	0,0018	0,0022

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