Species composition and structure of secondary mangrove forest in Rawa Timur, Central Java, Indonesia

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Abstract. According to the characteristics of their habitat, each mangrove forest communities have a typical specific locally species composition and stand structure. This research was conducted in January – February 2017 in mangrove forests of Rawa Timur, one of the mangrove forests region of Segara Anakan, Cilacap, Central Java, Indonesia. Six permanent plots (PP's) (50 x 50 m each) placed randomly in the study site. On each PP were identified the species name, the number of individual species, stem diameter, and height of crown tree. The research showed that in six permanent plots found 14 mangrove species (9 major species and 5 minor species) belonging to 10 genera of 8 families. Species from Rhizophoraceae (4 species) are the most frequently species found, followed by other species of Acanthaceae (2 species) and Lythraceae (2 species). Species of *Rhizophora apiculata* dominated seedling and sapling stages, while the species of *Avicennia alba* dominated tree stages. Mangrove species in Rawa Timur mangrove forest have stem diameter between 1.20 and 39.36 cm and crown height between 0.5 and 17.3 m. Stem diameter class of 1.2–5.0 cm and crown height class of 0.5–5 m has the most individual density, respectively 20,533 ind ha^{-1} (79.52% from the total number of individuals) and 21,675 ind ha^{-1} (83.95% from the total number of individuals).
Key Words: forest structure, human interference, mangrove communities, Segara Anakan Cilacap, spatial distribution.

Introduction. Mangrove forest is a group of the inter-tidal plants that grow dominantly at areas of tropical and subtropical coastline (Zhang et al 2007). The existence of mangrove forests has an important role towards the value of ecology, economy, and social coastal areas (Jachowski et al 2013). The values and roles of mangrove forest raise a lot of interest and concern to the existence of mangrove forests. Current researches have been focused towards the role of the mangrove forests, mainly due to the Indian Ocean Tsunami in 2004 (Barbier 2006). According to Wang et al (2007), mangrove forest ecosystem is being the first that will be affected by global climate change, because of its existence on the land and sea border.

Directorate of Forest and Land Rehabilitation (2014) stated that the Indonesian mangrove forest area is about 3.74 million ha, which is 24% of the mangrove forests of the world. The area is actually declining when compared to the mangrove forest area according to FAO (1982), which is 4.25 million ha (27% of the mangrove forests of the world). According to Bakosurtanal (2009), the remaining mangrove forests in Java Island are only about 34,481 ha. Segara Anakan region, Cilacap is the largest mangrove forest area in Java (Sukardjo & Yamada 1992) with an area of 21,750 ha in 1983 (White et al 1989). The existence of mangrove forests in the area is declining which caused by pollution, exploitation and conversion of mangrove forests into other uses and sedimentation (Winarno & Setyawan 2003). Recent data showed area of Segara Anakan mangrove forest is about 9,238 ha (Ardli & Wolff 2008). According to Setyawan et al (2002), the mangrove forest of Segara Anakan have 27 mangrove species which are 13 major species, 8 minor species, and 6 associations species.

Damage on the mangrove forests in Segara Anakan can threaten or even eliminate the existence of its mangrove vegetation. So that it is important to know the recent data on the species composition and mangrove forest structure in Segara Anakan. Data of species composition and forest structure is useful to know the condition of the balance of the forest communities (Meyer 1952), describes the interactions within and between species (Odum 1971; Ludwig & Reynolds 1988), and predict the tendency of the stand composition in the future (Whittaker 1974).

This study aims to elucidate the species composition and structure of mangrove forests in Rawa Timur, Cilacap, Central Java, which is managed by Perum Perhutani (The State of Forestry Corporation).

Material and Method

Study sites. The research was conducted in January – February 2017 in the mangrove forests of Rawa Timur, Cilacap, Central Java, Indonesia (Figure 1). This mangrove forest included brackish forest area of Cilacap geographically located between $7^0$30' and $7^0$44' southern latitude (S) and $108^0$42' and $109^0$2' in eastern longitude (E), stretching along the southern coast of Central Java and included into the area of the Segara Anakan, Cilacap. Based on the classification of Schmidt & Fergusson (1951), this mangrove forest area was included A climate type with average rainfall of 3,444 mm year^{-1}, and the average of rainfall per month ranging from 7 to 137 mm during the dry season and 226.4 to 852 mm during the rainy season. As for the average of monthly temperature was 26.9°C with wind speed ranging between 3 and 7 knots. The altitude of the place generally ranges between 0 and 5 m above mean sea level with alluvial soil type and fine soil texture (silty clay).

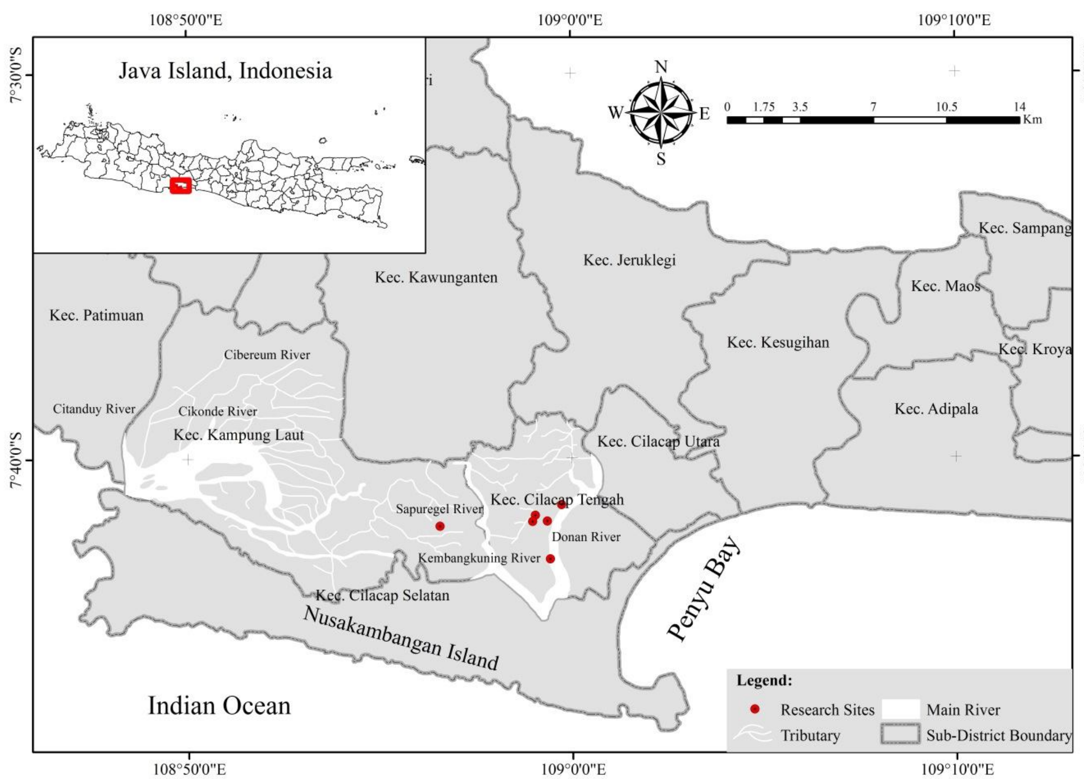

Figure 1. Research location.

Methods. The 50 x 50 m permanent plot (PP) (Kusmana et al 1992; Sukardjo & Yamada 1992) was established randomly at six locations: PP 1 ($07^0$41'S and $108^0$59'E), PP 2 ($07^0$41'S and $108^0$58'E), PP 3 ($07^0$41'S and $108^0$59'E), PP 4 ($07^0$41'S and $108^0$59'E), PP 5 ($07^0$42'S and $108^0$59'E), and PP 6 ($07^0$41'S and $108^0$56'E) (Figure 1). Furthermore, each PP was divided into 25 plots each 10 x 10 m, where each plot was divided into several sub-plots, such as 2 x 2 m sub plots for seedlings inventory (woody plants with height ≤1.5 m), 5 x 5 m sub plots for sapling inventory (woody plants with diameter <10 cm and height >1.5 m), as well as 10 x 10 m sub-plots for trees inventory (woody plants with diameter ≥10 cm and height >1. 5 m) (Sukardjo 1987) and palm (not woody plants, not branched until the first leaves, and the leaves attached to the midrib). At each PP was collected data of species name, the number of individual species, stem diameter (D) and tree height (H). Stem diameter were measured at 30 cm above the prop roots of *Rhizophora* spp. and 1.3 m above mean ground level (Diameter at Breast Heigh or DBH) for other mangrove species (Komiyama et al 2005). Furthermore, palm and trees stage that were found on every PP mapped their stem positions by measuring their coordinates.

Data analysis. The vegetation data were analyzed based on basal area (BA), density, relative density, frequency, relative frequency, dominance, and relative dominance. Importance Value Index (IVI) of a species derived from the sum of the relative density and relative frequency for seedling and sapling stages, and the sum of the relative density, relative frequency, and dominance relative for tree stage (Curtis & McIntosh 1950). The dominant species at any stage of growth is determined by the highest magnitude of IVI. The vegetation data is also used to analyze the community index as the Shannon-Weiner diversity index (H '), evenness index (J) (Legendre & Legendre 2012), and the index of species richness (d) (Margalef 1958). As for the palm species was only analyzed the density of individuals and the BA.

Forest structure was analyzed based on the vertical structure (stratification) and horizontal structure (stem diameter distribution), as well as the spatial distribution pattern. The vertical structure is described by individuals density at any crown height class at 5 m intervals, except for the lowest crown height class since beginning from 0.5 m. Furthermore, the horizontal structure is described by individuals density in each stem diameter class at 5 cm intervals, except for the lowest diameter classes because it begins from 1.20 cm diameter. The spatial distribution pattern of dominant and codominant species at any growth stage is calculated based on the Morishita index (I_d) (Morishita 1956) with the following equation:

$$I_d = q\left(\frac{\sum_{i=1}^{q} xi\,(xi-1)}{T(T-1)}\right) \qquad (1)$$

Where, I_d is the Morishita index, q is the number of sample plots, xi is the number of individual x species in the i-th (1,2,3, ..., q) sample plot, and T is the sum of all individuals in all sample plots.

The individual distribution is determined based on the following criteria: I_d = 1, individuals distribute randomly; I_d > 1, individuals distribute clumped; and I_d < 1, individuals distribute regularly. Testing I_d > 1 differ significantly with I_d = 1, using the F test. Testing I_d < 1 differ significantly with I_d = 1, used x^2 test (Ludwig & Reynolds 1988).

Results

Species composition. The results of vegetation analysis (Table 1) showed that there are 14 species of mangrove derived from 10 genera of 8 families, on six PP's (1.50 ha) that have been established in Rawa Timur mangrove forest. Species from Rhizophoraceae (4 species) is the most species often found, followed by other species from Acanthaceae

(2 species) and Lythraceae (2 species). As for PP's that have the most abundant species is PP 1 and PP 3, 11 species for each PP.

Table 1

Species found in PP of Rawa Timur mangrove forest, Cilacap, Central Java, Indonesia

Family	*Local name*	*Species*	*PP*					
			1	*2*	*3*	*4*	*5*	*6*
Primulaceae	Gedangan	*Aegiceras corniculatum***	v	v	v	v	v	v
Acanthaceae	Api-api putih	*Avicennia alba**	v	v	v	v	v	v
	Api-api hitam	*A. marina**	-	-	v	-	-	-
Rhizophoraceae	Tancang	*Bruguiera gymnorrhiza**	v	v	v	v	v	v
	Tingi	*Ceriops tagal**	v	v	v	v	v	v
	Bakau bandul	*Rhizophora mucronata**	v	v	v	v	v	v
	Bakau kacang	*R. apiculata**	v	v	v	v	v	v
Malvaceae	Dungun	*Heritiera littoralis***	v	-	-	-	-	-
Arecaceae	Nipah	*Nypa fruticans**	v	v	v	v	-	-
Euphorbiaceae	Buta-buta	*Excoecaria agallocha***	v	-	-	-	-	-
Lythraceae	Bogem	*Sonneratia caseolaris**	v	v	v	v	v	v
	Prapat	*S. alba**	v	v	v	v	v	v
Meliaceae	Nyirih	*Xylocarpus granatum***	-	-	-	-	v	-
	Nyuruh	*X. moluccensis***	-	-	v	-	v	v

PP: permanent plot, *: major mangrove species, **: minor mangrove species, v: found, -: not found.

The highest individual density and basal area (BA) of all species respectively were in the seedling stage (20,533±2,564 ind ha^{-1} or 80% of total) and sapling stage (23.47±8.38 m^2 ha^{-1} or 41% of total) (Table 2). The dominant species in Rawa Timur mangrove forest, namely: *R. apiculata* for seedling and sapling stages, *A. alba* for tree stage, and *N. fruticans* for palm. Plant community index of Rawa Timur mangrove forests (Table 2) showed that the lowest of Shannon-Weiner diversity index (H '), evenness index (J), and species richness index Margalef (d) for the tree stage, respectively are 0.93±0.40, 0.70±0.16, and 0.84±0.44. Sapling stage have the highest Shannon-Weiner diversity index (H') and Margalef species richness index (d) are respectively 1.62±0.08 and 1.34±0.13. Furthermore, seedling stage has the highest evenness index (J) as large as 0.81±0.05.

Table 2

Density, basal area, dominant and co-dominant species, and community index of Rawa Timur mangrove forest

Variable	*Growth stage*			
	Seedling	*Sapling*	*Tree*	*Palm*
Density (ind ha^{-1})	20,533±2,564	4,672±305	149±12	465±160
Basal area (m^2 ha^{-1})	14.51±1.65	23.47±1.40	4.47±0.39	7.29±2.51
IVI dominant and codominant species (%)	*R. apiculata* (67.27) *B. gymnorrhiza* (36.64)	*R. apiculata* (54.16) *A. alba* (37.44)	*A. alba* (140.02) *S. caseolaris* (84.30)	-
Species diversity (H')	1.52±0.23	1.62±0.08	0.93±0.07	-
Evennes (J)	0.81±0.05	0.76±0.04	0.70±0.16	-
Richness (d)	1.12±0.25	1.34±0.13	0.84±0.07	-

-: not found.

Forest structure. The vertical structure (crown stratification) of Rawa Timur mangrove forest ranged from 0.5 to 17.3 m (Figure 2). It showed that most species (83.95% of the total or 21,675 ind ha^{-1}) are included into crown height class of 0.5-5 m and a few of species has crown height more than 15 m (0.01% of the total, or 3 ind ha^{-1}). *R. apiculata* is a species that has the highest density on the 0.5–5.0 m and 5–10 m crown height classes, which respectively 12,250 ind ha^{-1} and 1392 ind ha^{-1}. Furthermore, for 10–15 m crown height class which has the highest density is *S. caesolaris* (18 ind ha^{-1}) and for more than 15 m height class are *S. caseolaris*, *S. alba* and *R. apiculata* (1 ind ha^{-1} each).

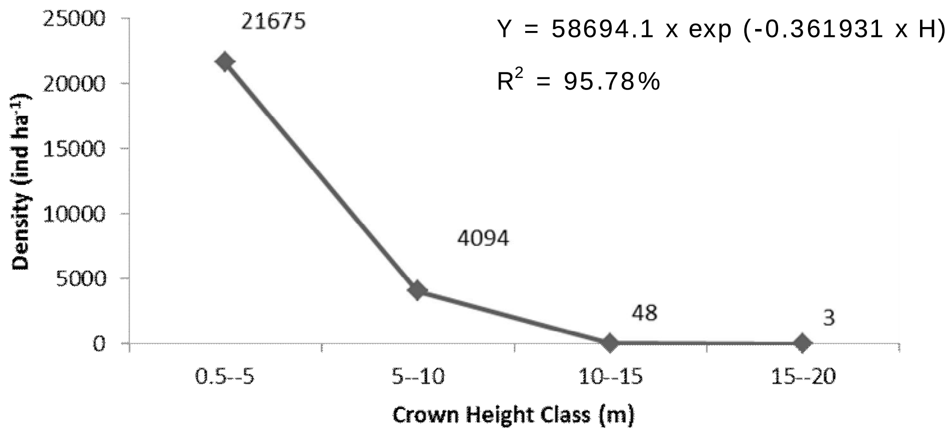

Figure 2. Density (Y) of every crown height class (H) of Rawa Timur mangrove forest.

Horizontal structure (stem diameter distribution) of Rawa Timur mangrove forest ranged from 1.20 to 39.36 cm (Figure 3). It described that the highest density is on 1.2-5.0 cm diameter class (79.52% of the total or 20,533 ind ha^{-1}). The most rarely individuals distribution found, is in diameter classes above 35 cm (0.01% of the total, or 3 ind ha^{-1}). *R. apiculata* is a species that has the highest density in 1.2–5.0 cm and 5–10 cm diameter class (6,250 ind ha^{-1} and 1,392 ind ha^{-1}). Furthermore, *A. alba* is a species that has the highest density on the other diameter classes.

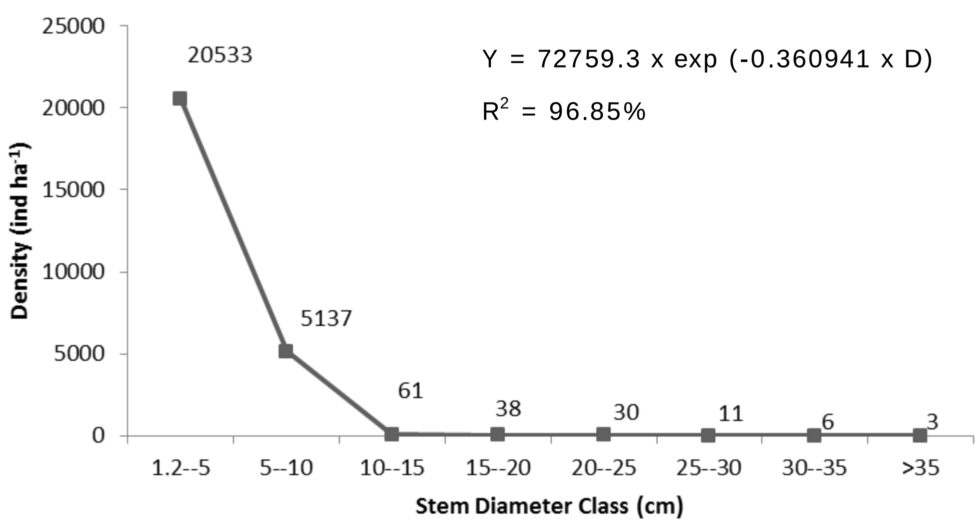

Figure 3. Density (Y) of every stem diameter class (D) of Rawa Timur mangrove forest.

Spatial distribution pattern of Rawa Timur mangrove forests based on value of Morishita index (Table 3) showed that most species of dominant and codominant at any growth stage distributed randomly and the remaining in clumped and regular. *N. fruticans* is the species that significantly clumped. In detail, spatial individual distribution of trees and palms on each PP can be seen in Figure 4.

Table 3

Morishita index value of dominant and codominant species on every growth stage of Rawa Timur mangrove forest

Growth stage	*Dominant and codominant species*	*Morishita index value*					
		PP 1	*PP 2*	*PP 3*	*PP 4*	*PP 5*	*PP 6*
Seedling	*R. apiculata*	3.35*	3.31	1.44	1.98	1.57	1.66
	B. gymnorrhiza	1.10	0**	1.82	4.44*	1.69	1.67
Sapling	*R. apiculata*	1.30	2.70*	1.19	1.25	1.29	2.47
	A. alba	2.39	1.14	1.60	1.17	3.68*	1.70
Tree	*A. alba*	0**	1.30	25.00	1.85	1.96	1.25
	S. caseolaris	3.57	-	2.14	2.37	4.17	1.52
Palm	*N. fruticans*	1.73**	21.15**	11.84**	25.00**	-	-

PP: permanent plot; *: significantly different from random distribution (I_d = 1) (P<0.05); **: significantly different from random distribution (I_d = 1) (P<0.01); -: not found.

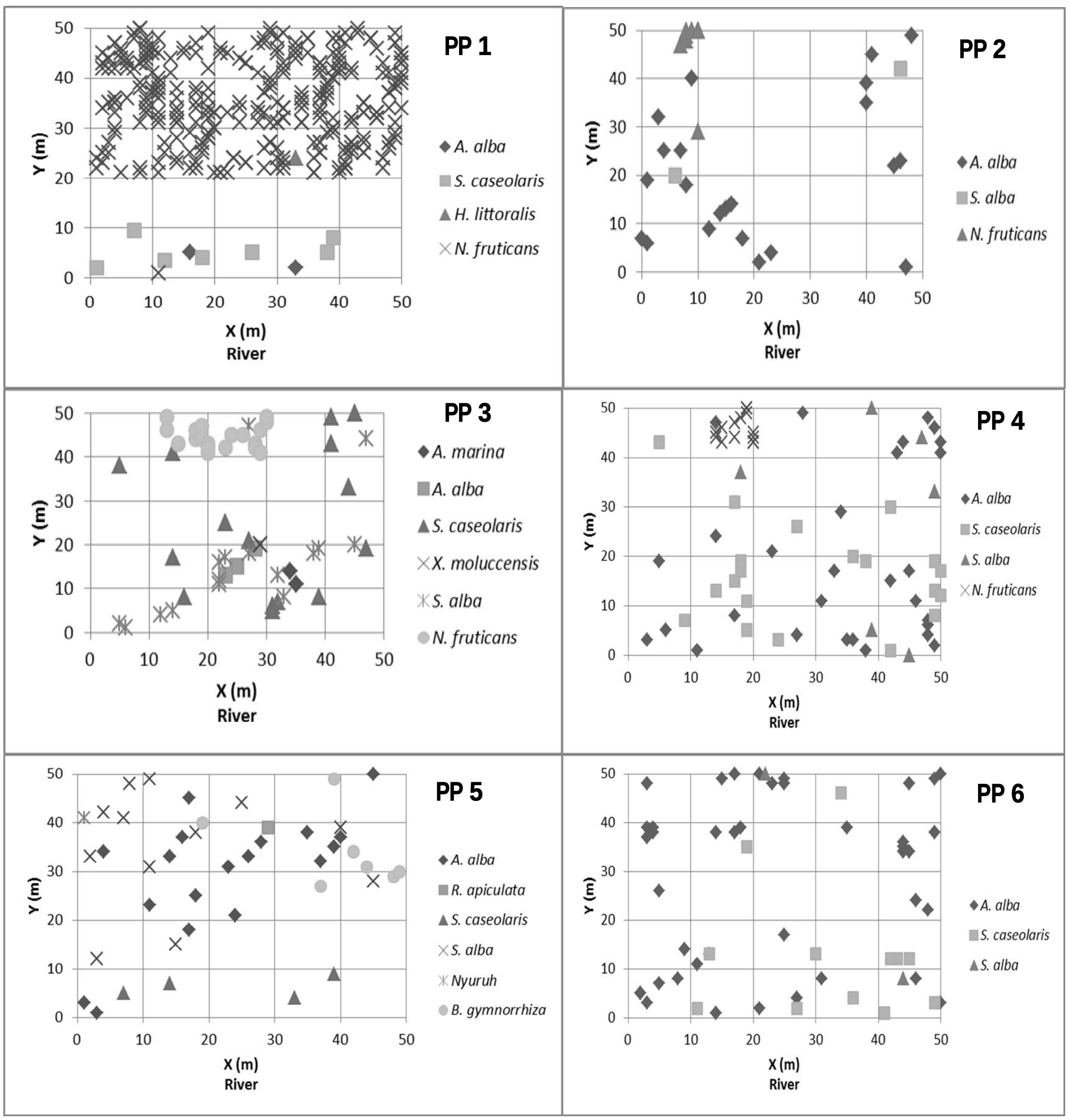

Figure 4. The spatial individual distribution of trees and palms on each PP at Rawa Timur mangrove forest.

Discussion

The species composition of Rawa Timur mangrove forests. Rawa Timur mangrove forest, generally consists of 14 mangrove species (13 tree species and one species of palm), including 9 species of major mangrove and 5 minor mangrove species (Table 1). It shared about 15% of mangrove species from the total 94 mangrove species (89 tree species and 5 palm species) in Indonesia (Kusmana 2014). The data also showed that the 27 mangroves species (13 major species, 8 minor species, and 6 associations species) in Segara Anakan region (Setyawan et al 2002), some still exist in Rawa Timur mangrove forests. Lack of mangrove species in Rawa Timur mangrove forests, according to Setyawan et al (2005) due to the large sea waves in south coast of Java that obstruct the arrival of propagules or mangrove seeds from other locations as well as the absence of extensive mangrove forests in the vicinity. However, the number of species in the study site is still more than some other mangrove communities in other regions (Table 4).

Table 4

The number of mangrove plant species on several mangrove forests

Location	*Communities type*	*No. of species*	*Source*
Cilacap, Central Java, Indonesia	*A. marina - S. alba* *R. apiculata - R. mucronata* *N. fruticans*	14	Present study
Bulaksetra, Pangandaran, West Java, Indonesia	*A. floridum – R. apiculata* *A. alba*	14	Kusmana & Ningrum 2016
Tiris, Indramayu, West Java, Indonesia	*A. marina - R. mucronata* *R. apiculata - R. mucronata*	8	Sukardjo et al 2014
Pulau Dua, Banten, Indonesia	*A. marina* *R. apiculata* *Thespesia populnea*	11	Sedayu & Sumadijaya 2012
Pulau Rambut, Jakarta, Indonesia	*R. mucronata*	11	Onrizal & Kusmana 2006
Talidendang Besar, Riau, Indonesia	*B. parviflora* *B. sexangula* *B. sexangula - N. fruticans*	8	Kusmana & Watanabe 1991
East Kalimantan, Indonesia	*R. apiculata - R. mucronata* *B. parviflora - B. sexangula*	5	Kusmana 1997
Pulau Sebuku, South Kalimantan, Indonesia	*R. mucronata*	9	Ghufrona et al 2015
Birem Bayeun and Rantau Selamat, East Aceh, Indonesia	*R. apiculata* *B. gymnorrhiza*	10	Nurlailita et al 2015
Passare Apua, Southeast Sulawesi, Indonesia	*R. apiculata* *B. gymnorrhiza*	13	Khaery et al 2016
Halmahera, Indonesia	*S. alba* *B. gymnorrhiza – X. granatum* *N. fruticans – R. stylosa*	14	Komiyama et al 1988
Bintuni Bay, West Papua, Indonesia	*R. apiculata - R. mucronata* *B. gymnorrhiza - C. tagal*	11	Sillanpaa et al 2017
Puerto Princessa Bay, Palawan Island, Filipina	*R. apiculata - R. mucronata* *S. alba – S. caseolaris* *Ceriops decandra – X. moluccensis*	20	Dangan-Galon et al 2016
Kamphuan Village, Ranong Province, Thailand	*R. apiculata - R. mucronata* *X. granatum - B. cylindrica*	15	Jachowski et al 2013

Location	Communities type	No. of species	Source
Kosrae Island, FSM	*B. gymnorrhiza – X. granatum S. alba*	4	Krauss & Allen 2003
Okukubi River, Okinawa Island, Jepang	*B. gymnorrhiza - Kandelia obovata*	3	Kamruzzaman et al 2017
South West coast of India	*A. officinalis R. mucronata Excoecaria agallocha*	14	Rani et al 2016
Mekong Delta, Vietnam	*A. alba - A. officinalis R. apiculata - R. mucronata*	4	Dung et al 2016

The individual density in Rawa Timur mangrove forests at young stages is larger than the adult stage or older (seedlings > saplings > tree) (Table 2). According to Fromard et al (1998), the individual density is the most decisive factor for the initial phase of mangrove forests development and young stands will be adults by reducing the number of individual density.

Basal area of all species (Table 2), showed that greatest basal area are at saplings stage (25.81 m^2 ha^{-1}) or 58% of the total basal area in Rawa Timur mangrove forests (44.79 m^2 ha^{-1}). The data showed that Rawa Timur mangrove forests were dominated by saplings stage. Low density and basal area at tree stage also indicates that Rawa Timur mangrove forests are in the process of growing into mature mangrove forest. In addition, low density and basal area at tree stage is also due to the disruption of the mangrove forest. According to Setyawan et al (2005), in mangrove forests Cilacap (Segara Anakan) is used to known as the richest location of mangrove and most extensive on Java island, but as the times progress, occur anthropogenic interference as tree felling and conversion into ponds and excess sedimentation of Citanduy river and Cimeneng or Cikonde rivers.

Stucture of Rawa Timur mangrove forest. Horizontal structure of Rawa Timur mangrove forest (Figure 3) showed the L-form or individual density decreases exponentially by increasing the size of the tree diameter. This indicates that the mangrove forests in the development phase (Joshi & Ghose 2014) and according to Meyer (1952), the mangrove forest is classified as balanced uneven-age forest. The existence of regeneration (small diameter) that are abundant, can guarantee forests sustainability in the future (Whittaker 1974), if there is no significant interference. Development and growth stage of Rawa Timur mangrove forest can also be seen from the vertical structure (Figure 2). Based on the classification of tropical rain forest canopy stratification (Soerianegera & Indrawan 1988), Rawa Timur mangrove forest consists of 3 layers of canopy, namely C layer (4–18 m), D layer (1–4 m), and E layer (0–1 m) which still keeps growing and developing. Individual density decreases exponentially with increasing height of the tree. According to Smith (1973), the vertical structure can be used to see light need of a species. Based on this aspect, tree species in Rawa Timur mangrove forest which have high crowns, are tolerant species to sunlight.

R. apiculata is the most dominating species at seedlings and saplings stage, followed by *B. gymnorrhiza*, and *A. alba* (Table 2). According to Hutching & Saenger (1987) and Waston (1928), *R. apiculata* and *R. mucronata* can grow on wet habitat conditions with salinity of 10-30‰ and can be found at the edges of the river. However, populations of *R. mucronata* not too dominant, it is suspected because of *R. mucronata* can not compete with *R. apiculata* which have same habitat. Such conditions are found in all PP. *B. gymnorrhiza* dominate mangrove forests climax zone until their transition to land forest characterized by the presence of *X. moluccensis* and *Lumnitzera racemosa* (Waston 1928). Such conditions are found in PP 3, PP 5, and PP 6 (Table 1). *N. fruticans* according to Odum (1971), Sukardjo (1985), and Tomlinson (1986), can form pure stands through vegetative propagation and dominates the border area between sea and freshwater ecosystems. Dominant condition of *N. fruticans* can be seen on the PP 1

(Figure 4). Tree stage was dominated by *A. alba* and *S. caseolaris* (Table 2 and Figure 4). According to Ng & Sivasothi (2001), generally *Avicennia* spp. and *Sonneratia* spp. can grow well on sandy soil and according to Waston (1928) the closest zone to the sea or river banks was dominated by *Avicennia* spp. and *Sonneratia* spp. with soft mud soil type which is rich in organic content. The dominance of *A. alba* and *S. caseolaris* at tree stage allegedly because of other species except *Avicennia* spp. and *Sonneratia* spp. (especially *Rhizophora* spp. and *Bruguiera* spp.) has occurred large scale exploitation (tree felling) in the past. Based on this, older plants do not dominate in Rawa Timur mangrove forest and most of them are in secondary succession stage, that dominated by pioneer trees like *Avicennia* spp. and *Sonneratia* spp. (Setyawan et al 2008). Moreover, Rawa Timur mangrove forest was not fully establish a clear zone based on the flooding frequency or salinity, like the commonly classification (Hutching & Saenger 1987; Waston 1928). It can be caused by the high rate of mangrove habitat conversion into other uses, trees felling, sedimentation, and pollution of the environment (Primavera 1993). As in this study, mangrove vegetation grows on the riverine environment and tributaries (Figure 4). *A. alba*, *S. caseolaris*, *S. alba*, *R. apiculata*, *R. mucronata*, *B. gymnorrhiza*, and *A. corniculatum* either separately or in groups were almost always found in each PP (Table 1). According to Setyawan et al (2008), these species are major mangrove that have adapted to tidal currents fluctuations that cause flooding and salinity variations.

Most of dominant and codominant species at every growth stage in each PP of Rawa Timur mangrove forest distributed randomly and the remaining distribute in clumped and regular (Table 3). Random dispersal patterns occur when individuals distributed in several places and clustered at the other place. The clumped distribution patterns can occur when an individual species can not survive in certain environmental conditions, so they tend to be clustered together in a support area (Amaral et al 2015).

Conclusions. Rawa Timur mangrove forests consist of 14 species of mangroves (9 major species and 5 minor species) from 10 genera of 8 families. The species of Rhizophoraceae (4 species) were the most common found, followed by the species of Acanthaceae (2 species) and Lythraceae (2 species). Most of dominant and codominant species in Rawa Timur mangrove forests have random distribution pattern. Mangrove species in Rawa Timur mangrove forest have stem diameter ranged from 1.20 to 39.36 cm and crown height from 0.5 to 17.3 m. Stem diameter class of 1.2–5.0 cm and crown height class of 0.5–5.0 m have the most individual density, respectively 20,533 ind ha^{-1} (79.52% from the total number of individuals) and 21,675 ind ha^{-1} (83.95% from the total number of individuals).

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