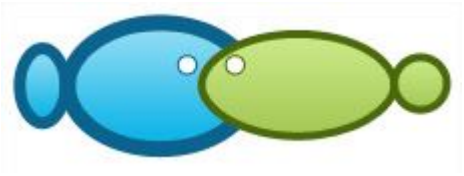

Structure and composition of riverine and fringe mangroves at Muara Kubu protected areas, West Kalimantan, Indonesia

[1,2]Teguh S. Nugroho, [3,4]Achmad Fahrudin, [3]Fredinan Yulianda, [5]Dietriech G. Bengen

[1] Doctoral Program of Marine and Coastal Resources Management, Bogor Agricultural University, Bogor 16680, Indonesia; [2] Department of Fisheries and Marine Science, Pontianak State Polytechnic, Pontianak 78124, Indonesia; [3] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor 16680, Indonesia; [4] Center for Coastal and Marine Resources Studies, Bogor Agricultural University, Bogor 16680, Indonesia; [5] Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor 16680, Indonesia. Corresponding author: T. S. Nugroho, tyo.teguh@gmail.com

Abstract. This paper describes the characteristics of riverine and fringe mangrove types at Muara Kubu Protected Areas, West Kalimantan, Indonesia. The characteristics of mangrove structure and composition were investigated to be used as a baseline for mangrove conservation management. Mangrove assessment through standard vegetation analysis includes area mangrove cover, species composition, distribution of diameter at breast height (dbh), density, basal area, frequency, significance value index (IVI), Shannon-Wiener diversity index (H') and dominance index (D). The significance of the difference between fringe and riverine mangrove were conducted using a t-test, and significantly different was defined at p-value < 0.05. Mangrove cover area in the study area has been measured at 3695.85 ha. We found 22 species and 11 families of true mangroves in the study area. Mangrove species which can generally be found in both riverine and fringe zone mostly come from the Rhizophoraceae family, including *Rhizophora apiculata, R. mucronata,* and *Bruguiera gymnorrhiza*. Specific species in the riverine zone were found include *Excoecaria agallocha, Xylocarpus granatum,* and *X. moluccensis*, while in fringe zones include *Avicennia alba, Sonneratia alba*, and *S. caseolaris*. Species with the respiratory root system are the main characteristic of the fringe type, this is due to the fringe zone facing the open sea. The number of seedling and sapling mangroves which important for regeneration is significantly more in the riverine (20,600 trees ha^{-1} for seedling and 3,152 trees ha^{-1} for sapling) than in fringe type (13,875 trees ha^{-1} for seedling and 1,980 trees ha^{-1} for sapling). Mangrove tree density in riverine type (740±28 trees ha^{-1}) is also significantly denser than fringe type (623±27 trees ha^{-1}). *Rhizophora apiculata* is the most important mangrove species in both riverine (IVI = 235±7%) and fringe (IVI = 186±19%). Diversity index (H ') of mangrove trees in the fringe type (0.87±0.14) is significantly greater than in the riverine type (0.48±0.07). Dominance index (D) of mangrove tree in fringe type (0.56±0.07) is significantly lower than riverine type (0.77±0.04).

Key Words: structure, composition, riverine, fringe, mangrove, protected areas.

Introduction. Mangroves are an important ecosystem, which functions as a protection, and support for life in coastal and sea (Kusmana 2015; Karlina et al 2016; Kusmana 2017). Mangroves themselves are a group of salt-tolerant plants which inhabit tidal zones and usually grow well on protected beaches. As one of the most productive ecosystems of the nutrient cycle, mangrove ecosystems greatly contribute to the provision of the energy need of the offshore ecosystem (Snedaker 1978; Awn et al 2016; Rani et al 2016). Mangrove ecosystems are also important in the global carbon cycle and function as a storage of organic carbon (Kathiresan & Bingham 2001; Murray & Vegh 2012; Alongi 2015; Murdiyarso et al 2015; Camp et al 2016; Rumengan et al 2018). Other functions of mangrove ecosystems include: a) as a coastal protection from abrasion/erosion, waves, storms, strong winds, sea level rise and seawater intrusion (Spalding et al 2014; Barbier

2015); b) as a spawning, nursery and feeding zone of various aquatic biota (Hutchison et al 2014); c) as habitat for various types of wildlife such as birds, primates, amphibians, reptiles, mammals, etc. (Garcia et al 2014); d) as sediment traps which is important in the formation of land (Willemsen et al 2016); e) producing wood and non-wood forest products; f) as support for coastal fisheries (Vincentius et al 2018; Wamnebo et al 2018); g) as reserve land for settlements and industry; h) as environmental protection; i) education, research, and ecotourism.

One of the regions in Indonesia which still has extensive, dense and protected natural mangrove ecosystems is Muara Kubu - Batu Ampar. It is a protected forest of mangrove, located in Kubu Raya District, West Kalimantan. This area is downstream of the Kapuas River, located in Kubu Raya District and has been designated a protected forest area since the 12th of October 1982 based on the Decree of the Agriculture Minister of the Republic of Indonesia No. 757 / Kpta / Um /10/1982. The decision to make the mangrove area Muara Kubu - Batu Ampar as a protected forest area of mangrove is an important and strategic step to maintaining sustainability and authenticity of mangrove ecosystems in this region with various functions.

The management of mangrove ecosystems in this area requires sufficient data and information about the characteristics of mangrove types. Based on hydro-geomorphology, mangrove forests have been categorized into several morphotypes, which are 1) fringe or coastal mangroves; 2) riverine or estuarine mangroves; 3) basin mangroves; 4) overwash mangroves, 5) hammock mangroves; and 6) dwarf or scrub (or chaparro) mangroves (Lugo & Snedaker 1973; Cintron et al 1978; Mitsch & Gosselink 2007). There are at least 2 types of mangroves in this research context: riverine and fringe mangroves. Riverine mangrove types are located in the areas along downstream of rivers, while the mangrove fringe types are in the zone along the coast facing the open sea.

The characteristics of the structure and composition of mangrove vegetation of riverine and fringe types in this study area are thought to be different because they are in different environmental positions and conditions. This current study aims to compare the mangroves structure and composition of riverine and fringe types. Information obtained from this study is expected to be a reference and consideration to the management of mangrove ecosystem conservation.

Material and Method

Description of the study sites. This research was carried out in Muara Kubu, protected forest area of mangroves, which is administratively located in the village of Dabong, Kubu District, Kubu Raya District, West Kalimantan Province, Indonesia (Figure 1). The research was conducted for four months, from December 2017 to mid-March 2018. The research location is approximately 80 km south of the city of Pontianak, the capital of West Kalimantan Province. This area can be accessed from Pontianak via land route to the port of Rasau Jaya, from which it continues to the destination location by river transportation such ferry, boat. The selection of the location of this study was based on the consideration that this location is a mangrove forest area, which is still natural and protected, so the results of the study may illustrate such natural conditions.

Data collection and sampling techniques. Satellite images data for mangrove cover distribution analysis were obtained with using satellite images *Landsat 8 OLI* (*path:* 121, *row:* 61) acquisition on September 27th, 2016 that were acquired and downloaded from http://earthexplorer.usgs.gov/.

Mangrove vegetation assessment followed the standard protocol, described by English et al (1997) as 'using quadratic transects along perpendicular lines from coastline/river line to land'. Each transect line/observation station consists of five plots of the square transect. The size of each square transect plot is 10 x 10 m^2, prepared for observing trees (dbh ≥ 10 cm), and the two plots with 5 x 5 m^2 with for sapling observations (2 cm ≤ dbh < 10 cm), and a plot of 2 x 2 m^2 for seedling observation (dbh < 2 cm) (Figure 2). The purposive sampling method was conducted to determine

mangrove sampling points. There were 13 mangrove observation stations (Figure 1 and Table 1). Those stations were divided into two groups based on the type of mangrove, namely five stations of riverine mangroves type and the rest is fringe mangrove type. Data collection was done by measuring the diameter at breast height (dbh) of each mangrove species in each transect plot (in each category of tree, sapling, and seedling). Individual plants found in the plot were identified following the nomenclature of Noor et al (2006); Dharmawan & Pramudji (2014).

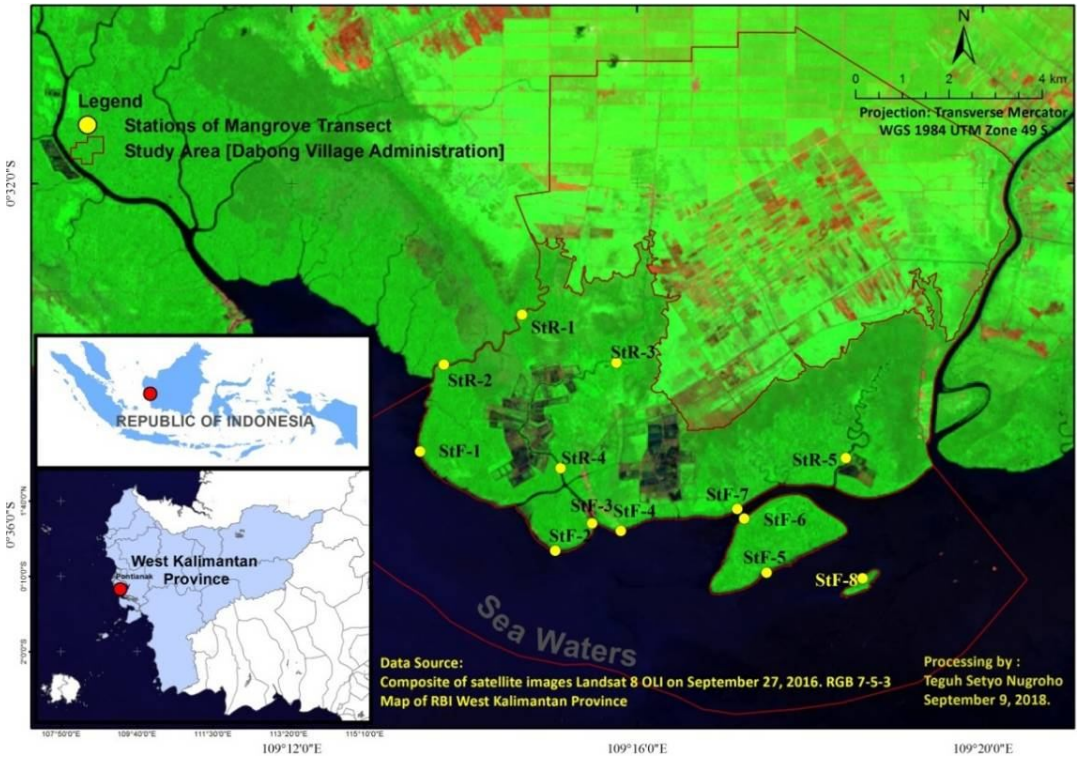

Figure 1. Map location of study area and mangrove observation stations at Muara Kubu, West Kalimantan, Indonesia.

Table 1

Location of mangrove observation stations at Muara Kubu, West Kalimantan, Indonesia

Location of mangrove observation stations	*Code*	*Latitude*	*Longitude*
I. Riverine mangroves type			
1. Dayak river upstream	StR1	109° 14' 40.018" E	0° 33' 32.510" S
2. Dayak river downstream	StR2	109° 13' 45.761" E	0° 34' 7.428" S
3. Sembuluk river upstream	StR3	109° 15' 45.696" E	0° 34' 6.230" S
4. Sembuluk river downstream	StR4	109° 15' 6.910" E	0° 35' 20.450" S
5. Mariam river	StR5	109° 18' 24.953" E	0° 35' 13.405" S
II. Fringe mangroves type			
1. Dayak river – Dabong island	StF1	109° 13' 29.319" E	0° 35' 8.709" S
2. Dabong island (west)	StF2	109° 15' 3.017" E	0° 36' 18.350" S
3. Dabong island (east)	StF3	109° 15' 28.728" E	0° 35' 59.272" S
4. Tanjung Nipah	StF4	109° 15' 48.741" E	0° 36' 4.509" S
5. Tiga island (south)	StF5	109° 17' 29.789" E	0° 36' 33.819" S
6. Tiga island (north)	StF6	109° 17' 14.297" E	0° 35' 55.805" S
7. Mariam river - Tanjung Nipah	StF7	109° 17' 9.542" E	0° 35' 49.124" S
8. Burung island	StF8	109° 18' 36.441" E	0° 36' 37.869" S

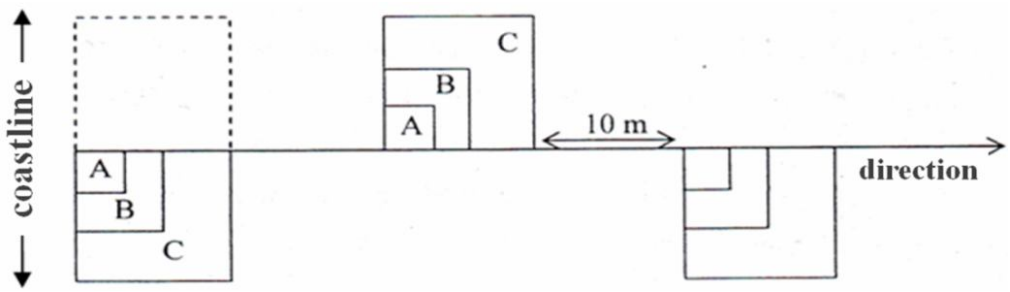

Figure 2. Scheme of sample plots placement for observing mangroves (English et al 1997): A: seedling observation plot (2 x 2 m^2); B: sapling observation plot (5 x 5 m^2); C: tree observation plot (10 x 10 m^2).

Data analysis. Spatial analysis of the extent and mangrove cover distribution followed the standard protocol described by INIAS (2015), which includes processing, interpreting and classifying the satellite images *Landsat 8 OLI*. The composite channel (band) employed for this purpose was RGB 5-7-3 in false color.

Analysis of mangrove vegetation structure and composition refers to English et al (1997), which includes the parameters: diameter at breast height (dbh), species basal area (Ci), species density (Di); species frequency (Fi); species importance value index (IVI); Shannon-Wiener diversity index (H'); and dominance index (D).

Statistical analysis. Comparisons between fringe and riverine mangrove type were conducted using t-test. The difference of mangrove characteristics between the fringe and riverine types in each parameter uses p-value with 95% confidence interval. The significance of differences was defined at p-value < 0.05.

Results and Discussion

Distribution and area of mangrove cover. The results of the spatial analysis conducted on Landsat *8 OLI* imagery (*path:* 121, *row:* 61) acquisition on September 27th, 2016, some provided insightful information on mangrove cover area in Muara Kubu, Kubu Raya Regency, West Kalimantan Province. The distribution of mangrove vegetation cover is nearly evenly distributed along Muara Kubu coast with an area of 3695.85 ha (Figure 3).

In the area of mangrove ecosystem, there is a non-mangrove region, covering people's residential areas, ponds, and open land. There are three locations of the pond located in the protected forest area of Muara Kubu: the Sembuluk (west) river, Tanjung Nipah (middle), and Marian River (east). The opening of the ponds in the mangrove protected area of Muara Kubu began in 1999 and continued to grow until 2007. There has been relatively no opening of the pond since then. Residential areas in protected forest of Muara Kubu are located at the downstream of the Sembuluk river and Dabong island (west) and at the downstream of the east of Kubu river (Olak-olak Kubu village). The village has been since the time of the Kubu Kingdom in around 1700. According to a study by Ilman et al (2016), mangroves have been systematically exploited in Indonesia since 1800. It is especially aimed for the cultivation process of brackish water shrimp, and for land conversion of settlements and logging.

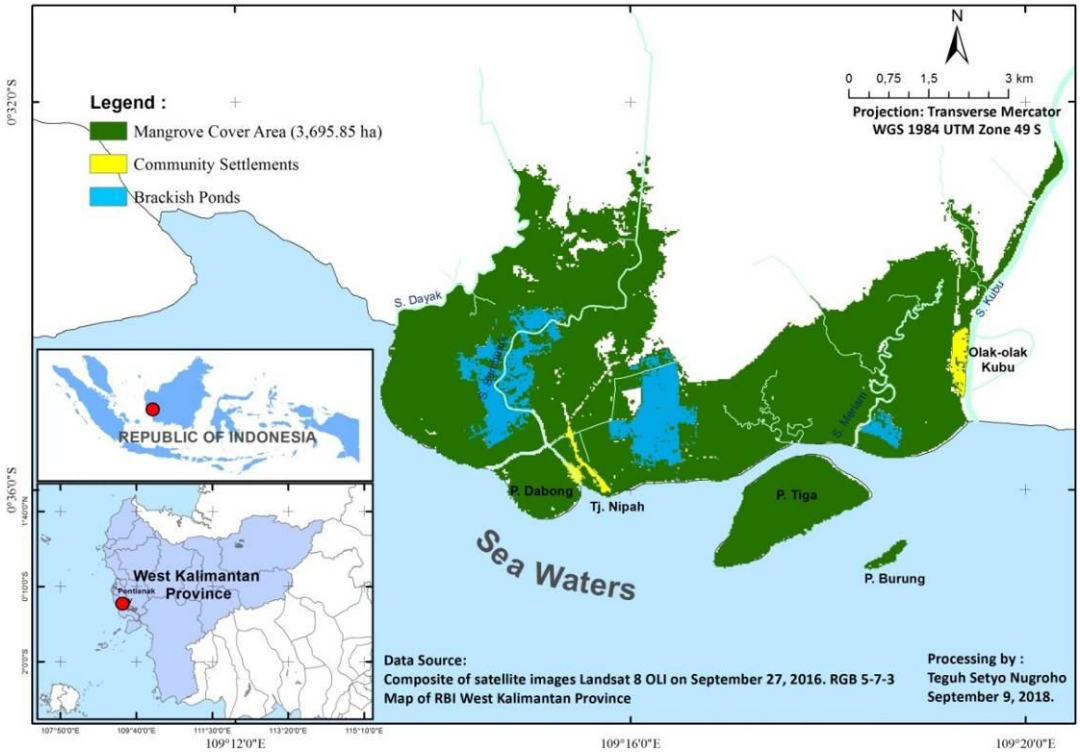

Figure 3. Map of mangrove cover distribution at Muara Kubu protected area.

Mangrove species composition. According to the results of direct observation with roaming methods and interviews with the locals, at least 21 types of true mangroves were found scattered in the mangrove ecosystem area of Muara Kubu (Table 2). Heriyanto & Subiandono's (2016) study found that there were 20 types of mangrove trees along 12 km in the concession area of PT. Kandelia Alam (close to the study location). They are *Rhizophora apiculata*, *R. mucronata*, *Bruguiera gymnorrhyza*, *B. cylindrica*, *B. sexangula, B. parviflora*, *Avicennia marina*, *A. alba*, *A. lanata*, *A. officinalis*, *Ceriops tagal*, *C. decandra, Candelia candel, Excoecaria agallocha, Lumnitzera racemosa, Xylocarpus granatum*, *X. moluccensis*, *Heritiera littoralis*, *Sonneratia alba*, and *S. caseolaris.*

Across all 13 transect track stations (each station consists of five plots), 434 trees, 395 saplings, and 428 seedlings, representing nine species in five families were measured. In riverine mangrove zones (five stations), seven mangrove species were found and in mangrove fringe zones (eight stations) six species of mangroves (Table 3).

Rhizophora apiculata can be found throughout the station and is a type of mangrove, which dominates the coastal area of Muara Kubu. Mangrove communities found both in the riverine zone and fringe zone mostly come from Rhizophoraceae family, including *Rhizophora apiculata, R. mucronata,* and *Bruguiera gymnorrhiza*. This finding is consistent with the results of a study by Murdiyarso et al (2015), suggesting that the dominant type of mangrove ecosystem in Kubu Raya is of *Rhizophora apiculata*.

In the fringe zone facing the sea, pioneering mangrove communities were found with breath rooting system, including *Sonneratia alba, S. caseolaris,* and *Avicennia alba. Avicennia* sp. grows on solid muddy sand, while *Sonneratia* spp. is connected to soft mud. Behind the two types were followed by *Rhizophora apiculata* and *R. mucronata* with a considerably wide area of distribution. Several *Bruguiera gymnorrhiza* ecosystems can be found increasingly towards the mainland. The communities of *Xylocarpus granatum, X. moluccensis,* and *Excoecaria agallocha* can be found river banks in the riverine zone. And towards the source of fresh water Nypa palm grow, especially on the banks of the river upstream up to the maximum tidal limit. The condition of mangrove types in Muara Kubu protected area is shown by Figure 4.

Table 2

True mangrove species composition along the coast of Muara Kubu, West Kalimantan, Indonesia

Family	*Scientific name*	*Local name*
Acanthaceae	*Acanthus ebracteatus*	Jeruju putih
Arecaceae	*Nypa fruticans*	Nipah
Avicenniaceae	*Avicennia alba*	Api-api
	Avicennia eucalyptifolia	Api-api
	Avicennia officinalis	Api-api
Combretaceae	*Lumnitzera littorea*	Teruntum
Euphorbiaceae	*Excoecaria agallocha*	Buta-buta
Meliaceae	*Xylocarpus granatum*	Nyirih jeruk purut
	Xylocarpus moluccensis	Nyirih batu
Myrsinaceae	*Aegiceras corniculatum*	Teruntung
Myrtaceae	*Osbornia octodonta*	Baru-baru
Rhizophoraceae	*Bruguiera cylindrica*	Tumuk putih
	Bruguiera gymnorrizha	Tumuk gelam
	Bruguiera parviflora	Lenggadai
	Ceriops tagal	-
	Rhizophora apiculata	Bakau Akik
	Rhizophora mucronata	Bakau
Sonneratiaceae	*Sonneratia alba*	Perepat / Pedada
	Sonneratia caseolaris	Berembang
	Sonneratia ovata	Kedabu
Sterculiaceae	*Heritiera globosa*	Dungun
	Heritiera littoralis	Dungun

Table 3

The composition of mangrove species was found in each transect track at Muara Kubu mangrove ecosystem

No	*Species*	*Transect track stations*												
		Riverine					*Fringe*							
		StR1	*StR2*	*StR3*	*StR4*	*StR5*	*StF1*	*StF2*	*StF3*	*StF4*	*StF5*	*StF6*	*StF7*	*StF8*
1	*Avicennia alba*						√	√	√		√	√	√	√
2	*Bruguiera gymnorrhiza*	√	√	√	√	√	√		√			√	√	√
3	*Excoecaria agallocha*				√	√								
4	*Rhizophora apiculata*	√	√	√	√	√	√	√	√	√	√	√	√	√
5	*Rhizophora mucronata*		√		√	√		√			√	√	√	√
6	*Sonneratia alba*	√					√	√	√	√	√	√	√	√
7	*Sonneratia caseolaris*													√
8	*Xylocarpus granatum*		√											
9	*Xylocarpus moluccensis*	√		√										
Number of species per station		4	4	3	4	4	4	4	4	2	4	5	5	6

According to Sreelekshmi et al (2018), *Rhizophora* spp. have large propagules which tend to be at the lower part and more frequently flooded levels. In contrast, *Sonneratia* spp. or *Avicennia* sp. have smaller propagules so that they tend to be found on the shores of the beach which are continuously flooded. *Excoecaria* sp. and *Bruguiera gymnorrhiza* are usually found in the intermediate zone. *Bruguiera* sp. was less salt tolerant so it was found abundantly in inland areas. Moreover, Robertson & Alongi (1992) found that *Avicennia alba* can be usually found toward the lower and middle intertidal region.

The structure of mangrove species in both riverine and fringe zones is strongly influenced by environmental conditions, such as increased freshwater and nutrient inputs (McDonald et al 2003; Urrego et al 2009), deeper water levels, and longer flooding periods (Krauss et al 2008). These conditions might explain lower pore water salinity (Castaneda-Moya et al 2006) having impacts on forest structure. In addition, fringe and riverine mangroves contain enhanced soil nutrient conditions, which are important for

vegetation development (Ukpong 2000; Mendoza et al 2012). Riverine mangroves are connected to soil Mg concentration, and fringe mangroves to soil Ca concentration (Urrego et al 2014).

a) Riverine mangrove at Dayak river b) Fringe mangrove at Dabong Island

Figure 4. Riverine and fringe mangrove types at the study site.

Distribution of mangrove diameters. Mangroves of tree category in Muara Kubu were dominated by diameter classes (dbh) of 20-30 cm and then accordingly followed by diameter classes of 10-20 cm, 30-40 cm, 40-50 cm, 50-60 and 60-70 cm. In some locations, large mangrove trees can be found with a diameter of 70-80 cm in a small amount. The number of mangroves of seedlings (dbh 0-2 cm) and of saplings (dbh 2-10 cm) was relatively higher (Figure 5).

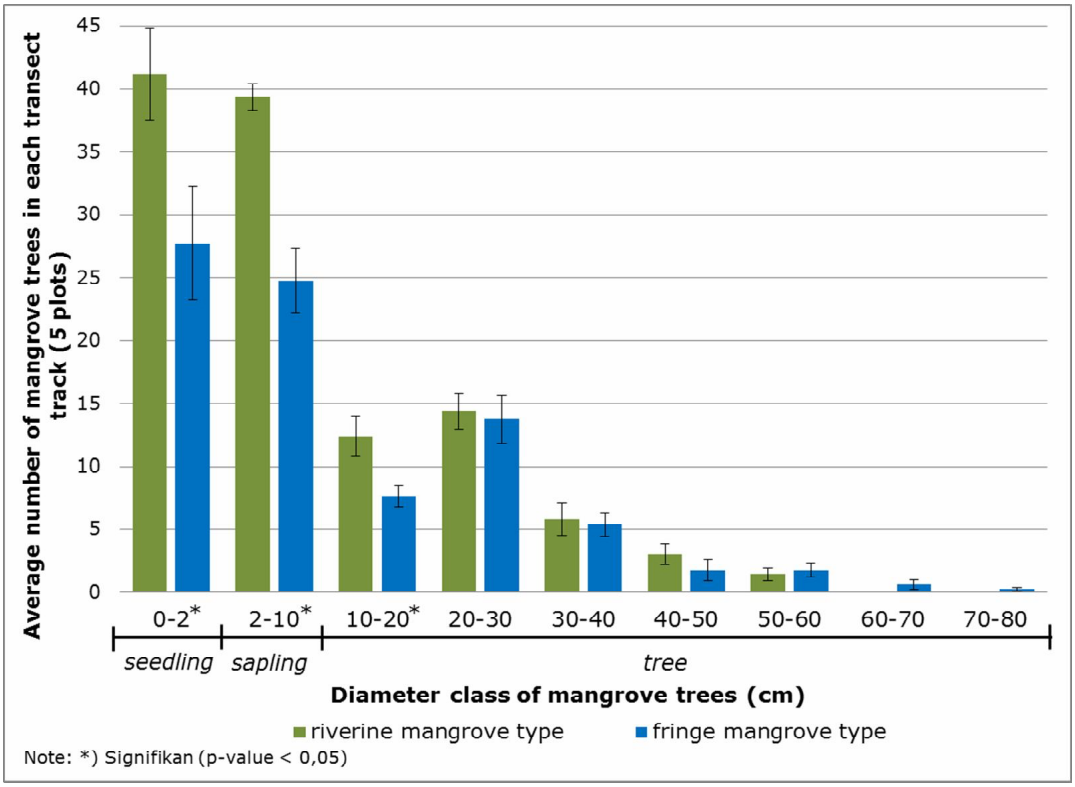

Figure 5. The comparisons of diameters (mean±standard error) between riverine and fringe mangroves.

The average number of mangrove seedlings (dbh 0-2 cm) in each station (5 plots) in riverine mangrove type was 41.2±3.65 trees (20,600 trees ha^{-1}), and significantly (p-$value_{0.031} \leq \alpha_{0.05}$) greater than the mangrove fringe type with 27.8±4.55 trees (13,875

trees ha^{-1}). In the sapling (dbh 2-10 cm) class, the number of mangroves in each station in riverine mangrove type was 39.4±1.03 trees (3,152 trees ha^{-1}), and significantly (p-value$_{0.001}$ ≤ α$_{0.05}$) also greater compared to mangrove fringe types, with 24.8±2.56 number of trees (1,980 trees ha^{-1}). So the number of trees for seedling and sapling classes in riverine mangrove types is significantly more than that of mangrove fringe types. Finding indicate that regenaration capacity of riverine mangrove type is considered as "good" as it has been in accordance with the regulation of Indonesian government regarding the minimum number of the young sapling trees. Data show that the number of young sapling trees of this particular type of mangrove has been above 2,500 ha^{-1} (Sillanpää et al 2017). However, no similar result is found in the type of fringe mangrove.

In the tree category, only the group of 10-20 cm diameter shows a significant difference (p-value$_{0.007}$ ≤ α$_{0.05}$) between the number of trees in the riverine mangrove type and of the type of mangrove fringe. The number of mangroves in the group of 10-20 cm diameter at each station in the riverine mangrove type was 39.4±1.03 trees (248 trees ha^{-1}), and the mangrove fringe type was 24.8±2.56 trees (153 trees ha^{-1}). The number of trees for the groups from diameter 20-30 to 70-80 cm between riverine mangrove types and mangrove fringe types show no significant difference (p-value > α$_{0.05}$) or they are similar. So, in general, the DBH distribution of tree categories in riverine and fringe mangrove types is relatively the same as the DBH higher tree, the difference is only in the 10-20 cm diameter group. This finding was in accordance with the study by Urrego et al (2014) focusing on mangrove forests of the Gulf of Urabá (Colombian Caribbean), while fringe and riverine mangroves exhibited superior structural vegetation development with higher trees DBH, height, and basal area.

The average number of trees in each station for the groups of diameter 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, and 70-80 cm of riverine type respectively are 14.4±1.44 trees (288 trees ha^{-1}), 5.8±1.28 trees (116 trees ha^{-1}), 3±0.84 trees (60 trees ha^{-1}), 1.4±0.51 trees (28 trees ha^{-1}), 0 trees, and 0 trees; whereas of the fringe type, are accordingly 13.8±1.88 trees (275 trees ha^{-1}), 5.4±0.92 trees (108 trees ha^{-1}), 1.8±0.84 trees (35 trees ha^{-1}), 1.8±0.59 trees (35 trees ha^{-1}), 0.6±0.38 trees (13 trees ha^{-1}), and 0.3±0.16 trees (5 trees ha^{-1}). The finding of tree diameters of 20-80 cm in riverine and fringe mangrove types were not different indicating that environmental conditions both in the riverine and fringe zones are still "good", so that the mangrove trees in both places can grow to the large size. Very large trees with a diameter of 60-80 cm were not found in riverine mangrove types, but are found only in small amounts of fringe mangroves. The very large size tree is located on the coastline area of the *Sonneratia alba* species.

Mangrove species density. Total density of riverine and fringe types of mangroves in tree, sapling and seedling categories shows significant differences (p-value < α$_{0.05}$). For the tree category, total density in riverine type (740±28 trees ha^{-1}) is greater than in the fringe type (623±27 trees ha^{-1}). The total density of the sapling category in riverine type (3,152±82 trees ha^{-1}) is also greater than in the fringe type (1,980±205 trees ha^{-1}). Likewise, the total density of the seedling category in riverine type (20,600±1,826 trees ha^{-1}) over numbers in the fringe type (13,875±2,275 trees ha^{-1}) (Table 4).

The difference of density in the category of trees between riverine and fringe types are significant in *Avicennia alba, Excoecaria agallocha, Rhizophora apiculata, Sonneratia alba,* and *Xylocarpus moluccensis*. In the sapling category, the significant difference of density between riverine and fringe types is in *Rhizophora apiculata* and *Sonneratia alba*, whereas in the seedling category a significant difference in density is only in the species of *Rhizophora apiculata.*

Rhizophora apiculata is the most common species which can be easily found in riverine and fringe types and has the highest density in all growth groups in the categories of tree, sapling, and seedling. The density of *Rhizophora apiculata* of riverine type is higher than that of fringe in all growth groups. In addition to *Rhizophora apiculata*, other common species which can be found in riverine and fringe types are *Bruguiera gymnorrhiza* and *Rhizophora mucronata*. Common species in riverine and fringe types are mostly dominated by the Rhizophoraceae family.

Table 4

The comparison density of tree and its regeneration (mean±standard error) between riverine and fringe mangroves

No	Mangrove species	Tree density (trees ha^{-1})			Sapling density (trees ha^{-1})			Seedling density (trees ha^{-1})		
		Riverine	Fringe	p-value	Riverine	Fringe	p-value	Riverine	Fringe	p-value
1	*Avicennia alba*	-	35±9	0.006*	-	10±10	0.227	-	125±82	0.130
2	*Bruguiera gymnorrhiza*	28±5	30±17	0.465	112±48	60±50	0.248	600±245	375±245	0.277
3	*Excoecaria agallocha*	8±5	-	0.029*	-	-	-	-	-	-
4	*Rhizophora apiculata*	648±40	438±41	0.003*	2912±149	1700±192	0.001*	19400±2027	11688±1868	0.011*
5	*Rhizophora mucronata*	40±21	48±17	0.395	128±109	130±62	0.493	600±400	1125±573	0.262
6	*Sonneratia alba*	4±4	70±14	0.002*	-	80±30	0.032*	-	563±290	0.080
7	*Sonneratia caseolaris*	-	3±3	0.227	-	-	-	-	-	-
8	*Xylocarpus granatum*	4±4	-	0.110	-	-	-	-	-	-
9	*Xylocarpus moluccensis*	8±5	-	0.029*	-	-	-	-	-	-
	Total	740±28	623±27	0.008*	3152±82	1980±205	0.001*	20600±1826	13875±2275	0.031*

*) Significance (p-value < 0.05).

Specific species which are usually only seen in riverine types include *Excoecaria agallocha, Xylocarpus granatum,* and *X. moluccensis*. These species are usually found on riverbanks in riverine zones. Whereas the specific species in the fringe type are dominated by pioneering mangrove groups with breath-root systems. These species include *Avicennia alba, Sonneratia alba,* and *S. caseolaris*. Pioneering species with the respiratory root system are the main identifiers of fringe type. This feature might be due to the fringe zone facing the open sea.

The value of density obtained in the study was found to be comparable with those in the studies by Heriyanto & Subiandono (2016) in the concession area of PT. Kandelia Alam, Kubu Village which is close to the study location. The total average of mangrove density in the concession area of PT. Kandelia Alam is 847 trees ha^{-1}, greater than the current study location. The number of density for the species of *Rhizophora apiculata* is 392 trees ha^{-1}; of *Bruguiera gymnorrhiza* 202 trees ha^{-1}; of *Sonneratia alba* 126 trees ha^{-1}; and of *Xylocarpus moluccensis* 127 trees ha^{-1}.

Basal area of mangrove species. The total basal area between riverine mangrove types and fringe for tree categories shows no significant difference (p-value ≥ $\alpha_{0.05}$) and for the sapling, category shows a significance difference (p-value < $\alpha_{0.05}$). For the tree category, the total area of basal in the riverine type is 44.91±5.48 m^2 ha^{-1} and is statistically relatively similar compared to the fringe type (46.17±6.44 m^2 ha^{-1}). Although the total density of trees category in the riverine type is significantly greater than the fringe, the total basal area in riverine and fringe types shows no differences. This is because mangroves in some fringe types (*Sonneratia alba*) have large tree diameters, especially in coastal areas. The total basal area of the sapling category in riverine type (8.84±0.42 m^2 ha^{-1}) is significantly greater than that of the fringe type (6.58±0.61 m^2 ha^{-1}). This is due to the significant density of the riverine type on the fringe type (Table 5).

Table 5

The comparisons basal area of tree and its regeneration (mean±standard error) between riverine and fringe mangroves

No	Mangrove species	*Tree basal area (m^2 ha^{-1})*			*Sapling basal area (m^2 ha^{-1})*		
		Riverine	*Fringe*	*p-value*	*Riverine*	*Fringe*	*p-value*
1	*Avicennia alba*	-	1.43±0.35	0.004*	-	0.05±0.05	0.227
2	*Bruguiera gymnorrhiza*	1.09±0.19	1.59±0.82	0.326	0.35±0.15	0.22±0.19	0.320
3	*Excoecaria agallocha*	0.20±0.12	-	0.029*	-	-	-
4	*Rhizophora apiculata*	41.59±5.79	30.07±4.02	0.060	8.08±0.51	5.59±0.61	0.008*
5	*Rhizophora mucronata*	1.51±0.81	1.61±0.59	0.460	0.41±0.32	0.35±0.18	0.431
6	*Sonneratia alba*	0.29±0.29	11.29±3.56	0.018*	-	0.38±0.15	0.039*
7	*Sonneratia caseolaris*	-	0.19±0.19	0.227	-	-	-
8	*Xylocarpus granatum*	0.05±0.05	-	0.110	-	-	-
9	*Xylocarpus moluccensis*	0.19±0.12	-	0.031*	-	-	-
	Total	44.91±5.48	46.17±6.44	0.447	8.84±0.42	6.58±0.61	0.011*

*) Significance (p-value < 0.05).

The differences of basal area in the category of trees in riverine and fringe mangrove types are significant in *Avicennia alba, Excoecaria agallocha, Sonneratia alba,* and *Xylocarpus moluccensis*. The basal area of *Rhizophora apiculata* has the statistically insignificant difference between riverine and fringe mangrove type, although the tendency is greater in riverine type. In the sapling category, a significant difference in the basal area of riverine and fringe mangrove types occurs in *Rhizophora apiculata* and *Sonneratia alba*.

The total basal area of the tree category is in riverine type (44.91±5.48 m^2 ha^{-1}) and fringe (46.17±6.44 m^2 ha^{-1}), greater than 25 m^2 ha^{-1}, suggesting that the mangrove in the study location is a mangrove pristine and still addresses the good condition. According to Komiyama et al (2008); Cavalcanti et al (2009); Kauffman et al (2011); and Sreelekshmi et al (2018), mangrove pristine with minimal impacts has a basal area of >

25 m^2 ha^{-1}, while the basal area of around 15 m^2 ha^{-1} could be considered as secondary forests, whereas disturbed forests have a basal area of < 10 m^2 ha^{-1}.

The frequency of mangrove species. The frequency of species indicates the possibility of finding certain species of mangroves on the transect. The difference in frequency in the category of trees between riverine and fringe types is significant in *Avicennia alba, Excoecaria agallocha, Rhizophora apiculata, Sonneratia alba,* and *Xylocarpus moluccensis*. In the sapling category, frequency differences between riverine and fringe types significantly occur in *Rhizophora apiculata* and *Sonneratia alba* species, whereas significant differences in frequency of the seedling category take place only in *Rhizophora apiculata* species (Table 6).

The frequency of *Rhizophora apiculata* in riverine mangrove types for the categories of tree, sapling, and seedling is 1±0, meaning that these species can be found in 100% of all transects. In the type of mangrove fringe, the frequency of *Rhizophora apiculata* for tree, sapling and seedling categories were 0.88±0.05, 0.80±0.05, and 0.80±0.08, respectively. This suggests that the discovery of the *Rhizophora apiculata species* in the transect of tree category is 88%, in the sapling and the seedling categories are 80%. From the data on the frequency of these species, *Rhizophora apiculata* is the species most easily found in riverine and fringe types. Species with a low frequency of species which are most rarely found in transects are *Sonneratia caseolaris, Excoecaria agallocha, Xylocarpus granatum,* and *X. moluccensis*.

Importance value index of mangrove species. Importance value index (IVI) of mangrove species describes the level of importance of a mangrove species community in an ecosystem. IVI categories of trees in riverine and fringe types differ significantly for *Avicennia alba, Excoecaria agallocha, Rhizophora apiculata, Sonneratia alba,* and *Xylocarpus moluccensis*. In the sapling category, the significance of IVI of riverine and fringe types is significant only in *Sonneratia alba* species, whereas in the seedling category there is no significant difference (Table 7).

The most important mangrove species in Muara Kubu in all growth classes both in riverine and fringe zones is *Rhizophora apiculata*. In addition, based on tree category in riverine mangroves, the IVIs of mangrove species are *Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza, Xylocarpus moluccensis, Excoecaria agallocha, Sonneratia alba,* and *Xylocarpus granatum,* respectively. Meanwhile, the IVIs of mangrove species in fringe type based on tree category include *Rhizophora apiculata, Sonneratia alba, Rhizophora mucronata, Avicennia alba, Bruguiera gymnorrhiza,* and *Sonneratia caseolaris*, respectively.

Rhizophora apiculata is species dominantly found in the study area. According to Sreelekshmi et al (2018), *Rhizophora* spp. are mangrove species which are very tolerant to the salinity, height and long-standing of water puddles, accumulation of sediment and soil nutrient conditions. In the mangrove fringe type, especially in the edge zone towards the seawater line, *Sonneratia alba* is the dominant species. *Sonneratia alba* is also very tolerant to puddles and high salinity, so it is close to the coastline where conditions are very hard. According to Ball & Pidsley (1995), *Sonneratia alba* grows in waters between 5 and 50% seawater.

Table 6

The comparisons frequency of tree and its regeneration (mean±standard error) between riverine and fringe mangroves

No	Mangrove species	Tree frequency			Sapling frequency			Seedling frequency		
		Riverine	Fringe	p-value	Riverine	Fringe	p-value	Riverine	Fringe	p-value
1	*Avicennia alba*	-	0.25±0.05	0.001*	-	0.03±0.03	0.227	-	0.05±0.03	0.130
2	*Bruguiera gymnorrhiza*	0.28±0.05	0.20±0.08	0.251	0.20±0.09	0.08±0.05	0.111	0.20±0.06	0.13±0.08	0.251
3	*Excoecaria agallocha*	0.08±0.05	-	0.029*	-	-	-	-	-	-
4	*Rhizophora apiculata*	1±0	0.88±0.05	0.046*	1±0	0.80±0.05	0.007*	1±0	0.80±0.08	0.032*
5	*Rhizophora mucronata*	0.28±0.14	0.30±0.10	0.453	0.16±0.12	0.20±0.08	0.391	0.24±0.16	0.23±0.11	0.469
6	*Sonneratia alba*	0.04±0.04	0.28±0.04	0.001*	-	0.18±0.06	0.021*	-	0.13±0.06	0.081
7	*Sonneratia caseolaris*	-	0.03±0.03	0.227	-	-	-	-	-	-
8	*Xylocarpus granatum*	0.04±0.04	-	0.110	-	-	-	-	-	-
9	*Xylocarpus moluccensis*	0.08±0.05	-	0.029*	-	-	-	-	-	-

*) Significance (p-value < 0.05).

Table 7

The comparisons of the importance value index (mean±standard error) between riverine and fringe mangroves

No	Mangrove species	Tree importance value index (%)			Sapling importance value index (%)			Seedling importance value index (%)		
		Riverine	Fringe	p-value	Riverine	Fringe	p-value	Riverine	Fringe	p-value
1	*Avicennia alba*	-	22±4	0.001*	-	2±2	0.227	-	3±2	0.132
2	*Bruguiera gymnorrhiza*	22±4	17±7	0.291	22±9	11±9	0.222	16±4	10±5	0.229
3	*Excoecaria agallocha*	6±3	-	0.029*	-	-	-	-	-	-
4	*Rhizophora apiculata*	235±7	186±19	0.036*	260±12	241±18	0.241	169±13	158±14	0.303
5	*Rhizophora mucronata*	24±12	26±9	0.442	19±14	24±10	0.379	15±10	19±10	0.392
6	*Sonneratia alba*	4±4	48±9	0.001*	-	21±7	0.017*	-	9±5	0.074
7	*Sonneratia caseolaris*	-	2±2	0.227	-	-	-	-	-	-
8	*Xylocarpus granatum*	3±3	-	0.110	-	-	-	-	-	-
9	*Xylocarpus moluccensis*	6±4	-	0.029*	-	-	-	-	-	-
	Total	300±0	300±0		300±0	300±0		200±0	200±0	

*) Significance (p-value < 0.05).

Diversity index (H'). Diversity index in the tree category of riverine and fringe types shows significant differences (p-value < $\alpha_{0.05}$), whereas in sapling and seeding categories there are no significant differences (p-value ≥ $\alpha_{0.05}$). In the category of the tree, the indigestible diversity of the fringe-type (0.87±0.14) is significantly greater than that of the riverine type (0.48±0.07). Diversity index in all growth groups in both riverine and fringe mangrove types is smaller than two, meaning that the level of mangrove diversity is low (Table 8). Mangrove diversity index (H') in the study area is comparable to Tanjung Prapat Muda-Tanjung Bakau (near the study location), which is 0.62 (Irpan et al 2017).

Table 8

The comparisons of diversity index (mean±standard error) between riverine and fringe mangroves

No	*Class of growth*	*Diversity index (H')*		
		Riverine	*Fringe*	*p-value*
1	Tree class	0.48±0.07	0.87±0.14	0.030*
2	Sapling class	0.26±0.08	0.41±0.13	0.201
3	Seedling class	0.23±0.11	0.39±0.14	0.206

*) Significance (p-value < 0.05)

Dominance index (C). Dominance index in tree category in riverine and fringe types shows differences significance (p-value < $\alpha_{0.05}$), whereas in sapling and seeding classes there is no significance in the differences (p-value ≥ $\alpha_{0.05}$). In the tree category, dominance index in riverine type (0.77±0.04) is significantly higher than in the fringe type (0.56±0.07). Dominance index at the study location is mostly in the high category (0.75 < C ≤1), and only in the mangrove fringe type is the dominance index tree in the medium category (0.5 < C ≤0.75). A high level of dominance suggests that there are species dominating other species (Table 9).

Table 9

The comparisons of dominance index (mean±standard error) between riverine and fringe mangroves

No	*Class of growth*	*Dominance index (C)*		
		Riverine	*Fringe*	*p-value*
1	Tree class	0.77±0.04	0.56±0.07	0.022*
2	Sapling class	0.86±0.05	0.78±0.07	0.218
3	Seedling class	0.89±0.06	0.79±0.08	0.180

*) Significance (p-value < 0.05)

Conclusions. This study has described the differences in the structure and composition of mangroves in riverine and fringe types in the study area. The number of mangroves in the growth category of seedling and sapling is more commonly found in riverine types than fringe, suggesting that the ability to supply seeds for regeneration is better in riverine types than fringe. Riverine type mangroves are also denser than the fringes. The dominant and important mangrove ecosystem in both riverine and fringe types is *Rhizophora apiculata*. Rhizophoraceae mangroves such as *Rhizophora apiculata, R. mucronata,* and *Bruguiera gymnorrhiza* can grow well in riverine and fringe zones. Specific species in the riverine types are usually found on river banks, include *Excoecaria agallocha, Xylocarpus granatum,* and *X. moluccensis*. Whereas the specific species in the fringe type are dominated by pioneering mangrove groups with breath-root systems, include *Avicennia alba*, *Sonneratia alba*, and *S. caseolaris*. Pioneering species with the pneumatophore root systems are the main identifiers of fringe type, which is due to the fringe zone facing the open sea.

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Authors:
Teguh Setyo Nugroho, Department of Fisheries and Marine Science, Pontianak State Polytechnic, Jenderal Ahmad Yani Street, P.O BOX 1286, Pontianak 78124, Indonesia, e-mail: tyo.teguh@gmail.com
Achmad Fahrudin, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB Dramaga Campus, Agatis Street, Bogor, 16680, Indonesia; Center for Coastal and Marine Resources Studies, IPB Baranangsiang Campus, Pajajaran Raya Street No. 1, Bogor 16127, Indonesia, e-mail: fahrudina@ipb.ac.id; fahrudina@yahoo.com
Fredinan Yulianda, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB Dramaga Campus, Agatis Street, Bogor, 16680, Indonesia, e-mail: fredinan@apps.ipb.ac.id, fredinan@indo.net.id
Dietriech Geoffrey Bengen, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB Dramaga Campus, Agatis Street, Bogor, 16680, Indonesia, e-mail: dieter@indo.net.id

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