Diversity and natural regeneration of mangrove vegetation in the tracking area on Kemujan Island Karimunjawa National Park, Indonesia

Adi Winata, Ernik Yuliana, Edi Rusdiyanto

Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Terbuka (The Indonesia Open University), Tangerang Selatan, Indonesia. Corresponding author: E. Yuliana, erniky157@gmail.com, ernik@ecampus.ut.ac.id

Abstract. Mangroves serve as important habitat for many species of aquatic biota, i.e. fish, mollusks, and crustaceans. This ecosystem also acts as sediment trap, protecting the adjoining coral reef systems. A field survey was conducted to analyze the structure and diversity of mangrove vegetation and mangrove regeneration levels in the tracking area on Kemujan Island, Karimunjawa National Park. Data was collected using the survey method and observation. The primary data collected included density, frequency, and dominance of mangrove tree species as well as substrate composition taken using the quadrant method arranged on a line transect. A total of 16 sample plots were taken in two line transects, laid in the field according to systematic sampling with a random start. The data collected were analyzed using important value index. As a result, there were 730 individuals of mangrove tree species in various growth-stages, counted in such sample plots, consisting of 12 species: *Avicennia marina, Bruguiera cylindrica, B. gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera littorea, L. racemosa, Rhizophora stylosa, R. apiculata, R. mucronata, Scyphiphora hydrophyllacea,* and *Sonneratia alba*. Among them, *Ceriops tagal* had the highest important value index (IVI) at the seedling level (126.26%) and sapling level (121.07%). At tree level, *Lumnitzera racemosa* dominated (117.82%). The type of substrate was dominated by sand 79.32% with a range from 71.16 to 95.02%, ash 13.20% with a range from 3.61 to 17.54%; clay 7.49% with a range from 1.37 to 12.48%. The composition of the substrate affected the dominant mangrove species, namely *Ceriops tagal* and *Lumnitzera racemosa*.
Key Words: important value index, ecosystem, mangrove, seedling, sapling, tree.

Introduction. The Karimunjawa National Park (KNP) is one of the national marine parks in Indonesia which is dedicated to the conservation of the marine ecosystem in the form of coral reef (Campbell et al 2013; Yuliana et al 2016). The KNP also has a mangrove ecosystem that covers an area of approximately 400 ha (Nababan et al 2010). Spread throughout a number of relatively small islands, this mangrove ecosystem is unique as it lacks freshwater sources such as large or slightly large rivers. Larger areas of mangrove are the ecosystem units found on Kemujan and Karimunjawa Islands, the two largest islands in KNP.

Mangroves are coastal forests found in sheltered estuaries and along river banks and lagoons in the tropics and subtropics. Thailand and Indonesia are a favorable place for growth of well structured mangroves, where the trees grow to a height of 30-50 m (Maiti & Chowdhury 2013). The mangrove ecosystem is an important and unique ecosystem in the coastal area (Natividad et al 2015). Mangroves are known as an ecosystem that traps silt and the sea currents' flotsam and jetsam, including organic and other waste from land. Because of its fertility, mangroves also act as habitat for various biota (Manson et al 2005; Kusumastanto et al 2006). However, mangroves are also vulnerable, extreme, and extremely dynamic because they lie in the transition between sea and land, the transition between freshwater and seawater, and are strongly affected by tidal dynamics. Therefore, most mangrove biota are specific, especially the aquatic ones, while the land animals are accustomed to sharing with other ecosystems around it.

A number of aquatic biota that are specific to mangroves are mudskippers, mangrove crab (*Scylla*), mud lobsters (*Thalassina*), a some snails (*Nerita, Telescopium*), and hermit crabs and shellfish that live in the mud (Nybakken 1988). For the marine ecosystem, mangrove groves are an important habitat for raising the young (nursery ground) for fish and prawns. The mangrove root system that intertwines and forms palisades functions like a fence that protects the prawn and fish spawn from predatorial fish.

Another ecological role played by the mangrove ecosystem is as a protector of the surrounding area from the destructive powers of ocean waves. Mangroves can reduce the effects of storm waves and protect the beach from storms, and could even break tsunami waves in India 2004 (Das & Crepin 2013). Mangroves also absorb carbon dioxide (CO_2) which is a greenhouse gas that causes global warming (Cahyaningrum et al 2014).

Moreover, the mangrove ecosystem is also beneficial to the locals in fulfilling a number of their daily needs (Indrayanti et al 2015). For example, mangrove wood (especially from *Rhizophora, Bruguiera* and *Ceriops*) is used as building materials, shellfish, snails, other crustaceans, and fish are sources of protein, and many ingredients for traditional medicine (*jamu*) are found in the mangrove ecosystem. Because of the various roles and benefits mangroves have for the environment and for humankind, they must be conserved so that they could continue to benefit the environment and also mankind (Nababan et al 2010).

Because of the aforementioned reasons, this article was written to describe the analysis results of: 1) the vegetation diversity, especially the mangrove species in the location; 2) the structure and diversity of seedlings and comparing them to the structure and diversity of adult trees; 3) substrate composition and other ecological factors.

Material and Method

The location and the time of study. This study was conducted in KNP in Jepara Regency (Figure 1), Central Java Province between July and August 2015. The research focused on Kemujan Island (Figure 2).

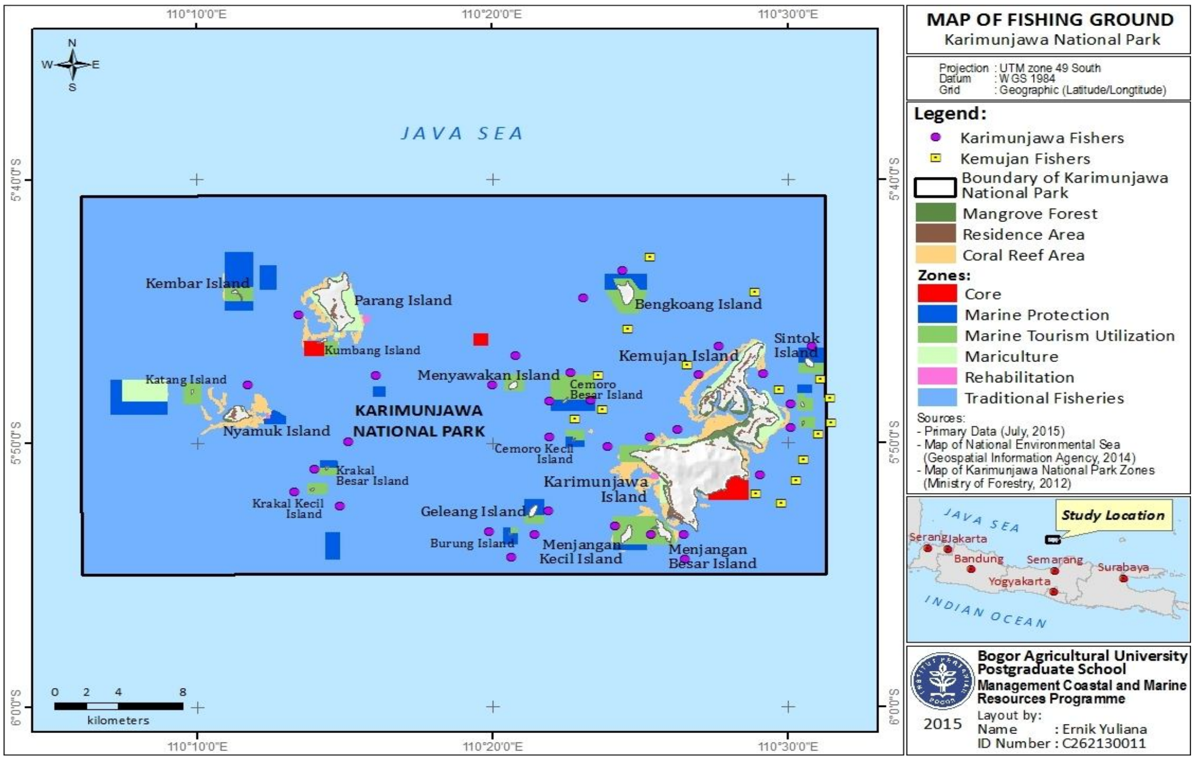

Figure 1. Study site in Karimunjawa National Park, Indonesia (Source: Yuliana et al 2016).

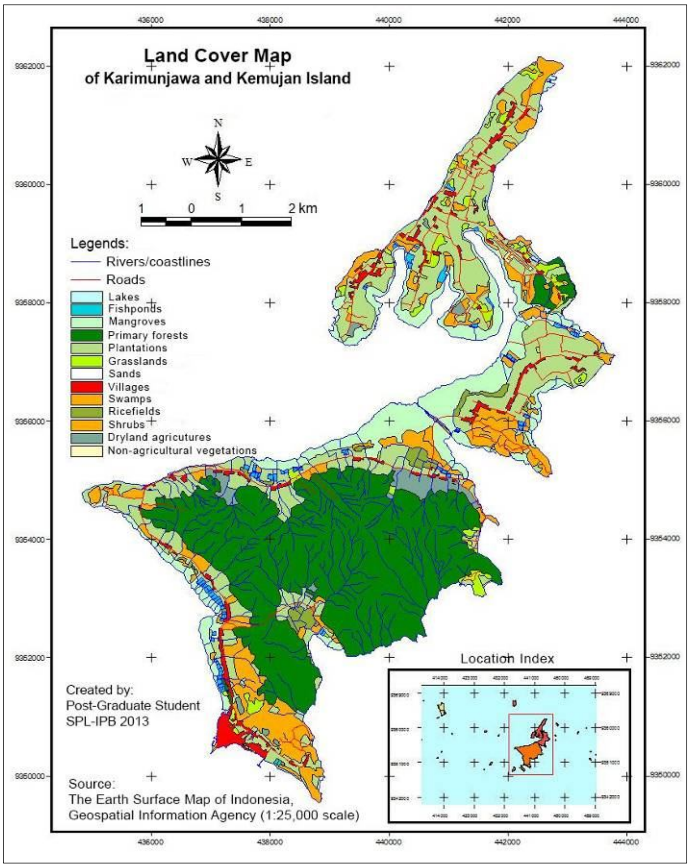

Figure 2. Karimunjawa and Kemujan Island in KNP (Source: Graduate Student, SPL-IPB 2013).

Tipes and sources of data. Data was collected in August 2015 using survey and observation methods. Mangrove tree samples were collected through systematic sampling with a random start by making ten vegetation analysis transects which were more or less perpendicular to the average coastline, so that they traverse the width of the mangrove forest from inland to the boundary on the seaside. The distance between transects were approximately 500 m.

The data collected in this study were primary data in the form of species diversity and vegetational structure of the trees and the regeneration level of the mangrove forest and the related substrate conditions (substrate type and salinity and the water depth during high tide). To describe the mangrove vegetation structure, the data for mangrove tree (and seedling) height, diameter at breast height (DBH), and tree density per hectare were collected. The definition of regeneration level used in this study is: 1) *Seedlings* are from sprouts to young plants up to 1.5 m high; 2) *Saplings* are plants higher than 1.5 m with a DBH of less than 10 cm; 3) *Trees* are plants with a DBH of more than 10 cm.

The data were collected through the multiple quadrats in belt transect method of vegetation analysis technique (Bengen 2002) which can be seen in Figure 3. In this method, the sample plots were constructed in various sizes of quadrats. The sample plot for seedlings were 2 x 2 m, for saplings 5 x 5 m, and for trees 10 x 10 m.

Substrate data was collected following the vegetation sample plots. Substrate samples were collected, one sample every 20 meters along the transect line. The texture of the substrate is strongly influenced by the composition of clay, silt and sand granules. To determine such texture, substrate samples was filtered, and their compositions were classified according to soil texture triangle of USDA (the United States Department of Agriculture).

Data analysis. The data were analyzed by calculating the Important Value Index (IVI) which consisted of species density, relative density, species frequency, relative frequency, species dominance, and relative dominance. The concept of IVI has been developed for expressing the dominance and ecological success of any species, with a single value (Nativadad et al 2015).

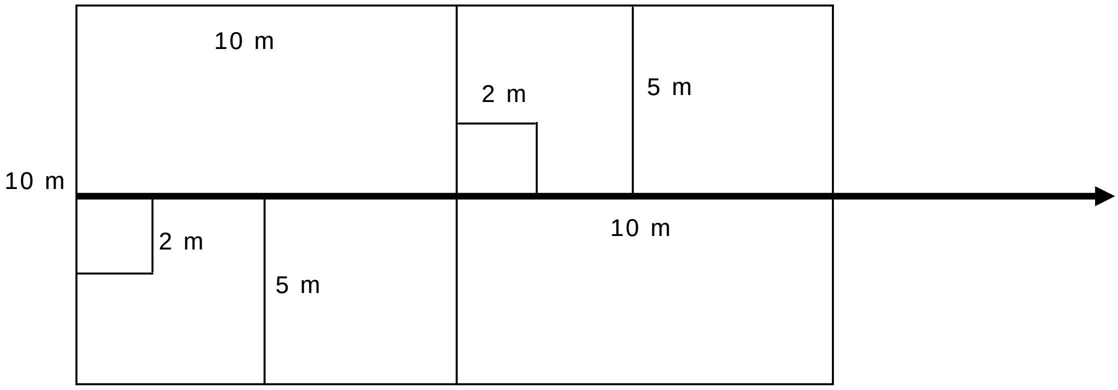

Figure 3. Placement of measuring plots based on the transect line plot method.

Results and Discussion

Zoning system. Administratively, the KNP is within the Karimunjawa Sub-district, Jepara Regency, Central Java Province. There are currently 4 villages around the area, namely Karimunjawa, Kemujan, Parang, and Nyamuk Villages that were established in August 2011. Based on the population census in Karimunjawa Sub-district in 2010, there were 8,733 people living around the KNP (Nababan et al 2010).

Government Law no 5/1990 defines a national park as a Nature Conservation Area which has an original ecosystem, managed using a zoning system and utilized for research, science, education purposes and to support cultivation, tourism and recreation. The KNP forest encompasses 1,285.50 ha of lowland tropical rainforest on Karimunjawa Island (Nababan et al 2010) and 396.4 ha of mangrove forest which are under the management of the KNP in the jungle/protection zone (KNPA 2012). These zones are on Karimunjawa Island and Kemujan Island. Some mangrove areas in other locations are Bengkoang Island, Menjangan Besar Island, Nyamuk Island, Parang Island, and other small islands which are under the jurisdiction of the local government (KNPA 2012).

Indonesia has high mangrove diversity; there are 48 true mangroves documented to grow in Indonesia. At least 25 species of true mangroves grow in KNP. Some plants that grow in mangrove forests such as those from the genus *Avicennia* might be overlooked due to similarities in fruit, leaf, and overall tree appearance and thus need reconfirmation such as *Avicennia alba* and *Avicennia officinalis*. The mangrove forests in KNP are known as *rancah*. The mangrove vegetation usually grow on sandy tidal beach locations, and rarely on muddy beaches because KNP does not have a river estuary. *Rhizophora* usually occupies the front position because its stilt roots create a barrier, enabling other species to grow. The mangrove species in KNP are dominated by those from the *Rhizophora* genus, *Ceriops tagal, Sonneratia, Bruguiera,* and *Lumnitzera* (KNPA 2012).

Observation results from the two transects and 16 plots revealed 730 individuals from 12 species of mangrove. Actually, during the field survey 13 tree species were discovered in the transects but only 12 were recorded in the sample plots. These species were *Avicennia marina, Bruguiera cylindrica, B. gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera littorea, L. racemosa, Rhizophora stylosa, R. apiculata, R. mucronata, Scyphiphora hydrophyllacea,* and *Sonneratia alba*; whereas the existence of *Aegiceras corniculatum* was observed but was not found in the measurement plots.

At tree level (DBH $\geq$ 10 cm) there were only 10 species, excluding *Avicennia marina* and *Bruguiera gymnorrhiza* which were only found at sapling level. At sapling level, six species were discovered; the two species mentioned above plus *Ceriops tagal, Excoecaria agallocha, Rhizophora apiculata,* and *R. mucronata.* At seedling level there were only four species, *Ceriops tagal, Excoecaria agallocha, Rhizophora apiculata,* and *R. mucronata.* At all levels, seedling, sapling, and tree, the most numerous species was

Ceriops tagal. The mangrove individual composition (Figure 4) demonstrates that the mangrove species with the largest percentage was *Ceriops tagal* at 57.81% followed by *Rhizophora apiculata* at 13.83%, *Lumnitzera racemosa* at 10.97%, *Excoecaria agallocha* 8.89%, *Rhizophora mucronata* 4.25%, *Lumnitzera littorea* 0.99%, whereas other six species together occupy the rest (4.25%).

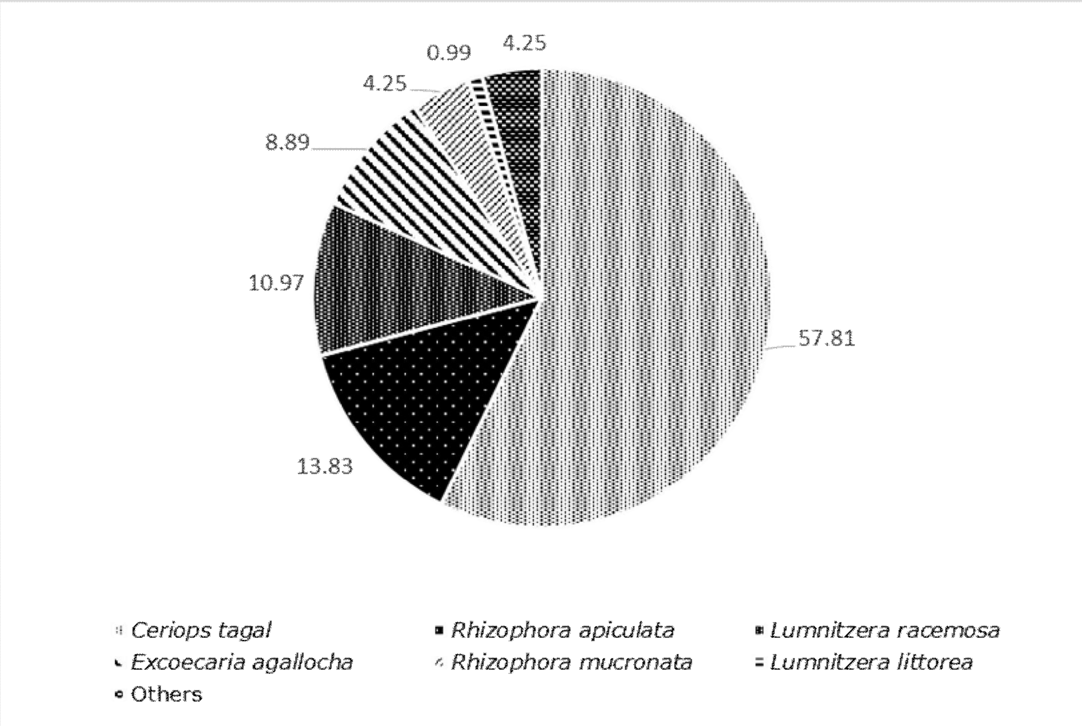

Figure 4. The mangrove species composition at the study site.

The mangrove species diversity and natural regeneration were observed from seedling, sapling, and tree levels. Natural regeneration was measured from the species density, relative density, species frequency, relative frequency, and important value index (IVI). The calculation of natural regeneration is useful for analyzing a mangrove species' regeneration ability.

Seedling. At seedling level, there were four mangrove species numbering 447 individuals.Mangrove diversity at seedling level is presented in Table 1. The mangrove with the highest species density at seedling level was *Ceriops tagal,* at 44,531.25 ind ha^{-1}, whereas *Rhizophora mucronata* had the lowest species density at 3,125.00 ind ha^{-1}. The total density of all species was 69,843.75 ind ha^{-1}. The species with the highest relative density at seedling level was *Ceriops tagal*. In mangrove zonation, this species is found behind the *Rhizophora* and *Bruguiera* zones (Kusumastanto et al 2006). Relative frequency is the mangrove species' frequency proportion in an ecosystem. This proportion demonstrates how large the proportion is compared to other species'. The mangrove species with the highest relative density was *Ceriops tagal* (62.50%).

The IVI of mangroves at seedling level is presented in Figure 5. IVI demonstrates the description of an influence or role played by a certain plant species in a community. IVI values range between 0 and 300%. The higher an IVI value, the better the role of a vegetation species is in a community. Based on the criteria of Ministry of Fisheries and Marine Affairs (2014), an IVI value < 100% is in the 'low' category, 100% < IVI < 200% is in the 'medium' category, and IVI > 200% is in the 'good' category. The highest IVI at seedling level was demonstrated by *Ceriops tagal* (126.26%), in the 'medium' category. The lowest IVI at seedling level was demonstrated by *Rhizophora mucronata* at 16.97% (low). *Rhizophora mucronata* was only found in areas which were inundated by seawater. The seedlings were also very rarely found.

Table 1

Mangrove diversity at seedling level

Species	Species density (ind ha^{-1})	Relative density (%)	Species frequency	Relative frequency (%)
Ceriops tagal	44,531.25	63.76	0.62	62.50
Excoecaria agallocha	12,968.75	18.57	0.06	6.25
Rhizophora apiculata	9,218.75	13.20	0.19	18.75
Rhizophora mucronata	3,125.00	4.47	0.13	12.50
Total	69,843.75	100.00	1.00	100.00

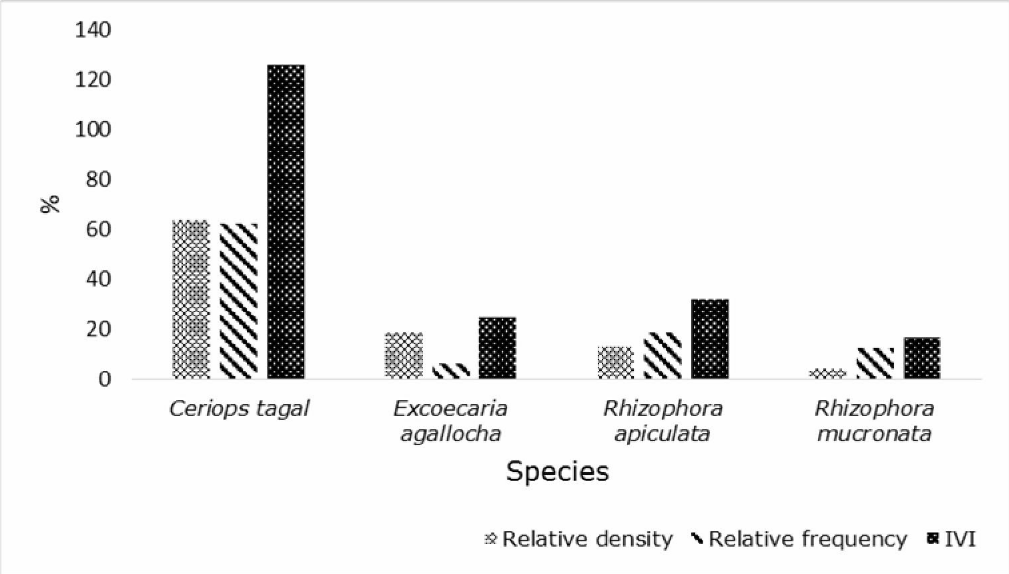

Figure 5. The IVI values of mangrove species at seedling level.

Sapling*.* At sapling level, there were six mangrove species numbering 159 individuals. The number of individuals at sapling level was lower than that of seedling level. There are a number of environmental factors that are necessary for the growth of seedlings into saplings. Therefore, not all seedlings grow into saplings. Mangrove species diversity at sapling level is presented in Table 2.

Table 2

Mangrove diversity at sapling level

Species	Species density (ind ha^{-1})	Relative density (%)	Species frequency	Relative frequency (%)
Avicennia marina	50	1.26	0.06	4.55
Bruguiera gymnorrhiza	25	0.63	0.06	4.55
Ceriops tagal	2,825	71.07	0.69	50.00
Excoecaria agallocha	25	0.63	0.06	4.55
Rhizophora apiculata	825	20.75	0.31	22.72
Rhizophora mucronata	225	5.66	0.19	13.63
Total	3,975	100.00	1.37	100.00

The species with the highest species density at sapling level was again *Ceriops tagal* (2,825 ind ha^{-1}), whereas the lowest was *Bruguiera gymnorrhiza* and *Excoecaria agallocha* at 25 ind ha^{-1}. The total density of all individuals was 3975 ind ha^{-1}. *Ceriops tagal* had the highest species frequency, while the lowest was exhibited by *Avicennia marina, Bruguiera gymnorrhiza,* and *Excoecaria agallocha.* The sapling level is an advancement of the seedling phase, but some species found in the sapling level were not found in the seedling level.

The IVI at sapling level was not dissimilar from that of the seedling level (Figure 6). The highest IVI at sapling level was exhibited by *Ceriops tagal* at 121.07% (medium). The lowest IVI at sapling level was exhibited by *Bruguiera gymnorrhiza* and *Excoecaria agallocha* at IVI 6.18% (low).

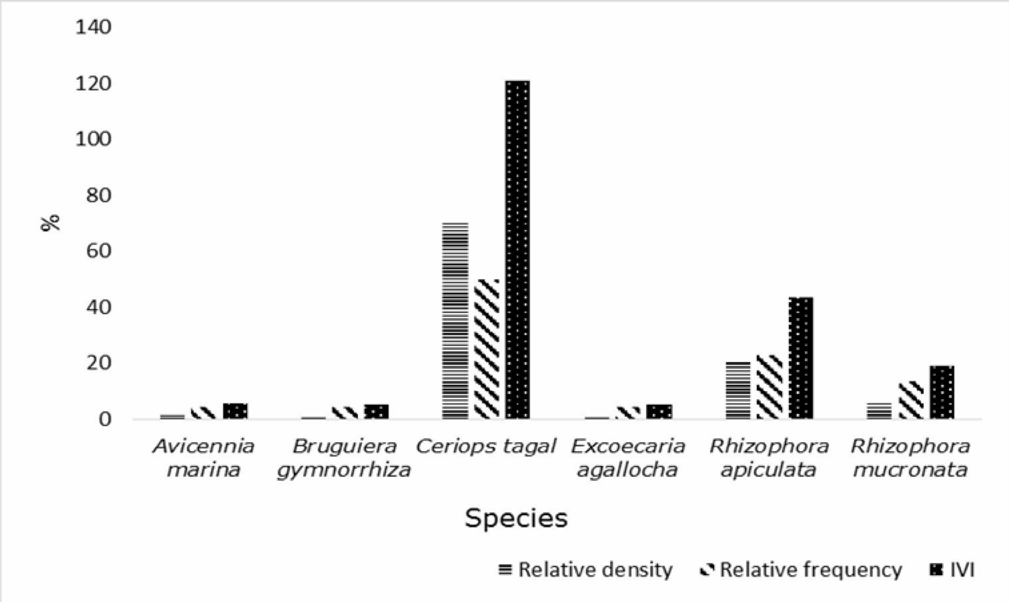

Figure 6. The IVI value of the mangrove species at sapling level.

Tree. At tree level, there were 10 species of mangrove numbering 124 individuals. The mangrove species density at tree level is presented in Table 3. The mangrove species with the the highest species density was *Lumnitzera racemosa* (312.5 ind ha^{-1}), followed by *Ceriops tagal* (262.5 ind ha^{-1}), whereas the lowest was exhibited by *Rhizophora mucronata, R. stylosa* and *Scyphiphora hydrophyllacea* at a species density of 6.25 ind ha^{-1} each. The total density all individuals was 775 ind ha^{-1} (Table 3).

If the total regeneration density at sapling and seedling levels are perused (3,975 individuals and 69,843.75 individuals per hectare, respectively), it can be said that regeneration is adequate, even above the standard. The FAO standard for mangrove forest sylviculture states that there needs to be (only) 2500 evenly dispersed mangrove seedlings per hectare except for the purpose of creating a short rotation energy forest (a firewood-producing forest) which requires 10-20 thousand seedlings per hectare (FAO 1994). Meanwhile, research in mangrove sylviculture at Matang Forest, Perak, Malaysia, revealed that 13 year old *Rhizophora apiculata* trees at a density of 9,250 ind ha^{-1} would thin out to 2,740 ind ha^{-1} five years later (Gong & Ong 1995).

Table 3

Mangrove relative density at tree level

Species	*Species density (ind ha^{-1})*	*Relative density (%)*	*Species frequency*	*Relative frequency (%)*
Bruguiera cylindrica	18.75	2.42	0.06	3.13
Ceriops tagal	262.50	33.87	0.50	25.00
Excoecaria agallocha	12.50	1.61	0.13	6.25
Lumnitzera littorea	37.50	4.84	0.25	12.50
Lumnitzera racemosa	312.50	40.32	0.63	31.25
Rhizophora apiculata	81.25	10.48	0.19	9.38
Rhizophora mucronata	6.25	0.81	0.06	3.13
Rhizophora stylosa	6.25	0.81	0.06	3.13
Scyphiphora hydrophyllacea	6.25	0.81	0.06	3.13
Sonneratia alba	87.50	4.03	0.06	3.13
Total	775.00	100.00	2.00	100.00

The results of the IVI calculation at tree level are presented in Figure 7. The species with the highest IVI was *Lumnitzera racemosa* at 117.82% followed by *Ceriops tagal* at 83.94%. The species with the lowest IVI was *Rhizophora mucronata* and *Scyphiphora hydrophyllacea*, each 4.46%. There were three species of mangrove at tree level that had the highest IVI, namely *Ceriops tagal, Lumnitzera racemosa*, and *Rhizophora apiculata.* The three species were the dominant species in the mangrove tracking area on Kemujan Island.

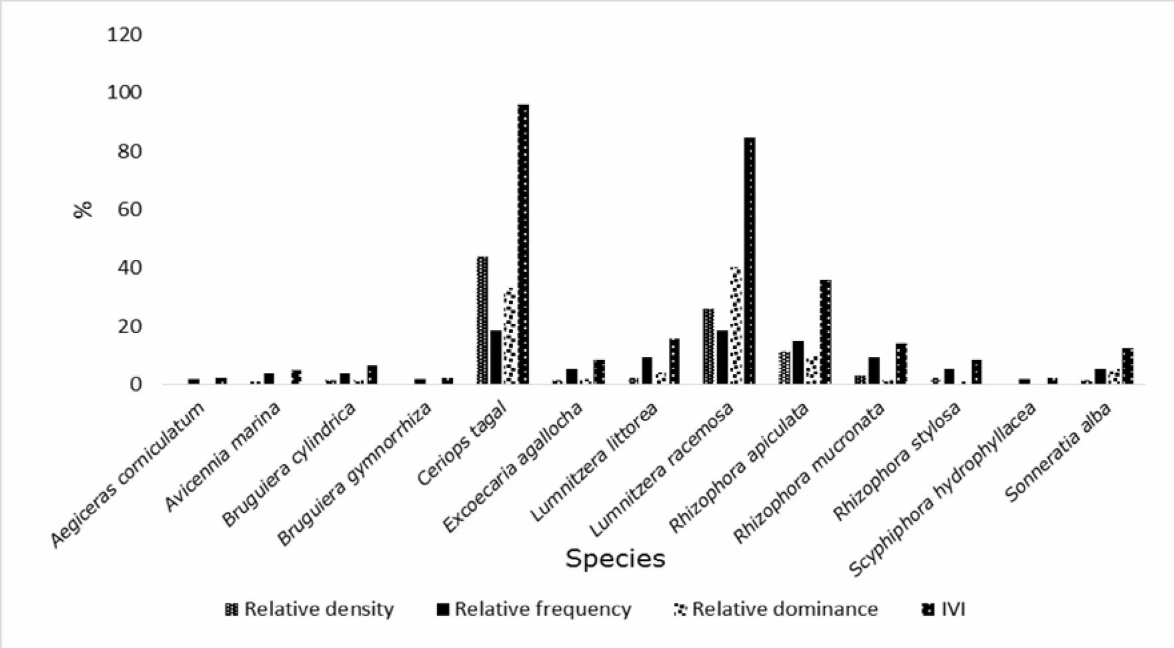

Figure 7. The IVI value of the mangrove species at tree level.

Substrate analysis. Substrate conditions play an important role in mangrove growth. The most common condition is a mangrove forest growing in clay mud mixed with organic materials. However, in some locations, the organic materials are very large in proportion, and some mangrove forests even grow on peat land. Another substrate is mud with a high proportion of sand, or even dominated by coral particles, on beaches close to coral reefs (Noor et al 1999). The type of substrate plays an important role in mangrove growth and the results of the composition measurement are presented in Table 4. The average substrate composition was sand 79.32%, ash 13.20% and clay 7.49%.

Table 4

Substrate type composition

Transect	*Plot*	*Texture (%)*		
		Sand	*Ash*	*Clay*
1	1	71.16	16.89	11.95
1	2	76.02	14.35	9.63
1	3	84.04	10.23	5.73
1	4	95.02	3.61	1.37
2	1	75.10	14.70	10.20
2	2	71.47	16.05	12.48
2	3	81.90	12.20	5.90
2	4	79.81	17.54	2.65
Average		79.32	13.20	7.49

Based on the order, Indonesian mangrove forest zonation according to Bengen (2002) is: a) the area closest to the sea, with a rather sandy substrate, often populated by

Avicennia spp. In this zone *Avicennia* spp. usually associates with *Sonneratia* spp. which mostly grow in deep mud that is rich in organic matter; b) more inland, the mangrove forest is usually dominated by *Rhizophora* spp. and *Bruguiera* spp., *Xylocarpus* spp. are also found in this zone; c) the next zone which is dominated by *Brugeria* spp. is the transitional zone between the mangrove forest and the lowland forest which is usually populated by *Nypa fruticans* and a number of other palms.

Conclusions. There were 730 individuals from 12 species of mangrove trees in the sample plot. These species were *Avicennia marina, Bruguiera cylindrica, B. gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera littorea, L. racemosa, Rhizophora stylosa, R. apiculata, R. mucronata, Scyphiphora hydrophyllacea,* and *Sonneratia alba*, whereas *Aegiceras corniculatum* was observed in the transect but not in the plot measured.

The natural regeneration density in the study location was 69843.75 individuals and 3975 individual per hectare for seedling and sapling level, respectively. These numbers were adequate, even more than needed, to guarantee the regeneration of the mangrove forest at the study location. However, if the species diversity was considered, it was not yet enough to ensure the regeneration of the mangrove species. At tree level, there were 124 individual from 10 species. At sapling level, there were 159 individuals from six species, while at seedling level there were 447 individuals from four species. Six species at tree level did not have natural regeneration (seedlings and saplings), while two other species were observed at sapling level but did not have natural regeneration (seedlings). This of course will threaten the sustainability of these species.

The mangrove species that had the highest species density at seedling level was *Ceriops tagal,* at 44531.25 ind ha^{-1}, while *Rhizophora mucronata* had the lowest species density lowest at 3125 ind ha^{-1}. The total species density for all individuals was 69843.75 ind ha^{-1}. At sapling level, the species with the highest species density was *Ceriops tagal* (2825 ind ha^{-1}), whereas the species with the lowest species density lowest was *Bruguiera gymnorrhiza* and *Exoecaria agallocha* at 25 ind ha^{-1}. The total species density for all individuals was 3975 ind ha^{-1}. The mangrove tree with the highest species density was *Lumnitzera racemosa* (312.5 ind ha^{-1}), followed by *Ceriops tagal* (262.5 ind ha^{-1}), whereas the lowest were *Rhizophora mucronata, R. stylosa* and *Scyphiphora hydrophyllacea* at species densities of each 6.25 ind ha^{-1}. The total species density for all individuals was 775 ind ha^{-1}.

The mangrove with the species frequency at seedling level was *Ceriops tagal* (0.63), and the lowest was *Exoecaria agallocha* (0.06). The mangrove with the highest species frequency at sapling level was *Ceriops tagal*, while the lowest were *Avicennia marina, Bruguiera gymnorrhiza,* and *Exoecaria agallocha.* The species with the highest species frequency at tree level was *Lumnitzera racemosa,* followed by *Ceriops tagal,* while the lowest were *Bruguiera cylindrica, Rhizophora mucronata, R. stylosa, Scyphiphora hydrophyllacea* and *Sonneratia alba.* The mangrove species with the highest dominance was *Lumnitzera racemosa* followed by *Ceriops tagal.* These two species had relatively large sizes and were numerous; therefore, they had relatively large biomass.

There were three species of mangrove at tree level with the highest IVI, namely *Ceriops tagal, Lumnitzera racemosa*, and *Rhizophora apiculata.* These three species were the dominant species in the mangrove tracking area on Kemujan Island. However, *Lumnitzera racemosa* did not have natural regeneration at seedling and sapling level, thus its regeneration was endangered.

The type of substrate that held an important role in the growth of mangrove had a composition of sand 79.32%, ash 13.20%, and clay 7.49%. This composition was suitable for the species growing in the study location.

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Authors:
Adi Winata, Faculty of Mathematics and Natural Sciences, Universitas Terbuka (The Indonesia Open University), Jl. Jabe Raya, Pondok Cabe, Pamulang, Tangerang Selatan, Indonesia 15418, e-mail: adit@ecampus.ut.ac.id
Ernik Yuliana, Faculty of Mathematics and Natural Sciences, Universitas Terbuka (The Indonesia Open University), Jl. Jabe Raya, Pondok Cabe, Pamulang, Tangerang Selatan, Indonesia 15418, e-mail: ernik@ecampus.ut.ac.id; erniky157@gmail.com
Edi Rusdiyanto, Faculty of Mathematics and Natural Sciences, Universitas Terbuka (The Indonesia Open University), Jl. Jabe Raya, Pondok Cabe, Pamulang, Tangerang Selatan, Indonesia 15418, e-mail: edi@ecampus.ut.ac.id

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