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Diversity and characteristics of mangrove vegetation in Pulau Rimau Protection Forest, Banyuasin District, South Sumatra, Indonesia

ERNIK YULIANA[1,♥], YUNI TRI HEWINDATI[1], ADI WINATA[1], WIBOWO A. DJATMIKO[2], ATI RAHADIATI[3]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Terbuka. Jl. Cabe Raya Pondok Cabe, Pamulang, Tangerang Selatan, Banten, Indonesia. Tel./fax.: +62-21-7490941, ♥email: ernik@ecampus.ut.ac.id

[2]The Indonesian Tropical Institute (LATIN). Jl Sutera No 1, Situgede, Bogor 16115, West Java, Indonesia

[3]The Indonesian Geospatial Information Agency. Jl. Raya Bogor Km 46, Nanggewer Mekar, Cibinong, Bogor 16911, West Java, Indonesia

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Abstract. *Yuliana E, Hewindati YT, Winata A, Djatmiko WA, Rahadiati A. 2019. Diversity and characteristics of mangrove vegetation in Pulau Rimau Protection Forest, Banyuasin District, South Sumatra, Indonesia. Biodiversitas 20: 1215-1221.* The purpose of the study was to analyze the flora diversity and characteristics of mangrove vegetation in Pulau Rimau Protection Forest, Banyuasin District, South Sumatra. Data collected were the number and girth diameter of mangrove tree species, and aquatic ecology parameters using transect method. The sample plots size were 2m×2 m; 5m×5 m; 10m×10 m; for seedling, sapling, and tree, respectively. The observation plots were arranged in a row of 120 m length on two sides of the forest edge, namely Calik Riverbank and Banyuasin Riverbank. Data were analyzed using importance value index (IVI), Simpson's diversity index and Sørensen's community similarity. The study revealed that there were differences in mangrove characteristics in two study sites. There were 57 plant species identified inside and outside sample plots, but only 15 species (26.32%) among them were categorized as true mangrove species. Inside the sample plots, there were 11 and 10 mangrove tree species recorded on the Calik Riverbank and Banyuasin Riverbank, respectively, but only 7 species among them were found in both sites. The mangroves on Calik Riverbank were dominated by Nypa (IVI 53.59%) and Bruguiera (51.12%), while those on Banyuasin Riverbank were dominated by Sonneratia (66.91%) and Avicennia (51.73%). The Simpson's diversity index for Calik Riverbank and Banyuasin Riverbank was 0.82 and 0.78, respectively, whereas the Sørensen's coefficient of community between the two sites was 0.67.

Keywords: Coefficient of community, diversity, diversity index, mangrove

INTRODUCTION

The mangrove ecosystem is one of the important ecosystems in coastal and marine areas, functioning as the habitat for various types of organisms. The mangrove ecosystem is a unique ecosystem, known as a trap for mud and debris carried by the ocean currents, including organic waste and other waste materials from land. The mangrove substrate is famous for its fertility, functioning as a habitat for various types of biotas (Winata and Rusdiyanto 2015). In coastal areas, this ecosystem mainly forms a green strip along the coast/estuary and is very important for fish hatchlings/fish and prawns as well as to maintain the quality of the fishery and ecosystem, and agriculture (Indrayanti et al. 2015).

Another ecological role played by the mangrove ecosystem is as a barrier to protect the adjacent areas from the destructive energy of waves. Mangroves can reduce the effect of storm waves and protect the area of beaches that are affected by storms, and had been observed to even weaken the tsunami wave in India in 2004 (Das 2013). Another benefit is that the mangrove ecosystem is also useful for the people around it for fulfilling some of their daily needs, for example utilizing mangrove wood (especially *Rhizophora*, *Bruguiera* and *Ceriops*) for building materials, harvesting shellfish, snails, crustaceans, and fish as a source of protein, and collecting ingredients for traditional medicine (Winata and Rusdiyanto 2015).

Because the mangrove plays various roles and has many benefits for the environment and the people, mangrove ecosystem must be preserved so that it may continue to provide ecosystem services for the benefit of humankind (Winata et al. 2017). Mangroves on northern Rimau Island have been declared as a coastal protection forest based on their location on the inside of the Banyuasin River estuary, on the east coast of Sumatra Island; namely Pulau Rimau Protection Forest (KPHL Unit I Banyuasin 2017). Besides functioning as protected forest, these mangroves also provide direct utilization functions for the surrounding community, for example as a source of firewood, nipa palm leaves as roofing material, fish, crabs, *et cetera*. To understand the importance of the mangrove area of the Pulau Rimau Protection Forest, there is a need for collection of the area's basic data, one of which is the vegetation diversity and the related mangrove vegetation characteristics.

The purpose of this study was to analyze the floral diversity and the characteristics of mangrove vegetation in the Pulau Rimau Protection Forest. The vegetation characteristics include the species composition and vegetation structure of the mangrove stands and the condition of the related substrate.

MATERIALS AND METHODS

Study area

The study area was the Pulau Rimau Protection Forest, in the Pulau Rimau Sub-district and Kuala Puntian Village, Tanjung Lago Sub-district, Banyuasin District, South Sumatra, Indonesia. Figure 1 showed the land cover map of Pulau Rimau and Tanjung Lago Sub-districts, where mangrove ecosystems are located along the coast.

Procedures

Object of study

The object of the study was the mangrove forest stands in the Pulau Rimau Protection Forest. The area studied were the mangrove forest areas which were often exploited by the community, both directly and indirectly, and were relatively close to settlements. Two sides of the Pulau Rimau Protected Forest, the west side on the banks of Calik River and the east side on the banks of Banyuasin River, were selected as study sites.

Vegetation data were collected through systematic sampling (Krebs 1989; Walpole 1995) by creating two transect paths which were placed approximately perpendicular to the banks of the larger rivers, e.g., Calik River (Penuguan River) and Banyuasin River, draw from the river banks to the forest interior. The two large rivers have widths of more than 1 km at the transect starting points.

Data collection

The data collected during this study were primary and secondary data. The primary data were the species composition, vegetation structure (tree density, basal area, and mangrove regeneration), and related substrate conditions (types of substrate, pH, river water turbidity and temperature). Secondary data included various supporting information which was required in the discussion and conclusion, including the interaction between local community and the mangrove forest.

The definition of regeneration level used in this study was: 1) Seedlings are regenerated from sprouts to young plants up to 1.5 m high; 2) Saplings are young trees from 1.5 m high to treelets with a DBH (diameter at breast height) of less than 10 cm; 3) Trees are stands with a DBH of 10 cm or more (Cintron and Novelli 1984; Soerianegara and Indrawan 1987).

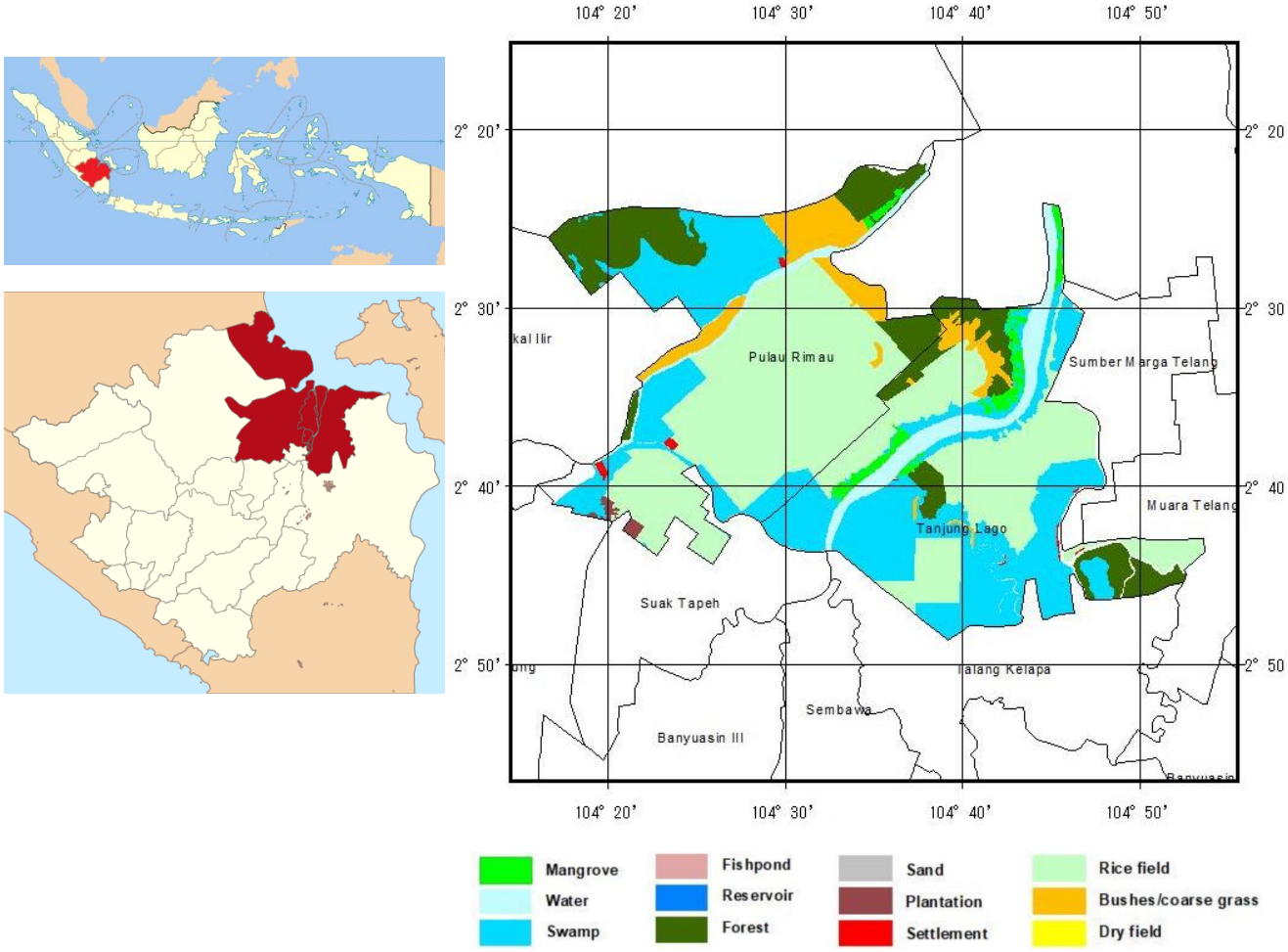

Figure 1. Land cover map of Pulau Rimau and Tanjung Lago Sub-districts, Banyuasin District, South Sumatra, Indonesia

Two study sites were chosen in the two sides of Pulau Rimau Protection Forest, namely the Calik Riverbank at the northwest side and the Banyuasin Riverbank at the southeast side of the forest. In each area, a transect line consisting of 12 plots was drawn; totaling 24 plots for both sides. Data were collected through a vegetation analysis technique using transect method (Soerianegara and Indrawan 1987; Bengen 2002). Sample plots were made in squares of varying sizes, e.g., 2 m x 2 m for seedlings; 5 m x 5 m for saplings; and 10 m x 10 m for trees. In the field, the three sizes of sample plots were arranged as drawn in Figure 2.

Data analysis

Flora diversity was analyzed descriptively by presenting the numbers and groupings of plant species. Vegetation structure was examined by calculating the Importance Value Index (IVI) which consists of relative species density, and relative species frequency. The Simpson's Diversity Index (1-D) and Sørensen's community similarity coefficient were calculated according to the formula in Krebs (1989).

RESULTS AND DISCUSSION

Mangrove floral composition

At least, there were 57 species of plants recorded inside and outside the sample plots; 24 among them were tree species and the remaining were shrubs and herbs. Out of 57 species, 15 species (26.32%) were known as true mangrove species and 18 species (31.58%) were categorized as associate mangrove species. The rest of them further categorized as 12 species (21.05%) of plants commonly found in swamps and 12 species (21.05%) of secondary terrestrial vegetation plants (Figure 3).

All of plant species found and their grouping (Table 1) is showing the diversity of mangrove flora in study sites. True mangrove, according to Tomlinson (1986), were mangrove species that have been possessing morphological specialization and physiological mechanisms that adapt them to their environment, occurring only in the mangrove environment and not extending into terrestrial communities. True mangroves are found exclusively in the mangrove habitat (Giesen and Wulfraat 2006; FAO 2007). Associate mangroves are often found in mangrove environment, but not exclusively as they could be found also outside mangroves (Tomlinson 1986; Noor et al. 1999; Giesen and Wulfraat 2006).

Species that are marked with an *s* in Table 1 showed that these species were typical flora of secondary vegetation, and most of them were pioneer species which readily invade open areas of forests. Species from the genera of *Macaranga* and *Mallotus*, together with *Commersonia*, *Trema*, and *Trichospermum*, are classified as short-lived pioneer trees (Whitmore 1984); species that grow quickly but also die or disappear quickly from the secondary vegetation community. Paperbark tree (*Melaleuca*) are often found dominating secondary forests that had burned, especially in peatland marsh areas (Anwar et al. 1984, Whitmore 1984, MacKinnon et al. 1996).

Secondary vegetation flora consisted also with shrubs and ground-dwelling herbs. Some herbaceous species such as *Cayratia* and *Cissus* vines, and *Mimosa* were adapted to dryland. Other herbaceous species that commonly found in disturbed mangroves were mangrove fern (*Acrostichum*), sea holly (*Acanthus*), sea derris (*Derris trifoliata*) and, in watery areas, *Cyperus malaccensis* (Phan and Hoang 1993).

Mangrove vegetation structure

There were 183 tree individuals from 14 mangrove species found inside the sampling plots. The species that comprise the mangrove forest studied were *Avicennia alba*, *A. officinalis*, *Barringtonia conoidea*, *Bruguiera gymnorrhiza*, *B. sexangula*, *Ceriops tagal*, *Excoecaria agallocha*, *Heritiera littoralis*, *Nypa fruticans*, *Pongamia pinnata*, *Rhizophora stylosa*, *R. mucronata*, *Sonneratia caseolaris*, and *Xylocarpus granatum*.

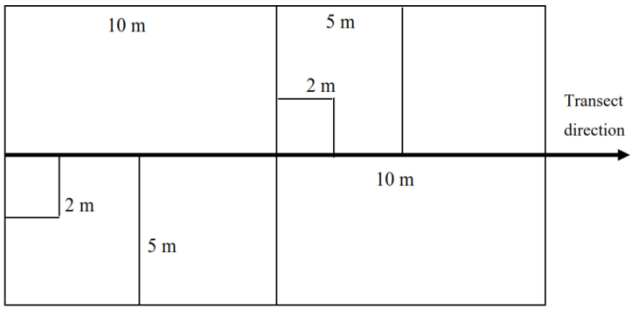

Figure 2. Placement of measurement plots according to the transect method

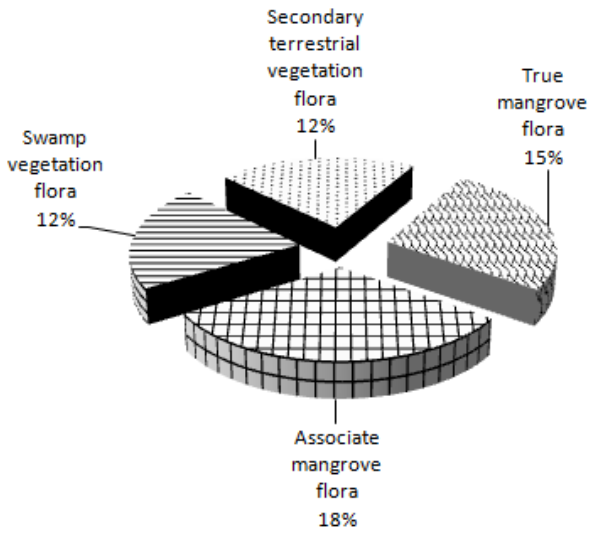

Figure 3. The floral composition of mangrove stands in the Pulau Rimau Protection Forest, Banyuasin, Indonesia

Table 1. A list of plant species found in the study area and their groupings

Family and scientific name	Local name	M	A	R	S
Acanthus ilicifolius	Jeruju	m			
Acrostichum aureum	Paku laut	m			
Allophylus cobbe	Penancang		a		
Alstonia spathulata	Pulai rawa			r	
Avicennia alba	Api-api putih	m			
Avicennia officinalis	Api-api ludat	m			
Barringtonia conoidea	Putat sungai		a		
Bruguiera gymnorrhiza	Tumu	m			
Bruguiera sexangula	Pertut	m			
Caesalpinia sp.	-		a		
Cayratia trifolia	Galing-galing				s
Cerbera manghas	Bintaro		a		
Ceriops tagal	Tengar	m			
Cissus hastata	Akar asam riang				s
Citrus sp.	Limau		a		
Commelina nudiflora	Gewor			r	
Crinum asiaticum	Bakung			r	
Cyperus javanica	Rumput lingsing			r	
Cyperus malaccensis	Wlingi laut		a		
Derris trifoliata	Tuba laut		a		
Eclipta alba	Urang-aring			r	
Eleocharis dulcis	Tike		a		
Excoecaria agallocha	Buta-buta	m			
Ficus benjamina	Beringin				s
Ficus sp	Ara			r	
Ficus sp.2	Ara rambat				s
Fimbristylis sericea	-			r	
Flagellaria indica	Rotan tikus		a		
Glochidion littorale	Dempul		a		
Heritiera littoralis	Dungun	m			
Hibiscus tiliaceus	Waru		a		
Imperata cylindrica	Ilalang				s
Leptochloa cf *neesii*	Perumpungan				s
Ludwigia octovalvis	Lombokan			r	
Lygodium flexuosum	Paku hata				s
Macaranga cf *hypoleuca*	Mahang putih			r	
Mallotus paniculatus	Balik angin				s
Melaleuca cajuputi	Gelam			r	
Melastoma malabathricum	Senggani		a		
Mimosa pigra	Sikejut besar			r	
Mimosa pudica	Sikejut				s
Nypa fruticans	Nipah	m			
Paspalum vaginatum	Rumput pahit				s
Phragmites karka	Perumpung			r	
Pluchea indica	Beluntas		a		
Pongamia pinnata	Malapari		a		
Rhizophora apiculata	Bakau minyak	m			
Rhizophora mucronata	Bakau kurap	m			
Scirpus cf *littoralis*	Endong		a		
Sonneratia caseolaris	Pedada	m			
Sphaeranthus indicus	Mundika				s
Stenochlaena palustris	Paku udang		a		
Sarcolobus globosus	Akar batu	m			
Terminalia catappa	Ketapang		a		
Uncaria sp.	Akar kekait				s
Wedelia biflora	Seruni		a		
Xylocarpus granatum	Nyirih	m			

Note: m = true mangrove flora, a = associate mangrove flora, r = swamp vegetation flora, s = secondary terresterial vegetation flora

According to stands composition, the mangrove forest on the Calik Riverbank was dominated by nipa palm (*Nypa fruticans*), accounting for approximately 30.86% of the number of trees recorded in the plot, followed by pertut (*Bruguiera sexangula*) 28.40% and kayu buta-buta (*Excoecaria agallocha*, blind-your-eye) 14.81% (Table 2). Meanwhile, the mangrove on the Banyuasin Riverbank was dominated by pedada (*Sonneratia caseolaris*, mangrove apple), consisting of 48.39% of the number of trees recorded in the plot. A large number of pedada individuals was because most of these trees were young, comprising the succession layers of the mangrove forest on the newly formed mud plains on the banks of Banyuasin River. The first plot on the river bank was even filled solely with *S. caseolaris* individuals at seedling and sapling stages. The next dominant species was api-api ludat (*Avicennia officinalis*) at 25.81%, and nipa palm at 12.90% (Table 2 and Figure 5).

The difference between the two mangrove forest stands was further supported by the results of the vegetation analysis which revealed that *Nypa fruticans*, *Bruguiera sexangula*, and *Excoecaria agallocha* were the top three in the Importance Value Index (IVI) of mangrove trees on the Calik Riverbank, with IVIs of 53.59%, 51.12%, and 33.00%, respectively. On the other hand, the mangrove trees with the top three IVI on the Banyuasin Riverbank were *Sonneratia caseolaris* (66.91%), *Avicennia officinalis* (51.73%), and then *Nypa fruticans* (31.42%) (Table 2, Figure 4 and Figure 5).

Diversity of fauna

There were at least 82 species of fauna found in the mangrove forest studied and the surrounding areas, consisting of 6 mammalian species, 56 avian species, 8 herpetofauna species (reptiles and amphibians), 8 fish species, and 4 crustacean species. A large number of bird species observed was associated with the ease of which they were observed, either when flying or not. The other groups of animals were more secretive or hidden in their habitats (bushes, burrows, or underwater). Among them, there were several species considered as important according to IUCN (The World Conservation Union), CITES (The Convention on International Trade of Endangered Species fo Flora and Fauna), or protected by Indonesian Law (Table 3).

Table 2. Three tree species with the highest Importance Value Index (IVI) in the two study locations

Species	∑ indiv.	RD (%)	F	RF (%)	IVI (%)	1 - D
Calik River Mangroves						
Nypa fruticans	25	30.86	0.83	22.73	53.59	0.82
Bruguiera sexangula	23	28.40	0.83	22.73	51.12	
Excoecaria agallocha	12	14.81	0.67	18.18	33.00	
Banyuasin River Mangroves						
Sonneratia caseolaris	45	48.39	0.42	18.52	66.91	0.78
Avicennia officinalis	24	25.81	0.58	25.93	51.73	
Nypa fruticans	12	12.90	0.42	18.52	31.42	

Note: RD = relative density; F = frequency; RF = relative frequency; IVI = important value index; 1 – D = Simpson's index

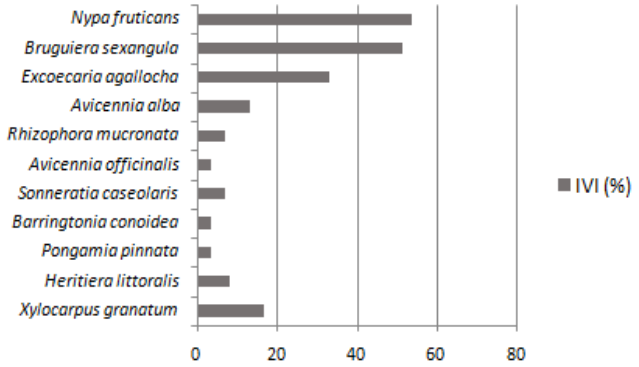

Figure 4. Importance Value Indices for the trees in the Calik Riverbank site

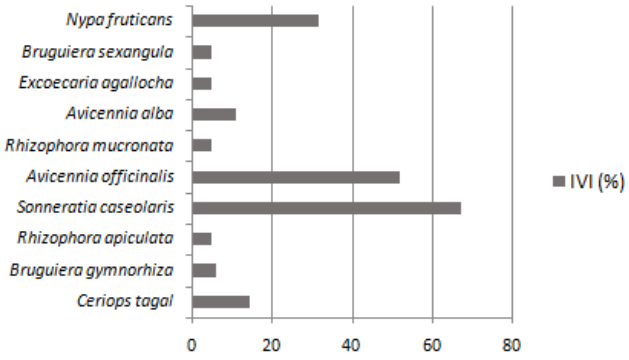

Figure 5. Importance Value Indices for the trees in the Banyuasin Riverbank site

Table 3. Important species of fauna recorded at the study sites and the surrounding areas

Scientific name	Local name	English name	IUCN	CITES	RI Law
Aethopyga siparaja	Burung-madu sepah-raja	Crimson sunbird	LC	-	L
Anthreptes malacensis	Burung-madu kelapa	Plain-throated sunbird	LC	-	L
Cinnyris jugularis	Burung-madu sriganti	Olive-backed sunbird	LC	-	L
Crocodylus porosus	Buaya muara	Salt-water crocodile	LC	App II	L
Halcyon smyrnensis	Cekakak belukar	White-throated kingfisher	LC	-	L
Haliaeetus leucogaster	Elang laut	White-bellied sea eagle	LC	App II	L
Haliastur indus	Elang bondol	Brahminy kite	LC	App II	L
Ictinaetus malaiensis	Elang hitam	Black eagle	LC	App II	L
Leptocoma calcostetha	Burung-madu bakau	Copper-throated sunbird	LC	-	L
Leptoptilos javanicus	Bangau tongtong	Lesser adjutant	VU	-	L
Macaca fascicularis	Monyet kra	Crab-eating monkey	LC	App II	-
Malayopython reticulatus	Ular sanca kembang	Reticulated python	NE	App II	-
Mycteria cinerea	Bangau bluwok	Milky stork	EN	App I	L
Pelargopsis capensis	Pekaka emas	Stork-billed kingfisher	LC	-	L
Prionailurus bengalensis	Macan akar	Leopard cat	LC	App II	L
Ptyas cf. *mucosus*	Ular tikus besar	Greater rat-snake	-	App II	-
Rhipidura javanica	Kipasan belang	Pied fantail	LC	-	L
Spilornis cheela	Elang ular bido	Crested serpent-eagle	LC	App II	L
Todiramphus chloris	Cekakak sungai	Collared kingfisher	LC	-	L
Trachypithecus cristatus	Lutung cingku	Silvered leaf-monkey	NT	App II	-
Varanus salvator	Biawak air	Common monitor	LC	App II	-

Notes: IUCN status: EN, Endangered; LC, Least Concern; NE, Not Evaluated; NT, Near Threatened; VU, Vulnerable; CITES: App I, listed in Appendix I; App II, Appendix II; RI Law: L, protected by the law (RI Government Regulation no 7/1999)

Discussion

The proportion of true mangrove species in the area studied was only one fourth of the total existing species (Figure 3), whereas the true mangrove species are the main component of the mangrove ecosystem which is the indicator of the condition of the mangrove forest itself (FAO 2007; WOA RPROC 2016). Tomlinson (1986) defined true mangrove species as mangrove species that have adapted well with high-salinity environments through both morphological and physiological adaptation mechanisms, so they only thrive in the mangrove ecosystem and play an important role in creating its community structure. True mangroves are naturally only found in the mangrove ecosystem (Giesen and Wulfraat 2006). Associate mangroves are plant species that are found living in the mangrove ecosystem but are able to live in other ecosystems (Noor et al. 1999). In Southeast Asia, Giesen and Wulfraat (2006) have listed 52 species of true mangroves and 216 species of associate mangroves, while in Indonesia the numbers are 43 species of true mangroves and 159 species of associate mangroves (Noor et al. 1999).

The high proportion of non-true mangroves, the associate mangrove group and non-mangroves (totaling 73.68%), recorded on the location suggested that the Rimau Island coastal protection forest was categorized as a disturbed ecosystem. Changes in the floristic composition of a mangrove forest could be due to natural changes in the environment or due to human actions or disruptions, or due to a combination of the two (Saenger 2002).

Referring to the composition of mangrove individuals that were recorded (Table 2, Figure 4 and 5), there was a clear difference between the mangrove forest stands on the Calik Riverbank and the Banyuasin Riverbank. Simpson's Diversity Index (1-D) for the two locations were 0.82 (Calik Riverbank) and 0.78 (Banyuasin Riverbank) (Table 2). The diversity index represents the chances of the next species being observed is differing from the previous one; therefore, a value of 0 means that the community is uniform or homogeneous and a value approaching 1 means that the community is highly diverse (Krebs 1989). The Simpson's Diversity Index found was fairly high; suggesting that the two locations studied had a rather high diverse vegetation.

From the mangrove tree species diversity point of view, the two mangrove stands were almost the same, having 11 species of trees recorded in the Calik Riverbank and 10 species of trees in the Banyuasin Riverbank; totaling 14 species. However, out of the 14 species, only 7 species were recorded in the sample plots of the two sides of the Pulau Rimau Protection Forest. Another 4 species were recorded only on the Calik Riverbank and the last 3 species were only observed on the Banyuasin Riverbank. Nevertheless, the Sørensen's coefficient of community was 0.67. This value suggests that the similarity between the two mangrove communities was relatively high. Theoretically, the Sørensen's coefficient of community ranges between 0.0 (or 0%, which means the two sample communities compared are not similar at all) and 1.0 (or 100%, which means the two samples are identical) (Krebs 1989; Mueller-Dombois and Ellenberg 2003). Index value greater than 65% suggests a fairly high floristic similarity (Prawiroatmodjo and Kartawinata 2014, Srivastava and Shukla 2016).

The difference in mangrove tree species, especially the dominating species, is believed to be associated with the substrate conditions that are different on the two sides of the Pulau Rimau Protection Forest. As mentioned above, the forest on the Banyuasin Riverbank is situated where new mud is deposited, leading to the domination of *Sonneratia caseolaris* and *Avicennia officinalis* in the succession of mangrove vegetation. On the other hand, the forest on the banks of Calik River is located on a substrate that is more settled and solid. This part is a transition between the mangrove forest dominated by *Bruguiera sexangula* and *Excoecaria agallocha* and the mangrove area was dominated by *Nypa fruticans*.

Avicennia and *Sonneratia* often dominated the foremost area of mangrove forests, or the area closest to the sea, with substrate in the form of soft mud with high organic matter content (Watson 1928; Sukarjo and Kartawinata 1979). This area is often referred to as the Zone 1 of mangroves, which is the outermost zone where new mud is deposited. In addition to these two genera (*Avicennia* and *Sonneratia)*, *Rhizophora* –especially *R. mucronata*– as mentioned by Steenis (1958), is known to prefer conditions where the substrate is deep soft mud.

The *Bruguiera* genus usually grows in the zone more inland, with a more settled substrate, more solid, and is only flooded by monthly tides. Even in the Calik Riverbank site, where *B. sexangula* dominated the stand, the species is only found inland, although not far from the edge of water. *B. cylindrica*, *B. parviflora* and *B. sexangula* also grow in areas not far from rivers, but on higher ground only inundated by tides once in a while (Watson, 1928; Steenis, 1958, Saenger 2002).

The nipa palm (*Nypa fruticans*) in the study sites were observed growing in a narrow strip along the banks of Calik River or forming a wide band behind the area populated by many mangrove trees. Nipa palms mainly grow in the interior of mangroves at the high tide mark, often forming pure stands alongside the river (Whitmore 1984; Gee 2001). However, the nipa palm is not very sensitive to changes in water salinity and is able to grow well at salinity level range of 1-30‰. The nipa palm is also known to favor places with strong water currents such as river banks (Steenis 1958). More inland, nipa palm might be associated with places with many mud lobster (*Thalassina anomala*) nesting mounds (Whitmore 1984).

Mangrove stand on the sides of Banyuasin River was dominated by *S. caseolaris*, particularly in the riverbank. *Sonneratia caseolaris* and *Nypa fruticans* are often dominant in areas with brackish water, especially along the riverside which has brackish to nearly-fresh water as the mangrove at the back of estuaries (Phan and Hoang 1993, Noor *et al*. 1999). Such situation agreed with the study sites that located far behind the Banyuasin River estuary, but could still be reached by the tidal waters.

From the conservation point of view, there were 16 species among recorded fauna in the study sites that protected under the Republic of Indonesia's law, consisting of 1 mammalian species, 14 avian species, and 1 reptilian species. One of the bird species, the milky stork (*Mycteria cinerea*), was declared as Endangered (IUCN 2017). This species was also listed in Appendix I CITES which means that the trade of this species is banned internationally (CITES 2017). Another stork species, the lesser adjutant (*Leptoptilos javanicus*), had its population declared as Vulnerable (IUCN 2017), while the silvered langur (*Trachypithecus cristatus*) was listed as Near Threatened (IUCN 2017). Meanwhile, there were another 11 species listed in Appendix II CITES, which means trade is controlled with a limited quota (CITES 2017). The high proportion of important species of fauna in the study sites (Table 3), e.g. 21 out of 82 species (25.61%), shows that the Pulau Rimau protection forest still has a significant role as habitat of wild fauna.

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