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Comparison of true mangrove stands in Dudepo and Ponelo Islands, North Gorontalo District, Indonesia

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Keywords: Basal area, Bray-Curtis, Diversity, Gorontalo, mangroves

INTRODUCTION

Until the end of 2000, Indonesia's mangrove forest area was estimated to be 3,112,989 ha or 22.6% of the total mangrove area in the world (Giri et al. 2011). Therefore, mangrove resources are important biological wealth of Indonesia's coastal areas. Mangrove forest becomes a transitional ecosystem in almost all coastal areas in the Indonesian Archipelago, ranging from Sumatra, Java, Kalimantan, Bali, Sulawesi, Maluku, to Papua island (Kusmana et al. 2003; Rugayah, 2007; Marbawa et al. 2014; Prasetiyo et al. 2014; Muhtadi et al. 2016; Setiawan et al. 2017; Wouthuyzen and Ahmad, 2018). Besides occupying large area, the mangroves in Indonesia are also known to have high diversity. Snedaker (1984) noted that there were at least 202 species of mangroves in Indonesia, 43 of which (consists of 33 species of trees and several species of shrubs) were true mangrove species, and the rest were other species that lived around mangroves, known as associated mangroves. Mangroves provide a variety of benefits, both goods and services for most communities in coastal areas. The essential ecological and economic functions of mangrove forests are that they provide materials needed by people for commercial, recreational, and also fishery purposes through environmental services as a spawning ground, nursery habitat for marine fauna (Zhang et al. 2007; Giri et al. 2011; Nfotabong-Atheull et al. 2011; Joshi and Ghose 2014; Hutchison et al. 2014).

The diversity of true mangrove species in northern Gorontalo coastal area was reported to be quite high. Kasim et al. (2017) recorded 19 species in eastern coast area, dominated by members of the Rhizophoraceae family both at genus and species levels. Meanwhile, two other species in this region which are important for global conservation are *Aegiceras floridum* Roem. & Schult (local name *Tongge*) and *Ceriops decandra* (Griff.) Ding Hou (local name *Posi-posi*). Further studies of mangrove forests condition are necessary for resource conservation and coastal land management. For Gorontalo-which is geographically laid in the heart of Wallacea (Gorlinski 2012)-the comprehensive studies of biodiversity in broader areas of mangrove distribution could provide the best choice of management strategies. In term of mangrove complexity study, the significance of the results will be obtained by excluding the species of associated mangrove into the analysis (Blanco et al. 1999). Hence, in this study, we only studied the true mangroves and their distribution. The study aimed to compare the community attributes (species composition, species importance value, and diversity) of true mangroves in Dudepo and Ponelo Islands,

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MATERIALS AND METHODS

Site of research

Dudepo and Ponelo Islands are two large islands in North Gorontalo District, Indonesia. They are separated administratively: Anggrek Sub-district and Ponelo Kepulauan Sub-district. Both areas are facing the Sulawesi Sea (Figure 1). The sites of research were located in 3 villages in Ponelo Kepulauan Sub-district, and 4 hamlets in Dudepo Island (Table 1).

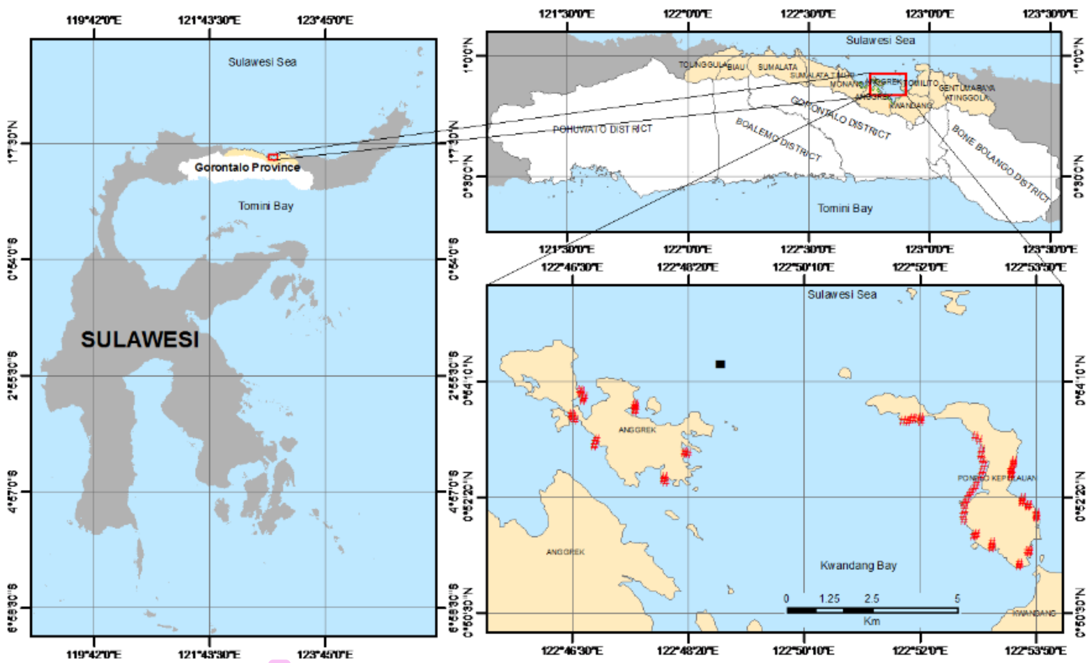

Figure 1. The research locations in Dudepo and Ponelo Islands, North Gorontalo District, Indonesia. The red dots showed the station positions and the line transects in each location

Table 1. Detailed information on the observed mangroves per station in Dudepo and Ponelo Islands, North Gorontalo District, Indonesia

Island	Station	Coordinate	Code of Transect	No. of quadrats	pH	Salinity (‰)	Temperature (ºC)	Substrate
Dudepo	Hamlet of Makassar	122º 46’ 33.52” E, 0º 53’ 35.75” N	ST1	3	6.5	28	30	Md
	Hamlet of Upo	122º 46’ 51.42” E, 0º 53’ 34.8” N	ST2	3	7.4	27-28	27.5-27.8	Md
	Hamlet of Tapia	122º 48’ 18.56” E, 0º 53’ 1.23” N	ST3	3	7.4	30	29.1-29.	Md, Sn
	Hamlet of Bolongo	122º 47’ 30.1” E, 0º 53’ 38.1” N	ST4	3	7.1	30-32	29.8-30.1	Md, Ms
Ponelo	Village of Atiola	122º 52’ 52.46” E, 0º 51’ 43.98” N	ST5	6	7.8	31-32	29-29.7	Md, Ms, Dc
		122º 53’ 8.8” E, 0º 51’ 33.58” N	ST6	3	8	31-33	29.5	Md, Ms, Dc
	Village of Malambe	122º 51’ 44.76” E, 0º 53’ 32.63” N	ST7	3	7.6	30-31	29.5-30.2	Ms
		122º 52’ 1.01” E, 0º 53’ 33.41” N	ST8	3	6.81	30-34	30.1-30.3	Sn, Dc
	Village of Ponelo	122º 53’ 33.92” E, 0º 52’ 44.85” N	ST9	4	6.82	33-35	29.4-30	Ms, Rc

Note: Md = Mud, Ms = Muddy sand, Dc = Dead coral, Rc = rocky, Sn = Sand

Research procedure

Field survey and data collection

The field survey was conducted from May to August 2017. Details of all stations, transects and locations are presented in Table 1. Data collection of mangrove was done using line-transects and 10 x 10 m quadrats made purposively. The interval of quadrats in each transect was 30 to 50 m, depending on the width of mangrove belt on the station. In each quadrat, data of trees, saplings, and seedlings, and also environmental condition were collected (Table 1). The width of mangrove belts was 140 to 657 m in Dudepo Island, and 40-300 m in Ponelo Island. The total areas of sampling in Dudepo and Ponelo Islands were 0.12 ha and 0.19 ha, respectively, resulted from 3 to 6 quadrats employed in perpendicular or parallel transects to shoreline.

Types and sources of data collected

Only true mangrove species were identified and counted in each quadrat. Mangrove species were identified according to the true mangrove description by Kusmana et al. (2003), Noor et al. (2012) and Wetland International (2017). The species name and diameter at breast height (DBH, at 1.3 m) were recorded. The mangrove plants were classified into three categories based on the growth stages as follows: 1) Seedling was any woody plant from sprouts to young mangrove up to 1.5 m high; 2) Sapling was any woody plant higher than 1.5 m with a DBH of less than 10 cm; 3) Tree was any woody plant with a DBH of more than 10 cm (Cintron and Novelli 1984; Cañizares and Seronay 2016; Joshi and Ghose 2014; Winata et al. 2017).

The data of mangrove area and distribution delineated from other land cover were calculated using Landsat-8 (OLI) Path / Row: 113/059, acquisition on September 21, 2017, obtained from U.S. Geological Survey Visualization Viewer or earth explorer which is available free to download through the http: //earthexplorer.com.

Data analyses

Landsat image analysis for mangrove distribution area

To determine the mangrove distribution area, the scene of image was cropped to the area being observed. Then, it was delineated using the mixed method of supervised classification and segmentation of band composites of RGB 654. SAGA GIS 6.3.0 software was used for all processes of mangrove delineation.

Analysis of mangrove structure

Vegetation data were analyzed using importance value index (IVI) of species (Cintron and Novelli 1984).

The importance value index for each species was calculated using this formula:

IVI = Relative Density + Relative Frequency + Relative Dominance

$$\text{Density of species i} = \frac{\textit{number of trees of species i}}{\textit{area of quadrats}}$$

$$\text{Relative density of species i} = \frac{\textit{Density of species i}}{\textit{Density of all species}} \times 100\ \%$$

$$\text{Frequency of species i} = \frac{\textit{number of quadrats where species i was found}}{\textit{total quadrats}}$$

$$\text{Relative frequency of species i} = \frac{\textit{Frequency of species i}}{\textit{frequency of all species}} \times 100\ \%$$

$$\text{Dominance of species i} = \frac{\textit{Basal area of species i}}{\textit{area of quadrats}}$$

$$\text{Relative dominance of species i} = \frac{\textit{Dominance of species i}}{\textit{Dominance of all species}} \times 100\ \%$$

The diversity, richness and evenness of species in stations and locations were analyzed using the Shannon-Wiener diversity index, H ′, Margalef wealth index, and Buzas and Gibson's evenness index. The similarity of the species composition and diversity indexes among all observed quadrats, in all stations and locations was then analyzed using multivariate clustering analysis (Bray-Curtis's index) (Hammer 2017). The procedure followed that described by Kasim et al. (2017) using PAleontological STatistics software (PAST Version 3.15).

RESULTS AND DISCUSSION

Mangrove extent and distribution

The map of the mangrove area and distribution based on the analysis of Landsat-8 OLI images between Dudepo and Ponelo Islands is presented in Figure 2, which shows the differences in distribution and mangrove area between the two islands. The mangrove area in Dudepo Island was larger (279.46 ha) than that in Ponelo Island (113.35 ha). The front area of both islands has relatively same situation of mangrove distribution in the north, directly facing the open area of the Sulawesi Sea. Hence, generally, the mangrove is located in the back area in both islands, facing the mainland (Kwandang and Anggrek), protected from the influence of waves. The mangrove distribution in Dudepo Island in the north is limited to the areas of small bay characterized by the presence of river flow influence and also the protection from the influence of waves.

Although there was the same intensive land cover change in upland area of both islands, we observed that-in term of habitat loss and natural life of mangrove-the mangrove ecosystem in Dudepo was more protected from the impacts of human activities than that in Ponelo. Not surprisingly, then, that the mangrove area on Dudepo was larger (2.47 times) than that in Ponelo.

Species composition and mangrove community structure

Table 2 shows the 13 species recorded (members of 6 genera of 4 families) which made up the true mangrove community in Dudepo and Ponelo Islands.

The maximum richest taxa in genus and species levels were found in Rhizophoraceae. Since this family always has the richest taxa in most mangrove ecosystems in the world, as proved in the present study, this family is referred to as the "true mangrove family" (Duke et al. 1998).

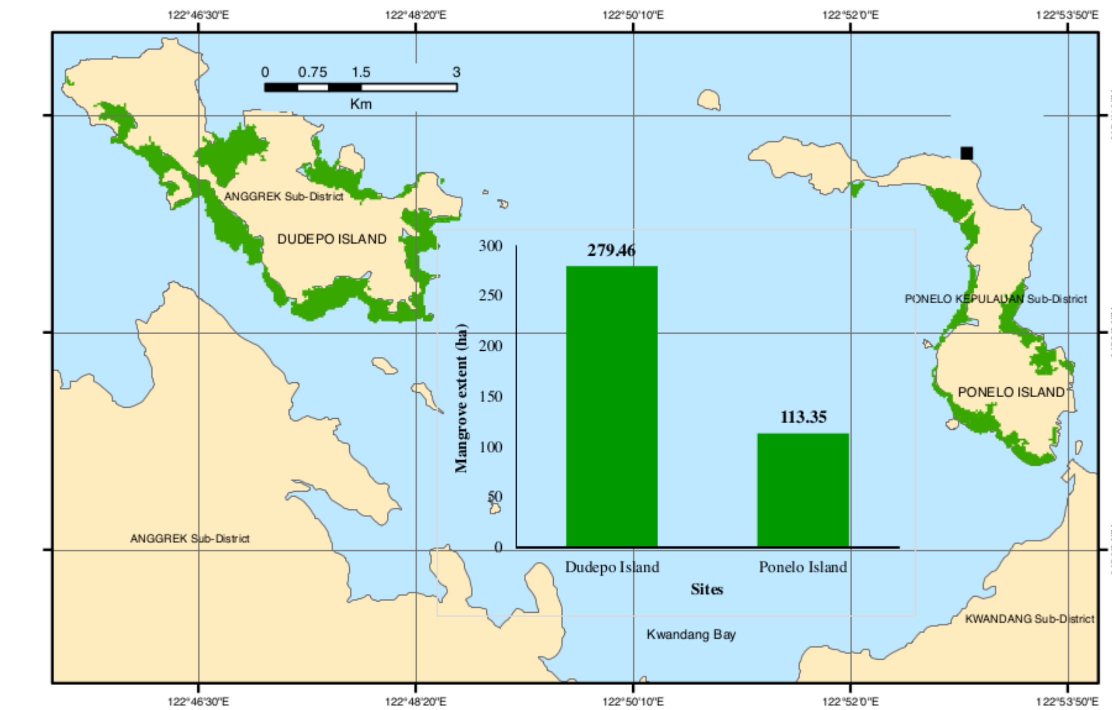

Figure 2. Map of mangrove extent and distribution areas in Dudepo and Ponelo Islands, North Gorontalo District, Indonesia from the image of Landsat-8 OLI analyzed with mixed method of supervised classification and segmentation technique of composite band RGB 654.

Table 2. Composition of true mangrove species recorded in Dudepo and Ponelo Islands, North Gorontalo District, Indonesia

Family	Genus	Species	Dudepo			Ponelo			Status in IUCN *Redlist*
			Tr	Sap	Seed	Tr	Sap	Seed	
Myrsinaceae	*Aegiceras*	*A. floridum* Roem. & Schult *)	+						Nt
Avicenniaceae	*Avicennia*	*A. alba* Blume *)				+		+	Lc
		A. lanata Ridley **)	+		+				Vu
Rhizophoraceae	*Bruguiera*	*B. gymnorhiza* (L.) Lam. *)	+		+				Lc
		B. parviflora Wight & Arn. ex Griffith *)				+			Lc
		B. sexangula (Lour.) Poir. **)				+	+	+	Lc
	Ceriops	*C. decandra* (Griff.) Ding Hou *)	+						Nt
		C. tagal (Perr) C.B. Rob. *)	+		+				Lc
	Rhizophora	*R. apiculata* Blume *)	+		+	+	+	+	Lc
		R. mucronata Lam. *)	+	+	+	+	+	+	Lc
		R. stylosa Griff. *)	+	+	+	+	+	+	Lc
Lythraceae	*Sonneratia*	*S. alba* Sm. *)	+			+	+	+	Lc
		S. caseolaris (L.) Engl. *)				+		+	Lc
		Sum	9	2	6	8	5	7	

Note: *) = species also recorded in eastern coast, **) = species is not recorded in eastern coast, *Tr=Tree, Sap=Sampling, Seed=Seedling*. status of redlist IUCN was referred to http: //www.iucnredlist.org Vu=vulnerable, Nt= near threatened, Lc= least concern

Comparison the species composition based on mangrove structure in Dudepo and Ponelo Islands, generally, showed that more tree species were recorded in Dudepo Island (9 species) than in Ponelo Island (8 species). The proportions of plants at different growth stages (trees-saplings-seedings) in the two islands respectively were 52.94%-11.76%-35.29% in Dudepo Island and 40.00%-25.00%-35.00% in Ponelo Island. In the context of conservation, we recorded 3 important species in Dudepo and Ponelo Islands, namely *Aegiceras floridum* Roem. & Schult and *Avicennia lanata* Ridley in Dudepo Island and *Bruguiera sexangula* (Lour.) Poir in Ponelo Island which are enlisted as near-threatened and vulnerable species in IUCN's red list.

Furthermore, we noted that the current numbers of species in Dudepo and Ponelo Islands were less than those recorded previously in the eastern coast (18 species of 9 genera of 8 families). However, we were getting a total of 21 species so far as the species richness of true mangrove in North Gorontalo District, by adding the current result recorded in both islands with those recorded in the eastern coast. Relatively, this number is higher than that recently reported by Widyastuti et al. (2018) for mangrove in Segara Anakan, Central Java, Indonesia, and also reported by Cañizares and Seronay (2016) for the mangrove richness in Barangay Imelda, Dinagat Island, Philippines. The number of 21 species as biological wealth of true mangrove species in North Gorontalo is almost comparable with that reported by Barik and Chowdhury (2014) for diversity in the Sundarbans Delta, West Bengal, Eastern India, and also that reported by Wouthuyzen and Ahmad (2018) in the Lease Islands (Saparua and Nusalaut Islands), Maluku Province, Indonesia.

Geographically, Maluku and Gorontalo in Sulawesi Island are parts of the same island group located in Wallacea in the center part and eastern area of the Indonesian archipelago. We argue, then, if this region is a high-diversity habitat for mangrove in Indonesia, though, more detailed information of this is needed to confirm it.

Mangrove structure

Comparison between the density of all mangrove plants, and diameter and basal of trees in Dudepo and Ponelo Island are presented in Table 3. While the mean tree density in Dudepo Island was higher (2133 ± 329.78 individuals.ha^{-1}), the mean density of seedlings was higher in Ponelo Island (2963 ± 443.22 individuals.ha^{-1}). The lower sapling density than that of seedlings in both islands was an interesting record. It seems there were factors controlling mangrove seedling survival to the sapling stage in both islands which we have not understood yet. Therefore, we suggest that the critical step in mangrove maturity occurs between the seedling and sapling stages.

Additionally, Koch (1997) proposed soil salinity, aeration, and resource availability may all be important determinants of mangrove seedling development to the sapling stage. By investigating abiotic factors influencing seedling development into sapling stage of *Rhizophora mangle* L. in South Florida, then, he concluded that low salinity stress, high light availability, and soil fertility were presumably the dominant factors controlling *R. mangle* seedling development to the sapling stage (height > 85 cm), and it was also hypothesized that soil anoxia was an important stressor in lagoonal-bay estuaries and marsh-mangrove ecotones with minimal tidal exchange. In the current research, the abiotic factors we measured included those related to mangrove growth, nevertheless it is misleading to conclude that those to be the factors influencing the phenomenon in both islands. More detailed and focused research related to this phenomenon is needed.

In spite of that confusing phenomenon, by comparing diameter and basal area of trees, we recorded the bigger mean diameter and basal area of trees in Dudepo Island than in Ponelo Island. The biggest diameter and basal area (29.26 ± 15.46 cm and 200.66 ± 3.57 m^{2}ha^{-1}) and also the highest tree density (2333 ± 91.72 individuals.ha^{-1}) were recorded in transects in Hamlet of Upo in Dudepo Island (ST2), which had relatively lower water salinity and temperature than other stations (Table 1).

Species ranks based on their importance value (IV) in Dudepo and Ponelo Islands are presented in Table 4. Based on IV, we found that *Rhizophora stylosa* Griff and *R. mucronata* Lam, respectively, were the dominant and codominant species in both islands. Importance Value Index (IVI) states the role of a plant species in the community. Theoretically, the greater the IVI of a species, the greater the role of the species in the community. If the IVIs are evenly distributed across all species measured, the community has high evennes index which lead to high diversity index. By applying certain limits for IVI, we can assume the diversity index from the number of species filtered at the limit. For communities having similar species richness the lower the number of species filtered at the limit, the lower the diversity index. Applying the limit value of 10% of species IVI, we got lower number of species in Dudepo Island (6 species with IVI range of 11.14-114.87%) than in Ponelo Island (7 species with IVI range of 13.29-82.18%), which indicated the higher mangrove species diversity index in Ponelo Island than in Dudepo Island. To confirm this, then diversity and dominance indexes were calculated.

Table 3. Comparison of mangrove structure among transects on Dudepo and Ponelo Islands.

Island	Code of Transects	Trees (ha^{-1})	No. of Species	Saplings. (ha^{-1})	No. of Species	Seedlings (ha^{-1})	No. of Species	Diameter (cm)*	Basal Area (m^{2}ha^{-1})*
Dudepo	ST1	2167 ± 104.1	3	0 ± 0	-	1267 ± -	1	17.52 ± 4.95	56.38 ± 0.51
	ST2	2333 ± 91.72	6	0 ± 0	-	1533 ± -	4	29.26 ± 15.46	200.66 ± 3.57
	ST3	2000 ± 134.35	3	133 ± 11.6	1	1533 ± 11.6	2	14.09 ± 3.39	34.65 ± 0.27
	ST4	2033 ± 100.94	3	100 ± 9.18	2	1367 ± 9.18	3	15.9 ± 4.59	45.19 ± 0.45
	Mean	2133 ± 329.78		58 ± 13.48		1425 ± 113.96		19.73 ± 10.65	84.22 ± 67.67
Ponelo	ST5	2217 ± 53.21	6	67 ± 2.8	2	3017 ± 87.22	5	19.45 ± 10.7	89.06 ± 0.98
	ST6	2200 ± 106.94	4	33 ± 2.01	1	3000 ± 82.17	4	16.91 ± 5.2	55.72 ± 0.5
	ST7	2000 ± 94.44	4	100 ± 4.59	1	2933 ± 73.92	4	16.73 ± 7.04	55.19 ± 0.68
	ST8	2033 ± 107.06	5	67 ± 2.92	2	4267 ± 126.51	5	17.22 ± 6.49	55.84 ± 0.64
	ST9	2025 ± 68.77	6	125 ± 3.9	4	1900 ± 55.07	6	14.87 ± 6.53	44.53 ± 0.44
	Mean	2111 ± 234.28		79 ± 14.51		2963 ± 443.22		17.04 ± 1.46	60.07 ± 15.12

Note: * diameter and *basal area* analyzed on trees category only.

Table 4. Comparison of importance value index (IVI) of species and their rank in Dudepo and Ponelo Islands.

Species	Diameter (cm)	Basal area (m^2ha^{-1})	Density (ha-1)	Frequency	IVI	Rank
Dudepo Island						
R. stylosa Griff.	15.81 ± 4.69	22.59 ± 0.11	1025 ± 3.51	1	114.87	1
R. mucronata Lam.	16.72 ± 5.02	14.64 ± 0.13	600 ± 3.34	0.5	65.5	2
A. lanata Ridley **)	32.55 ± 16.67	24.51 ± 1.04	233 ± 2.79	0.33	53.38	3
S. alba Sm.	37.04 ± 14.85	13.55 ± 0.92	108 ± 2.94	0.17	27.83	4
R. apiculata Blume	17.83 ± 3.91	1.75 ± 0.1	67 ± 1.73	0.17	11.86	5
B. gymnorrhiza (L.) Lam.	39.73 ± 20.75	5.26 ± 1.2	33 ± 1.73	0.08	11.14	6
C. tagal (Perr) C.B. Rob. *)	20.19 ± 3.93	1.38 ± 0.11	42 ± 2	0.08	6.93	7
C. decandra (Griff.) Ding Hou	15.92 ± 0.64	0.33 ± 0.01	17 ± 1	0.08	4.51	8
A. floridum Roem. & Schult *)	17.83 ± 0	0.21 ± -	8 ± -	0.08	3.97	9
Ponelo Island						
R. stylosa Griff.	15.05 ± 6.18	14.43 ± 0.08	647 ± 16.08	0.68	82.18	1
R. mucronata Lam.	16.16 ± 6.19	15.97 ± 0.1	647 ± 18.18	0.53	77.92	2
S. alba Sm.	24.84 ± 13.74	18.65 ± 0.44	289 ± 13.29	0.42	60.71	3
A. alba Blume	20.02 ± 6.02	7.23 ± 0.11	211 ± 16.64	0.21	30.19	4
R. apiculata Blume	14.7 ± 4.43	2.53 ± 0.05	132 ± 15.89	0.16	16.87	5
B. sexangula (Lour.) Poir.	15.53 ± 6.1	1.84 ± 0.08	79 ± 10.77	0.16	13.29	6
B. parviflora Wight & Arn. ex Griffith	17.69 ± 5.5	1.84 ± 0.09	68 ± 10.11	0.16	12.8	7
S. caseolaris (L.) Engl.	20.79 ± 5.06	1.32 ± 0.1	37 ± 12.89	0.05	6.04	8

Note: *) enlisted as near-threatened (NT) species, while **) was more critical with vulnerable status (Vu) globally in IUCN's red list

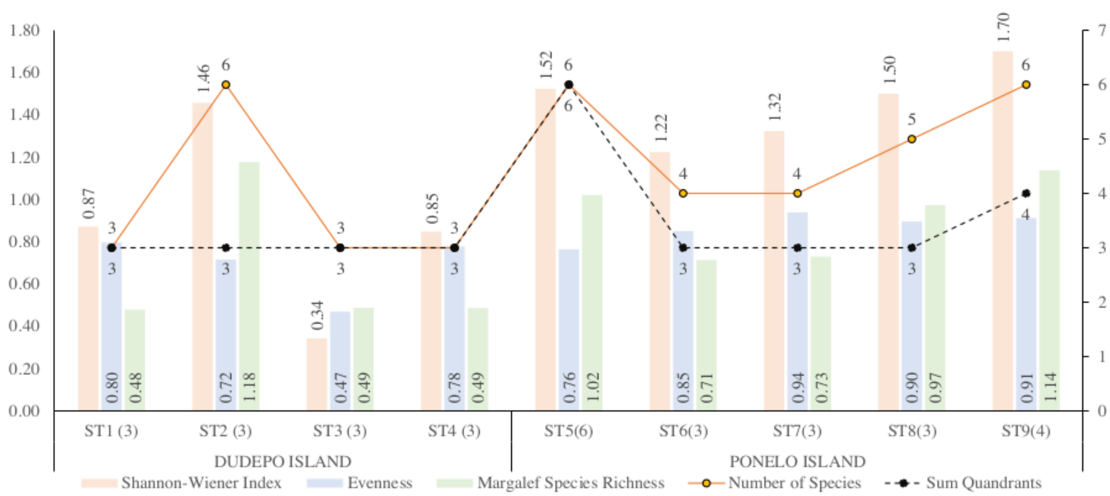

Figure 3. Comparison of Shannon-Wiener index, Margalef species richness idex, and evenness of tree category among transects in Dudepo and Ponelo Island

The indexes of species diversity, species richness and evenness of mangrove trees in all stations

The Shannon Index (H), the Margalef's species richness index, and the Buzas and Gibson evenness index for the tree category in all transects are shown in Figure 3.

Shannon-Wiener diversity index of mangrove trees in Dudepo Island ranged from 0.34 (ST3) to 1.46 (ST2) while in Ponelo Island was from 1.22 (ST6)-1.70 (ST9). This result confirmed the view above related to comparison of mangrove diversity index based on IVI of species in both islands. Further analysis then showed that the diversity index in Ponelo Island which was higher than the highest index in Dudepo Island (1.46) was found in transects in ST8 (1.50), ST5 (1.52) and ST9 (1.72). Although Ponelo Island had higher diversity index than Ponelo Island, since the Shannon diversity on both islands was less than 2, collectively, it was categorized into the low mangrove diversity.

When comparing the relationship between quadrat number with the indexes of diversity of Shannon, species richness, and species evenness in all transects employed, we didn't find in both Island the pattern which showed the increasing values of those indexes with the increasing sampling area as argued by Ismaini et al. (2015) for plant diversity they observed in upland regions (Dempo Mountain, South Sumatra).

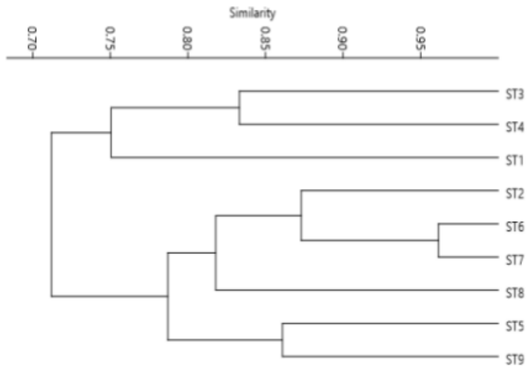

Figure 4. Dendrogram of similarity among transects in Dudepo Island (ST1, ST2, ST3, and ST4) and Ponelo Island (ST5, ST6, ST7, ST8, and ST9).

Multivariate clustering of mangrove

The Bray-Curtis similarity index was used to cluster the transects of mangroves in Dudepo and Ponelo Island. The mangrove variables compared were the indexes of Shannon diversity, the species richness, the Margalef evenness, number of species and quadrats in each transect. The similarity dendrogram among transects in both islands is shown in Figure 4. In this figure, it was known that both islands had similarity of 0.75. Both islands were similar on the lower value, about 0.72. Furthermore, the high dissimilarity of mangrove in Dudepo Island from Ponelo Island were found in ST1, ST3 and ST4. Transects in station of hamlet Upo (ST2) in Dudepo Island, in another side, was more similar to those in Dudepo Island with a similarity value of about 0.78.

With these results, then we concluded that while the mangrove in Dudepo Island was important by the occurrence of important species of IUCN's red list for conservation and also by the bigger diameter of trees, the true mangrove in Ponelo Island was more important by the higher diversity index and better regeneration.

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Comparison of true mangrove stands in Dudepo and Ponelo Islands, North Gorontalo District, Indonesia

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