Community structure of mangrove in Mantehage Island and Paniki Island, North Sulawesi, Indonesia

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Abstract. The determination of mangrove community structure was conducted in Mantehage Island and Paniki Island, North Sulawesi, Indonesia. The continous quadrant method was used. This method uses a 10x10 m quadrant as the observation base, an auxiliary line set cut (perpendicular to the coastline) on one part of the mangrove ecosystem as an observation track. A total of 8 different species of mangroves were identified in the study area belonging to Malpighiales (Rhizophoraceae), Myrtales (Lythraceae, Combretaceae) and Sapindales (Meliaceae). The most abundant mangrove species across the thirteen stations is *Ceriops tagal* with a density of 3,020 individuals per hectare. Species richness index, diversity index, evenness index and dominance index were calculated to determine the diversity of mangroves along the study area. Station 3 obtained the highest species richness and station 6 obtained the lowest species richness. Station 2 recorded the highest diversity and station 6 recorded the lowest diversity. Evenness index was highest at station 1, while the lowest was at station 3. The dominance index was the highest at station 6, while the lowest at station 2. The thirteen sampling stations are divided into 5 groups based on the abundance of 8 species of mangroves. The 5 groups are due to density of mangrove species, type of sediment, and coastal community activities.
Key Words: species density, richness, diversity, evenness, dominance, clustering.

Introduction. Mangroves are plants that live in tidal areas dominated by several species of trees that are capable of growing and developing in areas that have muddy substrates and are able to withstand the change of salinity. Mangrove ecosystem is a special type of tropical ecosystem found almost all along the beach or river estuary that is influenced by the tides of the sea water. Alongi (2008) described mangroves that are commonly found along the tropical and subtropical regions of the world. According to Giri et al (2011), mangroves are tropical and subtropical marine plants that used to cover up to 75% of tropical coastlines. Giri et al (2014) mentioned that mangrove forests are distributed in the inter-tidal zone along the coast in most of tropical and sub-tropical regions. Lugo (2002) described this ecosystem as occurring mainly in sheltered areas such as estuaries, bays and lagoons, and is considered an open system. Blasco & Aizpuru (2002), Dahdouh-Guebas et al (2005) and Duke et al (2007) mentioned that mangrove forests provide valuable ecosystems with significant production potentials. Mangroves also play an important role in managing coastal and marine ecosystems. Nagelkerken et al (2008) described mangrove ecosystem as being one of the most productive ecosystems in the subtropical and tropical coastal areas. Kusmana (2003) divided the mangrove forest function into three aspects, namely: (a) physical function, which can protect the environment of the influence of oceanography (tides, currents, hurricanes, and waves), controlling abrasion and preventing intrusion of sea water to land; (b) biological function, very related to fisheries such as nursery ground, feeding ground, and spawning ground of several types of fish, shrimp and is the supplier of elements – the main nutrients in beaches, especially seagrass areas and coral reefs; and (c) economic functions, as a source of first-class wood, pulp, paper materials, chips, and charcoal.

Dahuri et al (2004) explained that in Indonesia there are at least 202 species of mangrove plants, including 89 species of trees, 5 species of palms, 19 species of climbers, 44 species of soil herbs, 44 species of epiphytes and one species of ferns. From the 202 species of mangroves, 43 species are true mangroves.

The mangrove area in Indonesia, based on the image data of 2006-2009, is 3.244 million ha (Bakosurtanal 2009). The rate of mangrove deforestation in Indonesia is reported at 0.05 million ha per year (Ministry of Forestry of the Republic of Indonesia 2014). The reduction of mangrove forests in Indonesia is caused by several factors, namely: land conversion for other provisions, namely farms, settlements, plantations, agriculture, exploitation of mangrove wood for firewood, building materials etc. (Djamaluddin 2018a).

Bunaken National Park has small islands, namely Bunaken Island, Manado Tua Island, Mantehage Island and Nain Island. The total area of mangrove in the four small islands is 977.630 ha. The total area of mangrove especially in Mantehage Island is 893.800 ha. There are eight species of mangrove identified in this island, namely: *Rhizophora mucronata, Rhizophora apiculata*, *Rhizophora stylosa*, *Bruguiera gymnorrhiza*, *Bruguiera cylindrica*, *Ceriops tagal*, *Sonneratia alba*, and *Lumnitzera littorea* (Schaduw 2012). Mantehage Island is one of the islands located in the Wori Subdistrict of North Minahasa Regency, it stretches over 18.56 km^2 and is surrounded by mangrove forests.

This recent study was conducted to determine the species composition, abundance and diversity of mangrove found in Mantehage Island and Paniki Island, North Sulawesi, Indonesia.

Material and Method

Description of the study sites. This research was conducted from January to May 2019. The research locations were in Mantehage Island, Wori Sub-District, North Minahasa Regency, and North Sulawesi Province. Data collection of seaweeds was carried out in 13 stations. Stations 1, 2, 3 are in Paniki Island, north of Mantehage Island; Stations 4, 5, 6, western part of Mantehage Island; Stations 7, 8, 10, southern part of Mantehage Island; Stations 9, 11, eastern part of Mantehage Island; Stations 12, 13, northern part of Mantehage Island (Figure 1).

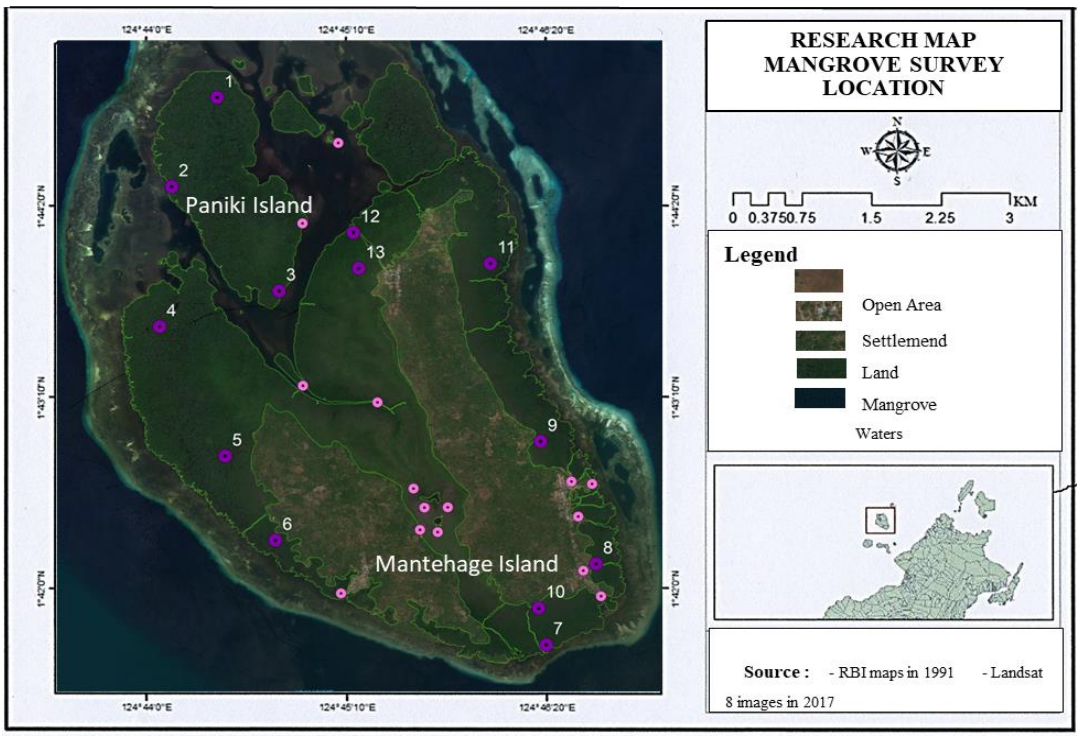

Figure 1. The location of Mantehage Island and Paniki Island, North Sulawesi, Indonesia.

Sampling techniques. This study applied the continous quadrant method (Djamaluddin 2018a). This method uses a 10x10 m quadrant as the observation base, an auxiliary line set cut (perpendicular to the coastline) on one part of the mangrove ecosystem as an observation track (Figure 2).

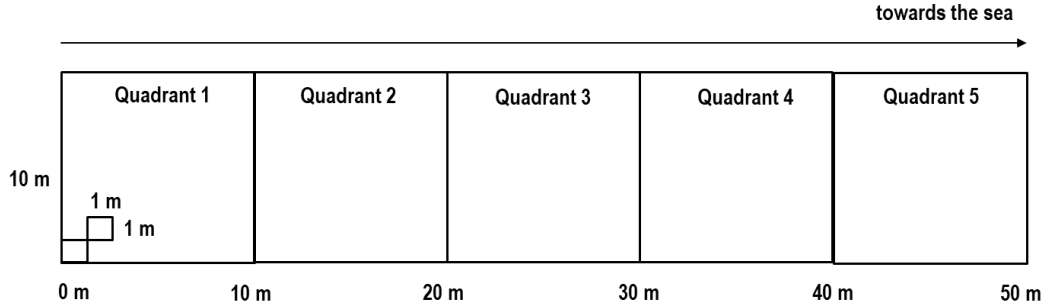

Figure 2. Continous quadrant method.

Sample identification. Identification of mangrove samples was conducted by using the references of Calumpong & Meñes (1997) and Djamaluddin (2018a).

Species density. Species density was calculated using a formula of Krebs (1999):

Species Density = Number of individuals per species / the area of the sample.

Richness index. The richness index (R) was calculated using the formula (Ludwig & Reynolds 1988):

$$R = (S - 1) / \ln (n)$$

Where S is the total number of species in a community.

Diversity index. The Shannon's index (H') was calculated using the formula (Ludwig & Reynolds 1988):

$$H' = -\sum \left(\frac{ni}{N}\right) \ln \sum \left(\frac{ni}{N}\right)$$

Where n*i* is the number of individuals of *i*th species and N is the total number for all *S* species in the community.

Evenness index. The evenness Index (E) was calculated using the formula (Ludwig & Reynolds 1988):

$$E = \frac{H'}{H'max}$$

Where H' is diversity index and H'max is maximum value of H' (i.e. ln(S)).

Dominance index. Dominance Index was calculated using the formula (Odum 1971):

$$D = \sum \left(\frac{ni}{N}\right)^2 = \sum Pi^2$$

Where D is n*i* is the number of individuals of *i*th species and N is the total number for all species.

Correspondence analysis. Correspondence analysis (CA) was used to provide a geometric presentation in which the studied variable was mapped into points in the cross axis. This CA is suitable for analyzing variables and observations that have been

presented in the form of contingency tables or matrices (Lebart et al 1982). The CA application in this study aimed to provide the best presentation simultaneously between species groups (i rows) and station groups (j columns), to get the correct correspondence or relationship between the two variables studied (species and stations). The notation used is:
$k = \sum\sum k_{ij}$ = effective total individuals (total amount);
$f_{ij} = k_{ij}/k$ = relative frequency;
$f_{i.} = \sum f_{ij}$ = relative marginal frequency.

In this case, the distance between 2 species i and i' is given by the formula (distance $\chi 2$):

$$d^2(i,i') = \sum_{j=1}^{p} \frac{1}{f_{.j}} \left(f_{ij}/f_{i.} - f_{i'j}/f_{i'.} \right)^2$$

In the same way, the distance between 2 stations j and j' is given by the formula:

$$d^2(j,j') = \sum_{i=1}^{n} \frac{1}{f_{i.}} \left(f_{ij}/f_{.j} - f_{ij'}/f_{.j'} \right)^2$$

According to Lebart et al (1982), this weighted distance has the advantage of meeting the principle of "equivalence distribution". Another advantage of using distance $\chi 2$ in CA is that variable and observation roles are symmetrical and are not affected by the presence of double absences on distance stability.
Two series of coefficients for each element of the two corresponding groups were calculated to interpret certain axes in the CA. This data display in the two-way contingency table through CA was done using the STATGRAPHICS Centurion packaging program through the correspondence analysis menu selection.

Results and Discussion

Species composition. There were 8 species of mangroves identified from 4 families: Rhizophoraceae, Lythraceae, Combretaceae, Meliaceae (Table 1).

Table 1

Summary of identified mangrove species

No.	*Class*	*Order*	*Family*	*Species*
1	Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora apiculata*
2				*Rhizophora mucronata*
3				*Rhizophora stylosa*
4				*Bruguiera gymnorrhiza*
5				*Ceriops tagal*
6		Myrtales	Lythraceae	*Sonneratia alba*
7			Combretaceae	*Lumnitzera racemosa*
8		Sapindales	Meliaceae	*Xylocarpus mekongensis*

Density parameter. At Station 1 there are 3 species that have a density of 20.00-420.00 with an average density of 196.33 individuals per hectare. The highest density species is *S. alba* with a density of 420.00 individuals per hectare, while the species that has the lowest density is *R. mucronata* with 20.00 individuals per hectare (Figure 3).

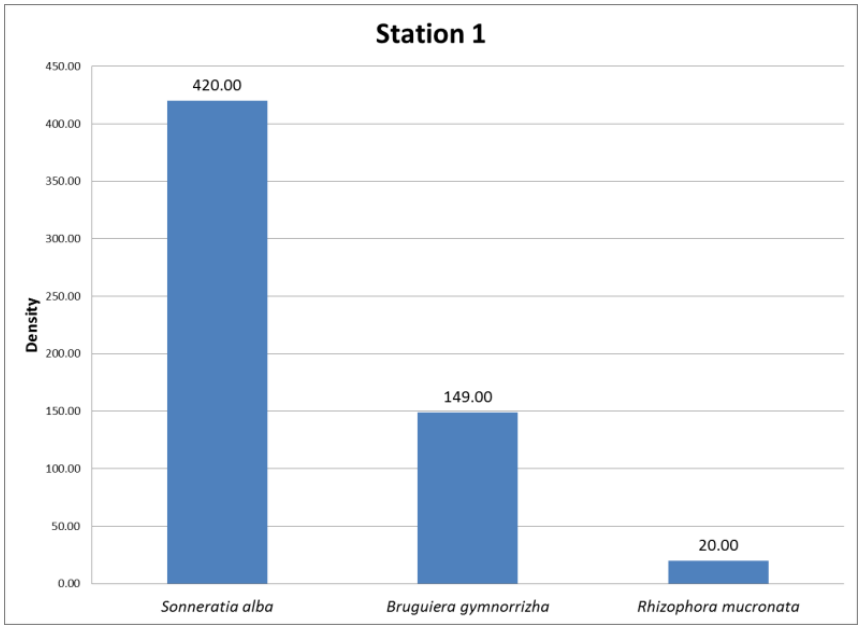

Figure 3. Mangrove density in station 1.

At Station 2 there are 4 species with a density between 40.00-260.00 individuals per hectare with an average density of 165.00 individuals per hectare. The highest density species are *R. mucronata* and *R. apiculata* with 260.00 individuals per hectare, while the species that has the lowest density is *S. alba* with a density of 40.00 individuals per hectare (Figure 4).

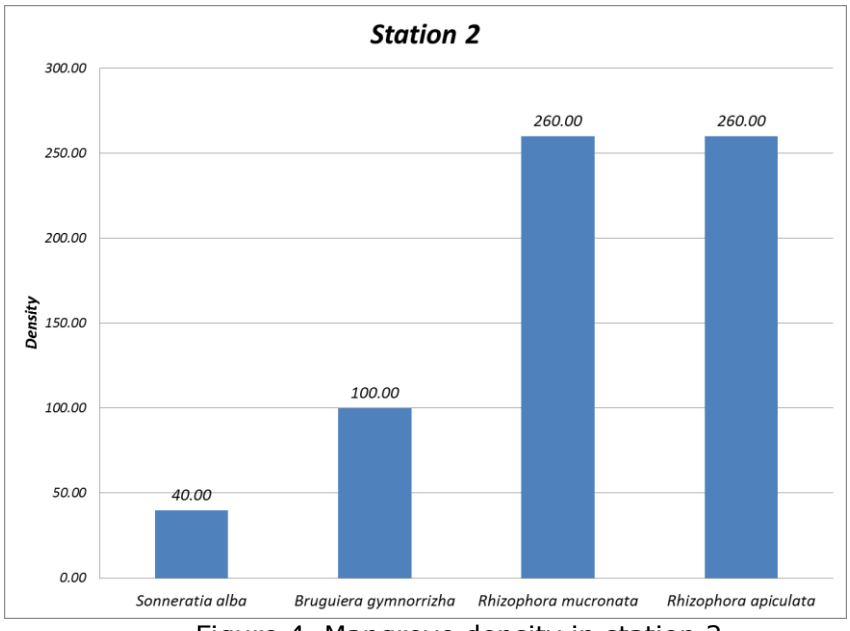

Figure 4. Mangrove density in station 2.

At Station 3 there are 5 species with a density between 20.00-1,360.00 individuals per hectare with an average density of 59.20 individuals per hectare. The species that has the highest density is *R. mucronata* with 1,360.00 individuals per hectare, while the species having the lowest density is *S. alba, B. gymnorrhiza* and *R. stylosa* with a density of 20.00 individuals per hectare (Figure 5).

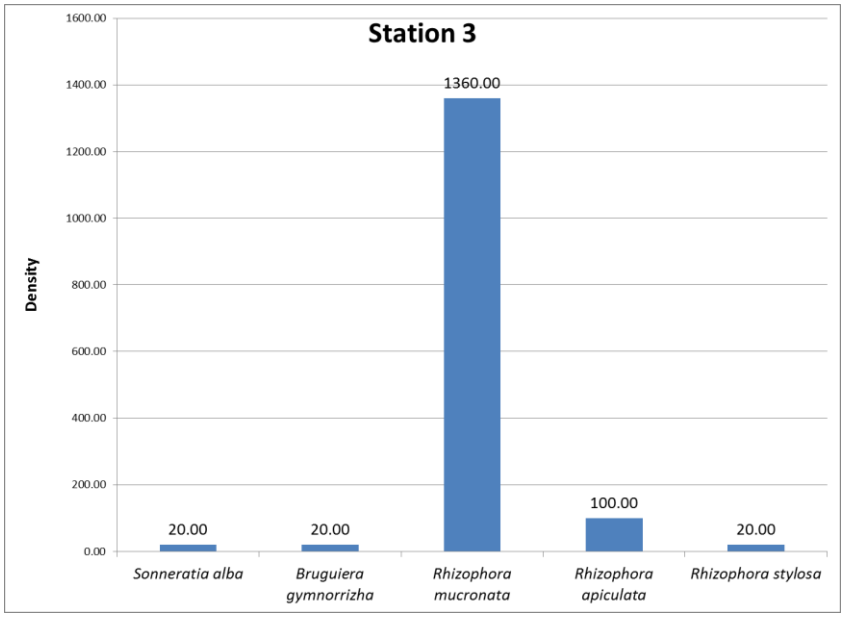

Figure 5. Mangrove density in station 3.

At Station 4 there are 4 species with a density between 20.00-700.00 individuals per hectare with an average density of 260.00 individuals per hectare. The species that has the highest density is *R. mucronata* with 700.00 individuals per hectare, while the species having the lowest density is *R. stylosa* with a density of 20.00 individuals per hectare (Figure 6).

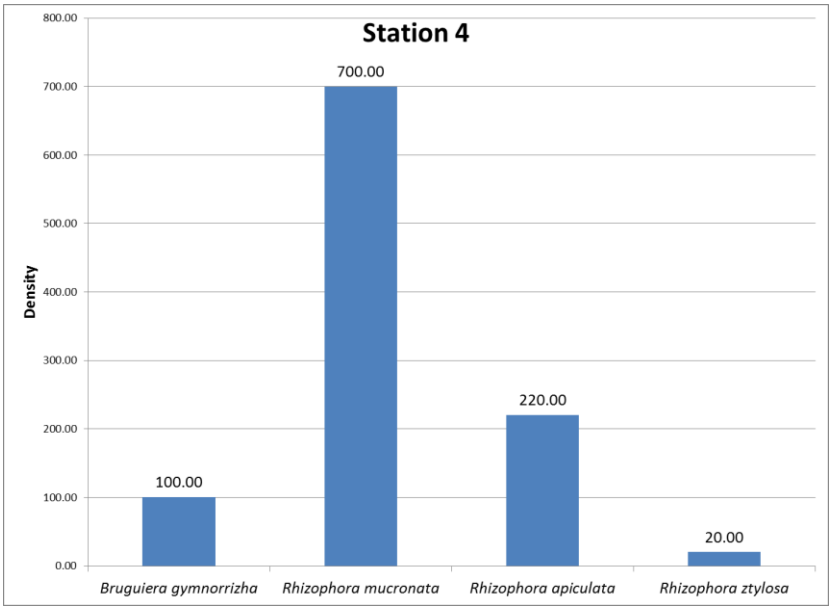

Figure 6. Mangrove density in station 4.

At Station 5 there are 3 species with a density between 20.00-420.00 individuals per hectare with an average density of 193.33 individuals per hectare. The species that has the highest density is *S. alba* with 420.00 individuals per hectare, while the species having the lowest density is *R. mucronata* with a density of 20.00 individuals per hectare (Figure 7).

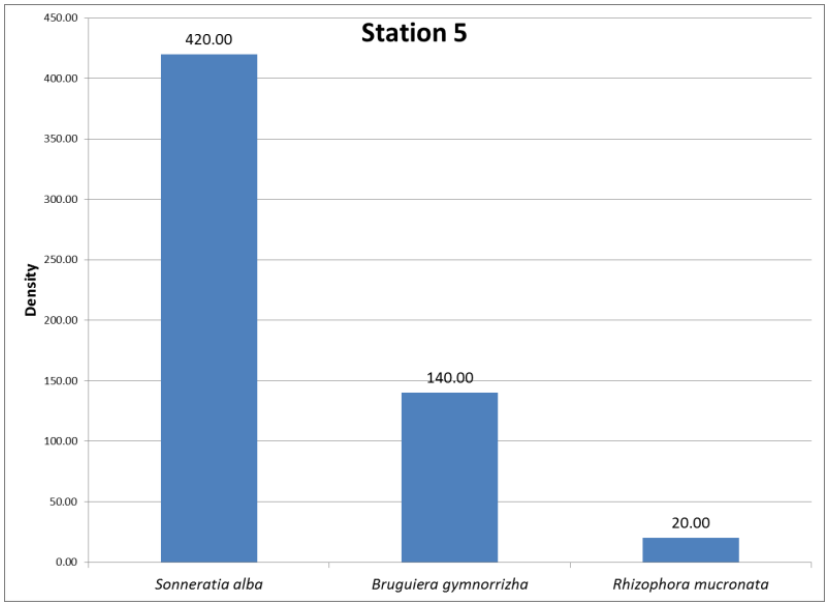

Figure 7. Mangrove density in station 5.

At Station 6 there is only 1 species, *R. apiculata* with a density of 800 individuals per hectare (Figure 8).

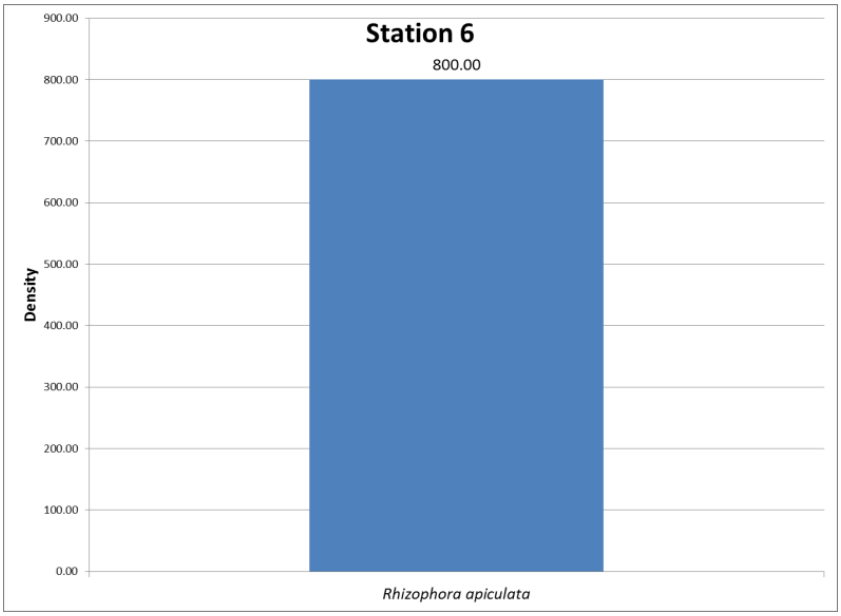

Figure 8. Mangrove density in station 6.

At Station 7 there are 2 species with a density between 40.00-1,420.00 individuals per hectare with an average density of 91.00 individuals per hectare. The species that has the highest density is *R. stylosa* with 1,420.00 individuals per hectare, while the species having the lowest density is *R. mucronata* with a density of 40.00 individuals per hectare (Figure 9).

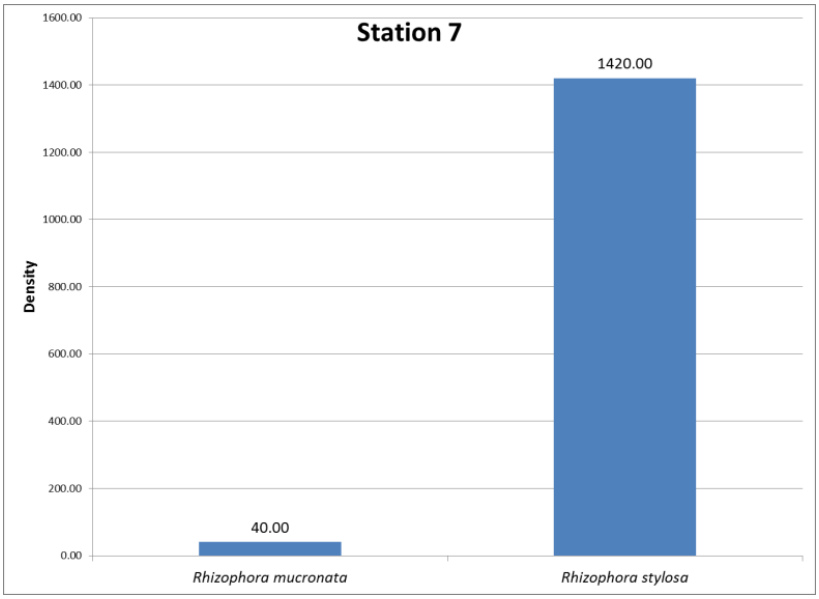

Figure 9. Mangrove density in station 7.

At Station 8 there are 3 species with a density between 20.00-2,480.00 individuals per hectare with an average density of 1,013.33 individuals per hectare. The species that has the highest density is *R. apiculata* with 2,480.00 individuals per hectare, while the species having the lowest density is *C. tagal* with a density of 20.00 individuals per hectare (Figure 10).

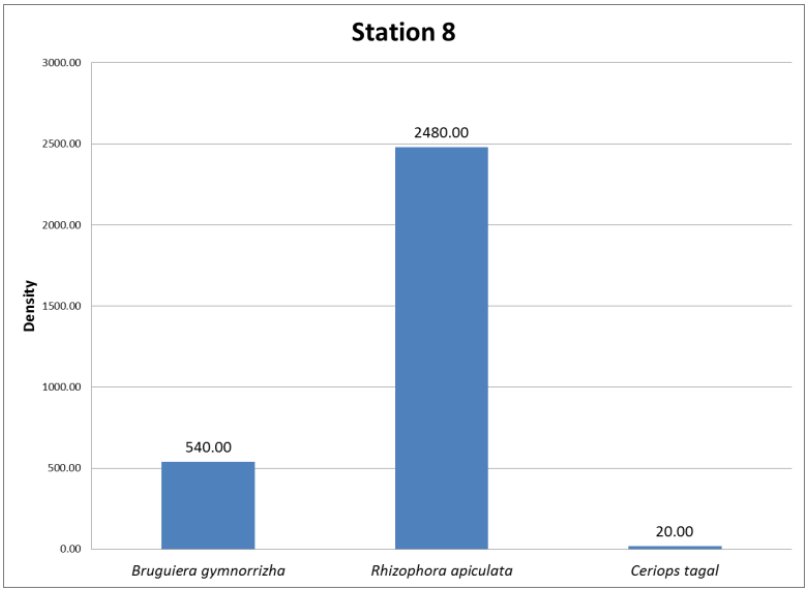

Figure 10. Mangrove density in station 8.

At Station 9 there are 3 species with a density between 40.00-3,020.00 individuals per hectare with an average density of 1,286.67 individuals per hectare. The species that has the highest density is *C. tagal* with 3,020.00 individuals per hectare, while the species having the lowest density is *B. gymnorrhiza* with a density of 40.00 individuals per hectare (Figure 11).

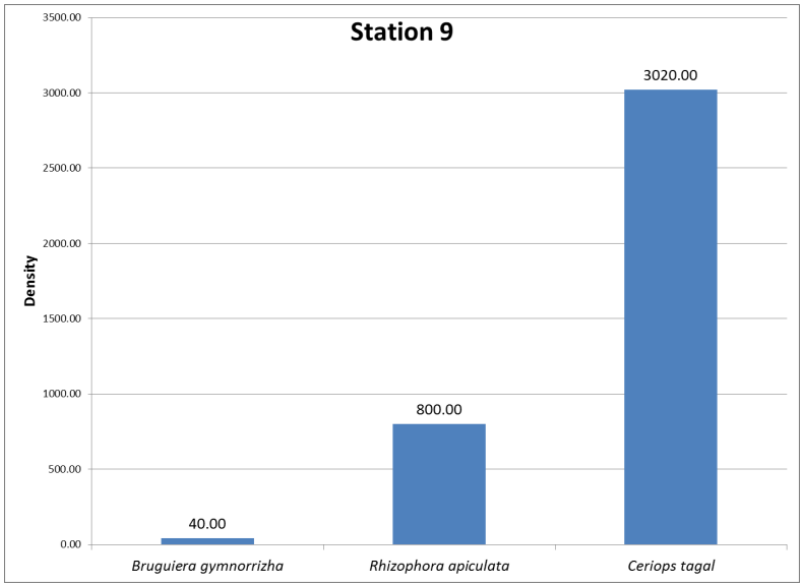

Figure 11. Mangrove density in station 9.

At Station 10 there are 3 species with a density between 80.00-1,040.00 individuals per hectare with an average density of 533.00 individuals per hectare. The species that has the highest density is *R. apiculata* with 1,040.00 individuals per hectare, while the species having the lowest density is *B. gymnorrhiza* with a density of 80.00 individuals per hectare (Figure 12).

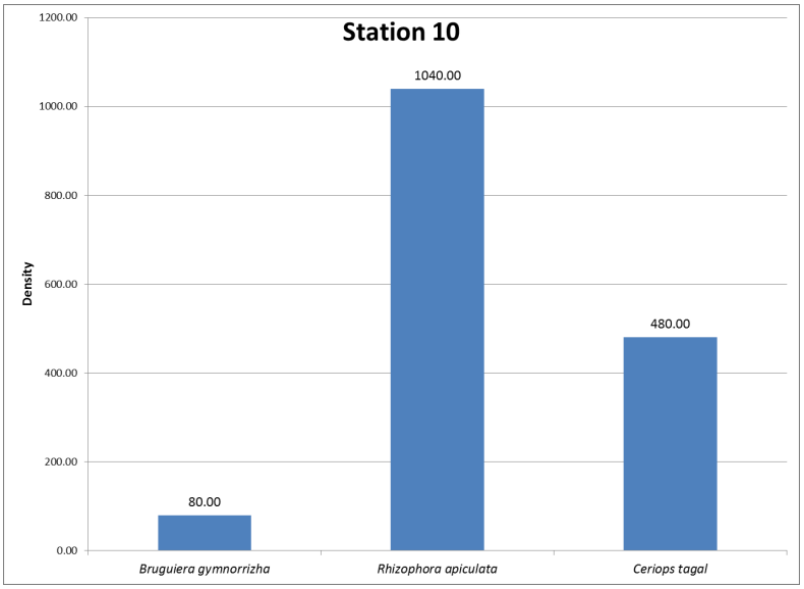

Figure 12. Mangrove density in station 10.

At Station 11 there are 3 species with a density between 20.00-1,640.00 individuals per hectare with an average density of 786.67 individuals per hectare. The species that has the highest density is *R. apiculata* with 1,640.00 individuals per hectare, while the species having the lowest density is *R. stylosa* with a density of 20.00 individuals per hectare (Figure 13).

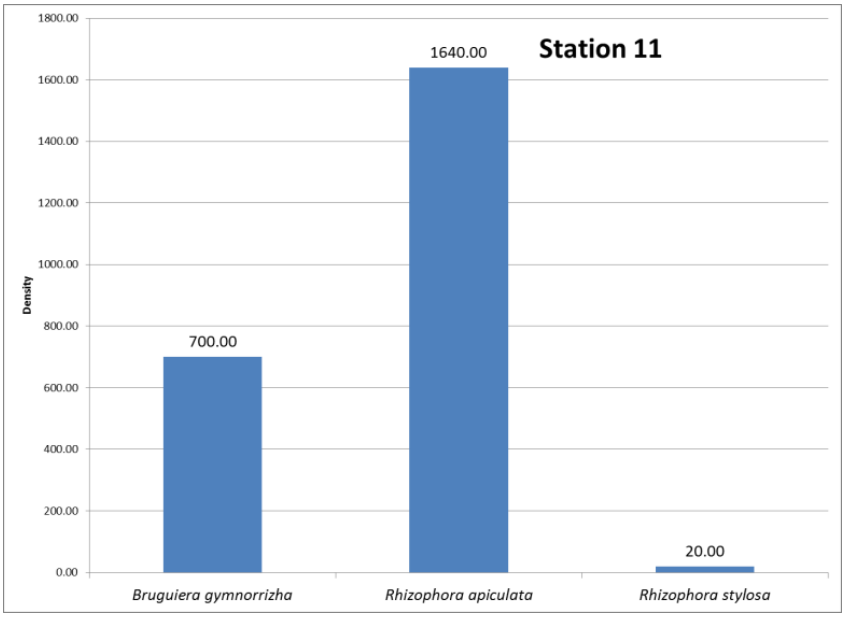

Figure 13. Mangrove density in station 11.

At Station 12 there are 4 species with a density between 40.00-1,160.00 individuals per hectare with an average density of 335.00 individuals per hectare. The species that has the highest density is *R. stylosa* with 1,160.00 individuals per hectare, while the species having the lowest density is *R. mucronata* and *B. gymnorrizha* with a density of 40.00 individuals per hectare (Figure 14).

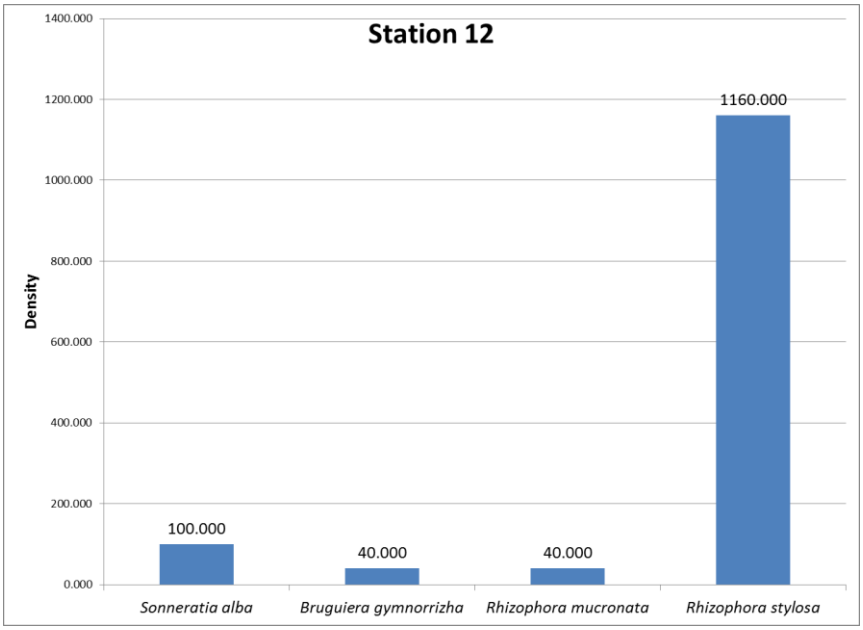

Figure 14. Mangrove density in station 12.

At Station 13 there are 3 species with a density between 40.00-2,180.00 individuals per hectare with an average density of 900 individuals per hectare. The species that has the highest density is *L. racemosa* with 2,180.00 individuals per hectare, while the species having the lowest density is *R. stylosa* with a density of 40.00 individuals per hectare (Figure 15).

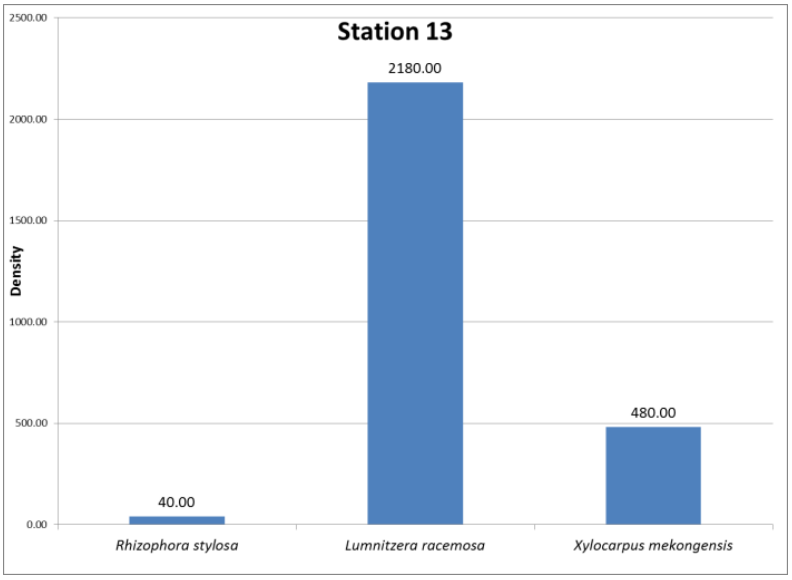

Figure 15. Mangrove density in station 13.

Richness index, Diversity index, Evenness index, Dominance index. Based on the calculation of several ecological indices from seaweeds at each station, the values of the Richness index (R), Diversity index (H´), Evenness index (E), and Dominance Index (D) are shown in Table 2.

Table 2

Value of mangrove community indices

Station	*D*	*H´*	*E*	*R*
1	0.584	0.693	0.631	0.594
2	0.337	1.190	0.858	0.858
3	0.805	0.450	0.279	0.924
4	0.442	0.888	0.808	0.460
5	0.552	0.675	0.614	0.422
6	1.000	0.000	-	0
7	0.947	0.126	0.181	0.233
8	0.697	0.506	0.461	0.398
9	0.665	0.566	0.515	0.380
10	0.515	0.791	0.720	0.456
11	0.872	0.280	0.255	0.447
12	0.757	0.528	0.381	0.713
13	0.684	0.542	0.494	0.408

Based on the results in Table 2, it appears that the highest species richness index value is 0.924 in station 3 and the lowest is 0 in station 6. The diversity index value in these thirteen locations shows that at station 2 the highest diversity value is 1.190, while the lowest was 0 at station 6. Evenness index value was highest, 0.858, at station 2, while the lowest was 0.181 at station 7. The species dominance index value is the highest, 1.000, at station 6, while the lowest, 0.337, is recorded at station 2.

The richness index value shows that the highest species richness is 0.924 at station 3. The lowest value at station 6 is 0.

Overall, 8 mangrove species were found in the thirteen stations, fewer than in Sidangoli, 10 species (Kepel & Marus 2010), Pohuwato Regency, 24 species (Opa & Djamaluddin, 2011), Bunaken National Park, 27 species (Djamaluddin 2018b), but more than in Namano and Waisisil, 3 species (Kepel et al 2012), Bunaken Island, 5 species, and Sarawet, North Minahasa Regency, 5 species (Mangindaan et al 2012), Tumbak, Southeast Minahasa Regency, 7 species and Sondaken, South Minahasa Regency, 6

species (Mangkay et al 2012), Manado Tua Island, 2 species, and Nain Island, 2 species (Schaduw 2012), Bahoi, North Minahasa Regency, 5 species (Dien et al 2016), Dudepo Cape, South Bolaang Mongondow, 7 species (Simbala et al 2017), Tongkaina, Manado, 8 species (Puasa et al 2018), Totok Bay, Southeast Minahasa Regency, 3 species (Rumengan et al 2018), Palaes, North Minahasa Regency, 6 species (Tulenan et al 2018), South Tabulo, Boalemo Regency, 7 species (Husuna et al 2019), Gamtala, West Halmahera Regency, 7 species (Nity et al 2019), and Lansa, North Minahasa Regency, 5 species (Sondak et al 2019).

The difference between the high and low levels of mangrove biodiversity obtained compared to other research results is due to differences in the number of sampling locations, as well as differences in environmental parameters both in coastal topography, type of sediment, and anthropogenic impacts. At the thirteen research stations showed that the area has a sloping beach topography, the substrate is generally mud and sandy mud. In the research location there is also no river flow, however, in some points there are human activities.

The diversity index value in the thirteen stations categorized as low. According to Odum (1971), the greater the value of H´ and E means the community is increasingly diverse.

Evenness index values at thirteen stations range in value from 0.314 to 1.000. This shows that the mangrove community in these thirteen stations is very varied. The station 1, 2, 4, 5, 6, and 10 show that the location of the mangrove community is stable, while station 3, 7, 8, 9, 11, 12, and 13 show that the location of the mangrove community is unstable. This is consistent with the statement of Odum (1971) that a community is said to be stable if the value of the evenness index of a species ranges between 0.6-0.8.

The dominance index value at the thirteen locations is categorized as high in station 3, 6, 7, 8, 9, 11, 12 and 13. This shows that in the eight stations there is dominance of species in the mangrove community. If the dominance index value is close to zero, it means that in the community there is no dominant organism or vice versa if the value approaches one means that in the community there is a dominant organism.

Correspondence analysis. Correspondence analysis (CA) is carried out based on density data (after log (x+1) transformation) in two-way contingency tables, namely 8 rows of species and 13 station columns. Station 1, 2 and 3 with muddy sediment in Paniki Island, station 4, 5, 6, 7, 8, 10, 12, and 13 (northern part, western part and southern part of Mantehage Island) with muddy sediment in Mantehage Island, and 9 and 11 (eastern part of Mantehage Island) with sandy mud sediment.

In this analysis, the total inertia obtained for the 6 axis was 3.0996, consisting of 1.0000 (32.2624%), 0.9320 (30.0684%), 0.4606 (14.8592%), 0.3814 (12.3051%), 0.2512 (8.1040%), and 0.0744 (2.4009%), with a total of 100% (Table 3).

Table 3

Inertia and chi-square decomposition

Dimension	*Singular value*	*Inertia*	*Chi-Square*	*Percentage*	*Cumulative percentage*	*Histogram*
1	1.0000	1.0000	41.0000	32.2624	32.2624	**********
2	0.9654	0.9320	38.2117	62.3308	62.3308	**********
3	0.6787	0.4606	18.8835	77.1900	77.1900	*****
4	0.6176	0.3814	15.6377	89.4951	89.4951	****
5	0.5012	0.2512	10.2989	97.5992	97.5992	***
6	0.2728	0.0744	3.0511	100.0000	100.0000	*
Total		3.0996	127.082			

Figure 16 is a dendrogram that classifies the thirteen sampling stations into 3 groups based on the abundance of 8 species. The three groups are Group I (station 13), Group II (station 1, 7 and 12), and Group III (station 2, 3, 4, 5, 6, 8, 9, 10, 11).

Figure 16 is a dendrogram that classifies the thirteen sampling stations into 3 groups based on the abundance of 8 species. The three groups are Group I (station 13), Group II (station 1, 7 and 12) and Group III (station 2, 3, 4, 5, 6, 8, 9, 10 and 11).

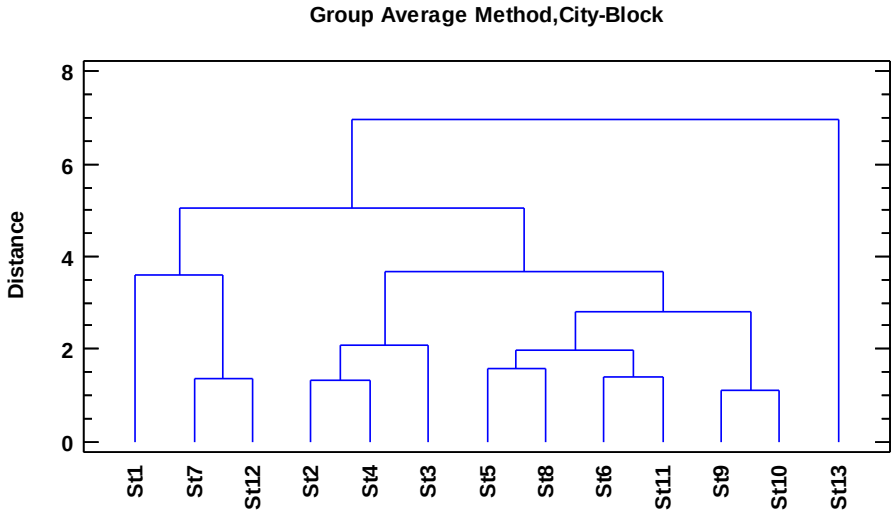

Figure 16. Cluster analysis dendrogram (stations).

Overall, mangroves are grouped into 3 station groups due to the density of mangrove, type of sediment and coastal community activities (seaweed farming, access to village) (Figure 17).

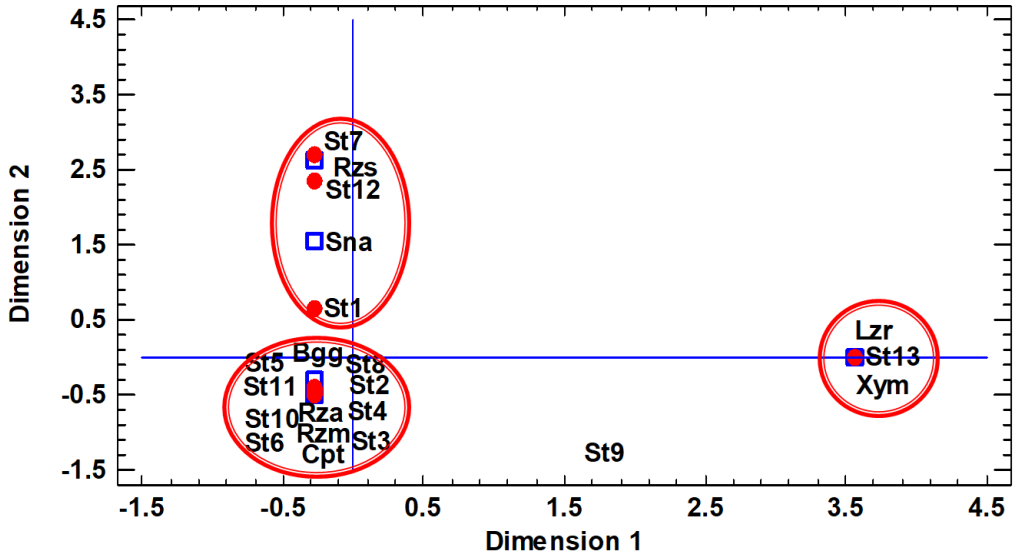

Figure 17. Correspondence map.
Rhizophora apiculata (Rza), *Rhizophora mucronata* (Rzm), *Rhizophora stylosa* (Rzs), *Bruguiera gymnorrhiza* (Bgg), *Ceriops tagal* (Cpt), *Sonneratia alba* (Sna), *Lumnitzera racemosa* (Lzc), *Xylocarpus mekongensis* (Xym).

Apparently, the 3 station groups are related to the high density (>2,000 individuals per hectare) of *L. racemosa*, 2,180.00 individuals per hectare and community activities of Tangkasi village, and low density (<1,000 individuals per hectare) of *X. mekongensis* 480.00 individuals per hectare in station 13 (northern part of Mantehage Island with muddy sediment) (Group I), moderate density (1,000-2,000 individuals per hectare) of *R. stylosa,* respectively 1,420.00 individuals per hectare in station 7 (southern part of Mantehage Island with muddy sediment), and 1,160.00 individuals per hectare in station 12 (northern part of Mantehage Island with muddy sediment), low density of *S. alba,*

420.00 individuals per hectare in station 1 (muddy sediment in Paniki Island) (Group II), low density of *R. mucronata* and *R. apiculata*, respectively 260.00 individuals per hectare in station 2 (muddy sediment in Paniki Island), moderate density of *R. mucronata,* 1,360.00 individuals per hectare in station 3 (muddy sediment in Paniki Island), and low density of *R. mucronata*, 700.00 individuals per hectare in station 4 (western part of Mantehage Island with muddy sediment), low density of *S. alba*, 420.00 individuals per hectare in station 5 (western part of Mantehage Island with muddy sediment), low density of *R. mucronata*, 800 individuals per hectare in station 6 (western part of Mantehage Island with muddy sediment), high density of *R. apiculata*, 2,480.00 individuals per hectare in station 8 (southern part of Mantehage Island with muddy sediment), moderate density of *R. apiculata* respectively 1,040.00 individuals per hectare in station 10 (western part of Mantehage Island with muddy sediment), and of 1,640.00 individuals per hectare in station 11 (eastern part of Mantehage Island with sandy mud sediment), and high density of *C. tagal*, 3,020.00 individuals per hectare in station 9 (eastern part of Mantehage Island with sandy mud sediment) (Group III).

Conclusions. The results of the mangroves inventory in Mantehage Island and Paniki Island totaled 8 species. The mangroves community structure shows that it is unstable with low values of diversity, and evenness, while the value of domination and species richness is high. The highest density of the mangroves found in station 9 is *C. tagal*. In general, mangroves species richness is found in the moderate category. Overall, mangroves are grouped into 3 station groups that are due to the density of mangrove species, type of sediment, and coastal community activities.

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