Community structure of mangrove in Jeflio Island, Sorong Regency, West Papua, Indonesia

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Abstract. Mangrove forests in Jeflio Island provide livelihoods for the local community with ecological, economical, and social benefits. This study aimed to determine the structure of mangrove community and its condition in Jeflio Bay. It measured the mangrove's density, mangrove's frequency, mangrove's dominance, importance value index, diversity index, evenness index, and dominance index. Water quality parameters include pH, water temperature, and salinity. The Line-transect Plot method was used to determine the bioecological conditions of mangroves. There were four species of mangroves, namely *Avicennia alba, Rhizophora mucronata, Bruguiera gymnorrhiza*, and *Xylocarpus granatum*. The total density value of mangroves at station 1 was 1,600 ind ha^{-1}, at station 2 was 1,966 ind ha^{-1}, at station 3 was 2,000 ind ha^{-1}, and at station 4 was 1,966 ind ha^{-1}. The density levels of mangrove vegetation in Jeflio Island at station 1, station 2, station 3, and station 4 was considered high as they were ≥ 1,500 ind ha^{-1}. *B. gymnorrhiza* had the highest density of 1,000 ind ha^{-1} at station 4. The highest frequencies of mangrove vegetation were found at stations 3 and 4 for *R. mucronata* relatively at 42.86% and *B. gymnorrhiza* at 42.86%. *R. mucronata* was the most dominant at station 3 relatively at 72.76%. The highest importance value index was found at station 3 with 160.6% of *R. mucronata*. The diversity indexes at stations 1, 2, 3, and 4 were each classified moderate because they were in the range of $0 < H' < 3$. The evenness index at station 1 was 0.94, station 2 was 0.95, station 3 was 0.91, and station 4 was 0.91. This showed that the evenness indexed were high. The average dominance index of mangrove vegetation in Jeflio Island was 0.4 indicating low dominance. Water quality parameters obtained the highest pH of 7.38 at station 3, the highest salinity of 28.33 ‰ at station 2, and the highest water temperature of 30.0°C at station 3. In total, there were 2 clusters where stations 3 and 4 were in one cluster, and stations 1 and 2 were in another cluster based on the density and frequency of mangroves as well as water quality parameters such as water temperature, pH, and salinity. Variations in mangrove density and frequency, as well as water quality parameters such as water temperature, pH, salinity at stations 1 and 2 were higher than those at stations 3 and 4.

Keywords: density, frequency, dominance, important value index, PCA analysis.

Introduction. A coastal area is a border area between land and sea where interaction between people and living things occurs. Different ecosystem characteristics e.g., coral reef, mangrove forests, seagrass beds, sandy beaches, and others need to be stable and thus guarded (Cahyanto & Kuraesin 2013). Mangrove forests are productive ecosystems and have complex functions, such as physical, biological, and socio-economic functions. Mangrove forests are qualitatively productive because they act as natural habitats (spawning, breeding, and food serving) for various types of fish, shrimp, and crab, and as sources of germplasm and genetics. Moreover, mangrove forests provide valuable ecosystem benefits for coastal communities, tourist attractions, nature conservation, education, and research (Eddy et al 2016).

The composition and structure of mangrove forest vegetation varies, depending on geophysical conditions, geography, hydrology, biogeography, climate, soil, and other environmental conditions (Latuconsina 2018). The difference between high and low levels of mangrove biodiversity is due to sampling location, as well as differences in environmental parameters both in the coastal topography, sediment types, and anthropogenic impacts (Opa et al 2019). Water quality such as salinity, water pH, water temperature, dissolved oxygen, BOD and turbidity indicate significant seasonal variation (Toriman et al 2013).

Mangrove forests also provide valuable ecosystem services to coastal communities, tourist attractions, nature conservation, education and research (Eddy et al 2016). The increase in the population around the mangrove forest causes the necessity of life to increase and as a result the use that occurs exceeds the acceptable limit of change and eventually an imbalance or damage occurs in the mangrove forest ecosystem (Romy 2018). Although all efforts have been made to reduce forest damage, many problems are still found. The productivity of mangrove forests has decreased significantly. This decline differs from habitat to habitat, but is generally related directly or indirectly to human activities (Dhond 2012). The role of mangroves in mitigation of global warming is also important (Senoaji & Hidayat 2016). Understanding the structure of mangrove forests is ecologically important, as it provides useful information for sustainable management and conservation (Sarno et al 2015).

The size of the mangrove area in West Papua is 499,373.32 hectares which are divided into 466,671.72 hectares (93.32%) for non-critical mangroves and 32,701.6 hectares (6.68%) for critical mangroves (Murtiningsih 2020). Problems in mangrove management include illegal logging, limited efforts to rehabilitate mangrove conservation or protected areas, lack of awareness and understanding of mangroves and mangrove ecosystem, absence of integration between economic interests and conservation of mangrove areas or ecosystems, lack of coordination of parties related to mangrove management, absence of coordination forums such as the Provincial Mangrove Working Group (Murtiningsih 2020).

The mangrove forests in Jeflio Island provide livelihoods with ecological, economical, and social benefits for the local community. This study aimed to determine the structure of the mangrove vegetation in Jeflio Island and the existing condition of mangrove vegetation in the island.

Material and Method

Research site. This study was carried out in Jeflio Island, Sorong regency, West Papua province from March to April 2020 (Figure 1).

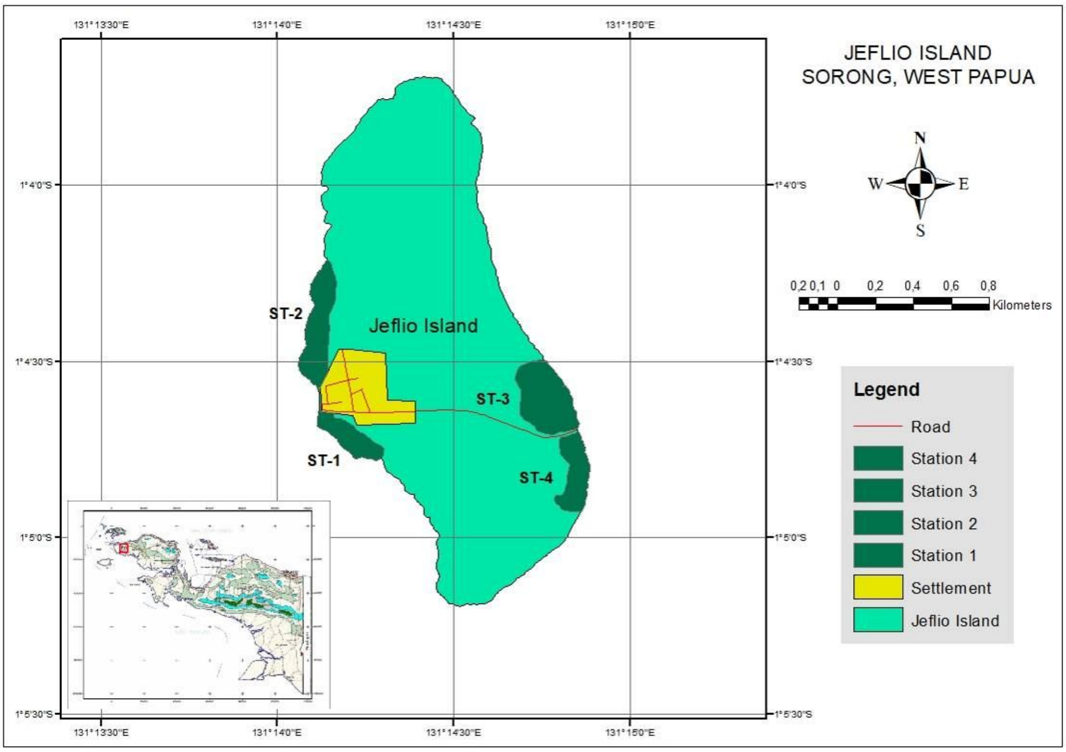

Figure 1. Research site in Jeflio Island, West Papua, Indonesia.

The collected data were mangrove's density, mangrove's frequency, mangrove's dominance, importance value index, diversity index, evenness index, and dominance index. Water quality parameters measured were pH, water temperature, and salinity. To determine the bioecological conditions of mangroves, the Line-Transect Plot method was utilized. Sampling of mangrove ecosystem with a plot sampling approach was done in a line drawn across the ecosystem areas (Decree of Indonesian Ministry of Environment No. 201 of 2004). The measurement mechanism for mangrove bioecological data was in several steps: 1) the research location was selected based on representatives of the existing of mangrove vegetation; 2) the research location was divided into 4 observation stations: station 1 for existing mangrove tourism, station 2 for mangrove areas near residential areas, stations 3 and 4 for mangrove areas on the left and right of the main road to Jeflio Island, respectively; 3) at each observation station, a line transect was determined from the sea to the land (perpendicular to the coastline) along with the mangrove forest zones; 4) along the line transect, 3 plots were placed randomly in the form of squares with a size of 10 x 10 meters; 5) in each specified sample plot, each type of mangrove plant was identified, and then the number of each type and the size of the trunk circle of each mangrove tree at breast height (more than 4-cm tree diameter with a height of more than 1 m); 6) in each sample plot, the water pH, salinity, and temperature were measured.

Data analysis. To find out the structure of the mangrove vegetation, the biological parameters measured were mangrove density, relative density, frequency, relative frequency, dominance, relative dominance, and important value index (Legendre & Legendre 2012). They were measured using the following formula.

$$\text{Population density (ind ha-1)} = \frac{\text{Number of individuals}}{\text{Total sampled areas}}$$

$$\text{Frequency} = \frac{\text{Number of plots in which a species occurs}}{\text{Total sampled plots}}$$

$$\text{Dominance} = \frac{\text{Total basal areas of each species tree from all plots}}{\text{Total areas of all measured plots}}$$

$$\text{Relative density (\%)} = \frac{\text{Number of individuals in each species}}{\text{Total individuals of all species}}$$

$$\text{Relative dominance (\%)} = \frac{\text{Total basal areas of species}}{\text{Basal area of all species}}$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency of a species}}{\text{Several frequencies for all species}}$$

Importance value index (IVI) = Relative density + Relative dominance + Relative frequency

Diversity index. The Shannon's diversity index (H') is calculated using this following formula (Ludwig & Reynolds 1988):

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

Notes: ni is the number of individuals in each species; N is the total number of all individuals.
Diversity index criteria are divided into 3 (three) categories: H' < 1 = low species diversity; 1 < H' < 3 = moderate species diversity; H' > 3 = high species diversity.

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

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

Notes: H' is diversity index, H'max is ln S, and S is the number of species.
E = 0-1; E approaching 0 means the distribution of individuals between species is not even or there are dominant types; E approaching 1 means the distribution of individuals between species is even.

Dominance index. Dominance index is calculated using the following formula (Odum 1971):

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

Notes: Pi= ni / N, ni is the number of individuals in each species, and N is the total number of all species.
The dominance index ranges from 0 to 1. The smaller the dominance index value shows that there are no dominant species; otherwise, the greater dominance indicates that there are dominant species.

Principal Component Analysis (PCA). Principal component analysis (PCA) is a technique for reducing the dimensionality of such datasets, increasing interpretability but at the same time minimizing information loss. It does so by creating new uncorrelated variables that successively maximize variance. Finding such new variables, the principal components, reduces to solving an eigenvalue/eigenvector problem, and the new variables are defined by the dataset at hand, not a priori, hence making PCA an adaptive data analysis technique (Jolliffe & Cadima 2016). In this study, PCA analysis was used to map the density, frequency, pH, salinity, and water temperature at each observation station. The PCA analysis was performed using XLSTAT Software 2021.

Results and Discussion

Mangrove species. There were 4 mangrove species from 3 families, namely Verbenaceae, Rhizophoraceae and Meliceae. The 4 species found were *Avicennia alba*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza* and *Xylocarpus granatum* (Table 1).

Table 1

Composition of mangrove species

No.	*Family*	*Species*
1	Verbenaceae	*Avicennia alba*
2	Rhizophoraceae	*Rhizophora mucronate*
3	Rhizophoraceae	*Bruguiera gymnorrhiza*
4	Meliaceae	*Xylocarpus granatum*

Parameters of density and relative density of mangrove. The total density value of mangrove at station 1 was 1,600 ind ha^{-1}, at station 2 was 1,966 ind ha^{-1}, at station 3 was 2,000 ind ha^{-1} and at station 4 was 1,966 ind ha^{-1}. The density of mangrove vegetation on Jeflio Island at station 1, station 2, station 3 and station 4 were in the dense criteria, namely ≥ 1,500 ind ha^{-1}. Based on the Decree of the State Minister for the Environment No. 201 of 2004 that the quality standard criteria are mangrove density, dense density ≥ 1,500 ind ha^{-1}, moderate ≥ 1,000-1,500 ind ha^{-1} and rarely < 1,000 ind ha^{-1}. *B. gymnorrhiza* has the highest density of 1,000 ind ha^{-1} at station 4. The highest relative density is at station 1 where there was the species *R. mucronata* 39.58%, at station 2 there was the species *R. mucronata* 32.20%, at station 3 there was the species *B. gymnorrhiza* 48.33% and the highest relative density at station 4 where there was the species *B. gymnorrhiza* 50.85% (Table 2). Environmental conditions and human population activities also have an influence on the density of mangrove species. The lowest mangrove density is at station 1 which is a mangrove tourism area. This is thought to be due to the high population pressure in this area before this area was designated as a tourist area, so that currently, through cooperation with various parties, mangrove plants have been replanting in the area. The more individual mangrove found, the higher the density value. The highest species density is caused by suitable substrate and the ability of mangroves to adapt to environmental conditions. Mangrove species that have low density are due to the high utilization of mangrove species, unsuitable habitats or substrate, the presence of interactions between species or the inability of mangrove species to adapt to environmental conditions. Habitat characteristics affect the spatial distribution of mangroves (Lahabu et al 2015; Poedjirahajoe et al 2017).

Parameters of frequency and relative frequency. The highest frequency at station 1 was in the species *R. mucronata* and *B. gymnorrhiza* with a relative frequency of 33.3%, at station 2 there were the species *R. mucronata, B. gymnorrhiza* and *X. granatum* with a relative frequency of 30.0%, at stations 3 and 4 the highest frequency was for the species *R. mucronata* and *B. gymnorrhiza* with a relative frequency of 42.86%. *R. mucronata* has been found at all stations. The value of the frequency of the presence of mangrove species is influenced by the number of species found in each plot (Serosero et al 2020). The frequency value of the presence of mangrove species is influenced by the number of species found in each quadrant, the more quadrants are found in mangrove species, the higher the mangrove presence frequency value (Haya et al 2015) (Table 2).

Parameters of dominance and relative dominance. *R. mucronata* has the highest dominance at all the four stations, with a relative dominance value at station 1 of 62.94%, station 2 of 46.96%, station 3 of 72.76% and station 4 amounting to 49.87%. The highest relative dominance of *R. mucronata* was at station 3 at 72.76%. *R. mucronata* is the dominant species at each station because it is able to adapt to various environmental conditions, and it also breeds fast (Usman et al 2013) (Table 2).

Importance value index (IVI). *R. mucronata* had the IVI values as follows: at station 1 - 135.86%, station 2 - 109.16%, station 3 - 160.61%, and *B. gymnorrhiza* had the highest IVI at station 4 (143.16%). The highest IVI is found at station 3, 160.61% (Table 2). IVI shows the range of indices that describe the community structure and distribution patterns of mangroves. The differences in IVI of mangrove species are due to competition in each species to obtain nutrients and sunlight at the research location. Apart from nutrients and sun, other factors that cause differences in mangrove species density are the type of substrate and the sea tides (Supriharyono 2007; Parmadi et al 2016).

Diversity index (H'). The diversity index at station 1 was 1.3, at station 2 was 1.3, at station 3 was 1 and at station 4 was 1. The diversity index of all stations was in the medium diversity range with index values in the range of $1 < H' < 3$. Overall, the mangrove vegetation diversity index on the island of Jeflio was 1.15 with the criteria of moderate diversity, sufficient productivity, fairly balanced ecosystem conditions, moderate ecological pressure (Sipahelut et al 2020) (Table 3).

Evenness index (E). The evenness index at Station 1 was 0.94, at station 2 was 0.95, at station 3 was 0.91 and at station 4 was 0.91. The evenness index at all stations shows that the evenness of species is classified as high. Evenness is an indicator of dominance in each species in a community. The difference in evenness values indicates the presence of species that dominate or have high individual values (Nahlunnisa et al 2016) (Table 3).

Dominance index (D). The dominance index at station 1 was 0.3, at station 2 was 0.3, at station 3 was 0.4 and at station 4 was 0.4. The average dominance index of mangrove vegetation on the island of Jeflio was 0.4 indicating that the dominance is low (there are no species that dominate the other species), the environmental conditions are stable, and there is no ecological pressure on the biota in that location (Supriadi et al 2015) (Table 3).

Table 2

Density, relative density, frequency and relative frequency, dominance and relative dominance and importance value index

Station	*Species*	*Density (ind ha^{-1})*	*Relative density (%)*	*Frequency*	*Relative frequency (%)*	*Dominance*	*Relative dominance (%)*	*Importance value index (%)*
1	*Avicennia alba*	100.00	6.25	0.33	11.11	10,241.51	1.87	19.23
	Rhizophora mucronata	633.33	39.58	1.00	33.33	34,4465.23	62.94	135.86
	Bruguiera gymnorrhiza	333.33	20.83	1.00	33.33	109,095.67	19.93	74.10
	Xylocarpus granatum	533.33	33.33	0.67	22.22	83,471.34	15.25	70.81
Total		1,600.00	100.00	3.00	100.00	547,273.75	100.00	300.00
2	*Avicennia alba*	166.67	8.47	0.33	10.00	41,109.34	6.34	24.81
	Rhizophora mucronata	633.33	32.20	1.00	30.00	304,485.14	46.96	109.16
	Bruguiera gymnorrhiza	566.67	28.81	1.00	30.00	173,497.88	26.76	85.57
	Xylocarpus granatum	600.00	30.51	1.00	30.00	129,315.29	19.94	80.45
Total		1,966.67	100.00	3.33	100.00	648,407.64	100.00	300.00
3	*Avicennia alba*	0.00	0.00	0.00	0.00	0,00	0.00	0.00
	Rhizophora mucronata	900.00	45.00	1.00	42.86	1,041,886.49	72.76	160.61
	Bruguiera gymnorrhiza	966.67	48.33	1.00	42.86	368,460.96	25.73	116.92
	Xylocarpus granatum	133.33	6.67	0.33	14.29	21,690.55	1.51	22.47
Total		2,000.00	100.00	2.33	100.00	1,432,038.00	100.00	300.00
4	*Avicennia alba*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Rhizophora mucronata	900.00	45.76	1.00	42.86	59.81	49.87	138.49
	Bruguiera gymnorrhiza	1,000.00	50.85	1.00	42.86	59.32	49.46	143.16
	Xylocarpus granatum	66.67	3.39	0.33	14.29	0.81	0.67	18.35
Total		1,966.67	100.00	2.33	100.00	119.94	100.00	300.00

Table 3

Diversity index, evenness index and dominance index

Site	*H'*	*E*	*D*
Station 1	1.3	0.944965	0.3
Station 2	1.3	0.947129	0.3
Station 3	1	0.910239	0.4
Station 4	1	0.910239	0.4

Water quality parameters. Based on the water quality parameters of the mangrove vegetation, it was found that the average pH at station 1 was 7.09, at station 2 was 7.18, station 3 was 7.45 and station 4 was 7.38. The salinity at all stations is in the range of 25-28.33 ‰. The water temperature at station 1, station 2, station 3 and station 4 is in the range of 28.87-30^{o}C. The highest pH is at station 3 which is 7.38, the highest salinity is at Station 2 which is 28.33 ‰ and the highest water temperature is at station 3 which is 30^{o}C (Figure 2). Water temperature is still in the normal range between 28 and 29^{o}C; salinity is good enough for mangrove growth which ranges from 29 to 31 ‰, and the normal water pH is in the range from 6.8-7.5 (Hariyanto et al 2019). The diversity of salinity occurs due to evaporation, fresh water supply, mixing of sea water, location and size of the sea, humidity, and mineral content (Poedjirahajoe & Matatula 2019).

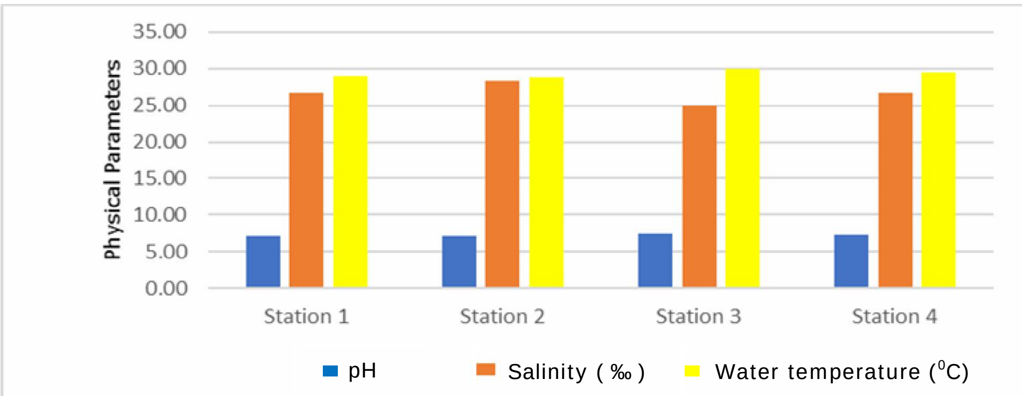

Figure 2. Water quality parameters.

PCA analysis. The main component 1 (F1) has a large eigen value of 3.8 with a diversity value of 76.19%. The main component 2 (F2) has an eigen value of 1.05 with a diversity value of 21.07%, and the main component 3 (F3) with an eigen value 0.14 with a diversity value of 2.75% (Table 4).

Table 4

Eigen values

	F1	*F2*	*F3*
Eigenvalue	3.809	1.053	0.137
Variability (%)	76.185	21.065	2.750
Cumulative (%)	76.185	97.250	100.000

PCA reduces 5 attribute dimensions to 2 dimensions (mapped in preference mapping). As a result of this reduction in dimensions, some information was lost (ie 21.07%). Reduction of 5 dimensions to 2 dimensions with the main component analysis method still provides a diversity of variations of 97.25%. Based on Figure 2, the attributes of mangrove frequency and salinity had a position that was close to and far away from other attributes. Mangrove density and pH attributes were in the same quadrant. The water temperature attribute was in a different quadrant but still in a position close to the pH attribut (Figure 3).

The score plot graph in the main component analysis aims to show the relationship between the samples tested. The score plot graph depicts the graph between F1 and F2 based on the main component analysis which explains the relationship between the samples. Based on the score plot graph (Figure 4) and biplot (Figure 5), the four stations were in different quadrants. Stations 3 and 4 had an adjacent position so that they show almost the same characteristics between stations 3 and 4 while station 1 and 2 had different characteristics.

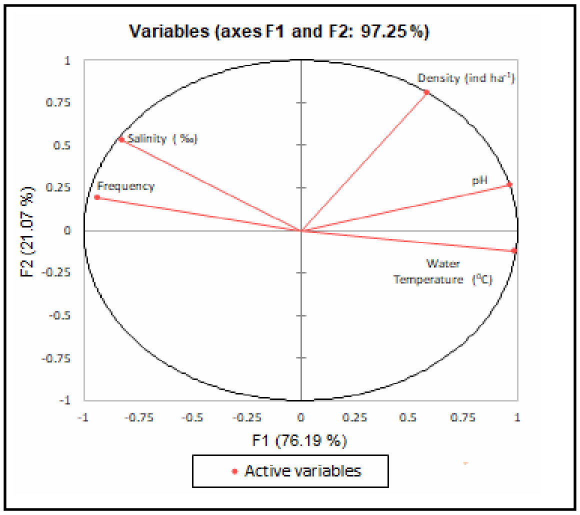

Figure 3. Water quality parameters.

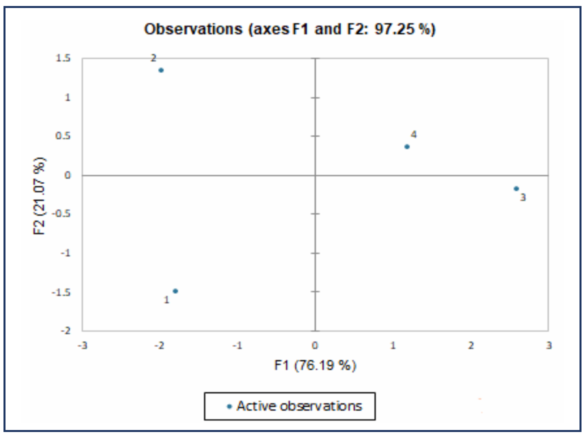

Figure 4. The score plot graph.

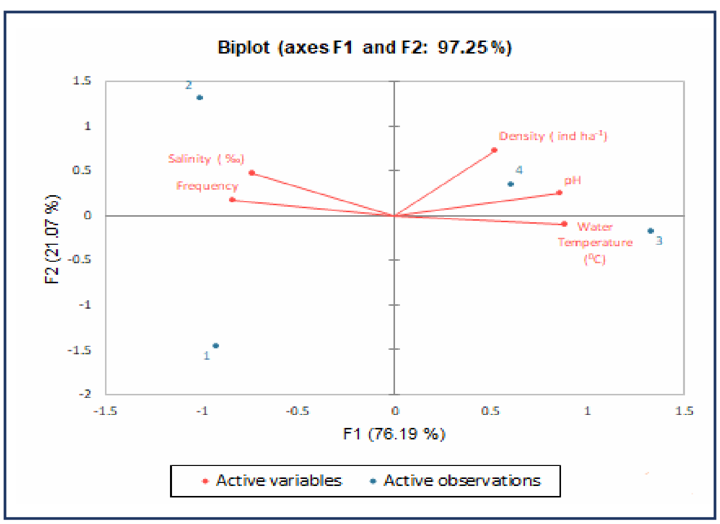

Figure 5. The biplot graph.

Based on the results of the main component analysis, it can be seen that at station 1 there is no influence between variables. At station 2, it can be seen that the mangrove frequency is influenced by salinity because these variables are close to each other. The highest mangrove frequency was found at station 2 with R*. mucronata* with a relative frequency of 30.0%, *B. gymnorrhiza* with a relative frequency of 30.0%, and *X. granatum* with a relative frequency of 30%. According to Barik et al (2018), *Bruguiera* is a type of mangrove that is commonly found in mesohaline areas. Stations 3 and 4 had almost the same characteristics because they are close to each other. It can be seen that the physical parameters of pH and air temperature had an effect on mangrove density.

Based on the dendogram (Figure 6) there were 2 colors where stations 3 and 4 were in the same cluster and stations 1 and 2 were in the same cluster which was based on mangrove density and frequency as well as water quality parameters including pH, and salinity. Variations in mangrove density and frequency, as well as water quality parameters such as water temperature, pH, salinity at Stations 1 and 2 were higher than those at Stations 3 and 4.

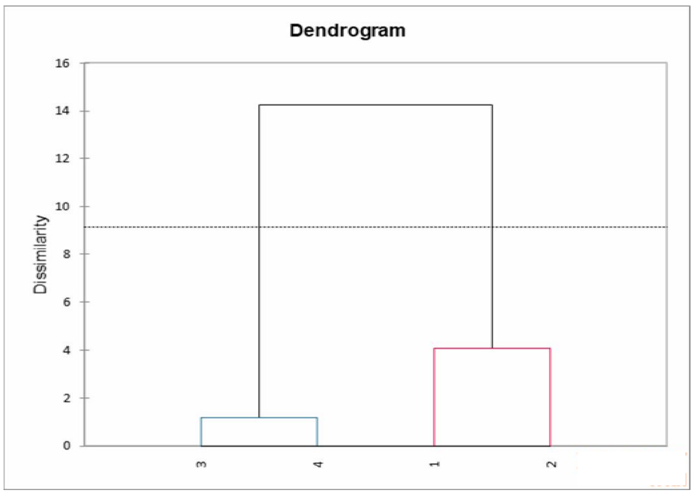

Figure 6. Cluster analysis dendogram (station).

Conclusions. Based on the results of the study there were 4 types of mangroves from 3 families Verbenaceae, Rhizophoraceae and Meliceae. The four species found were *A. alba*, *R. mucronata*, *B. gymnorrhiza* and *X. granatum*. The species *B. gymnorrhiza* had the highest density of 1,000 ind ind ha-1 at station 4. The highest frequencies at stations 3 and 4 were 42.86% for *R. mucronata* and *B. gymnorrhiza*, respectively. *R. mucronata* has the highest dominance at station 3 (72.76%) and has the highest IVI at station 3 (160.6%). Diversity index at station 1, station 2, station 3 and station 4 respectively classified as moderate. Overall, the mangrove vegetation diversity index at the Jeflio Island was 1.15. The evenness index at station 1 was 0.94, station 2 was 0.95, station 3 was 0.91 and station 4 was 0.91. This shows that the evenness index is high. The dominance index at Station 1 was 0.3, Station 2 was 0.3, Station 3 was 0.4 and Station 4 was 0.4. The average dominance index of mangrove vegetation on the island of Jeflio was 0.4 indicating that the dominance is low. Mangrove water quality parameters obtained the highest pH of 7.38 at station 3, the highest salinity of 28.33 ‰ at station 2 and the highest water temperature of 30.0°C at station 3. In total there are 2 clusters where stations 3 and 4 are in the same cluster and stations 1 and 2 are in the same cluster which is based on the density and frequency of mangroves as well as water quality parameters including water temperature, pH and salinity.

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