The diversity of coral reefs in Kaana Waters Enggano Island, Bengkulu

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Abstract. Coral reef ecosystems are among the most sophisticated and specialized in the tropics. It is distinguished by its high levels of productivity and biodiversity. Along the shore of Kaana Village, coral reef ecosystems are almost dispersed. Reef fish, sea cucumbers, and shellfish are among the coral reef-related resources utilized by the inhabitants of this settlement. This research aims to identify the community structure of the coral reefs in the surroundings of Kaana waters, Enggano Island. Additionally, this study attempts to assess coral reef coverage. This investigation was carried out in August 2021 at depths of 3 and 7 meters in Ubik, Air Baun, Kikuba, and Sawang Pari points adopting a survey method. The Line Intercept Transect observation method was analyzed to evaluate the diversity of coral reefs (55 m long). There are 45 species, which belong to 25 genera and 10 families. Kaana's coral cover falls bad to moderate (13.5 to 30.75 percent), with an average of 21.60 percent.

1 Introduction

Enggano Island is one of the archipelago's most remote islands. with a coastline of 126.71 kilometers and a plain area of 39,586.74 hectares. Geographically, Enggano Island is located west of Sumatra Island, in the Indian Ocean, between 102°05' and 102°25' east longitude and 5°17' and 5°31' south latitude. From Bengkulu City's Pulau Baai port to Enggano Island is roughly 110 nautical miles [1]. Administratively, Enggano Island consists of a single subdistrict that is part of the North Bengkulu Regency and Bengkulu Province. Enggano Island comprises of six settlements, namely Kahyapu, Kaana, Malakoni, Apoho, Meok, and Banjarsari Village.

Ka'ana is one of the nearby communities, roughly 45 minutes away from Kahyapu. Ka'ana is surrounded by the open ocean to the north, protected forests to the south, Kahyapu to the east, and Malakoni to the west. The maritime areas of Ka'ana contain the potential for coral reefs, which the community has utilized as fishing grounds and as a source of other biological resources. The waters of Ka'ana are utilized by the surrounding community as one of the coastal tourism spots. Coral reef ecosystems are nearly dispersed around the coastal of Kaana, where conditions are exceptionally abundant. The economic and ecological benefits of coral

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reefs are numerous. In terms of the economy, coral reefs can serve to attract tourists. Moreover, coral reefs provide a habitat for species of considerable economic value. Coral reefs may sustain food sources, fishing output, and industry, and they can also serve as an alternative tourist destination [2,3].

The waterways of Kaana provide the majority of residents, who are predominantly fishermen. In addition, coral is used as a construction material by the local population. Additionally, the local population uses the waterways of Kaana as a tourist attraction. These operations will also have an effect on the condition of the coral reef ecosystem and associated biota in Kaana's waters. This study seeks to evaluate the structure of the coral reef habitat community and the percentage of live coral cover in Kaana's waters.

2 Materials and methods

2.1 Study area

This study was carried out between December 2020 and April 2021. In August of 2020, an initial survey was employed to conduct the research. This study is conducted in the waters surrounding Kaana, Enggano District, North Bengkulu Regency, Bengkulu Province, while data analysis is conducted at the Fisheries Laboratory of the Marine Science Study Program, Faculty of Agriculture, Bengkulu University. During this phase, preliminary surveys or field observations, data collecting on research sites and literature study on the research object were conducted. Based on the survey, the observation sites have been separated into four locations: Ubik, Air Baun, Kikuba, and Sawang Pari waters. The observations were conducted in the waterways surrounding Kaana. The determination of the observation station is based on a number of criteria, including the criterion of water area representativeness. Additionally, the region is protected from disruptions caused by fishermen, locals, waves, and currents. When collecting data, the most important aspect of the observation station to consider is the safety and work safety component [4]. The study employed repetition, which was conducted three times at each research site by determining the coordinates using GPS. Parallel to the beach, data collecting was conducted at a depth of 3 and 7 meters in the Kaana Waters.

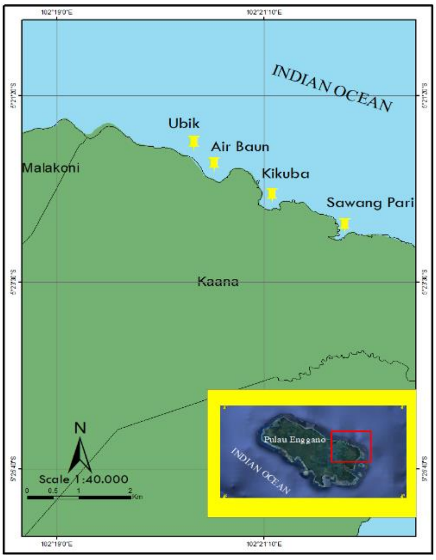

Fig. 1. Map of study sites in Kaana waters, Enggano, North Bengkulu – Indonesia.

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2.2 Data analysis

2.2.1 Coral reef condition assessment

Data collection in this study used the line transect method which refers to English et al. [5]. Changes in lifeform were recorded with an accuracy of one cm with examples for example 0-T1 recorded as L1, T1-T2 recorded as L2, then T2-T3 recorded as L3 and so on (Figure 2 and Figure 3).

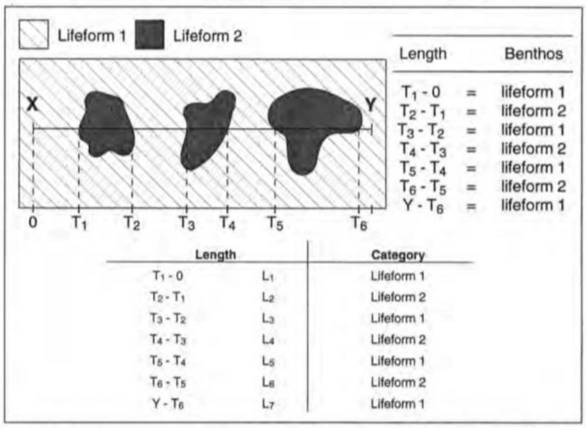

Fig. 2. How to record coral colony data on line transect method [5].

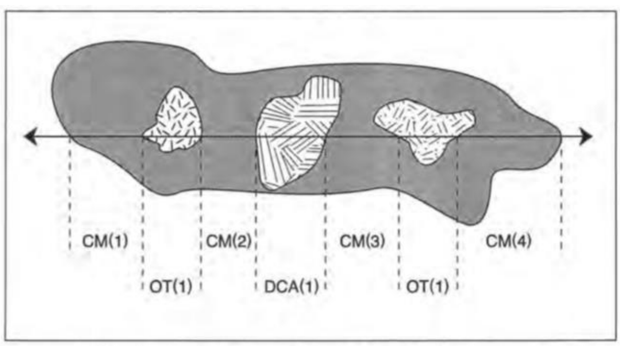

Fig. 3. Massive coral colonies of large size (CM) crossing a single colony more than once. If the transect line passes through directly above the colony, it is considered as different lifeform [5].

2.2.2 Observation of coral reef condition

Observation of coral reef cover with Line Intercept Transect (LIT) or line transect methods. A 20-meters line transect was utilized to collect data or conduct assessments of coral reefs with 3 repetitions. The measurement begins with the installation of a line transect utilizing a 70 m roll meter, followed by the measurement of a 20 meters' length with a 10 meters' interval. The first measurement is taken at a distance of 0 to 20 meters, the second measurement is taken from a distance of 25 to 45 meters, and the third measurement is taken from a distance of 50 to 70 meters. At a depth of 3 and 7 meters' parallels to the beach below the transect line, observations were conducted in the Ka'ana waters. In accordance with this procedure, coral reef components are measured in centimeters relative to the coral organism. Figure 4 shows this coral reef observation with an illustration.

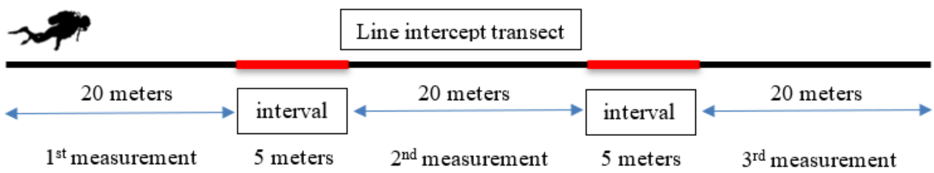

Fig. 4. Illustration of coral reef observation using the LIT method.

As shown in Figure 2, observations of fundamental habitat-filling biota and other components are based on lifeforms with particular codes [5].

Table 1. List of basic components of coral reef ecosystems.

Categori		**Code**	**Information**
Dead Coral		DC	Just died, white color or dirty white
Dead Coral with Alga		DCA	Coral still standing, skeletal structure still visible
Acropora	Branching	ACB	At least 2° branching. Has axial and radial corallite
	Encrusting	ACE	Usually is the basis of the immature acropora form
	Submassive	ACS	Upright with a wedge-like shape
	Digitae	ACD	Branches no more than 2°
	Tabulate	ACT	Shaped like a flat table
Non-Acropora	Branching	CB	At least 2° branching. Has axial and radial corallite
	Encrusting	CE	Mostly bound to the substrate (moves). At least 2° branching
	Foliose	CF	Corals are attached to one or more points, such as leaves, or in the form of plates
	Massive	CM	Like a boulder or a mound
	Submassive	CS	Small pole, knob or wedge
	Mushroom	CMR	Solitary, live coral free of genera
	Heliopora	CHL	blue coral
	Millepora	CML	fire coral
	Tubipora	CTU	Shaped like small pipes
Soft Coral		SC	Soft coral
Sponge		SP	
Zoanthids		ZO	
Others		OT	Ascidians, anemon, georgonian etc.
Alga	Alga assemblage	AA	
	Corallinee alga	CA	
	Halimeda	HA	
	Macroalga	MA	
	Turf Alga	TA	
Abiotik	Sand	S	Sand
	Rubble	R	Small coral fracture
	Silt	SL	Muddy sand
	Water	W	Water
	Rock	RCK	Rock

Source: [5]

2.2.3 Percentage of coral cover

The percentage of coral cover for each category of coral lifeform can be found using the following formula [5]:

$$\%\mathrm{Ci} = \left(\frac{pi}{p}\right) 100\% \quad (1)$$

Information :
Ci = percent cover of a coral lifeform (%)
pi = total length of a category lifeform (cm)
p = total length of a category lifeform (cm)

Table 2. Category percentage coral cover.

Percentage Coral Cover (%)	Condition of Living Coral Reef
0 – 24,9	Damaged
25 – 49,9	Medium
50 – 74,9	Good
75 – 100	Very Good

Source : Decree of the Minister of the Environment No. 47 Year 2001

2.2.4 Similarity of coral reef basic habitat

The Multi-Variable Statistical Package (MVSP) software was used to assess the Bray-Curtis index to determine the similarity of basic coral reef habitats. The Bray-Curtis similarity index formula [6,7] is:

$$S_{jk} = 100\left(1 - \frac{\Sigma|Y_{ij} - Y_{ik}|}{\Sigma|Y_{ij} - Y_{ik}|}\right) \quad (2)$$

Information:
S_{jk} = index of similarity between examples j and k in percent
Y_{ij} = number of species i in column j
Y_{ik} = number of species j in column k

3 Result and discussion

3.1 Coral reef habitat

In the waters of Ubik, Air Baun, Kikuba, and Sawang Pari, observations of coral reefs were conducted. The four places are coral reef ecosystems that extend from the coast to a depth of seven meters. **Ubik** waters is close to the Ka'ana and Malakoni trans dusun' community, roughly 200 meters from the Ka'ana and Malakoni boundary. Ubik 3 meters can be accessed through beach entry up to 200 meters offshore from the shoreline. Merbau (ironwood-*Intsia bijuga*), mangrove, and ketapang (*Terminalia cattapa*) tree present along the coastline. Ubik 7 meters is located 10-20 meters from Ubik 3 meters which strong waves and currents are occurred at this area. **Air Baun**, the location of this study is far from the Ka'ana town but easily accessed, which is a location of coral mining activities, as evidenced the stone heaps collected by people seen during the observation. Observation at depth 3 and 7 meters by beach entry from beach line to 100 meters inshore. **Kikuba,** the significance of this place is that there are coastal resource users, such as sand miners, and coastal vegetation, including mangroves, nipa palm, sea pandanus, and other huge trees. The bottom of the Kikuba waters is covered with numerous coral fragments that have been colonized by algae. The location of **Sawang Pari** lies near the Kahyapu waters or near the border of Kahyapu and Ka'ana. This area is remote from human settlements which should be accessed by boat. There are coral fragments and chunks of dead coral covered with algae, as well as a few living corals, on the bottom of the sea. Sawang Pari is used for fishing, netting, and stingray capture because there are numerous stingrays in this area and many people come here to collect them. Along the shore of Sawang, there are several types of coastal vegetation, such as mangroves. This region features high waves and currents since the ocean conditions are more open.

In addition to assess corals benthic community, we collected water quality as indicators for the survival of coral reef. This is due to the fact that the majority of human activities in Ka'ana Village are located in coastal areas, which will have direct or indirect effects on the surrounding ecosystem. Temperature, turbidity, brightness, pH, salinity, and dissolved oxygen were measured in situ. The results of the average repeated measurements of the water quality indicators at each of the 8 observation stations are shown in Table 3.

Table 3. The water quality variables in Ka'ana waters.

Parameter	Ubik 3 m	Ubik 7 m	Air Baun 3 m	Air Baun 7 m	Kikuba 3 m	Kikuba 7 m	S.Pari 3 m	S.Pari 7 m	Condition Optimum
Temperature (˚C)	28	28	28	28	28	28	28	28	28-30
Salinity (˚/˳˳)	33.7	33.7	34	33.2	34	34.0	33.8	33.5	33-34
pH	7.80	7.78	7.81	7.75	7.73	7.78	7.76	7.77	7-8.5
Brightness (%)	100	100	100	100	100	100	100	100	> 5 m
Turbidity (NTU)	0.28	0.58	0.22	0.56	0.35	0.15	0.27	0.15	<5 NTU
DO (mg/l)	5.9	5.9	5.8	5.9	5.57	5.9	5.8	5.7	>5 mg/l
Phosphate (mg/l)	0.0018	0.0012	0.0119	0.0025	0.0036	0.0007	0.0042	0.0002	0.015 mg/l
Ammonia (mg/l)	0.20	0.12	0.18	0.14	0.10	0.08	0.12	0.05	0.3 mg/l
Nitrate (mg/l)	0.019	0.001	0.251	0.014	0.013	0.002	0.011	0.018	0.008 mg/l
Nitrite (mg/l)	0.053	0.006	0.012	0.021	0.020	0.023	0.019	0.012	

According to Decree No. 51 of the Minister of Environment of the Republic of Indonesia [8], the optimal quality level for water is between 28 and 30ºC. The findings of temperature measurements at eight locations indicate the same temperature, 28 ºC. According to the water quality standard, optimal temperatures range from 28 to 30 degrees Celsius. According to research by Zamdial et al. [9], the temperature of one of Enggano Island's seas was 30ºC. This also demonstrates that the temperature of the waters surrounding Enggano Island is still conducive to the establishment of coral reefs.

The salinity of the waters of Ka'ana varies between 33-34 ppt. According to Minister of Environment Decree No. 51 of 2004 [8], salinity values between 33-34 ppt are deemed to be optimal. According to research conducted by Zamdial et al. [9], the salinity of the waters surrounding Malakoni was 33 ppt. This indicates that the salinity level on Enggano Island is still within the acceptable range for the survival of coral reefs. In addition, Souhoka [10] noted that a salinity range between 25-40 ppt is optimal for coral formation and growth.

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The pH range of Ka'ana's waters is 7.72–7.81, according to measurements based on the Minister of the Environment's Decree No. 51 (2004) [8], a pH range of 7–8.5 has been designated as the optimal quality level. The greatest pH, 7.81, was measured at Ubik 3 meter, while the lowest pH, 7.72, was measured at Sawang Pari 3 meter; each station has a distinct pH, as shown in Table 3. In the study conducted by Nugraha et al. [11], the pH measurement in Kahyapu was determined to be 7.85. Therefore, it is evident that the pH values of the water in a few settlements on Enggano Island are still conducive to the survival of aquatic organisms.

At 8 locations, the brightness metrics measured in the seas of Ka'ana are 100%. The Decree No. 51 of the Minister of the Environment (2004) [8] specifies that 100% brightness is optimal. 100% is used as the average homogenous value for the brightness value. This indicates that sunlight may reach the bottom of the ocean, allowing zooxanthellae's photosynthesis processed effectively and fostering the formation of coral reefs [12].

High levels of turbidity in water under typical climatic circumstances may indicate the presence of suspended particles. The waters of Ka'ana have a maximum turbidity of 0.58 NTU at Kikuba, 3 meters, and a minimum turbidity of 0.12 NTU at Sawang Pari, 7 meters. According to Ministerial Decree No. 51 (2004) [8], a turbidity level of 5 NTU is deemed optimal. According to Zulfianti [13] that the water clarity is optimal for the growth of coral reefs as a habitat for coral biota.

According to Giyanto et al. [14] which oxygen plays a significant function in the aquatic ecosystem as a chemical element utilized by biota for metabolic processes. According to dissolved oxygen (DO) measurements, the dissolved oxygen concentration in Ka'ana Village is between 5.6 and 5.9 mg/l. The Decree of the Minister of the Environment No. 51 [8] stipulates that dissolved oxygen levels in waters more than 5 mg/l are optimal. The high concentration of dissolved oxygen in each habitat can result from the diffusion of oxygen from the surrounding atmosphere [14].

3.2 Condition of coral reefs and benthic communities

Observations of the status of live coral reefs at eight research stations found that, according to Minister of Environment Decree No. 4 of 2001, 30.67% at Ubik 3 meters, of live coral cover classified into the category of "medium" at 3 meter baun water 25.83%, 7 meter baun water 30.75%, 3 meter Kikuba 13.84%, Kikuba 7 meters 17.67%, Sawang Pari 3 meters 16.83%, and Sawang Pari 7 meters 13.50%. When compared to other locations, specifically Kahabi, which is one of the coastal areas in Enggano with a percentage of 6.6% [15], and several points on Pulau Satu, Pulau Merbau, and Pulau Dua [16] with percentages of 34.35% (good), 16.78%, and 20.53% are classified as of "damaged"category. The high percentage of dead coral in the waters of Ka'ana Village, which was caused by coral reef mining and the use of sand to construct houses and other buildings, demonstrates the severe damage to coral reefs that has occurred [17].

Overall, Faviidae predominate non-scleractinian coral reefs in the waters of Ka'ana Village, although other basic habitat fauna is scarce. The proportion of cover of abiotic components along the transect was dominated by dead coral covered with algae (51.19 %), broken coral (22.43 %), and sand (4.41%), which are prevalent substrate types, as shown in Figures 5 and 6.

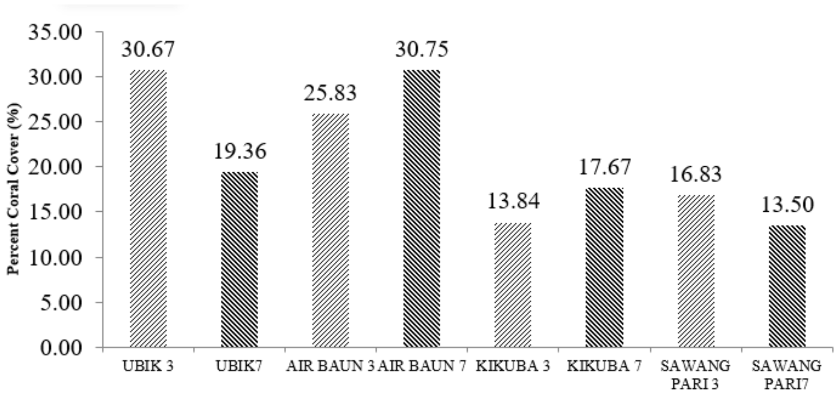
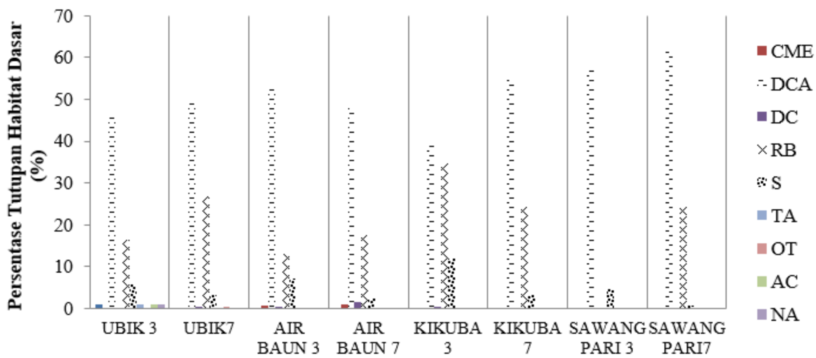


Fig. 5. Percentage of the observation site's coral reefs that are alive.



Information : AC: Acropora, NA: Non Acropora, DCA: Dead Coral With Algae, CME: Coral Millepora, OT: Others, RB: Rubble, S: Sand

Fig. 6. Percentage of live coral cover and other benthic categories at each site.

3.3 Coral reef diversity

The diversity of coral reefs at the observation sites can be seen in Table 4.

Table 4. Types of coral reefs found at the observation site.

No	Famili/Spesies	Ubik		Air Baun		Kikuba		Sawang Pari	
		3 m	7 m	3 m	7 m	3 m	7 m	3 m	7 m
	ACROPORIDAE								
1	*Acropora brueggemani*	+							
2	*Acropora digitifera*	+							
3	*Acropora humilis*	+	+	+	+	+		+	+
4	Acropora formosa		+	+	+				+
5	Isopora palifera		+		+				
6	*Acropora pistillata*			+					
	FAVIIDAE								
7	*Caulastrea echinulata*	+	+	+	+	+	+	+	+
8	*Caulastrea furcata*	+	+		+	+			+
9	*Favia favus*	+	+		+		+	+	+
10	*Goniastrea aspera*	+	+	+	+	+	+	+	+

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Table 4. Cont.

11	*Goniastrea favus*	+							
12	*Goniastrea pectinata*	+	+						
13	*Goniastrea retiformis*	+		+	+	+			+
14	Goniastrea favulus		+		+				
15	*Montastrea curta*	+	+						+
16	Montastrea magnistellata		+						
17	*Platygira verweyi*	+	+		+	+		+	+
18	Favites complanata		+		+			+	
19	Favites pentagona				+				
20	Platygyra sinensis				+				
21	*Echinopora pacificus*			+					
22	*Favia stelligera*			+					+
23	*Favites abdita*					+			
24	*Leptastrea transversa*					+	+		+
25	*Montastrea valenciennesi*					+	+		
	AGARICIIDAE								
	Gardineroseris planulata	+							
26	*Coeloseris mayeri*			+				+	+
27	Leptoseris incrustans							+	
28	Pavona decussata							+	
	POCILLOPORIDAE								
29	*Pocillopora damicornis*	+					+	+	
30	*Pocillopora eydouxi*	+							
31	*Pocillopora verrucosa*	+	+						
32	*Stylophora pistillata*	+	+	+	+	+	+	+	+
33	Seriatopora caliendrum				+		+		
34	Seriatopora hystrix				+	+			
	FUNGIIDAE								
35	*Fungia fungites*	+	+		+				
36	Fungia corona						+		
37	Ctenactis echinata						+		
	MERULINIDAE								
38	Merulina scabricula		+						
39	Millepora tenera			+	+				
	PORITIDAE								
40	Porites cylindrica		+	+	+	+	+		+
41	*Porites lichen*					+			
	SIDERASTREIDAE								
42	Psammocora digitata		+						
	PECTINIIDAE								
43	Pectinia alcicornis				+			+	
	DENDROPHYLLIDAE								
44	Turbinaria Stellulata							+	

Observations at 8 locations in the waters of Ka'ana revealed 45 species, 10 families, and 25 genera. Comparable to other regions of the Indian Ocean, the coral diversity in the western waters of Sumatra is generally modest. Local communities that engage in coral reef mining are responsible for the lack of biodiversity in this location. The distribution of coral species is largely determined by ecological and biological factors such as wave energy and larval availability. Additionally, the type of substrate influences the larvae's capacity to adhere [18].

Coral species from the Faviidae, Acroporidae, and Pocilloporidae families predominate over species from other families, with as many as 19 species from the Acroporidae and Pocilloporidae tribes and a total of 6 species from the Faviidae tribe. Favidae has a sturdy build and a wide geographic range [19], including the waters of Enggano. Typically, the architecture of this type resembles a large dome or a flat. This helps it to endure harsh conditions, such as strong currents and waves. These corals are classified as slow-growing due to their dense growth forms [20]. Slow-growing corals have, on average, a more robust structure that is not easily damaged by high waves and currents. Two genera of Acroporidae, Acropora and Isopora, were discovered at the observation site. Acropora has nearly identical qualities to Astreopora, including small corallites, no columella, simple septa, and the absence of a distinctive and extratentacular structure, but the corallites of Astreopora are larger and grow well with simple columella [21].

There were 3 genera of Pocilloporidae found at the observation site, namely Pocillopora, Stylophora, and Seriatopora. These genera had the characteristics of branching or submassive colonies, covered with spots (verrucosae), relatively submerged corallites, small, two-story, and united with columella, as well as corallites filled with small thorns [21].

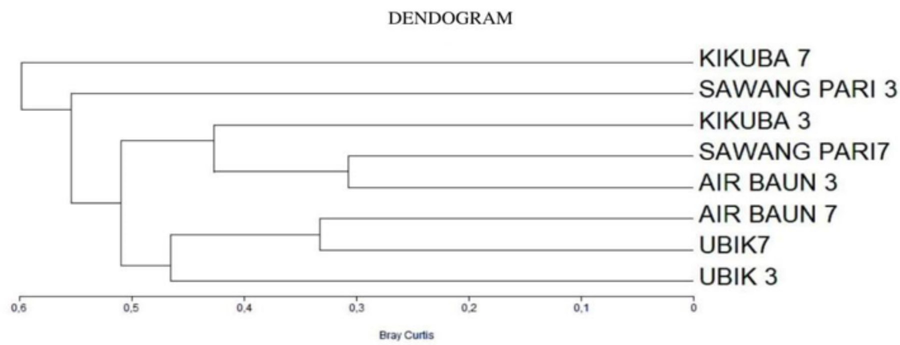

Fig. 7. Dendogram of similarity of basic coral reef habitat.

The dendogram depiction reveals that the most similar habitats of coral reefs are Air Baun 3 meters and 7 meters Sawang Pari (Group 1) and Air Baun 7 meters and 7 meters Ubik (Group 2). Kikuba 7 meters and Sawang Pari 3 meters are quite dissimilar to other stations, which had inequality values of 55.4% and 59.9%, respectively.

4 Conclusion

According to coral reef cover data, 45 species of coral reef communities belonging to 10 coral reef families can be identified, with a proportion of each station falling into the category of "poor." The 7 meter Air Baun station had the highest coral reef cover percentage at 30.75 %, while the 7 meter Sawang Pari station had the lowest coral reef cover percentage around 13.50 %.

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