



The ecological structure of macroalgae community (seagrass) on various zones in the coastal waters of Nusalaut Island, Central Maluku District, Indonesia

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Abstract. The purpose of this research is to obtain data and information regarding the condition and diversity of macroalgae species in the waters of Nusalaut Island, Central Maluku District. The research was conducted in four locations on Nusalaut Island, namely Ameth, Nalahia, Sila, and Leinitu. The sample was collected by using *intercept* line transect method (1 m × 1 m and 25 cm x 25 cm) along the coastal areas. The ecological structure of the macroalgae community is determined from several ecological aspects, such as the index of diversity (H'), index of dominance (D), index of evenness (E), density (Ki), relative density (KRi), abundance (KLi), relative abundance KLRI), frequency of occurrence (Fi), relative frequency of occurrence (FRi), and important value index (INP). *Gracilaria salicornia* has the highest density and abundance at stations I and II, while *Sargassum cinctum* and *Liagora viscida* have the lowest density and abundance. The highest density at Station III is of *Padina australis* and the lowest is *Gracilaria salicornia*. The highest density at station IV is of *Hypnea valentiae* and the lowest is of *Gracilaria corticata*. The frequency of occurrence of macroalgae species describes the macroalgae opportunities in the observation plot. The macroalgae of the *Gracilaria* genus have a dominant distribution, particularly *G. salicornia*. Regarding the distribution percentage of macroalgae cover, station I has the highest distribution percentage of macroalgae cover (varies) of 15 species out of a total of 17 species (all observation stations). Species *Dictyopteris acrostichoides* and *L. viscida* can only be found at station II and station IV. Species *G. salicornia*, *Halimeda opuntia*, *H. valentiae*, and *P. australis* can only be found at station III. Ecologically, macroalgae distribution is found in near residential area on station I. In addition to station I, other stations are coastal areas without settlement. Station I has the highest diversity index, station III has the highest evenness index, and the relative dominance index is the same for all four stations.

Key Words: ecological structure, macroalgae communities, coastal waters, Nusalaut Island.

Introduction. Indonesia is an archipelago country in which the ocean area is wider than the land area, reaching three quarters of it (Sinyo & Somadayo 2013). The reports of KPMG Indonesia (2015) found that Indonesia's water area is 5.8 million square kilometers or 62% of Indonesia's total area. The sea area allows Indonesia to have great potential of marine resources, and it is known as a country with rich biodiversity in the world (Handayani & Kadi 2007).

Macroalgae or seaweed is one of the marine commodities that have high biodiversity with more than 10,000 species (Philips 2001; Ang et al 2013). Macroalgae in Indonesian water reaches 782 species, which is about 8.6% of the total biota in the sea (Dahuri 1998; Anggadiredja et al 2006). This is also supported by the statement of Wawa (2005), that the macroalgae habitat in Indonesia reaches 1.2 million hectares.

Macroalgae (seaweed) is a low-level macroscopic plant, and it cannot be distinguished among its roots, stems, and leaves (Sumich 1992; Aljabarin & Al Jarrah 2017). Sinyo & Somadayo (2013) also reveal that macroalgae belong to low level plants containing chlorophyll, so that it is able to do assimilation, which is the process of

photosynthesis. The whole body of macroalgae is called thallus, which is a vegetative body of macroalgae that has not experienced differentiation of roots, stems, and leaves as in high level plants (Sumich 1992; Smagula & Connor 2007). Rahmawati et al (2015) and Lavanya et al (2017) classify macroalgae into three classes based on pigments, namely Chlorophyceae (green macroalgae), Phaeophyceae (brown macroalgae), Rhodophyceae (red macroalgae) which have many species and live together to form a community.

The macroalgae community can be studied based on the existence of various types of macroalgae that live together. One of the characteristics of community level is the high diversity of species when composed by many species of macroalgae, otherwise the low diversity of macroalgae community when composed by a few species of macroalgae (Pratama et al 2015; Hadisusanto et al 2015; Czerwik-Marcinkowska et al 2015). High species diversity shows that the community stability is in prime condition (stable), or the water quality is clean. In contrast, low species diversity indicates that biota quality is unstable or polluted (Fachrul 2007). Odum (1994) states that species diversity has a number of components, namely diversity index, dominance index, evenness index, density, abundance, frequency of occurrence, and important value index.

Nusalaut Island is one of the small islands with an area of 919.5 ha, which is ± 2 hours by motorboat from Ambon Island, the capital of Maluku Province. The coastal area of Nusalaut Island has a variety of habitat characteristics, both substrate composition and other characteristics. Islami (2012) states that the coastal area of Nusalaut Island has a substrate dominated by sand and coral fragments. These substrate characteristics allow a wide range of macroalgae to be found. In addition to the substrate, the distribution of macroalgae is also influenced by the environmental condition of its habitat, both physical and chemical conditions, or the combination of both. The research on the condition of macroalgae ecosystem has not been done before, so that there is no clear information about the condition of macroalgae. The purpose of this research is to obtain data and information regarding the condition and diversity of macroalgae species in the water of Nusalaut Island, Central Maluku District.

Material and Method. This study was conducted in the coastal water of the Nusalaut Island, Central Maluku District, at coordinate 03°34'30" - 3°45'40" latitude and 128°42'15" - 128°52'45" in March 2016. The northern part borders on Saparua Subdistrict, the south part borders on Banda Sea, the west part borders on Banda Sea, and the east part borders on Banda Sea. Administratively, Nusalaut Island belongs to the Central Maluku District with an area of about 32.50 sq km, and has a coastline length of 25.928 Km. Nusalaut sub-district consists of 7 villages: Ameth, Akoon, Abubu, Titawaai, Leinitu, Sila and Nalahia. All of these villages are located in coastal areas (Islami 2015).

The research location was determined by purposive sampling by considering the location of the habitat of macroalgae (Figure 1). The locations determined as the research area were Ameth Village (station I), Nalahia Village (station II), Sila Village (location III) Village and Leinitu Village (station IV) (Figure 2). Vertical transects were then made on the selected stations, which were placed perpendicular to the coastline starting from the highest tidal limit to the sea with a transect length of 100 m with the distance between transects 25 m. Every 5 m distance from the highest tidal limit in each transect was placed observation plot with size 1 x 1 m and 25 x 25 cm plots as many as 20 plots. The macroalgae data were collected by using direct observation on the station and recording the macroalgae species (Anggadiredja et al 2006; Al-Yamani et al 2014). The data on the physico-chemical factors of the environment (temperature, current strength, turbidity of salinity, pH, nitrate, phosphate and dissolved oxygen in seawater) were carried out on each observation plot. The macroalgae community structure was then determined from several aspects of ecology, namely, diversity index (H'), dominance index (D), evenness index (E), density (Ki), relative density (KRi), abundance (KLi), relative abundance (KLRi), frequency of occurrence (Fi), relative frequency of occurrence (FRi), and important value index (INP).



Figure 1. Photo of the research area in the red box.

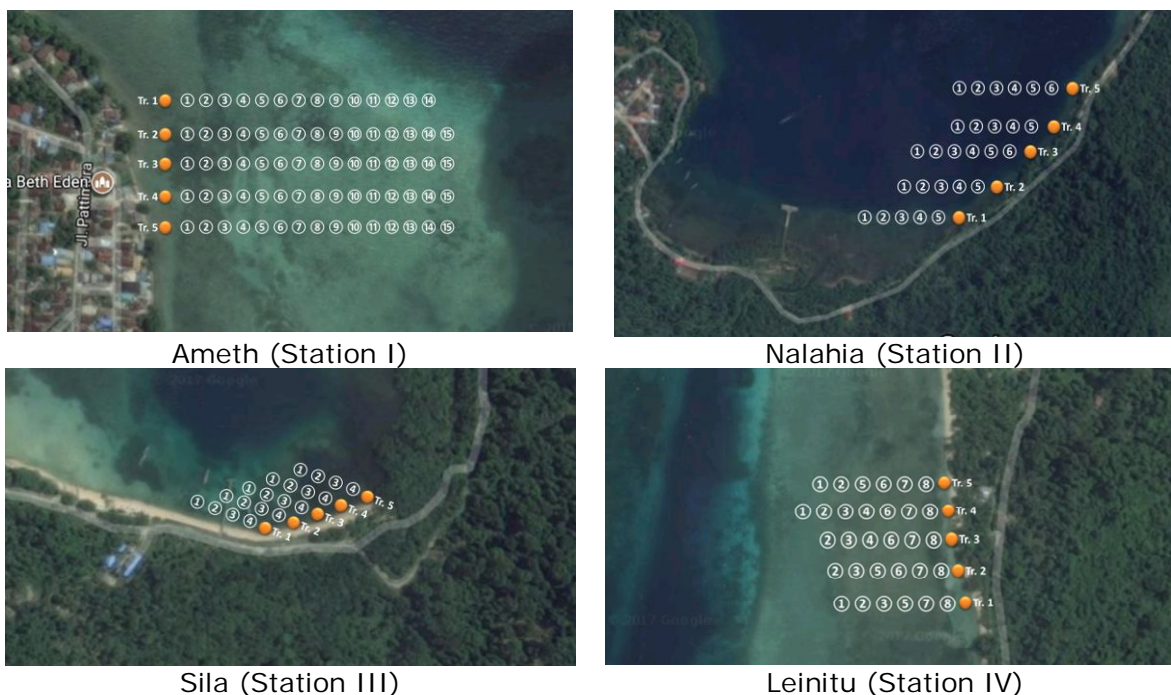


Figure 2. Determination of transects and plots in the research area (Note: ● transects, ○ plots).

Results and Discussion

Density, abundance, frequency of occurrence, and important value of macroalgae species in the coastal water of Nusalaut Island, Central Maluku District.

The results of the observations on the four stations (Figure 2) show that each observation station had different density, abundance, and frequency of occurrence, especially the macroalgae species found, which is presented in Tables 1-4. The highest density at Station I was *Gracilaria salicornia* and the lowest density was *Sargassum cinctum*. The highest density at Station II was *G. salicornia* and the lowest density was *Liagora viscida*. The highest density at Station III was *Padina australis* and the lowest density was *G. salicornia*. The highest density at station IV was *Hypnea valentiae* and the lowest density was *Gracilaria corticata*. Density, abundance, and frequency of occurrence are ecological parameters that describe the distribution of species in an environment. The three parameters are interconnected and positively correlated. Therefore, if the density value increases, the abundance value and the frequency of occurrence will also increase, and

this will increase the important value index of the species (Odum 1994; Rumahlatu et al 2008).

Table 1

Relative density (KR), relative abundance (KLR), relative frequency of occurrence (FR), and important value index (INP) of macroalgae species at station I (Amet Village) in the coastal waters of Nusalaut Island, Central Maluku District

No.	Macroalgae species	KR	KLR	FR	INP
1	<i>Caulerpa serrulata</i>	2.911	3.428	3.909	10.248
2	<i>Codium decorticatedum</i>	7.351	6.925	8.143	22.419
3	<i>Dictyosphaeria cavernosa</i>	4.439	5.211	5.863	15.513
4	<i>Halimeda opuntia</i>	3.202	3.771	3.583	10.556
5	<i>Neomeris annulata</i>	11.281	7.885	8.795	27.961
6	<i>Padina australis</i>	5.604	6.582	6.189	18.375
7	<i>Sargassum cinctum</i>	1.019	1.611	1.629	4.259
8	<i>Acanthophora dendroides</i>	3.275	3.840	3.257	10.372
9	<i>Acanthophora spicifera</i>	8.952	8.433	9.120	26.505
10	<i>Galaxaura subfruticolosa</i>	1.237	2.914	1.629	5.780
11	<i>Gracilaria corticata</i>	12.154	11.450	11.075	34.679
12	<i>Gracilaria dura</i>	10.407	9.804	10.098	30.309
13	<i>Gracilaria salicornia</i>	13.319	12.547	11.726	37.592
14	<i>Hypnea valentiae</i>	7.933	7.473	8.143	23.549
15	<i>Laurencia papillosa</i>	6.914	8.125	6.840	21.879

Table 2

Relative density (KR), relative abundance (KLR), relative frequency of occurrence (FR), and important value index (INP) of macroalgae species at station II (Nalahia Village) in the coastal waters of Nusalaut Island, Central Maluku District

No.	Macroalgae species	KR	KLR	FR	INP
1	<i>Codium decorticatedum</i>	14.319	14.186	13.793	42.298
2	<i>Acanthophora spicifera</i>	14.319	14.186	12.643	41.148
3	<i>Gracilaria dura</i>	14.084	13.953	12.643	40.680
4	<i>Gracilaria salicornia</i>	29.108	28.837	31.034	88.979
5	<i>Hypnea valentiae</i>	26.056	28.813	25.287	77.156
6	<i>Liagora viscida</i>	3.052	3.023	4.957	11.032

Table 3

Relative density (KR), relative abundance (KLR), relative frequency of occurrence (FR), and important value index (INP) of macroalgae species at station III (Sila Village) in the coastal waters of Nusalaut Island, Central Maluku District

No.	Macroalgae species	KR	KLR	FR	INP
1	<i>Halimeda opuntia</i>	30.000	28.850	30.610	8.940
2	<i>Padina australis</i>	40.000	38.460	34.700	113.700
3	<i>Gracilaria salicornia</i>	6.000	9.620	10.200	25.800
4	<i>Hypnea valentiae</i>	24.000	23.080	24.490	72.200

Table 4

Relative density (KR), relative abundance (KLR), relative frequency of occurrence (FR), and important value index (INP) of macroalgae species at station IV (Leimita Village) in the coastal waters of Nusalaut Island, Central Maluku District

No.	Macroalgae species	KR	KLR	FR	INP
1	<i>Codium decorticatedum</i>	9.428	13.545	10.345	33.318
2	<i>Dictyopteris acrostichoides</i>	19.714	16.995	19.540	56.249
3	<i>Acanthophora spicifera</i>	8.285	8.928	9.195	26.409
4	<i>Gracilaria corticata</i>	2.571	5.541	4.598	12.710
5	<i>Gracilaria dura</i>	8.857	9.544	8.046	16.447
6	<i>Gracilaria salicornia</i>	6.286	6.773	9.195	22.254
7	<i>Hypnea valentiae</i>	33.143	28.571	27.586	89.300
8	<i>Liagora viscida</i>	11.714	10.099	11.494	33.307

The frequency of occurrence of macroalga species describes the opportunity of macroalgae in the observation plot. Macroalgae of the *Gracilaria* genus have a dominant distribution, particularly *G. salicornia* which has the highest ecological parameter value (density, abundance, and frequency of occurrence) at stations I and II. But at station III and IV, *G. salicornia* and *G. corticata* became the individual with the lowest ecological parameters. The diverse frequency and distribution of the species is thought to be due to the relatively stable physico-chemical conditions of the water. The nutrients carried by water and substrates are the factors of the macroalgae growth. According to Connel (1974) and de Sherbinin et al (2007), a stable aquatic environment would indicate a balanced number of individuals from all existing species, otherwise the aquatic environment is experiencing many changes which would lead to the low species distribution and tend to have dominant individuals.

In addition to the water condition factor, species adaptation is also a key to the macroalgae density in the coastal area of Nusalaut Island. *Sargassum cinctum* and *L. viscida* had the lowest density value, thus, it is believed to be the barrier species. According to Bruckner & Dempsey (2015), the density of macroalgae is strongly influenced by the changes of the seasons and the unstable substrate conditions of coral exposure and are likely to lead to the low species distribution and the presence of dominant individuals.

Percentage of macroalga coverage distribution in the coastal waters of Nusalaut Island, Central Maluku District. Density, abundance, and frequency of occurrence produce diverse distributions at each observation station. The percentage of macroalgae coverage distribution is shown in Figure 3.

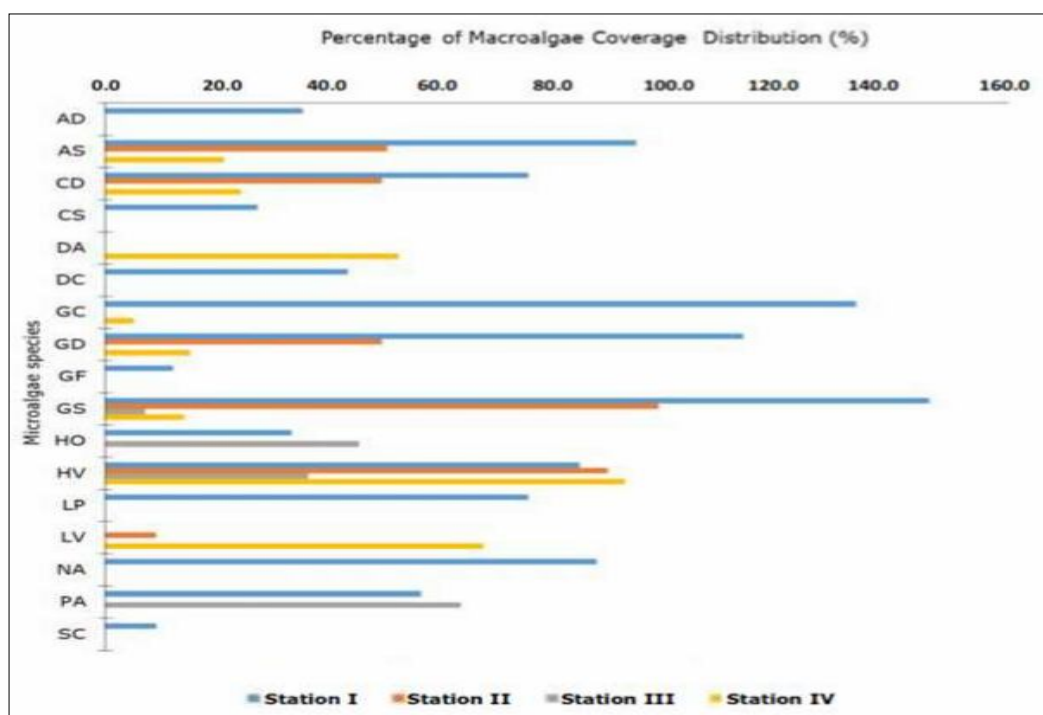


Figure 3. Percentage of macroalgae coverage distribution of *Acanthophora dendroides* (AD), *Acanthophora spicifera* (AS), *Codium decorticatam* (CD), *Caulerpa serrulata* (CS), *Dictyopteris acrostichoides* (DA), *Dictyosphaeria cavernosa* (DC), *Gracilaria corticata* (GC), *Gracilaria dura* (GD), *Galaxaura subfruticolosa* (GF), *Gracilaria salicornia* (GS), *Halimeda opuntia* (HO), *Hypnea valentiae* (HV), *Laurencia papilosa* (LP), *Liagora viscida* (LV), *Neomeris annulata* (NA), *Padina australis* (PA), and *Sargassum cinctum* (SC) at station I, station II, station III, and station IV.

Station I has the highest percentage of macroalgae coverage distribution (diverse) of 15 species out of a total of 17 species (all observation stations). Species *D. acrostichoides* and *L. viscida* can only be found at station II and station IV. *G. salicornia*, *H. opuntia*, *H. valentiae*, and *P. australis* species can only be found at station III. Bold & Wynne (1985)

states that macroalgae is a living macrobentos whose life attaches it self to various substrates, such as rocks, corals, sand, and mud. Thus, the substrate found in each station are suitable for the habitat of macroalgae.

The presence of macroalgae in the coastal water of Nusalaut Island is quite a few, only 17 species. This is in contrast to Papalia & Arfah (2013) who found 33 macroalgae species in the water of Amabalau and its surrounding. Papalia (2015) found 47 species on Haruku Island, and Hatta et al (1991) found 76 species on Kai Island, Southeast Maluku. This is because different natural conditions will certainly have different environmental factors that affect the presence of macroalgae. In places with dead coral substrate, massive corals and more stable sand were found more macroalgae species than those with only sand and mud places (Atmadja 1999). Furthermore, Diaz-Pulido & McCook (2008) explain that the increase in the number of individuals and species of an organism occurring in an area is due to its varying substrate. In addition to substrate, it is also influenced by environmental factors, such as temperature, salinity, light intensity (brightness) and current velocity (Dawes 1981). According to Atmadja & Sulistijo (1980), there are 88 macroalgae species in the water of Maluku.

Distribution of macroalgae in the coastal water of Nusalaut Island, Central Maluku District. The distribution of macroalgae in coastal areas is also strongly influenced by the geographical factors. In general, the sampling locations at the 4 stations are the cape area (station I and station III) and the bay area (station II and station IV) as what can be seen in Figure 3. The terrestrial condition is an island with a rather dense settlement leaving an ecological space for macroalgae in coastal areas.

Station 3 has a less varied combination of substrate structure. This causes that the algae species found there were not varied either. Conversely, station 1 has a varied combination of substrate structures, so that the algae species found there were also varied. According to Diaz-Pulido & McCook (2008), the combination of substrate structure greatly determines the variation of seaweed species. On the beach with almost similar substrate structure, the species diversity also tends to be similar. The algae found were *H. opuntia*, *P. australis*, *G. dura*, *G. corticata* and *G. salicornia*. The three genera above (*Halimeda*, *Padina* and *Gracilaria*) were found in all research sites and they were found almost in all plots. It shows that the three algae genera have a high tolerance to drought at the lowest tide. This is consistent with the statement of Kadi (2004), that in the substrate of reef exposure relatively close to the mainland at the lowest tide, the growing macroalgae exhibit a high tolerance to drought, especially from the *Halimeda*, *Padina*, *Gracilaria* and *Sargassum* genera.

In general, the condition of the coastal water of Nusalaut Island has exposure to reefs with similar substrate base in all the four research stations. The coastal areas are covered with mud, sand, dead coral fragments and towards the reef with dead coral interspersed with live coral, while the mouth of the lake (lagoon), the substrate is dominated by muddy sand. In the coastal areas, grass generally grows quite evenly. Such aquatic area is a habitat for macroalgae growth; *Halimeda* and *Caulerpa* can grow well on mud, sand and dead coral fragments substrate, while *Padina*, *Sargassum*, and *Gracilaria* are found in dead coral reefs.

Diversity index, dominance index, and index of macroalgae species in coastal waters of Nusalaut island, Central Maluku District. Diversity is a very important parameter to compare various communities of marine biota, especially to determine the effect of water quality (Figure 4).

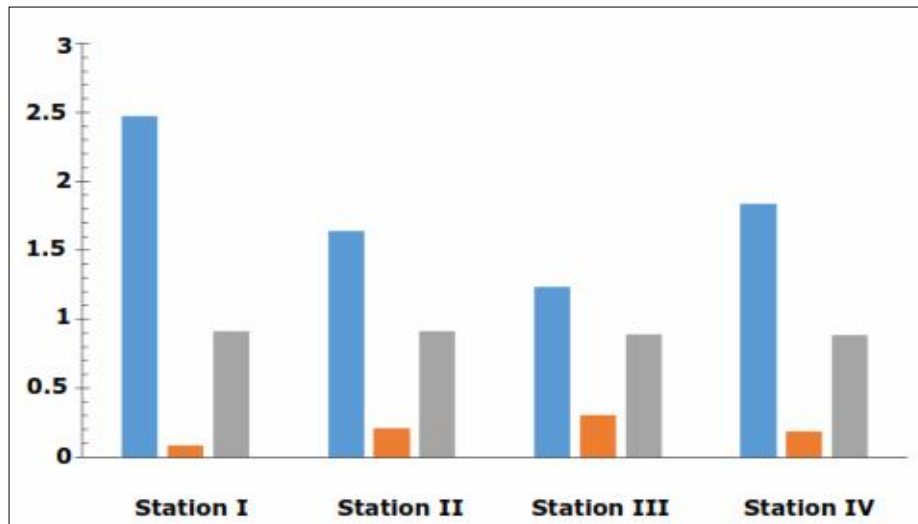


Figure 4. Diversity index - H' (■), dominance index - D (■), and evenness index - E (■) of macroalgae species in Station I, II, III, and IV in the coastal waters of Nusalaut Island, Central Maluku.

The highest diversity index is in station I, followed by station IV, station II, and station III. The average of the diversity index of all observation stations is 1.796. Station I has the highest biodiversity index due to the discovery of 15 of the 17 identified macroalgae species in the region. Indirectly, it is known that this area has a good supportive ecology for several macroalgae species. According to Shannon & Weaver (1963) in Romimohtarto & Juwana (2001), the index value $H' = 1.0-3.0$ then the diversity of species in a territorial water is included in the moderate category. Diversity index is often associated with water conditions, so that it can be used as an indicator of water cleanliness. The diversity of macroalgae species in the coastal water of Nusalaut Island shows that the water condition is contaminated with moderate category. According to Fachrul (2007), if the value of $H' = 1.0-3.0$ indicates a moderately polluted water quality, $H' < 1$ indicates a heavily polluted water quality, otherwise $H' > 4$ indicates clean water.

The highest evenness index is in station II, followed by station I, station III, and station IV. The average of the evenness index in all observation stations is 0.900. In general, the evenness index between stations is not too much different. It is suspected that the distribution of the species tends to be heterogeneous and the number of the species is strongly influenced by the large number of occurrence and individual macroalgae present in coral exposure (Krebs 1989; Grevo 2004). The limit of the uniformity index value (E) indicating environmental condition in stable condition ranges from 0.75 to 1.00 (Hukom 1998).

In general it appears that the value of diversity is directly proportional to uniformity and inversely proportional to the value of dominance. The highest dominant index is at station III, followed by station II, station IV, and station I. The average of the dominance of all observation stations is 0.197. The macroalgae have a high adaptation rate making them able to live on diverse substrate conditions (Jorgensen et al 2005). The D value < 0.5 indicates a low dominance, otherwise if D reaches 1, then the dominance is the highest (Odum 1994). A stable uniformity indicates that the number of macroalgae found is not so different (even). This is also evidenced by the low dominance value (no dominant species). The uniformity of macroalgae species in this water is said to be more evenly because macroalgae can grow optimally. Macroalgae can grow optimally because the water conditions and the environmental factors are stable. Namakule et al (2017) explained that the diversity of organisms in the waters is strongly influenced by environmental factors.

The macroalgae communities which have high biodiversity values are generally in good water condition, and otherwise poor water conditions will produce lower diversity. The diversity and the uniformity of macroalgae species from the calculations in the Jikumerasa water have a quite high value, both in quality and in quantity. When

compared to the other regions such as Riau and Bangka Islands, the number of macroalgae species reaches 24 species, the diversity index is 1.9048 and the uniformity index is 0.662 (Kadi 2006). According to Odum (1994), diversity has the highest value if all individuals come from different genus or species; otherwise the diversity has the lowest value when the individuals come from the same genus or species.

Conclusions. Macroalgae found on the Nusalaut Island was 17 species representing 12 genera, namely *Acanthophora*, *Codium*, *Caulerpa*, *Dictyopteris*, *Gracilaria*, *Halimeda*, *Hypnea*, *Laurencia*, *Liagora*, *Neomeris*, *Padina*, and *Sargassum*. The density and abundance of the *Gracilaria* genus are higher than those of other genera. Geographically, the distribution of macroalgae in the waters of Nusalaut Island is higher in the residential area of Ameth village. Ameth village is the location which has the highest diversity index value (H') 2.475. The dominance index of species (D) is the highest in station III and the highest evenness index (E) is found in station II. In general, the ecological structure of the macroalgae community is evenly distributed along the coastal water.

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