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Diversity of Macroalgae Species on Pramuka Island, Thousand Islands Regency, DKI Jakarta Province

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Abstract

Macroalgae are marine plants that are included in the Thallophyta division because they cannot be distinguished between their roots, stems and leaves. Life is widespread in almost all coastal areas of Indonesia, including the coast of the Thousand Islands. Pramuka Island is included in the Thousand Islands Regency, DKI Jakarta Province. As an inhabited island, anthropogenic activities on Pramuka Island vary greatly, so the waters on Pramuka Island cannot be separated from anthropogenic pressures that can threaten marine biota on Pramuka Island, one of which is macroalgae. The relationship between decreasing macroalgae diversity and environmental quality needs to be considered, because the presence and loss of macroalgae is very important for the sustainability of macroalgae in the Thousand Islands and their conservation. The aims of this study were (1) to determine the diversity of macroalgae on Pramuka Island; and (2) to determine the relationship between diversity and water quality on Pramuka Island. The research method is a survey method using the quadratic transect method. Analysis of macroalgae species diversity data using the Shanon-Wiener diversity index. Dominance with the Simpson dominance index. The Diversity Index and Dominance Index were calculated using the PAST.4.0 software. The link between environmental quality and diversity uses Principal Component Analysis (PCA). The results showed that the diversity of macroalgae on Pramuka Island was in the medium category, which ranged from 1.273 to 2.281. The diversity of macroalgae in Pramuka Island waters is influenced by physical factors such as salinity, depth and current speed, temperature, brightness, TDS , and chemical factors of nitrate, DO, Hg;Pb;Cu;

Keywords : Diversity, water quality, macroalgae, Pramuka Island

INTRODUCTION

Macroalgae are widespread in almost all regions of Indonesia. Because Indonesia is an archipelagic country and has the longest coastline. Some areas, such as the Kepulauan Seribu reef area, have high macroalgae biodiversity. Macroalgae are one of the important marine primary producers, because they support the life of other organisms at a higher tropic level in aquatic ecosystems, and contain chlorophyll for photosynthesis and some pigments. Macroalgae are marine plants that are included in the Thallophyta division because they cannot be

distinguished between their roots, stems and leaves. Macroalgae are categorized simply into green macroalgae (Chlorophyta), brown macroalgae (Phaophyta or Ochrophyta) and red macroalgae (Rhodophyta) (Roem *et al*., 2017; Wulandari *et al*., 2020, Handayani, *et al*., 2023)). Macroalgae can be utilized because they have potential as bioaccumulators, bioremediation and biomonitoring of heavy metals in waters (Zeraatkar *et al*., 2016; Seoane *et al*., 2020).

Macroalgae have an ecological role as primary producers in the food chain (Prathep *et al*., 2011; Satheesh and Wesley, 2012), providing habitat for other small marine biota such as crustaceans, mollusks, and echinoderms (Okuda, 2008; Prathep *et al*., 2011), nursery areas (Chaves et al., 2013; Giakoumi et al., 2012), shelters (Amsler *et al*., 2015), spawning grounds, and food sources for marine life (Filbee-Dexter and Scheibling, 2014; Tolentino *et al*., 2008 ; Williams and Smith, 2007; Mauffrey et al., 2020)), and plays a role in the blue carbon system (Chung *et al*., 2011; Chung et al., 2013; Sondak *et al*., 2017) .

Macroalgae has economic benefits as raw materials in several industries, such as the carrageenan industry and the agar industry (Bolton *et al*., 2007). In addition, macroalgae is an excellent commodity to develop because of its chemical content in it, so that macroalgae can be used as a source of food and a source of medicines (Yudasmara, 2011; Nurjanah *et al*., 2016; Hidayat *et al*., 2018; Dwimayasanti , 2018; Kalani *et al*., 2019; Dumilag, 2019). So that the existence and diversity of macroalgae need to be managed and preserved.

The diversity of macroalgae in an area is determined, among other things, by habitat structure or substrate type, because each macroalgae occupies a habitat with a different substrate. The main basic substrates include sand, coral rubble, dead coral and rock (Ferawati *et al*., 2014; Johan *et al*., 2015; Miala *et al*., 2015; Handayani, 2020; Windarto *et al*., 2021). Apart from the type of substrate, other physical factors also affect the diversity of macroalgae species such as temperature, brightness, currents, and chemical factors such as salinity, degree of acidity (pH), nitrate and phosphate as well as biological factors such as predation by herbivorous fish and competition between types of macroalgae. Macusi and Deepananda, 2013; Cleary *et al*., 2016; Zhao *et al*., 2016; Namakule *et al*., 2017; Dwimayasanti & Kurnianto, 2018; Voerman et al., 2019). Anthropogenic activities such as coastal development, tourism, pollution, and natural factors such as climate change are also factors causing decreased diversity and abundance of macroalgae (Retnaningdyah *et a*l., 2019; Orfanidis *et al*., 2021).

Pramuka Island is an inhabited island, administratively located in the Thousand Islands Regency, DKI Jakarta Province. Pramuka Island is the administrative center of the Thousand Islands Regency. So many anthropogenic activities are carried out on this island, such as traditional inter-island boats, tourism (diving and snorkeling), pollution, fishing and development of coastal areas. The cumulative impact of anthropogenic pressure is the main factor in decreasing the diversity of macroalgae in waters (Orfanidis *et al*., 2021).

High anthropogenic activity on an island will have an impact on habitat destruction, and decrease the quality of coastal waters ecosystems, thereby threatening marine biota, one of which is macroalgae (Retnaningdyah et al., 2019; Orfanidis et al., 2021). While macroalgae is an excellent commodity to develop because of its chemical content in it, so macroalgae can be used as a source of food and a source of medicines (Nurjanah et al., 2016; Hidayat et al., 2018; Kalani et al., 2019)

Damage to marine ecosystems will have an impact on the instability of these aquatic ecosystems, decreasing marine natural resources, and resulting in the extinction of marine biota, one of which is macroalgae. The relationship between decreased macroalgae diversity and

environmental conditions needs to be considered, as the presence and loss of macroalgae are critical for evaluating the role of ecological processes and for managing direct and indirect anthropogenic pressures. This is very necessary for the sustainability of macroalgae in the Thousand Islands and their preservation. The purpose of this study was to determine the diversity of Pramuka Island macroalgae; and to determine the environmental factors that affect the diversity of macroalgae in Pramuka Island.

METHOD

This research was conducted in April 2021. This study has four stations: Pramuka Island (Figure 1)

Figure 1. Map of Research Locations

The data collection on macroalgae with a survey using the square transects method. First, on each sampling station, three transects of line 50 m long perpendicular to the coast to the tubing with a distance between transects of 20 m are made. Next, the observations were made by placing squared transects measuring 1x1 m at a distance of 5 m from the coastline. Then, subsequent placement of the square plot at a distance of 10 m from the first laying, and so on to 50 m (Figure 2).

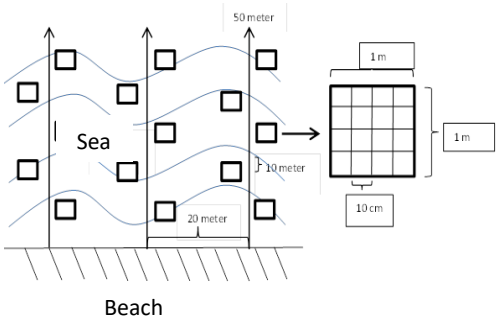

Figure 2. Sampling Plot Laying Design (Handayani *et al*., 2023)

The species of macroalgae, substrates, and environment were observed. The measurements include temperature, Salinity, Brightness, Current, TDS, Depth, Substrate, pH, DO, Nitrate and orthophosphate (APHA 2017), Hg, Pb, and Cu (Li *et al*. 2020). In addition,

environmental parameters such as substrate, temperature, salinity, brightness, current, TDS, depth, pH, and DO are measured in the field. At the same time, chemical parameters such as Nitrate, Orthophosphate, Hg, Pb, and Cu are analyzed at the Productivity and Aquatic Environment Laboratory IPB-Bogor (Table 1).

Table 1. Measurement of aquatic environmental parameters

Parameters	Unit	Metodh/Tools	Measurement
Temperature	^{O} C	Lutron seri T 017219	In situ
Brigthnees	m	Secci disc	In situ
Salinity	Ppt/ $^{0}/_{00}$	Lutron TF 06213	In situ
Current velocity	$m.s^{-1}$	Floating droudge	In situ
Dept	m	Regular Stick	In situ
pH		Lutron seri TP 07	In situ
DO	$mg.L^{-1}$	Lutron Seri WAC-2019CP	In situ
Nitrate	$mg.L^{-1}$	APHA, 23rd Edition, 4500-P-E, 2017	Laboratory
Orthophospat	$mg.L^{-1}$	APHA, 23rd Edition, 4500-NO3-E, 2017	Laboratory
Hg	$mg.L^{-1}$	IK-LAB-logam-04 (Cold Vapor)	Laboratory
Pb	$mg.L^{-1}$	IK-LAB-logam-11 (Ekstraksi-GFAAS)	Laboratory

The identification of macroalgae species found was determined using the identification book and journals (Lima *et al.* 2017; Lim *et al.* 2017; Joshi 2022; Atmadja *et al*. 1996; Trono 1997; Bolton *et al*. 2007; Handayani *et al*, 2023). In addition, the identification also uses macroalgae scientific nomenclature that is in international force today.

Data analysis includes the Shannon-Wiener diversity index, the index to equal, and the dominance index using PAST 4.0 software. In addition, the linkages between parameters were tested using Principal ComponenAnalysis (PCA).

RESULT AND DISCUSSION

Macroalgae Composition

The results of the identification of macroalgae found at the study site were divided into 3 groups, namely Chlorophyta, Phaeophyta (Ochrophyta), and Rhodophyta with 26 species of macroalgae. The species of macroalgae found are shown in Table 2 below:

Table 2. Species of Macroalgae Found on Pramuka Island

Division	Class	Family	Species
Chlorophyta	Chlorophyceae	Halimedaceae	*Halimeda laccunalis* W.R.Taylor
		Halimedaceae	*Halimeda macroloba* Decainsne
		Halimedaceae	*Halimeda oppuntia* (Linnaeus) J.V.Lamouroux
		Halimedaceae	*Halimeda macrophysa* Askenasy
Chlorophyta	Chloropyceae	Caulerpaceae	*Caulerpa lentillifera* J. Agardh
		Caulerpaceae	*Caulerpa taxifolia* (M.Vahl) C. Agardh
		Caulerpaceae	*Caulerpa sertularoides*

			(S.G.Gmelin) M. Hawe
		Caulerpaceae	*Caulerpa racemosa* (Forsskal) J.Agardh
		Caulerpaceae	*Caulerpa serrulata* (Forsskal) J. Agardh
		Caulerpaceae	*Caulerpa sp* J.V.Lamouroux
Chlorophyta	Chlorophyceae	Dasycladaceae	*Neomeris annulata* Dickie
	Chlorophyecae	Ulvaceae	Enteromorpha intestinalis (Linneus) Nees
	Ulvophyceae	Boodleaceae	Boodlea composita (Harvey ex J.E. Gray) Egerod
Phaeophyta	Phaeophyceae	Dictyotaceae	*Padina tetrasomastica* Hauck
		Dictyotaceae	*Padina australis* Hauck
		Dictyotaceae	*Dictyota bartayresiana* J.V. Lamouroux
Division	Class	Family	Species
Phaeophyta	Phaeophyceae	Sargassaceae	*Sargassum binderi* Sonder ex J.Agardh
		Sargassaceae	*Cystoceria* sp C. Agardh.
Ochrophyta	Phaeophyceae	Sargassaceae	*Tubinaria ornata* (Turner) J.Agardh
		Sargassaceae	*Turbinaria conoides* (J.Agardh) Kutzing
Rhodophyta	Rhodopyceae	Hypneaceae	*Hypnea asperi* Kutzing.
Rhodopyta	Rhodophyceae	Corallinaceae	*Corallina* sp Linnaeus
		Corallinaceae	Amphiroa fragillisima (Linnaeus)J.V.Limouroux.
Rhodophyta	Rhodophyceae	Soliericeae	*Eucheuma spinosum* J.Agardh
		Rhodomelaceae	*Acanthophora muscoides* (Linnaeus) Bory
Rhodophyta	Phaeophyceae	Gracilariaceae	*Gracilaria salicornia* (C.Agardh) Dawson

From the identification of macroalgae on Pramuka Island, 13 species of Chlorophyta were found, 7 species of Phaeophyta/Ochrophyta, and 6 species of Rhodophyta (Figure 3)

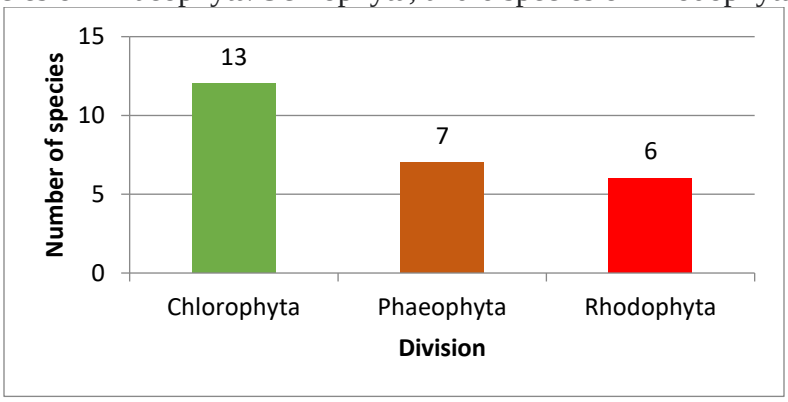

Figure 3. Histogram of Macroalgae Composition

Diversity Index

Based on the results of analysis of the diversity index (H`) of macroalgae at the study site, it was shown that the value of species diversity at Station I was 1.273; Station II, namely 2,022; Station III is 2,281, Station IV is 1,892 (Figure 4).

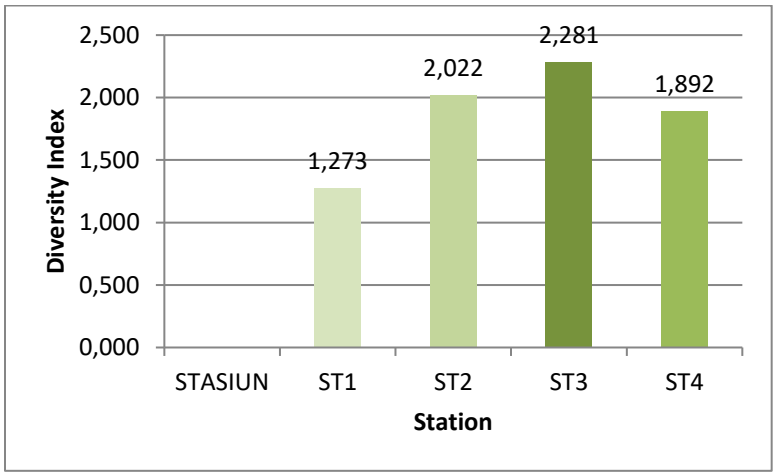

Figure 4. Histogram of Macroalgae Diversity Index

Dominance Index

The dominance index is used to determine the dominance of a species so that it can be identified that several species of macroalgae species dominate. Based on the results of the macroalgae dominance index analysis at the research station, as shown in Figure 5.

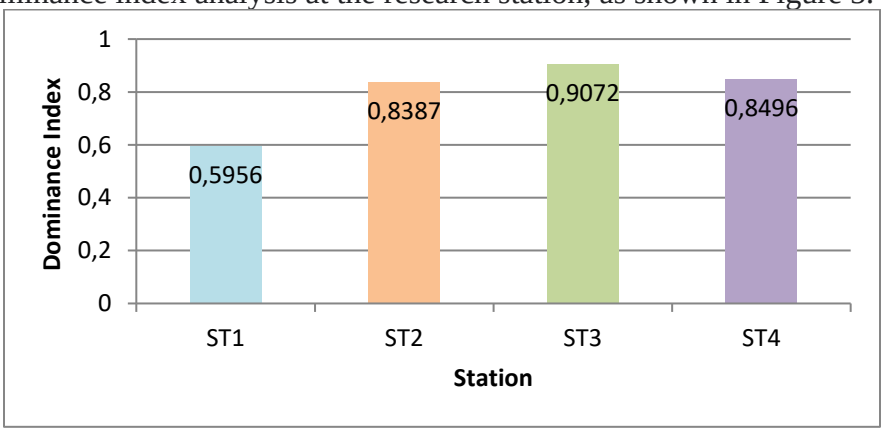

Figure 5. Histogram of Macroalgae Dominance Index Values

Water Quality of Pramuka Island

The existence and diversity of macroalgae are also influenced by water conditions, both physical and chemical. The measurement results of several water parameters such as temperature, salinity, current, pH, brightness, nitrate and orthophosphate are shown in Table 3

Table 3. Water Quality of the Thousand Islands

PARAMETERS	PRAMUKA ISLAND

	STATION 1	STATION 2	STATION 3	STASIUN 4
Physics				
Temperature (° C)	28	27.6	27.2	27.4
Salinity (°/₀₀)	31	31	32	30
Brigthness (%)	100	100	100	100
Current velocity (m/s^{-1})	0.12	0.11	0.24	0.29
Depht (m)	0.16	0.23	0.35	0.58
Substrate	Sand, DC	Sand,DC	Sand, DC	Sand, DC
Chemestry				
pH	8.2	8.13	7.95	8.31
DO (mg.L^{-1})	6	4.43	4	5
Orthophospat (mg.L^{-1})	<0.002	<0.002	<0.002	<0.002
Nitrate (mg.L^{-1}))	0.13	0.27	0.141	0.153
Heavy metals				
HG (mg.L^{-1})	0.0005	0.0005	0.0005	0.0005
PB (mg.L^{-1})	0.007	0.007	0.007	0.007
CU (mg.L^{-1})	0.007	0.007	0.007	0.007

Information: DC : dead coral

Relationship between Diversity and Water Quality

Based on the results of PCA analysis using three characterization roots (each axis F1 = 36.52 % F2 = 17.00 %, and F1-F2 = 53.53%) (Figure 6).

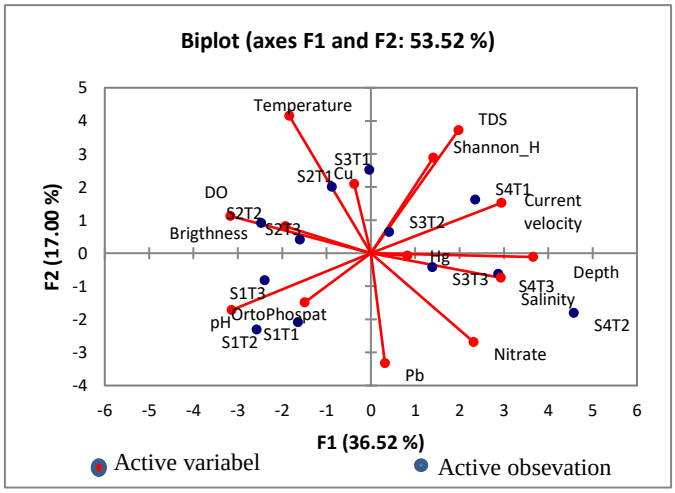

Figure 6. Relationship between Macroalgae Diversity and Water Quality

Discussion

Macroalgae Composition

The highest species composition of macroalgae on Pramuka Island is from Chlorophyta, maybe this is due to the substrate, because sand substrate is a suitable substrate for macroalgae growth from Chlorophyta, (Johan et al., 2015; Arami et al., 2018). The high Chlorophyta in Pramuka Island waters is thought to be due to the type of substrate at the study

site consisting of sand and sandy mud, where the substrate is a good growing place for Chlorophyta macroalgae. This is by the statement of Kadi and Atmajadja (1998), locations with sand habitats are mostly overgrown by Chlorophyta and Phaeophyta macroalgae. Macroalgae from Chlorophyta generally respond quickly to nutrient enrichment and tend to dominate in shallow water environments (Montenegro et al., 2010). Chlorophyta are suitable for growing on sand substrates in the intertidal zone and are tolerant of lower salinity (Johan et al., 2015; Anggadiredja, 2017; Isham et al., 2018; Abdullah et al., 2020). Sand substrate is an unstable medium so it is easily blown away when there are big waves, but certain species can grow, such as Chlorophyta (Ferawati et al., 2014)

Diversity Index

The diversity index on Pramuka Island shows a diversity value ranging from 1.273 to 2.281 which is included in the medium category. This indicates a relatively high level of diversity in macroalgae communities in the waters.

The diversity index is used to measure the diversity of species within a community, where higher values indicate greater species diversity. The highest species diversity was found at Station 3 of 19 species with the highest diversity index value of 2.281, while the lowest species diversity was found at Station 1 of 15 species with a diversity index value of 1.273. The diversity index on the island of Pramuka, the Thousand Islands, is greater than 1, smaller than 3. According to Fachrul, 2007, the diversity index value between 1 <H`< 3, belongs to the medium species diversity category. The diversity index of a community can describe its level of stability. The moderate diversity index was caused by environmental conditions which were still quite stable and the large number of macroalgae species found. High diversity in the macroalgae community indicates the existence of environmental conditions that support the growth and abundance of various macroalgae species .

Stable aquatic ecosystems can play a role in encouraging high catches. The high diversity of macroalgae in the waters has an important ecological value. Macroalgae not only play a role in marine ecosystems as the main producers that produce oxygen and food for other organisms, but also provide shelter and habitat for various marine organisms (Prathep et al., 2011; Satheesh and Wesley, 2012; Chaves et al., 2013 ; Filbee-Dexter and Scheibling, 2014)

Dominance Index

The Dominance Index value ranges from 0.5956 – 0.9072, this value is in the high category. Based on the results of observations, it can be concluded that the dominance of macroalgae in Pramuka Island waters at each Observation Station is low to high dominance, so combined the dominance is high. This means that there are dominant macroalgae but not those that dominate other macaroalgae because of the many species of macroalgae found.

Water Quality of Pramuka Island

1. Temperature

   The temperature in the waters of Pramuka Island is in the range of 27-28 ^{o}C. This temperature is still included in the optimum temperature range for macroalgae life, namely 25^{o}C–30^{o}C. This temperature is the optimum temperature for macroalgae to carry out photosynthesis.

2. Salinity

In this study, the salinity at the Pramuka Island Research Station was 30-32 $^{0}/_{00}$. This salinity figure is included in the optimum salinity range (± 35 $^{0}/_{00}$) which can affect the rate of photosynthesis and macroalgae growth.

3. Depth and Brightness

The results of depth measurements recorded on Pramuka Island were 0.16 – 0.58 m. Depth affects the diversity of macroalgae. The shallower the waters, the more exposure to sunlight can cause physiological stress for macroalgae, especially for macroalgae that have thin thallus. The brightness found on Pramuka Island is still considered to be the optimum brightness figure because according to State Ministerial Decree No. LH. 51 (2004) the brightness standard is over 3 m. Depth and brightness are very important in the intake of sunlight which is the main component in the process of photosynthesis (Berwick, 1983).

4. Current velocity

The current velocity on Pramuka Island is 0.12-0.29 $m.s^{-1}$. Optimum current velocity (0.05 -1.00 $m.s^{-1}$) is required to support the growth and distribution of macroalgae. Movement of water is necessary for the continued growth of macroalgae, which is related to increasing the rate of absorption of nitrate and the transport of carbon and nutrients from the water column to the surface of the thallus. If the current velocity is too weak, it can result in the accumulation of organic matter, causing one type of macroalgae to become dominant over another less adaptable type. On the other hand, if the current velocity is too strong, it will result in excessive and unevenly distributed sediment transport, which can cause a low level of macroalgae cover.

5. Substrate

Based on the results of the analysis of the particle size of the substrate, it is known that Pramuka Island is dominated by the sand sediment fraction (93.18%) and the remainder is in the form of silt and clay fractions. This may also be one of the reasons for the greater number of species on Rambut Pramuka Island where most of the species found are sandy substrate types. This can be seen at Stations 3 and 4 where the substrate mostly consists of the sand fraction, the type of macroalgae found is the type of macroalgae Chlorophyta which likes sand substrate.

6. Degree of acidity (pH)

The results of pH measurements on Pramuka Island were 7.95 -8.31, the pH value was included in the optimal pH range according to State Ministerial Decree No. LH. 51 (2004) ie 7 - 8.5. The degree of acidity (pH) can affect the species composition. The pH value is very important as a water quality parameter because it will control the reaction rates of some materials in water and determine CO_2 levels. Macroalgae can thrive at optimal pH because at this optimal pH, the compounds needed for photosynthesis by macroalgae are in abundance (Widianingsih, 1991; Nybakken, 1993). The degree of acidity or pH also affects the growth of macroalgae. A good degree of acidity (pH) for macroalgae growth is in the pH range of 6.8-9.6 (Luning, 1990), whereas according to Anggadireja *et al* (2006), the optimum pH conditions for macroalgae growth range from 6.8-8.2. So the pH on the island of macroalgae is still quite ideal for the growth of macroalgae.

7. Nitrates and orthophosphate.

Nitrate is a chemical compound that functions as a nutrient in seawater. Nitrate levels in Pramuka Island waters range from 0.13-0.27 $mg.L^{-1}$ Normal nitrate levels in marine waters

generally range from 0.001-0.007 mg.L^{-1} (Brotowidjoyo et al., 1995). The Ministry of Environment (2004) set a quality standard for nitrate compounds for marine biota of 0.008 mg.L^{-1}. The range of nitrate content in Pramuka Island waters is above the quality standards for marine biota, but still within the limits. Phosphate is one of the nutrients needed and affects the growth and development of macroalgae. The results of measuring phosphate levels on Pramuka Island ranged from 0 < 002 mg.L^{-1}. The range of phosphate levels is still within safe limits for marine biota. The Ministry of Environment, (2004) determined the quality standard for phosphate compounds for marine biota at 0.015 mg.L^{-1}, which is safe for water fertility.

8. Heavy Metals

Metal weight measurement is used as a way to determine metal contamination in water. Results of heavy metal measurements on Pramuka Island for Mercury (Hg) 0.005 mg.L^{-1}, Lead (Pb) 0.007 mg.L^{-1} and Copper (Cu) around 0.007 mg.L^{-1}. The Hg level in Pramuka Island waters is above the quality standard for marine biota. The Ministry of Environment, (2004) set the quality standard for Hg compounds for marine biota at 0.001 mg.L^{-1}. The high content of Hg, Pb, and Cu in Pramuka Island waters, above the safe limit for marine biota, is suspected that Pramuka Island is a residential island and the center of government, and is located because it is in an area of high industrial activity and anthropogenic activity. Activities of cruise ships and traditional ships used as a means of transportation and recreation as well as industrial activities in the waters of the Thousand Islands can affect the value of the metal content of Pb and Cu. (Cordova and Muhtadi, 2017; Sachoemar, 2018)

The relationship between diversity and water quality

The presence of macroalgae is influenced by water conditions, both physical and chemical. Several factors measured in the field showed quite large variations at each observation point. Figure 6 shows that there are 4 groups of stations with similarities with their preferences. Group 1 : S2T2;S2T3;S3T3; S4T1; S4T2;S4T3 with preference for nitrate, DO, Depth salinity, current velocity. Group 2 : S1T2,S1T3 with pH preference. Group 3:S2T1;S3T1; S3T2 with Hg preference; Pb; Cu; Temperature, Brightness, TDS. Group 4: S1T1 with a preference for orthophosphate. The diversity of macroalgae in Pulau Seribu as a whole at the station is in the moderate category. The highest Diversity Index value was at Station 3 and the lowest was at Station 1. The main factor suspected of causing the high diversity index value at Station 3 compared to other Stations was that Station 3 was far from human activity so the types of macroalgae found were also more numerous than those at Stations other.

CONCLUSION

Based on the results of identification in the waters of Pramuka Island, it was found that there were 26 species included in the division Chlorophyta 13 species, Phaeophyta/Ochrophyta 7 species and Rhodophyta 6 species. The diversity of macroalgae on Pramuka Island is included in the moderate category because there are still many types of macroalgae found. The diversity of macroalgae in Pramuka Island is influenced by environmental quality. Physical factors that affect the diversity of macroalgae such as temperature, brightness, depth, current velocity, salinity, TDS, and chemical factors include Nitrate, DO, Cu, Pb, Hg, and DO.

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