JPPIPA 11(7) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Macroalgae Community Structure on Different Substrate in Sabang Waters

Darlina[1], Saida Rasnovi[2*], Amalia[2]

[1] Master in Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia.
[2] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia.

Received: May 19, 2025
Revised: June 06, 2025
Accepted: July 25, 2025
Published: July 31, 2025

Corresponding Author:
Saida Rasnovi
saida_rasnovi@unsyiah.ac.id

DOI: 10.29303/jppipa.v11i7.11610

Abstract: Research on analysis of macroalgae community structure on different substrates in Sabang waters to identify, analyzing diversity, abundance, and important value index. The data collection method was carried out by purposive sampling using a plot of 1x1 m^2 with 10 plots per transect. Sampling was carried out at three stations, namely Station I on Pasir Putih with a medium fine sand substrate, Station II at Anoi Itam with a gravel sand substrate, and Station III on Rubiah Island with a fine sandy clay substrate. Data were analyzed using the Importance Value Index (IVI) and the Shannon-Wiener Diversity Index. The environmental parameters at each station that were measured were substrate particles, temperature, brightness, depth, and current velocity, while the chemical parameters were salinity, pH, COD, phosphate, and nitrate. The results of the study found 2615 macroalgae individuals consisting of three divisions. Chlorophyta division consists of 9 species, Rhodophyta was 7 species, and Phaeophyta was 1 species (*Dyctyota dichotoma*). The highest Important Value Index at each research station consisted of the Chlorophyta division with two species, namely *Dictyosphaeria cavernosa* (IVI = 59.18) and *Halimeda opuntia* (IVI = 54.15). The value of the diversity index (H') of macroalgae in Sabang waters is moderate, namely in Pasir Putih as much as 2.18, Anoi Itam and Rubiah Island as much as 2.01, and 1.97, respectively. The study concluded that the macroalgae community structure in Sabang waters exhibits moderate species diversity, with the Chlorophyta division, particularly *Dictyosphaeria cavernosa* and *Halimeda opuntia*, showing the highest importance value indices across different substrates.

Keywords: Anoi Itam; Macroalgae; Pasir putih; Rubiah Island; Sabang

Introduction

Sabang is an archipelago located in Aceh Province, Indonesia with coordinates 5°46'28" to 5°54'28" North Latitude and 95°13'12"to 95°22'36" East Longitude. (Agustina et al., 2021). Sabang is a marine tourism place that is often visited by local and foreign tourists. The flora and fauna of Sabang's waters have beauty and appeal for diving enthusiasts. The waters of Sabang have a marine biodiversity of flora and fauna that have an important role in ecology and economy. Macroalgae is one of the groups of flora found in these waters.

The term macroalgae, sometimes known as seaweed, refers to thousands of species of macroscopic, multicellular marine algae that range in size from a few centimeters to 30 meters. Macroalgae are lower plants (Thallophyta), which cannot be differentiated between root, stem, and leaf organs. It is estimated that there are approximately ten million types of macroalgae distributed on the earth's surface (Festi et al., 2022). Indonesian waters have 729 types of macroalgae. There are 3 macroalgae divisions, namely Clorophyta (green macroalgae), Phaeophyta (brown macroalgae), and Rhodophyta (red macroalgae) (Arista et al., 2022).

How to Cite:
Darlina, Rasnovi, S., & Amalia. (2025). Macroalgae Community Structure on Different Substrate in Sabang Waters. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 331–339. https://doi.org/10.29303/jppipa.v11i7.11610

The role of macroalgae in marine ecosystems is as a producer of herbivorous fish and a source of oxygen, fish spawning sites, current resistance, and shelter for another marine biota (Rume & Yohanista, 2022). In addition, macroalgae, also known as seaweed, has a very high potential to be used as food, medicine, animal feed, industrial materials, cosmetics, organic fertilizers, and even biofuels (Litaay et al., 2022).

The presence of macroalgae is influenced by the substrate. The substrate as a base for macroalgae growth greatly influences the diversity and density of macroalgae (Samman & Achmad, 2023). Macroalgae communities can survive by attaching to natural or artificial substrates found in the waters. The ability to grow macroalgae on available media or substrate is a requirement for life. One of the networks owned by macroalgae to attach to the substrate is holdfast, which is a network that resembles roots. Holdfast functions absorb food essences and adhere to the substrate so that it is not easily carried away by currents (Sugiana et al., 2022).

The substrates on the coastal of Sabang are highly diverse, comprising rocky areas mixed with fine sand, medium sand, coarse sand, gravel, hard gravel (stones larger than gravel), and sandy loam. In the Pasir Putih area, medium to fine sand predominates, while the Anoi Itam region is mainly composed of gravel. In contrast, the waters around Rubiah Island are primarily characterized by clay. Macroalgae research on different substrates in Sabang waters is very important to determine the most suitable habitat for macroalgae life so that it can be applied to the potential for macroalgae cultivation. The research on macroalgae in Sabang waters is vital as it addresses the relationship between substrate types and macroalgae diversity, which has been underexplored in this region. Previous studies have highlighted the ecological and economic significance of macroalgae, their role in marine ecosystems, and their potential applications in various industries. However, the specific influence of different substrate types on macroalgae community structure in Sabang, a marine biodiversity hotspot, remains less studied. Existing research has acknowledged the importance of substrates for macroalgae attachment and growth, but detailed studies on how various substrates impact macroalgae diversity and abundance in Sabang's unique waters are scarce. This research fills that gap by focusing on substrate-specific macroalgae distribution in an archipelagic context with diverse ecological conditions. The objective of this study is to identify and analyze the diversity, abundance, and important value index of macroalgae communities on different substrate types in Sabang waters, as well as to assess the influence of environmental and chemical parameters on macroalgae distribution across three distinct stations.

Method

This research was conducted in the waters of Sabang, covering two sub-districts, namely Sukakarya and Sukajaya Districts. Station I is located in White Sands with medium to fine sand substrate, Station II in Anoi Itam Waters with gravel sand substrate, and Station III in Rubiah Waters with clay substrate. The map of the research location can be seen in Figure 1.

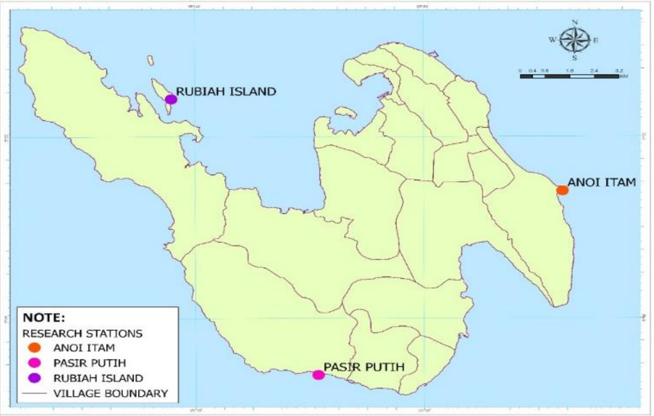

Figure 1. Map of the research area

Data Collection

The method used was purposive sampling, chosen due to the substrate variation at each sampling point, namely Pasir Putih, Anoi Itam, and Rubiah Island. For each predetermined station, five transect lines were created, and placed parallel to the shoreline. The length of the transect line was 100 meters. Between one transect to another, the interval was 10 meters. Each transect made 10 plots with a distance of each plot as far as 10 meters. The plot is 1x1 m (Figure 2). The number and types of macroalgae present in each plot were counted and collected for the inventory process. Sampling was carried out at low tide (Hadath et al., 2023). Macroalgae identification used Indentication of Macroalgae Diversity at Kelapa Payuran Beach Tuban Regency (Nursika & Cintamulya, 2022), Identifikasi Makroalga di Perairan Moudulung Kabupaten Sumba (Tega et al., 2020), and Species Composition of the Green Macroalgae (Chlorophyta) Species in The Waters of Blue Marlin Beach, Gorontalo, Indonesia (Nane, 2023). Macroalgae identification was carried out at the Botanical Laboratory and Herbarium, Department of Biology, Faculty of Mathematics and Natural Sciences, Syiah Kuala University.

Environmental parameter data such as temperature, brightness, depth, current velocity, pH salinity, and DO were performed in situ on each plot. Measurements of phosphate, nitrate, and COD have been carried out ex-situ at the Biology Laboratory of Ar-Raniry State Islamic University. Substrate samples were taken from each plot and analyzed using a stratified sieve at the Laboratory of the Marine, Marine and Fisheries Faculty, Syiah Kuala University.

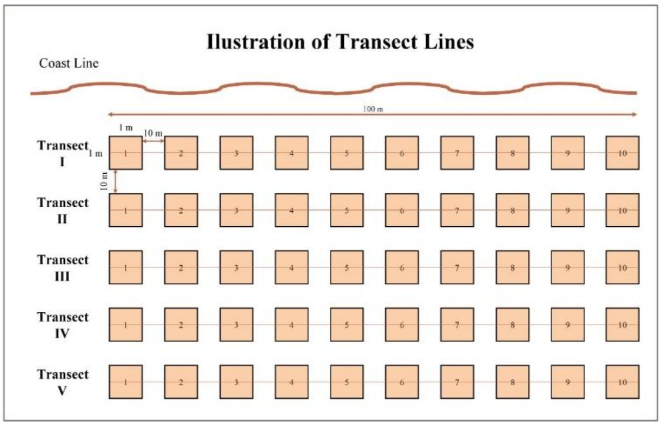

Figure 2. Illustration of transect lines

Data Analysis

The macroalgae composition was analyzed using the Important Value Index (IVI) formula. IVI is obtained from the sum of Relative Density (KR) and Relative Frequency (FR) (Sugiana et al., 2022) as follows:

$$IVI = Kr + Fr \quad (1)$$

$$K = \frac{\text{The number of individuals of a spesies}}{\text{Area of plots}} \quad (2)$$

$$KR = \frac{\text{The density of a species}}{\text{Density of all species}} x100\% \quad (3)$$

$$F = \frac{\text{Number of compartmens where a species is found}}{\text{sum of all sample plots}} \quad (4)$$

$$FR = \frac{\text{Frequency of species}}{\text{Frequency of all species}} \ x\ 100\% \quad (5)$$

The Shannon-Wiener Index (H') for diversity is calculated using the following formula:

$$H' = -\sum pi \ln pi \quad (6)$$

$$pi = ni/N \quad (7)$$

By criteria:
H′ < 1 = Low diversity
1 < H′ ≤ 3 = Medium diversity
H′ > 3 = High diversity (Septiady et al., 2023)

Result and Discussion

Macroalgae Division Composition

Macroalgae in Sabang waters found 17 species from three divisions. Chlorophyta division consists of 9 species, Rhodophyta 7 species, and Phaeophyta only one species. The composition of Chlorophyta in Sabang waters reached 1967 individuals or 75% of the total (2615 individuals). This is because the Chlorophyta division has more species than the Rhodophyta and Phaeophyta divisions. The composition of the macroalgae is influenced by the density and frequency of macroalgae (Septiady et al., 2023).

Several previous studies reported that the Chlorophyta division was the most commonly found species. In the Beach of Sombano found 9 species of Chlorophyta, 4 species of Rhodophyta, and 2 species of Phaeophyta (Festi et al., 2022). Another study on Tunda Island in the north of the Java Island also found that the Chlorophyta division has the most species compare to Phaeophyceae, and Rhodophycea (Srimariana et al., 2020). While macroalgae division Rhodophyta 5 species and division Phaeophyta 4 species. The following research results state that Chlorophyta is the division of macroalgae with the largest number found (Mushlihah et al., 2021). The high number of macroalgae in the Chlorophyta division both in terms of species and the number of individuals is due to the Chlorophyta division having excellent adaptability to environmental conditions so that it has a wide distribution and is phytobenthic (Nane, 2023; Ira et al., 2023). The composition of the macroalgae division in Sabang waters can be seen in Figure 3.

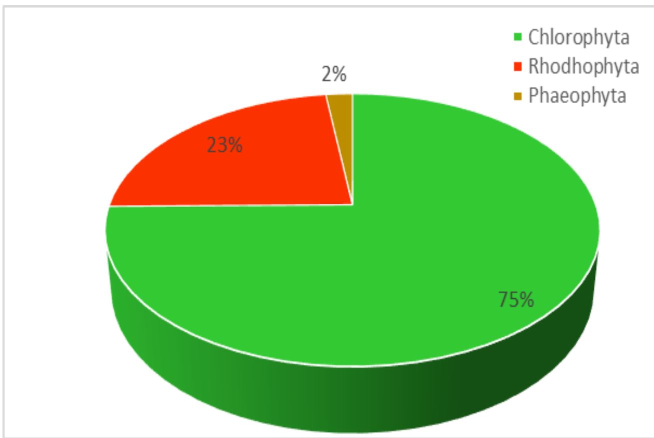

Figure 3. Composition of macroalgae division in Sabang waters

Macroalgae Density

The species density, which refers to the number of individuals per species in a specific area, was found to be highest at Station I (Pasir Putih), followed closely by Station II (Anoi Itam). The densities at these two stations were similar, likely due to the sand substrate mixed with dead coral, which provides a favorable environment for macroalgal growth. In contrast, Station III had lower species density. This difference is attributed to variations in the substrate composition, as the substrate analysis showed that macroalgae thrive better in coarse substrates, such as gravel sand. These results, detailed in

Table 1, underscore the importance of substrate composition in supporting macroalgae communities. The gravel sand substrate provides good oxygen exchange for macroalgae life (Rombe et al., 2023). In coral reefs, macroalgal density is often influenced by substrate characteristics, with coarse substrates allowing for better water circulation and nutrient availability, which can improve oxygen exchange and facilitate macroalgal growth. Studies show that coarse sediments like gravel sand help in maintaining good water flow, which prevents stagnation and enhances gas exchange, critical for macroalgal respiration and nutrient absorption (Lenzo et al., 2023; Fabricius et al., 2023).

Table 1. Substrate Analysis Results

Station	Percent sample weight (%) per class (microns)									Total	Texture group results
	4000	2000	1000	500	250	125	63	38	(%)	Mean	
I	8.64	6.20	13.88	22.97	24.67	10.28	13.22	0.13	100.00	690.9	Gravelly sand
II	2.06	1.22	32.05	45.73	17.23	1.23	0.36	0.12	100.00	927.7	Slightly gravelly sand
III	4.81	0.49	17.51	48.67	26.25	2.00	0.22	0.05	100.00	744.7	Gravelly sand

Some areas of Anoi Itam waters feature dead coral, though not as extensively as in Pasir Putih. Dead coral mixed with sand creates an ideal substrate for macroalgae growth, providing a stable environment that allows macroalgae to thrive. In contrast, Station III at Rubiah Island shows significantly lower macroalgae density. This reduced density is likely due to the substrate conditions, where living coral dominates, creating competition for essential resources like oxygen and nutrients. Live coral reefs are not conducive to macroalgae growth, as they compete for space and hinder macroalgae's ability to establish itself. The substrate plays a crucial role in macroalgal density, as supported by previous studies that indicate dead coral fragments, combined with environmental factors such as water brightness, air circulation, and current velocity, significantly impact macroalgae growth and development (Domu & Meiyasa, 2023; Irfan et al., 2021). The previously discussed variations in macroalgae density across the different stations can also be linked to the physical and chemical parameters of the water in the study area. Table 2 presents the measurements of the physical parameters, while Table 3 shows the chemical parameter results. These values indicate that the water conditions in Sabang are within the normal range for supporting macroalgae growth. Furthermore, the neutral pH levels in the water suggest that the Sabang waters are relatively free from pollution, providing a conducive environment for the development and sustainability of macroalgae populations.

Table 2. The Average Value of Water Physics Parameters

Station	Location	Transect	Substrate	Temperature (°C)	Brightnes (m)	Depth (m)	Current speed (m/s)
I	Pasir Putih	1	Gravelly sand	31 ± 0.42	1.33 ± 0.28	1.33 ± 0.28	0.06 ± 0.01
		2		30 ± 0.95	235 ± 0.17	2.35 ± 0.17	0.07 ± 0.01
		3		30 ± 0.97	3.06 ± 0.26	3.06 ± 0.26	0.07 ± 0.01
		4		29 ± 0.48	4.32 ± 0.23	4.32 ± 0.23	0.06 ± 0.01
		5		29 ± 0.67	5.29 ± 0.25	5.29 ± 0.25	0.06 ± 0.01
II	Anoi Itam	1	Slightly gravelly sand	31 ± 0.67	1.28 ± 0.25	1.28 ± 0.25	0.06 ± 0.01
		2		30 ± 0.42	2.41 ± 0.28	2.41 ± 0.28	0.05 ± 0.01
		3		30 ± 1.2	3.23 ± 0.34	3.23 ± 0.34	0.06 ± 0.01
		4		29 ± 0.48	4.43 ± 0.19	4.43 ± 0.19	0.06 ± 0.01
		5		28 ± 0.92	5.59 ± 0.24	5.59 ± 0.24	0.06 ± 0.01
III	Rubiah Island	1	Gravelly sand	30 ± 0.57	1.62 ± 0.23	1.62 ± 0.23	0.04 ± 0.01
		2		30 ± 0.74	2.7 ± 0.28	2.7 ± 0.28	0.05 ± 0.01
		3		29 ± 0.57	3.35 ± 0.34	3.35 ± 0.34	0.06 ± 0.01
		4		29 ± 0.42	4.54 ± 0.25	4.54 ± 0.25	0.07 ± 0.01
		5		29 ± 0.71	5.49 ± 0.30	5.49 ± 0.30	0.06 ± 0.01

Table 3. The Average Value of Water Chemistry Parameters

Station	Location	Transect	Salinity (ppt)	pH	DO (mg/L)	COD (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)
I	Pasir Putih	1	30 ± 0.94	7 ± 0.09	7 ± 1.17	2	0.24	0.41
		2	31 ± 0.97	7 ± 0.09	7.2 ± 0.09	2	0.32	0.11
		3	31 ± 0.67	7 ± 0.16	7.6 ± 0.28	2	0.1	0.21
		4	31 ± 0.57	7 ± 0.17	7.2 ± 0.28	1	0.29	0.31
		5	32 ± 0.68	7 ± 0.42	6.8 ± 0.19	1	0.08	1.75
II	Anoi Itam	1	30 ± 0.84	7 ± 0.42	6.8 ± 0.14	1	0.02	0.41

Station	Location	Transect	Salinity (ppt)	pH	DO (mg/L)	COD (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)
		2	30 ± 1.14	6.8 ± 0.10	6.8 ± 0.22	1	0.97	1.95
		3	31 ± 0.74	6.9 ± 0.04	6.9 ± 0.46	2	0.1	1.13
		4	31 ± 0.97	7 ± 0.13	7 ± 0.37	1	0.12	0.82
		5	31 ± 0.79	7 ± 0.43	6.8 ± 0.22	2	0.09	1.03
III	Rubiah Island	1	29 ± 0.57	7 ± 0.33	6.8 ± 0.08	1	0.94	2.47
		2	30 ± 0.99	6.9 ± 0.04	7 ± 0.33	2	0.15	0.82
		3	31 ± 0.47	7 ± 0.33	6.9 ± 0.46	1	0.19	3.29
		4	30 ± 0.68	7 ± 0.47	7.2 ± 0.34	2	0.09	1.03
		5	31 ± 1.20	7 ± 0.42	6.8 ± 49	1	0.13	0.21

The density and frequency of macroalgae can also be influenced by seasonal variations. Certain species exhibit seasonal growth patterns, thriving and developing during specific periods. According to Rugebregt et al. (2021), macroalgae are classified as seasonal protists, meaning their abundance is often higher during their peak growing season. During these periods, a substantial increase in macroalgae density can be observed. However, it is important to note that this study did not analyze seasonal effects, as the research was conducted during a specific time frame. For future research, investigating seasonal variations in macroalgae growth could provide deeper insights into their life cycles and environmental interactions. The density values of macroalgae species for each station are detailed in Table 4, illustrating the current observations.

Table 4. Macroalgae Density at the Research Station

Division	Species	Station I		Station II		Station III	
		K	KR	K	KR	K	KR
Chlorophyta	*Acentabularia calyculus*	1.14	4.43	0.00	0.00	0.02	0.47
	Boergesenia forbesii	2.76	10.72	3.34	14.96	0.54	12.74
	Codium edule	0.00	0.00	0.54	2.42	0.00	0.00
	Codium repens	0.70	2.72	0.00	0.00	0.00	0.00
	Dictyosphaeria cavernosa	1.52	5.91	4.66	20.90	1.16	27.36
	Halimeda macroloba	2.66	10.33	1.46	6.54	0.02	0.47
	Halimeda opuntia	8.52	33.10	1.38	6.18	1.14	26.89
	Valonia aegagrophylla	1.00	3.89	5.14	23.03	0.00	0.00
	Valonia ventricose	1.62	6.29	0.00	0.00	0.02	0.47
Rhodophyta	*Amphiroa fragillisima*	2.92	11.34	0.00	0.00	0.16	3.77
	Callophyllis crispate	0.84	3.26	0.96	4.30	0.20	4.72
	Gigartina scottsbergii	0.00	0.00	0.00	0.00	0.22	5.19
	Gracilaria eucheumoides	0.00	0.00	0.04	0.18	0.00	0.00
	Hypnea flagelliformis	0.00	0.00	0.00	0.00	0.22	5.19
	Hypnea pannosa	0.24	0.93	2.04	9.14	0.36	8.50
	Portieria hornemanii	0.54	2.10	2.76	12.40	0.18	4.25
Phaeophyta	*Dyctyota dichotoma*	1.28	4.97	0.00	0.00	0.00	0.00
Total		25.74	100	22.32	100	4.24	100

Macroalgae Frequency

Frequency is the probability of the presence of a macroalgae species appearing. The greater the frequency value, the greater the chance of the presence of species appearing in a plot. Species frequency is one of the parameters that can describe the distribution pattern in an ecosystem. The frequency value is influenced by the value of the plot where the species is found (Irfan et al., 2021). Based on Table 5 shows that the highest frequency level of macroalgae species is at Station I in Pasir Putih waters. The most frequent macroalgae species is *Halimeda opuntia*, with a frequency of 0.32 and a relative frequency of 21.05%. In contrast, *Hypnea pannosa* has the lowest frequency at 0.02 and a relative frequency of 1.32%. At Station II in Anoi Itam, *Dictyosphaeria cavernosa*, *H. macroloba*, and *Portieria hornemanii* each have a frequency of 0.22 (relative frequency of 15.94%). At Station III in Rubiah Island, *D. cavernosa* again shows the highest frequency at 0.28 and a relative frequency of 31.82%, while the lowest frequency is shared by four species, each at 0.02 (relative frequency of 2.27%).

Seven species are always present at each station, namely *H. macroloba, H. opuntia, D. cavernosa*, *Boergesenia forbesii, H. pannosa, Callophyllis crispata*, and *P. hornemani* (Table 5). The high level of frequency in some macroalgae species is due to these species being widely distributed in the observation area and able to adapt to a variety of substrates. This species can live in various substrates such as fine sand, medium-fine sand, gravel sand, and fine sandy loam.

In the research conducted by Ramirez et al. (2022), on Pucung Island, Malang Village, Riau Province, the macroalga *Halimeda* sp., lives in the sea and grows on the bottom of the water and is attached to a type of substrate of gravel, sand and coral fragments. In addition, these species have a wider tolerance to environmental physicochemical factors, this is what causes the frequency of these species to always be present at each research station.

Table 5. Frequency of Macroalgae at the Research Station

Division	Species	Station I		Station II		Station III	
		F	FR	F	FR	F	FR
Chlorophyta	*Acentabularia calyculus*	0.08	5.26	0.00	0.00	0.02	2.27
	Boergesenia forbesii	0.12	7.89	0.16	11.59	0.16	18.18
	Codium edule	0.00	0.00	0.02	1.45	0.00	0.00
	Codium repens	0.04	2.63	0.00	0.00	0.00	0.00
	Dictyosphaeria cavernosa	0.08	5.26	0.22	15.94	0.28	31.82
	Halimeda macroloba	0.24	15.79	0.22	15.94	0.04	4.55
	Halimeda opuntia	0.32	21.05	0.06	4.35	0.08	9.09
	Valonia aegagrophylla	0.04	2.63	0.12	8.70	0.00	0.00
	Valonia ventricosa	0.04	2.63	0.00	0.00	0.02	2.27
Rhodophyta	*Amphiroa fragillisima*	0.20	13.15	0.00	0.00	0.04	4.55
	Callophyllis crispata	0.16	10.53	0.14	10.15	0.02	2.27
	Gigartina scottsbergii	0.00	0.00	0.00	0.00	0.08	9.09
	Gracilaria eucheumoides	0.00	0.00	0.02	1.45	0.00	0.00
	Hypnea flagelliformis	0.00	0.00	0.00	0.00	0.04	4.55
	Hypnea pannosa	0.02	1.32	0.2	14.49	0.02	2.27
	Portieria hornemanii	0.08	5.26	0.22	15.94	0.08	9.09
Phaeophyta	*Dyctyota dichotoma*	0.10	6.58	0.00	0.00	0.00	0.00
Total		1.52	100	1.38	100	0.88	100

Five species were found exclusively at certain stations: *Codium repens* and *Dyctyota dichotoma* were observed only at Station I, *Codium edule* and *Gracilaria eucheumoides* at Station II, and *Gigartina scottsbergii* appeared solely at Station III. This indicates that these species are closely associated with specific substrate types, which provide the necessary conditions for their growth. Substrate variability has a significant impact on the distribution and frequency of macroalgae species in Sabang waters. Research by Li et al. (2022) and Pereira (2020) highlights that macroalgae species' adaptability is shaped by their surrounding environmental conditions, especially substrate type, which is crucial for their nutrient uptake and structural support. For instance, substrates like dead coral fragments or coarse sand provide optimal environments for settlement and growth. As Srimariana et al. (2020) noted, the number of macroalgae species varies significantly depending on their adaptability and the suitability of environmental factors. Moreover, Domu et al. (2023) support this, stating that variations in macroalgae density often reflect the species' adaptability to the local substrates and conditions.

Important Value Index (IVI)

The important value index provides an overview of the role of the species in the community. The importance value index can also determine the level of abundance of a species in the community, thus forming a particular community structure. The important value index is the result of the sum of the relative density with the relative frequency (Alule et al., 2020). From the results of research in Sabang waters, the highest important value index at each station was from the Chlorophyta division (Table 6).

Two species, *D. cavernosa* and *H. opuntia*, have the highest Important Value Index (IVI) in this study. *D. cavernosa* recorded the highest IVI values at Stations II (36.82) and III (59.18), while *H. opuntia* had the highest IVI at Station I (54.15). This indicates that both species play significant roles in shaping the community structure of their environment. *H. opuntia* is consistently found at all research stations, demonstrating its ability to tolerate various substrates in the waters of Sabang. The morphology of the macroalgal thallus is key to their adaptation to these conditions. According to Dawes (1998), Kooistra et al., (2003), and Gerung (2012), the structural adaptations of thalli in different macroalgal species influence their ecological roles and enhance their survival in diverse marine environments. The thallus of *H. opuntia* is segmented, rich in lime, and forms colonies, with adhesive structures called rhizoids (Asih et al., 2019). This adaptation allows the species to thrive and grow even in sandy substrates. In contrast, *D. cavernosa* features a sac-like thallus that is hollow and spherical when young, becoming convoluted and irregularly lobed as it ages. This structure easily breaks away, allowing it to develop into independent plants (Stimson et al., 1996), facilitating reproduction and propagation.

Table 6. Importance Value Index (IVI) of Macroalgae at the Research Station

Division	Species	Station		
		I	II	III
Chlorophyta	*Acentabularia calyculus*	9.69	0.00	2.74
	Boergesenia forbesii	18.62	26.56	30.92
	Codium edule	0.00	3.87	0.00
	Codium repens	5.35	0.00	0.00
	Dictyosphaeria cavernosa	11.17	36.82	59.18
	Halimeda macroloba	26.12	22.48	5.02
	Halimeda opuntia	54.15	10.53	35.98
	Valonia aegagrophylla	6.52	31.72	0.00
	Valonia ventricose	8.93	0.00	2.74
Rhodophyta	*Amphiroa fragillisima*	24.50	0.00	8.32
	Callophyllis crispata	13.79	14.45	6.99
	Gigartina scottsbergii	0.00	0.00	14.28
	Gracilaria eucheumoides	0.00	1.63	0.00
	Hypnea flagelliformis	0.00	0.00	9.73
	Hypnea pannosa	2.25	23.63	10.76
	Portieria hornemanii	7.36	28.31	13.34
Phaeophyta	*Dyctyota dichotoma*	11.55	0.00	0.00
Total		200.00	200.00	200.00

Macroalgae Diversity Index

The diversity index is the adaptation role of a population that will be part of the species interaction. The factor that determines the level of diversity is the presence of the number of species and the abundance of each species. Diversity is influenced by species richness. Species richness is the total number of species present in a community (Srimariana et al., 2020). The results of the analysis of the macroalgae diversity index in Sabang waters, the highest was at Station I in Pasir Putih waters with H'= 2.18, second at Station II Anoi Itam with a value of H'= 2.01 and the lowest was at Station III on Rubiah Island with value of H'= 1.97. This value indicates that the macroalgae diversity index belongs to the "medium" category. The value of the diversity index if $1 < H' < 3$ then indicates that the species diversity is "medium" in an area. If H' 2.0 then the diversity index is low. Meanwhile, if H' 3, then the diversity index is high (Sriwahjuningsih et al., 2022). The diversity index is of medium value, describing the condition of the waters at the study site that is still in good condition with the presence of a substrate that can be tolerated for macroalgae life. The species diversity index is categorized as high if the community is composed of many species with the same or almost the same species abundance, and if the community is composed of a few dominant species, the diversity is classified as low (Pradana et al., 2020).

Conclusion

The composition of macroalgae across the three research stations revealed 17 species from three divisions: Chlorophyta (green macroalgae), Rhodophyta (red macroalgae), and Phaeophyta (brown macroalgae). Station I (Pasir Putih) had the highest macroalgae composition, followed by Station II (Anoi Itam), with Station III (Rubiah Island) having the lowest. The Chlorophyta division, specifically *D. cavernosa* and *H. opuntia*, dominated in terms of the highest Important Value Index (IVI) across all stations. The diversity index (H') indicates that macroalgae species diversity at all stations falls within a medium range. These findings suggest that although species composition varies across stations, macroalgae diversity remains relatively moderate throughout the study area.

Acknowledgments
All author would like to thank to all parties who has supported this research.

Author Contributions
All authors contributed to writing this article.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Agustina, S., Maulana, Y., & Zahara, N. (2021). Vegetation Analysis of Tree Types in the Mountain Area of Iboih Village, Sukakarya District, Sabang City. *Prosiding Seminar Nasional Biotik*, 101–105. https://doi.org/10.22373/pbio.v9i1.11527.

Alule, M., Maabuat, P. V., & Saroyo. (2020). Diversity and Seagrass Important Index in Coastal Gemeh District, Talaud Islands District, North Sulawesi. *Biofaal Journal*, *1*(2), 85–92. https://doi.org/10.30598/biofaal.v1i2pp85-92

Arista, T. V., Aldya, R. F., & Prasetiyo, N. A. (2022). Study of Macroalga Diversity at Clungup Beach, Malang Selatan. *Jurnal Biologi Dan Pembelajaran Biologi*, *7*(1), 72–80. https://doi.org/10.32528/bioma/v7i1.6087

Asih, T., Khayuridlo, M., Noor, R., & Muhfahroyin, M. (2019). Biodiversity and potential use of macro algae in Pesisir Barat Lampung. *Biosaintifika: Journal of Biology & Biology Education*, *11*(1), 100-107. https://doi.org/10.15294/biosaintifika.v11i1.16532

Dawes, C. J. (1998). The Role of Morphology in the Adaptation of Marine Algae to their Environments. *Journal of Phycology*, *34*(3), 385-394. https://doi.org/10.1046/j.1529-8817.1998.340385x.

Domu, U., & Meiyasa, F. (2023). Exploration of Macroalgae Diversity and Analysis of Chemical Composition Based on Abundance in Warambadi Waters, East Sumba. *Jurnal Pengolahan Perikanan Tropis*, *1*(1), 29–39. https://doi.org/10.58300/planet.v1i01.481

Fabricius, K. E., Crossman, K., Jonker, M., Mongin, M., & Thompson, A. (2023). Macroalgal cover on coral reefs: Spatial and environmental predictors, and decadal trends in the Great Barrier Reef. *Plos One* *18*(1), e0279699. https://doi.org/10.1371/journal.pone.0279699

Festi, Jumiati, & Aba, L. (2022). Identification of Types of Macroalgae in Sombano Beach Waters, Wakatobi Regency. *Jurnal Penelitian Biologi Dan Kependidikan*, *1*(1), 11–24. Retrieved from http://jurnal-umbuton.ac.id/index.php/penalogik/article/view/2531

Gerung, G. S., & L. M. (2012). Adaptive Strategies of Macroalgae: Structural and Functional Traits. *Algae*, *27*(2), 201-214. https://doi.org/10.4490/algae.2012.27.2.201.

Hadath, D. S. B., Kepel, R. Ch., Rangan, J. K., Sangari, J. R. R., Mantiri, R. O. S. E., & Lasabuda, R. (2023). Community Structure of Macroalgaes in Coastal Waters of Molas, Bunaken District, Manado City. *Jurnal Ilmiah Platax*, *11*(2), 353–361. https://doi.org/10.35800/jip.v11i2.47937

Ira, Sara, L., Erawan, M. T. F., Mansyur, A., Annaastasia, N., Achmad, A., Nurgayah, W., & Findra, M. N. (2023). Study on Seaweed Community in Bombana Waters of Southeast Sulawesi. *Journal of Fishery Science and Innovation*, *7*(2), 143–157. https://doi.org/10.33772/jsipi.v7i2.486

Irfan, M., Ali, S. M., & Muchdar, F. (2021). Effect of Substrate Type on The Growth of Seaweeds Gelidium sp. In Controlled Container. *Jurnal Marikultur*, *3*(1), 34–44. https://doi.org/10.21608/ejabf.2024.373406

Kooistra, W. H. C. F., & J. E. J. (2003). Morphological and Ecological Adaptations in Marine Macrophytes. *Marine Biology*, *143*(4), 719-731. https://doi.org/10.1007/s00227-003-1002-2.

Lenzo, D., Colangelo, M. A., Pasteris, A., Rindi, F., Pistocchi, R., & Pezzolesi, L. (2023). Understanding the role of macroalgal complexity and allelochemicals production in invasive and non-invasive macroalgae in the North-Western Adriatic Sea: effect on the associated communities. *Water, 15*(9), 1697. https://doi.org/10.3390/w15091697

Li, X., Chen, J., Li, J., Wang, K., & Wang, Z. (2022) Determination of intertidal macroalgae community patterns using the power law model. *Plos One,* *17*(11), e0277281. https://doi.org/10.1371/journal.pone.0277281

Litaay, C., Arfah, H., & Pattipeilohy, F. (2022). Potential of Seaweed Biological Resources on Ambon Island Beaches as Food Ingredients. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *25*(3), 405–417. https://doi.org/10.17844/jphpi.v25i3.41647

Mushlihah, H., Amri, K., & Faizal, A. (2021). Diversity and Distribution of Macroalgae to Environmental Conditions of Makassar City. *Jurnal Ilmu Kelautan*, *7*(1), 16–26. http://dx.doi.org/10.20956/jiks.v7i1.14856

Nane, L. (2023). Species Composition of the Green Macroalgae (Chlorophyta) Species in the Waters of the Blue Marlin Beach, Gorontalo, Indonesia. *Fisheries and Society*, *3*(2), 1–6.

Nursika, & Cintamulya, I. (2022). Identification of Macroalgae Diversity at Kelapa Panyuran Beach Tuban Regency. *Indonesian Journal of Biotechnology and Biodiversity*, *6*(3), 102–109. https://doi.org/10.47007/ijobb.v6i3.144

Pereira, L. (2022). Macroalgae: Diversity and conservation. In *Life Below Water* (pp. 527-539). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-71064-8_33-1

Pradana, F., Apriadi, T., & Suryanti, A. (2020). The Composition and Distribution Pattern of Macroalgae in Mantang Baru Village Waters, Bintan Regency, Riau Islands. *Biospecies*, *13*(2), 22–

31. https://doi.org/10.22437/biospecies.v13i2.8513

Ramirez, A. M., Crespo, J. M., Royo, L., Tuya, F., Silvo, I. C., Hernan, G., Briones, L. P., Terrados, J., & Thomas, F. (2022). A Tropical Macroalga (Halimeda incrassata) Enhances Diversity and Abundance of Epifaunal Assemblages in Mediterranean Seagrass Meadows. *Frontiers in Marine Science*, *9*, 1–14. https://doi.org/10.3389/fmars.2022.886009

Rombe, K. H., Rahman, A., Mardiana, & Rosalina, D. (2023). Composition and Density of Algae Types in Banda Sea Marine Tourism Park Central in Central Maluku Regency. *Nekton*, *3*(1), 1–12. https://doi.org/10.47767/nekton.v3i1.383

Rugebregt, M. J., Pattipeilohy, F., Matuanakotta, C., Ainarwowan, A., Abdul, M. S., & Kainama, F. (2021). Potential of Seaweed in East Seram Waters, East Seram Regency, Maluku. *Jurnal Ilmu Lingkungan*, *19*(3), 497–510. https://doi.org/10.14710/jil.19.3.497-510

Rume, M. I., & Yohanista, M. (2022). Macroalgae Community Structure on the South Coast of Pruda Village, Sikka Regency. *Aquanipa, Jurnal Ilmu Kelautan Dan Perikanan*, *4*(2). Retrieved from https://aquanipa.nusanipa.ac.id/index.php/aquanipa/article/view/47/59

Samman, A., & Achmad, M. J. (2023). Diversity and Distribution of Red Algae (Rhodophyta) in Ternate Island Waters. *Jurnal Kelautan Tropis*, *26*(1), 148–154. https://doi.org/10.14710/jekk.v%25vi%25i.13342

Septiady, D., Hendrawan, I. G., & Putra, I. N. G. (2023). Diversity of Macroalgae Types in Gilimanuk Bay Waters Bali. *Jurnal Ilmiah Multidisiplin*, *2*(10), 4831–4843. https://doi.org/10.56799/jim.v2i10.2253

Srimariana, E. S., Kawaroe, M., & Lestari, D. F. (2020). Biodiversity and Utilization Potency of Macroalgae at Tunda Island. *Jurnal Ilmu Pertanian Indonesia*, *25*(1), 138–144. http://dx.doi.org/10.18343/jipi.25.1.138

Sriwahjuningsih, Hernawati, D., & Raharjo, C. M. (2022). Analysis of Diversity and Abundance of Macroalgae in the Rancabuaya Beach Area, Purbayani Village, Garut Regency. *Journal Scientific of Mandalika*, *3*(3), 117–126. https://doi.org/10.36312/10.36312/vol3iss3pp117-126

Stimson, J., Larned, S., & McDermid, K. (1996). Seasonal growth of the coral reef macroalga Dictyosphaeria cavernosa (Forskål) Børgesen and the effects of nutrient availability, temperature and herbivory on growth rate. *Journal of Experimental Marine Biology and Ecology*, *196*(1-2), 53-77. Retrieved from https://www.researchgate.net/publication/327212942

Sugiana, I. P., Faiqoh, E., & Wiyanto, D. B. (2022). Community Structure of Epiphyte Microalgae on Artificial Substrate in Serangan Waters, Bali. *Jurnal Kelautan Dan Perikanan Terapan*, *5*(1), 17–25. http://dx.doi.org/10.15578/jkpt.v5i1.10603

Tega, Y. R., Meiyasa, F., Henggu, K. U., Tarigan, N., & Ndahawali, S. (2020). Identification of Macroalgae in Moudolung Waters, East Sumba Regency. *Jurnal Pendidikan Dan Biologi*, *12*(2), 202–210. http://dx.doi.org/10.25134/quagga.v12i2.2751