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Diversity of Macroalgae in The Coastal Waters of Gunung Payung, Bali

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Abstract

Macroalgae are multicellular organisms that are part of algae with large or macro sizes and are classified as multicellular organisms. Gunung Payung Beach is a beach located in Kutuh Village, South Kuta District, Badung Regency, Bali. This beach has wave barriers in the form of coral reefs that serve as habitats for several types of macroalgae. This study aims to determine the diversity, coverage percentage, and importance value index of macroalgae in the waters of Gunung Payung Beach. The research was conducted from September to November 2023. The method used in this study is descriptive quantitative. The research location was divided into 3 stations, and the research was conducted using 1×1 m quadrat transects. Based on the research, a total of 47 species of macroalgae were found in the waters of Gunung Payung Beach. These macroalgae species came from 3 divisions: 13 species of Chlorophyta, 27 species of Rhodophyta, and 7 species of Phaeophyta. *Ulva lactuca* and *Hypnea valentiae* are macroalgae species with the highest coverage percentage at all stations. The calculation of the Shannon-Wiener diversity index shows that the diversity of macroalgae in the waters of Gunung Payung Beach is categorized as moderate, with values ranging from 1.948 to 2.916. The highest diversity index was found at station 2, which is 2.916. The highest macroalgae importance value index at all stations is Ulva lactuca. The growth of macroalgae is influenced by substrate factors and water quality. Gunung Payung Beach has suitable water conditions for the growth of macroalgae.

INTRODUCTION

Macroalgae are marine organisms that include low-level plants with undifferentiated leaves, stems, and roots. Macroalgae body parts that resemble roots, stems and leaves are called talus (Sumarni *et al.,* 2019). Macroalgae is one of the important biota that make up the marine ecosystem because it has good ecological, biological, and economic benefits (Ayhuan *et al.,* 2017). Economically, macroalgae can be utilized for various high-value industrial activities. Ecologically, macroalgae play an important role in maintaining the balance of aquatic ecosystems which act as primary producers that produce oxygen and as a food source in the marine ecosystem food chain

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(Srimariana *et al.*, 2020). Macroalgae colonies can also provide shelter and a nurturing habitat. Macroalgae are also known to have the potential to store carbon to reduce global warming. The existence of macroalgae needs to be maintained and managed for habitat sustainability, given its high benefits (Handayani, 2019).

Macroalgae habitat is generally shallow water that can still be penetrated by sunlight and has a high level of brightness (Riniatsih *et al*., 2017). Macroalgae can generally be found in intertidal and subtidal areas by living attached to the substrate. A Holdfast rhizoid is an organ used by macroalgae to attach to the substrate. The substrate used to grow by macroalgae consists of hard substrates, namely dead corals, living corals, and rocks, as well as fine substrates consisting of sand and sandy mud (Watung *et al.*, 2016). Macroalgae are usually found in coastal waters with sandy coral substrates, such as those found in the waters of Gunung Payung Beach. Gunung Payung Beach is one of the beaches in Bali, precisely located in Kutuh Village, South Kuta District, with beautiful beaches (Setiyarti *et al*., 2018). Gunung Payung Beach has characteristics of beaches with sandy coral substrates and high water brightness that are suitable for a macroalgae habitat. The coastal waters of Gunung Payung Beach possess a natural defense system in the form of an extensive barrier reef. During low tide, these reefs become visible and function as wave breakers. Furthermore, the exposed portions of the reef during low tides provide an ideal habitat for macroalgae (Arthana, 2009).

The waters of Kutuh Village were once the center of seaweed cultivation for the South Kuta area in 2010, with a bottom substrate of sandy stones suitable for the growth of seaweed or macroalgae (Prabawa, 2017). The waters of Kutuh Village are also an area designated as an algae minapolitan area with fairly high diversity (Sabdaningsih *et al*., 2013). Based on the results of research by Putri *et al*. (2023) in the waters of Pandawa Beach, there are 17 types of macroalgae with a moderate diversity index category. Pandawa Beach is part of the Kutuh Village water area, which has a higher level of tourism activity compared to Gunung Payung Beach. The difference in the level of tourism activity is thought to affect the diversity of macroalgae in the waters of Gunung Payung Beach. However, there is still no information about macroalgae diversity in the waters of Gunung Payung Beach, so it is necessary to conduct research on macroalgae diversity in the waters of Gunung Payung Beach.

This research is also important as baseline data for more complex ecological studies in the future and further as a basis for managing the coastal waters of Gunung Payung Beach and its surroundings. This research was conducted to know the types of macroalgae, the percentage of macroalgae cover, macroalgae diversity, macroalgae importance index, and water quality parameters found in the waters of Gunung Payung Beach.

METHODOLOGY

Ethical Approval

No animals were harmed or improperly treated during this research.

Place and Time

This study was conducted in the waters of Gunung Payung Beach located in Kutuh Village, South Kuta District, Badung Regency, Bali Province. The research location was divided into 3 stations. Data collection was carried out in September-November 2023. Identification of macroalgae samples was carried out at the Fisheries Laboratory, Faculty of Marine and Fisheries, Udayana University. The research location map can be seen in Figure 1.

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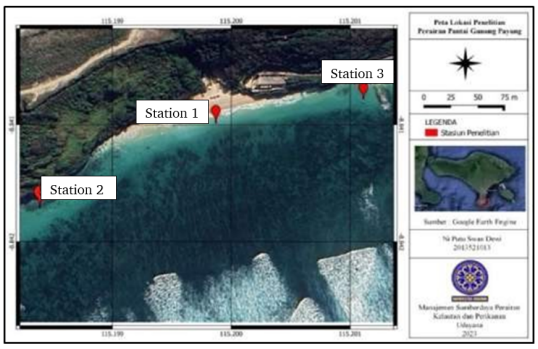

Figure 1. The location of the research shows that the research area is divided into three stations.

Research Materials

Materials used in this research were a 1×1 m quadrant transects, refractometer (Atago Refrakto Manual, Japan), pH meter (Keletool EZ-9909, Malay), Secchidisk (locally fabricated), current ball (locally fabricated), smartphone (Samsung A13 4G, Indonesia), and sample plastic (Basal Teknik Bag Sampel 30×45 cm, Indonesia).

Research Design

The data collection method used in this research is the quantitative descriptive method. The research location was divided into three stations using a purposive sampling method based on the level of human activity that takes place in Gunung Payung Beach Waters. Station 1 is a station with high human activity. The activities carried out in the waters include swimming, canoeing, and surfing. Station 2 is a medium human activity category; the activities conducted are limited to taking photographs near the cliffs and canoeing. Station 3 is a low human activity category, this location tends to be quiet, with few visitors coming to the area.

Work Procedure

Sampling was conducted using 1×1m quadrant transects at the lowest tide. At each station, a 10 m line was drawn perpendicular to the shoreline with repetition to the shore. The quadrant transect was placed at the first point where macroalgae were found. This point was measured and then repeated according to the distance between the edge and the first point. Repetition was carried out towards the shore until macroalgae were no longer found. Macroalgae samples found in each quadrant transect were taken and put into plastic to be separated into species. Species found were identified using the identification book Carpenter and Niem (1998) and algabase.org. and classified using the World Register of Marine Species (WORMS). Transect placement at each station is presented in Figure 2.

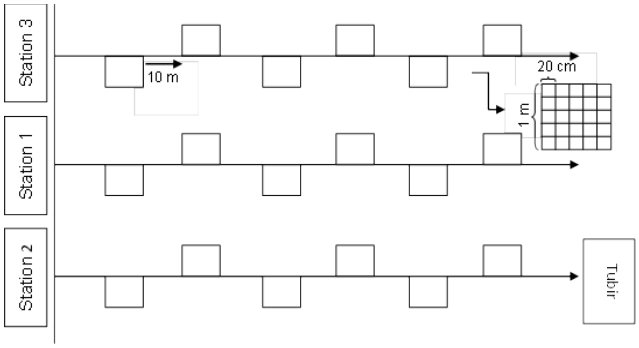

Figure 2. Illustration of Transect Placement at Research Station.

Description: The small boxes represent the placement of transects, while the large box is a 1×1 m² transect, divided into 25 smaller squares. The long line represents the line drawn from the shoreline to the reef edge for positioning the transects.

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Data Analysis

Percentage of Macroalgae Cover

The calculation of the percentage of macroalgae cover was done using the following equation (Fachrul, 2007).

$C = CiA \times 100$

Where C is the percentage cover; ∑Ci is the number of cover units of each type of macroalgae; and A is the total number of grids (quadrants) used

Diversity Index

The diversity index is calculated using the Shannon-Wiener formula (H') shown in the equation (Fachrul, 2007).

$H' = -i = 1spi(\log pi)$

With a diversity index value of $H' \leq 1$ is low diversity; $1 < H' < 3$ is moderate diversity; $H' \geq 3$ is high diversity. Where H' is the diversity index; s is the number of colonies of each species; and pi is the number of.

Importance Value Index of Macroalgae

The macroalgae Importance Index is influenced by relative frequency, relative density, and relative cover. Relative Frequency (FR), is the ratio between the frequency of the i-th species (Fi) and the total frequency for all species. The relative frequency of seaweed is calculated by the formula (Fachrul, 2007):

$IVI = FR + KR + PR$

The gonad maturity index and hepatopancreas index data obtained in this study will be processed using ANOVA statistical data with a confidence level of 95% using SPSS 25. Duncan's further test will be carried out if they are significantly different. Guidelines for decision-making are as follows: if the significance value is > 0.05, then there is no significant difference in the rate of gonad maturity between feed treatments; if the significance value is < 0.05, then there is a significant difference in the rate of gonad maturity between feed treatments. If it is significantly different, the Duncan test will be continued to get the best treatment.

RESULTS AND DISCUSSIONS

Species Composition

Based on observations, 47 species of macroalgae were found, consisting of 12 species of Chlorophyta (Green Algae), 27 species of Rhodophyta (red algae), and 8 species of Phaeophyta (brown algae). The results of this study are more than those found in Pandawa Beach Waters, which are located close to Gunung Payung Beach Waters. Macroalgae species found in Pandawa Beach Waters were 17 species, consisting of 3 species of Clorophyta, 12 species of Rhodophyta, and 2 species of Phaeophyta (Putri *et al*., 2023). This can allegedly occur due to data collection at different times. According to Kang *et al*. (2011), the growth of macroalgae is erratic and based on the season, so the number in the waters at a certain time can be very much, but at other times, it can also not be found at all.

Macroalgae are found more in the Eastern season (April- July) than in other seasons (Papalia and Arfah, 2013). The dry season is the season with the highest density of macroalgae in Indonesia (Kadi, 2017). In addition to seasonal differences that affect seaweed growth, habitat can also affect the species of seaweed that grow. The substrate is a place to grow and attach macroalgae. Substrates in the form of coral fragments are very suitable for the attachment of various species of red and brown macroalgae (Sukiman *et al*., 2014), while green macroalgae are often found on sand substrates and dead coral fragments (Pulukadan *et al*., 2013).

Rhodophyta is the division with the most species found in Gunung Payung Beach Waters, namely 27 species. Rhodophyta usually lives attached to the substrate of living and dead coral fragments or on coral reef beds (Ira *et al*., 2018). This statement is by the substrate of Gunung Payung Beach Waters, which is a sandy coral flat so that more species of Rhodophyta are found.

In Gunung Payung Beach Waters, 13 species of macroalgae from the Clorophyta division. One of the species from the Clorophyta is *Ulva lactuca*. *U. lactuca* is the

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most common species found on the study site. *U. lactuca* lives at a low depth of 0.5-5 m. The substrate on which it settles is the most common. The substrate that *Ulva lactuca* is attached to is a dead coral substrate in the coral reef exposure area and can live in brackish waters. This species has a good ability to live and is quite widespread in shallow waters in Indonesia (Atmadja *et al.*, 1996). Phaeophyta is the least commonly found division, with 8 species. Phaeophyta is found in very low numbers due to seasonal factors, namely in September, and is difficult to grow in sand habitats and dead coral fragments (Ira *et al*., 2023).

In general, the substrate in Gunung Payung Beach Waters is sandy coral, but some parts have sand and sand substrates with dead coral fragments. Areas that have wider coral flats are overgrown with more macroalgae species. Station 2 is a station with a wider coral flat so that more species live, namely a total of 40 species.

Station 1 is a station with fewer coral flats and is dominated by sand substrates so that fewer species are found, namely 21 species. Macroalgae species found at station 3 totaled 25 species. Although station 1 has a shorter coral flat distance and has quite a lot of sand substrate, station 3 has a part of the shoreline with a sandy rock substrate so that species can be found whose habitat is suitable for the area, such as *Padina* sp. This causes more macroalgae species to be found at station 3.

Percentage Cover of Macroalgae Species in Gunung Payung Coastal Water

The highest percentage of macroalgae cover in Gunung Payung Beach Waters is the Clorophyta division, with a cover percentage value of 34.92%-49.40% (Table 1). This event can be interpreted that the Chlorophyta division has good adaptability, especially *U. lactuca* as a species with the highest percentage of species cover at all stations with a range of values of 19.6-23.08%, activities in Gunung Payung Beach Waters have not affected macroalgae growth. The high percentage is thought to be due to the high nitrate content and strong currents. Quiet waters are not good for the habitat (Figure 3). This is thought to be because Ulva lactuca has a wide thalus and a wide habitat distribution (Yudasmara, 2011).

The highest percentage of macroalgae cover was found in Station 1 at 86.30%. Station 1 is the station that has the highest activity but also has a high percentage of cover. This shows that the level of activity in the waters of Gunung Payung Beach has not affected the growth of macroalgae. The high percentage is thought to be due to the high nitrate content and strong currents. Quiet waters are not good for macroalgae habitat because they will cause the accumulation of silt and attached epiphytes that inhibit macroalgae growth (Ayhuan *et al*., 2017).

Station 2 has a macroalgae cover percentage value of 85.75% which is dominated by the Rhodophyta division at 46%. Rhodophyta dominates at this station because the water substrate at this station is under the habitat of Rhodophyta, which is a hard substrate. This statement is emphasized by the statement from Prasetyaningsih and Rahardjo (2016), which states that the Rhodophyta group is a type of macroalgae that has a habitat with a hard substrate. The station with the lowest percentage of macroalgae cover was station 3 at 82.77%.
The division with the lowest percentage of macroalgae cover is Phaeophyta. Phaeophyta is rarely found because most of its life is found in deeper waters with little sun intensity (Yudasmara, 2011). The macroalgae species with the lowest percentage cover is *Glacilaria textorii* with a value of 0.31%. *G. textorii* usually lives in the tidal zone which has a slightly muddy substrate (Muangmai *et al*., 2014), so the amount of Gracilaria textorii is difficult to grow in the waters of Gunung Payung Beach.

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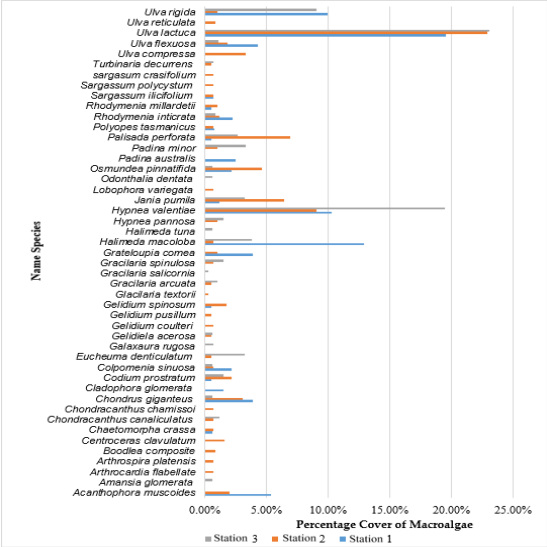

Figure 3. Diagram of Percentage Cover of Macroalgae Species in Gunung Payung Coastal Waters.

The highest percentage of macroalgae cover was found in Station 1 at 86.30%. Station 1 is the station that has the highest activity but also has a high percentage of cover. This shows that the level of activity in the waters of Gunung Payung Beach has not affected the growth of macroalgae. The high percentage is thought to be due to the high nitrate content and strong currents. Quiet waters are not good for macroalgae habitat because they will cause the accumulation of silt. Accumulation of silt and attached epiphytes that inhibit macroalgae growth (Ayhuan *et al*., 2017).

Table 1. Percentage Cover of Macroalgae Division at Each Station.

Station	Clorophyta	Phaeophyta	Rhodophyta	Total
1	49.40	5.40	31.50	86.30%
2	34.92	4.83	46.00	85.75%
3	39.31	4.62	38.85	82.77%

Station 2 has a macroalgae cover percentage value of 85.75%, which is dominated by the Rhodophyta division at 46%. Rhodophyta dominates at this station because the water substrate at this station is under the habitat of Rhodophyta growth, namely a hard substrate. This statement is emphasized by the statement from Prasetyaningsih and Rahardjo (2016), which states that the Rhodophyta group is a type of macroalgae that has a habitat with a hard substrate. The station with the lowest percentage of macroalgae cover was station 3 at 82.77%.

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Macroalgae Diversity in Gunung Payung Coastal Waters

Based on the calculations that have been done, it is found that the diversity of macroalgae in the waters of Gunung Payung Beach is included in the moderate category (Table 2). This indicates that the waters of Gunung Payung Beach are in good condition. The diversity index can also be an indicator of environmental assessment (Aziz and Chasani, 2020). Arfah and Patty

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(2016) said that waters that have high macroalgae diversity values are generally waters in good condition, otherwise poor water conditions will show lower diversity.

Table 2. Macroalgae Diversity Index Value in Gunung Payung Coastal Waters.

Station	Diversity Index	Category
1	1.948	Moderate
2	2.916	Moderate
3	2.375	Moderate

The moderate diversity index is due to differences in the number of individuals of each macroalgae species that vary. Some species have a large number of individuals, but some other species have a small number of individuals. The value of diversity is determined by two important factors, namely the number of families and the number of individuals of each species, so that the number of individuals determines the value of diversity. If individuals in a habitat are evenly distributed, then the value of species diversity in that habitat tends to be high as well (Sinyo and Somadoyo, 2013).

Differences in the results of macroalgae diversity in Gunung Payung Beach Waters can occur due to substrate dominance and water tourism activities carried out in coastal waters. According to Nurkiama *et al*. (2015), differences in substrate can also affect macroalgae diversity in intertidal areas. In waters whose substrates are dead rock coral fragments, massive corals, and more stable sand, the level of algae diversity is higher than in waters whose substrates are sand and mud alone. From the observation results, the substrate in Gunung Payung Beach Waters is dominated by sandy coral substrates, but in some areas, there are many sand substrates.

Station 1 is the station that has the lowest diversity index of 1,812 with a moderate category. The lowest macroalgae diversity at station 1 is thought to be due to the influence of high tourist activity. Human activities can influence biodiversity as they affect the ability of certain species to adhere to substrates, making it difficult for some species to attach to the substrate. The percentage of macroalgal cover refers to the extent of coverage by macroalgal species that have already attached to the substrate. In the coastal waters of Gunung Payung, human activities have not yet impacted the percentage of macroalgal cover, but they do affect the diversity of macroalgae. High and low human activity on the coast can directly affect macroalgae diversity (Putri *et al*., 2023). The substrate at station 1 is also mostly a sand substrate, so some types of macroalgae are difficult to grow.

Station 2 is the station that has the highest diversity index of 2.916. Station 2 is located in an area where most of the area is sandy coral flats. Water tourism activities in this area are only for a few tourists who ride canoes. Dense tourist activities at station 2 are photo activities on the beach, which, at low tide, are filled with macroalgae. The edge of the beach at this station is a rock filled with macroalgae. This happens because this part is a tidal area that gets the acquisition of solar intensity for a greater photosynthesis process (Yudasmara, 2011). Macroalgae that grow in this area tend to be small and are slightly damaged due to frequent trampling. The diversity index at Station 3 is 2,375 with a moderate category. This can happen because the number of water tourism activities is lower than in the other stations. However, at station 3, the sand substrate is more than at station 2, so it can affect the growth of several types of macroalgae.

Importance Value Index of Macroalgae in Gunung Payung Coastal Waters

The macroalgae species that has the highest importance value index (IVI) in Gunung Payung Beach Waters is *Ulva lactuca* species with a value range of 54.04%-67.83%. The IVI of *U. lactuca* is highest in all three stations, so it can be said that *U.*

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lactuca has the greatest role in the macroalgae community in Gunung Payung Beach Waters. This is by the statement from Pramesti *et al*. (2016) that the species with the highest IVI results indicate that the species has a high role in a community. The species that have the lowest IVI at each station are different. The results of the calculation of the macroalgae importance value index in Gunung Payung Beach Waters can be seen in Figure 3.

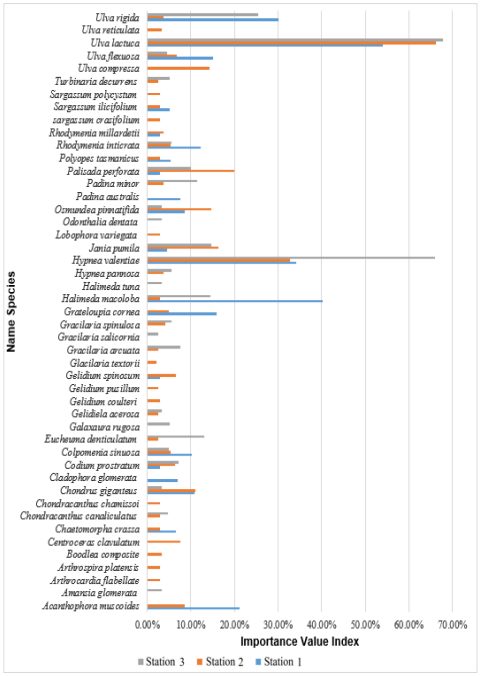

Figure 4. Diagram of Importance Value Index of Macroalgae in Gunung Payung Beach Waters.

The highest IVI value at Station 1 was *U. lactuca* with a value of 54.04%, and the lowest was *Codium prostratum*, *Gelidium spinosum*, *Palisada perforata*, and *Rhodymenia millardetii,* which each had the same value of 2.88%. The highest IVI value at Station 2 was *U. lactuca,* with a value of 66.37% and the lowest at Station 2 was *G. textorii* at 2.06%. The highest IVI value at Station 3 was *U. lactuca* with a value of 67.83% and the lowest was *G. salicornia* species with 2.47%.

U. lactuca has a high IVI because of its abundance in the water. *U. lactuca* was found in every station and almost every transect. Species that have a high IVI are caused by high values of relative density, relative frequency, and relative cover of the species. The high number of species in a water body is thought to be due to its epiphytic nature and is found in abundance at all observation times (Pramesti *et al*., 2016). This is similar to the statement of Oryza *et al*. (2016) that *Ulva* sp. can be found on rock substrates and corals and attached to other algae.

Macroalgae diversity in Gunung Payung Beach Waters can generally be categorized as moderate, with a total of 47 macroalgae species. The percentage of macroalgae cover at each station ranged from 82.77% to 86.30%. The highest percentage of macroalgae species cover was *U. lactuca* species, with total cover ranging from 19.6%-23.08%, and the lowest was *G. salicornia* at 0.31%. The highest Index of Importance was found in *U. lactuca* species at 67.83%, and the lowest was *G. textorii* at 2.06%.

Water Quality

Water quality parameters assessed in the waters of Gunung Payung include temperature, brightness, salinity, pH,

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current speed, nitrate, and phosphate (Table 3). The temperature recorded at the research site ranges from 29.4 to 31.1°C. Based on the research findings, pH values range from 7.37 to 7.49, which are within favorable ranges that do not hinder the growth and development of macroalgae. The optimal pH and temperature for macroalgae are between 7-8.5 and 26-31°C (Nikhlani and Kusumaningrum, 2021).

The brightness level is 100% at a depth of 1.5 meters, indicating that good light penetration is essential for macroalgae photosynthesis. Salinity levels measured at the research site are 33-34‰. Current speed is a supportive factor for macroalgae growth, as waves significantly influence aeration, nutrient transport, and water mixing (Ayhuan *et al.*, 2017). Research results show current speeds ranging from 0.12 to 0.25 m/s, indicating favorable conditions that support seaweed growth. The optimal current speed range for seaweed growth is between 0.2 m/s and 0.35 m/s (Atmadja *et al.*, 1996). Strong currents facilitate optimal growth conditions by effectively distributing nutrients across the area (Sormin *et al.*, 2015).

Macroalgae require nutrients such as nitrate and phosphate for photosynthesis. The Nitrate values found in Gunung Payung Beach Water ranged from 0.399 to 0.422 mg/l and phosphate below 0.0001 mg/l across all stations, which are conducive to macroalgae growth (Ira *et al.*, 2018). Overall, the conditions in Gunung Payung Beach Waters are favorable for macroalgae growth.

Table 3. Results of the Water Quality Measurement at Gunung Payung Beach.

station	phosphate	nirate	temperature	current	salinity	brightness	pH
1	<0.0001	0.399	29.4	0.25	34	100%	7.49
2	<0.0001	0.415	30.1	0.12	34	100%	7.37
3	<0.0001	0.422	31.1	0.24	34	100%	7.39

CONCLUSION

Macroalgae diversity in Gunung Payung Beach Waters can generally be categorized as moderate with a total of 47 macroalgae species. The percentage of macroalgae cover at each station ranged from 82.77%-86.30%. The highest percentage of macroalgae species cover was *Ulva lactuca* species with total cover ranging from 19.6%-23.08%. The lowest was *Gracilaria salicornia* at 0.31%. The highest importance value index was found in *Ulva lactuca* species at 67.83%, and the lowest was *Gracilaria textorii* at 2.06%.

CONFLICT OF INTEREST

There is no conflict of interest among all authors upon writing and publishing the manuscript.

AUTHOR CONTRIBUTION

The contributions of each author are as follows: Ni Putu Swan Dewi collected and analyzed the data, compiled it, and prepared the manuscript. Ayu Putu Wiweka Krisna Dewi participated in the conception and design of the experiment and prepared the manuscript, and Dewa Ayu Angga Pebriani participated in the preparation of manuscript.

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