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Diversity and Distribution of Phaeophyta Macroalgae in Pedalen Coastal Waters, Kebumen

(Diversitas dan Sebaran Makroalga Phaeophyta di Perairan Pantai Pedalen, Kebumen)

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ABSTRACT

Pedalen Beach, Kebumen, has a type of water substrate consists of sand, coral fragments, and coral overgrown with macroalgae. This study aims to determine the species diversity and distribution pattern of Phaeophyta found in that waters. This research is to explore and utilize macroalgae as a sustainable alginate resource. This study uses a survey method, employing the line transect method randomly. The research variables were species diversity and the distribution pattern of Phaeophyta. The main parameters were the number of species and individuals of each species. Supporting parameters include current velocity, nitrate content, brightness, depth, tide, salinity, temperature, and pH. The data were analyzed using the Shannon-Wiener diversity index (H') to determine the level of species diversity and the Morisita distribution index (Id) to describe the distribution pattern of macroalgae species. We found five Phaeophyta species consisting of Padina australis, Dictyota dichotoma, Turbinaria ornata, Sargassum crassifolium, and S. polycystum. The diversity of Phaeophyta is classified as low diversity index value (H') with distribution patterns of uniform macroalgae species. The results of the measurement of physical and chemical factors of the waters showed that the condition of the Pedalen Beach waters was quite good for the growth of Phaeophyta.

Keywords: alginate, macroalgae species, Phaeophyta, water substrate

ABSTRAK

Pantai Pedalen Kebumen memiliki tipe substrat dasar perairan berupa pasir, pecahan karang, dan batu karang yang ditumbuhi makroalga. Penelitian ini bertujuan memetakan diversitas spesies dan pola sebaran makroalga Phaeophyta yang terdapat di pantai tersebut dalam upaya menggali dan memanfaatkan makroalga sebagai sumber daya alginat berkelanjutan. Dalam survei ini sampel diambil menggunakan metode *line transect* secara acak. Parameter utama yang diamati ialah jumlah spesies dan jumlah individu setiap spesies. Parameter pendukung terdiri atas kecepatan arus, kandungan nitrat, kecerahan, kedalaman, pasang surut, salinitas, suhu, dan pH. Data yang diperoleh dianalisis menggunakan indeks keanekaragaman Shannon-Wiener (H‟) untuk menentukan tingkat keanekaragaman spesies dan indeks penyebaran Morisita (*Id*) guna menggambarkan pola sebaran spesies Phaeophyta. Ditemukan 5 spesies Phaeophyta yang terdiri atas *Padina australis, Dictyota dichotoma*, *Turbinaria ornata, Sargassum crassifolium*, dan *S. polycystum*. Diversitas makroalga Phaeophyta di perairan ini tergolong sedang dengan nilai indeks H‟ 2,021 dan pola sebaran spesies makroalga mengelompok. Hasil dari pengukuran faktor fisik dan kimawi perairan menunjukkan kondisi perairan Pantai Pedalen cukup baik untuk pertumbuhan makroalga Phaeophyta.

Kata kunci: alginat, Kebumen, Phaeophyta, lingkungan pantai, spesies makroalga

INTRODUCTION

Pedalen Beach is located between Logending and Menganti Beaches, Kebumen. The geographical location of the beach is flanked by two hills of teak forest located in Pedalen Bay, which is very good for landing fishing boats. The beach is located in Argopeni Village, Ayah District, Kebumen Regency, about 4.8 km from Kebumen city (Romadi 2008). The beach is surrounded by rocks that form karst hills. The beach is approximately 2 km to the east from Menganti Beach and up the mountain road for about 10 minutes. Astronomical location of this coastal waters is 109°23'27–109°23'29 East Longitude and 7°43'51 –7°43'59 South Longitude.

The predominant coral substrate protects macroalgae from waves and high current speeds on the beach; macroalgae can be firmly attached and not easily hit by waves. A stable coral substrate is a good place for macroalgae growth. Brown macroalgae (Phaeophyta) contain alginate, which is widely used in various industries as gelling agents, stabilizers, emulsifiers, suspenders, and as dispersing agents for a product. To sustainably diversify alginate resources,

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an actual and accurate database of brown macroalgae in Kebumen is urgently needed so that planning analysis, decision-making, and evaluation of the processing of economic value macroalgae resources in an area can be carried out appropriately.

Information on species diversity, the density of organisms, and the state of environmental factors is basic information that is very important in aquaculture cultivation because to live and grow marine organism has different living conditions (Papalia & Arfah 2013). Therefore, the diversity of macroalgae species in Indonesia should be continually carried out, considering that changes in coastline caused by natural factors cause habitat changes, especially in coastal areas. This condition is exacerbated by the rapid development of coastal areas, sand mining, dock construction, tourism, and transportation activities which have led to a decline in the ecosystem function of coastal areas and the carrying capacity of the existence and life of marine potentials. It causes resources to be even more depressed.

Pedalen Beach is a tourist beach in Ayah, Kebumen Regency. It has a sand-type bottom substrate, a mixture of sandy coral fragments and coral rocks. The protected type of the beach is classified as a beach with semi-open protection. Beaches with semi-open protection tend to have high currents and wave velocities so that only macroalgae firmly attached to a hard substrate can survive the brunt of high currents and waves. Compared to the coast in the waters of Cilacap, the existence of Nusakambangan Island as protection makes the current speed and wave height better for macroalgae growth (Kholilullah *et al.* 2017).

Brown macroalgae grow enormously on beaches with a coral bottom substrate and sloping waters. Kadi (2017) stated that brown macroalgae in Indonesian waters are often found in coastal waters with reef exposure. However, coral reef beaches in Indonesia are still under-exploited for macroalgae cultivation. One of the obstacles to developing macroalgae cultivation in an aquatic area is the unavailability of accurate data and information about the land area and the feasibility of the location for its development. Based on this, a study was conducted to determine the diversity of brown macroalgae and their distribution patterns in Pedalen waters. This information is used as data on natural resource wealth, potential cultivation areas, and potential macroalgae species in the waters of Kebumen Regency, which can be used as a reference for sustainable resource management policies through effective and efficient macroalgae cultivation.

MATERIALS AND METHOD

This observation was conducted at Pedalen Beach, Kebumen, Central Java, at coordinates 7°43'56.5S–109°23'27.6E (Figure 1). The coordinate point contains coral as a habitat for macroalgae. Sampling was done by line transect method randomly. The macroalgae sampling technique used a random transect. Sampling was conducted from June to August when brown seaweed began to be blooming (seasonal effect). A sampling of macroalgae using the line transect method with a total horizontal length of 200 m (30% of the shoreline length) and a vertical length of 50 m towards the sea as many as six subtransects (three coral substrates and three mixed substrates). Quadrant plot size 1 m x 1 m was placed randomly on different substrates.

The variables measured included species diversity and distribution patterns of Phaeophyta species. The main parameters observed were the number of species and the biomass of each species. Supporting parameters include water current, nitrate content, brightness, depth, tide, salinity, temperature, and pH. The relation between macroalgae diversity and water physicochemical characteristics was carried out by BIOENV multivariate analysis using Primer 7.

This study used materials from macroalgae, concentrated chloride, sulfanilamide solution, and N-(1-naphthyl)-ethylenediamine dihydroxyde solution. The tools used were GPS, depth sounder, pH meter, litmus paper, hand refractometer, secchi disk, UV-Vis spectrophotometer, 0.45 size filter paper, and cool box.

The collected brown macroalgae were observed for the shape/type of branching, the shape and size of the thallus, and the shape of the holdfast and then matched with the pictures and identification book of Geraldino *et al.* (2005), Ni-Ni-Win *et al.* (2013), Noiraksa *et al.* (2006), and Ramesh *et al.* (2019). The

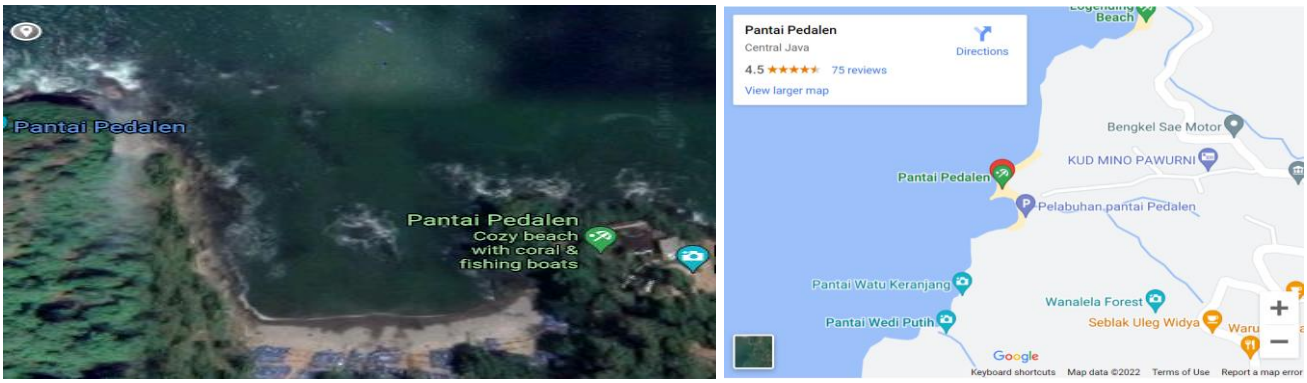

Figure 1 Research location at Pedalen Beach.

physicochemical parameters of the waters consisted of current speed, brightness, depth, tides, temperature, nitrate levels, salinity, and acidity.

The species and biomass data obtained were analyzed using the Shannon-Wiener diversity index (H') and the Simpson dominance index (D). The Shanon-Winner diversity index used the following formula (Nolan & Callahan 2006; Herlinawati *et al.* 2018):

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

$$pi = \frac{ni}{N}$$

Where:
H '= Shannon-Wiener diversity index
pi = Proportion of the i-th species in the total sample
ni = The number of biomassa in plot i
N = The total number of biomassa of all species

The distribution of macroalgae, obtained by changing the distribution data and the macroalgae biomass, is presented in graphical form. The calculation result of the Morisita distribution index, according to Krebs (2009), with the following formula:

$$Id = n\left[\frac{\sum Xi^2 - \sum Xi}{(\sum Xi)^2 - \sum Xi}\right]$$

Where:
Id = Species dispersion index
N = Number of sampling units
Xi = Number of biomassa of a species in plot *i*
X = The total biomass

The calculated diversity index of the Shanon-Winner were analyzed based on the table of water stability. The qualitative diversity is: H'< 1 for low diversity, 1 < H' <1.5 for moderate diversity, 1.6 <H' <3 for high diversity, and H' > 3 for very high diversity. The distribution index of Morisita follows the rules: Ip =1, the species had a random distribution pattern, Ip >1, the species had a clustered distribution pattern, and Ip <1, the species had a uniform distribution pattern (Lika et al. 2021).

RESULTS AND DISCUSSION

Five species of Phaeophyta macroalgae, namely *Padina australis, Dictyota dichotoma, Turbinaria ornata, Sargassum crassifolium*, and *S. polycystum* were identified on Pedalen Beach (Algaebase 2020) (Figure 2). Phaeophyta macroalgae can be found in protected areas in the littoral, sublittoral zones, and in deeper water areas. It is supported by the statement of Widyartini *et al.* (2017) that the Phaeophyta division can be found in protected areas in littoral and sublittoral areas and thrives on coral substrates. The diversity of this macroalgae at the beach is classified as moderate, with a clustered distribution pattern. The physicochemical factors of the waters showed that the aquatic environment of the beach was exceptionally good for the growth of Phaeophyta.

Phaeophyta species that grow on hard coral substrates are more numerous than those that live on a mixed substrate of coral rubble and sand substrates. The highest average biomass is from *S. polycystum* (1,630 g.m^{-2}), and the lowest is from *Dictyota dichotoma* (8 g) (Table 1). The coral substrate is a hard

a. *Sargassum crassifolium* b. *Sargassum polycystum*

c. *Dictyota dichotoma* d. *Padina australis* e. *Turbinaria ornata*

Figure 2 Species of brown macroalgae from Pedalen Beach, Kebumen.

Tabel 1 Macroalgae biomass from Pedalen Beach.

Species	Biomass (g)
S. polycystum	1630
S. crassifolium	53
D. dichotoma	8
T. ornota	39
P. australis	23

substrate consisting of rock and coral, which is stable so that macroalgae can be firmly attached to the substrate and is not easily blown away during big waves. Ferawati *et al.* (2013), stated that a stable substrate is the best place for macroalgae growth. Growth of macroalgae on mixed substrate, which consists of coral or coral fragments mixed with sand, is less stable so that it is easily blown away by the movement of large and strong waves. On sand substrates, macroalgae species are often not growing because sand is a substrate easily washed away by waves or currents. Besides, the resistance tends to be less strong to stick, and thallus that is not too strong to withstand strong currents can also affect it.

Substrate differences, stability, surface hardness, and substrate porosity influence the biomass of macroalgae species for the growing and abundance (Nurkiama *et al.* 2015). In addition, water conditions can affect the diversity of macroalgae. Mushlihah *et al.* (2021) stated that the diversity of macroalgae tends to be high in good water conditions. Conversely, poor water conditions tend to show a low level of diversity. Another factor that can affect the diversity of macroalgae is excessive human activity. Pedalen Beach, which is classified as a tourist beach that is always crowded with people during holidays and on weekends, is an example of excessive human activity that can inhibit macroalgae growth. The H' calculation gives 0.17327–0.35024, meaning that it has a low level of diversity, referring to Krebs (1989), where if the value of H' <1 diversity is low, the value of 1<H'<3 is moderate diversity, and the value of H'>3 is high diversity.

The analysis of the distribution pattern using the Morisita distribution index of 0.1641–0.86823. As interpreted by Lika *et al.* (2021) and Krebs (2009), Id = 1, means that the species have a random distribution pattern, Id>1, the species have a distribution pattern in the group, and Id<1, the species have an even distribution pattern. Thus, all macroalgae species have an even distribution pattern.

Aquatic environmental conditions can influence the distribution pattern of macroalgae in nature. Each species has its environmental tolerance range. Under the law of equilibrium (Lika *et al.* 2021; Krebs 2009), organisms that live in nature have ecological minimum and maximum limits, which are the upper and lower limits of the tolerance range for survival. A population can survive within the limits of the tolerance range, conditions of abiotic factors, and the availability of specific resources. Suciati (2006) states that each organism's tolerance range is different. In general, some organisms in nature have a broad tolerance (stenohalyne), and some have a narrow tolerance (eurihalyne).

The physicochemical parameters of the waters are quite good to support macroalgae growth. The measured physical parameters consisted of current velocity, temperature, brightness, and tides; while the chemical parameters included nitrate, salinity, and acidity (pH). The physicochemical parameters of the waters showed that the water conditions were quite good, according to the reference, in supporting the growth of macroalgae, except for the depth parameter, which was relatively low because the sampling was carried out at the lowest low tide.

Water temperature is an environmental factor limiting macroalgae's presence in Pedalen Beach waters. The temperature range of 29–30°C is considered normal for water temperature. Ilham *et al.* (2014) stated that macroalgae are found in tropical waters with a temperature range of 28–30°C with sufficient light intensity. It is confirmed by Marianingsih *et al*. (2013) that the optimum temperature for the presence of macroalgae is 25–31°C and meets the macroalgae tolerance criteria. Water temperature is essential in helping metabolic processes and photosynthesis in macroalgae. An increase in metabolic processes will accompany an increase in water temperature. The increased metabolism, the more nutrients are needed in the growth process.

The presence of macroalgae is also affected by the salinity. The salinity obtained at the location of the Pedalen waters is in the range of 27–28 ppt. The salinity range of the waters is less than optimal for macroalgae growth. According to Sudradjat (2015), good and optimal salinity for the growth of Phaeophyta macroalgae ranges from 28 to 35 ppt. At this salinity, the process of absorption of nutrients by diffusion can take place well. Salinity is a hypertonic macroalga environmental condition so that the fluid in the cell tends to move into the cell membrane, resulting in a lack of fluid in the cell. Therefore, macroalgae must cope with water loss when the salinity is high enough (Anton 2017).

The pH level affects the growth of macroalgae. The pH in Pedalen waters was 8.6. This condition is not optimal for macroalgae growth. According to Anggadireja *et al*. (2010), the optimum pH for seaweed growth ranges from 6.8 to 8.2. The degree of acidity (pH) is a water chemical environmental factor that determines whether or not the growth of macroalgae is good.

Currents make a significant contribution to the distribution and presence of macroalgae. The current velocity was 0.3–0.5 m/s. The optimum current for macroalgae growth is 0.2–0.4 $m.s^{-1}$ (Serdiati & Widiastuti 2010). Strong currents in the waters of Pedalen Beach are strong enough that it is not optimal for macroalgae growth. The living macroalgae have a holdfast that is firmly attached to the coral. It follows Dwimayasanti & Kurnianto (2018) statement that

strong currents interfere with spore attachment and inhibit the growth of macroalgae whose thallus is fragile.

The depth measurements at the time of sampling ranged from 22.5 to 52.7 cm, indicating a fairly low depth. Low depth because sampling was done at the lowest tide. Jaya & Rasyid (2009) reported that the optimum water depth for macroalgae growth is 60–120 cm. The brightness of the water during the macroalgae sampling process was 10.2–23 cm. The brightness of the water plays an important role in supporting the survival of macroalgae. The brightness level that meets the criteria will support the acceptance of sunlight related to the penetration power of light into the water so that it helps the smooth process of photosynthesis. The reception of perfect sunlight will facilitate the absorption of nutrients. It will directly affect the increase in the length and weight of seaweed (Anton 2017). The level of brightness of the water is very dependent on the suspended solids' load. Good turbidity level for macroalgae growth to the limit of 5.0 meters or the limit of the sun can penetrate the water. Turbidity provides information on the lack of brightness of the waters due to colloidal and suspended materials such as mud, organic and inorganic materials (Wilson 2010). The turbidity value in Pedalen waters was 1.62 NTU. It is still a safe level of water quality standards related to turbidity, which is <5 NTU (Kepmen LH No. 51 of 2004). Turbidity affects the power to enter light for the photosynthesis process. This turbidity level is caused by waves and currents (Denny 2021).

Nitrate is an organic element needed by macroalgae. The nitrate parameters in these waters were 0.485−0.6562 ppm. Therefore, the nitrate content is less than optimal for macroalgae nutrition. Furthermore, the range obtained is less than optimal for macroalgae growth. According to Jaya & Rasyid (2009) and Rahmawati & Abdillah (2019), the nitrate content for macroalgae growth is 0.9–3.0 ppm. Furthermore, Fikri *et al.* (2015) mentioned the optimal range of nitrate for macroalgae growth ranges from 0.9 to 3.5 ppm. Ira *et al.* (2018) confirmed that nitrate levels exceeding 5 ppm indicate the occurrence of environmental pollution, which can come from human and animal activities.

Tidal parameters measured using WXTide32 software is from 0.1 to 2.1 m with a wave height range of 1.9 m. This condition is the optimal condition for macroalgae growth according to the reference according to Jaya & Rasyid (2009) and Kholilullah (2017), where the optimal tidal conditions for macroalgae growth are 1-3 m.

CONCLUSION

Morphological observations of thallus from Pedalen Beach Kebumen found five species of Phaeophyta macroalgae, namely Padina australis, Dictyota dichotoma, Turbinaria ornata, Sargassum crassifolium, and S. polycystum. Thus, Phaeophyta diversity in Pedalen Beach is classified as low with a uniform distribution pattern.

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