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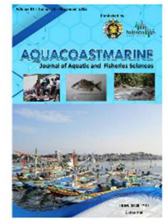

Macroalgal Diversity in Intertidal Zone of Mbuluk Beach, Gunungkidul, Indonesia

Keanekaragaman Makroalga di Zona Intertidal Pantai Mbuluk, Gunungkidul, Indonesia

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ABSTRACT

Mbuluk Beach is one of the new tourist beaches in Gunungkidul Regency, D.I. Yogyakarta. Mbuluk Beach is a small beach that is characterized by a rocky substrate along the coastal area and is overgrown with macroalgae. Despite the distinctiveness of the substrate conducive to macroalgae growth, the exploration of macroalgae diversity along this particular beach has never been studied. This research aims to study the diversity of macroalgae in the intertidal zone of Mbuluk Beach and determine the physicochemical parameters that characterize the environment. This research was conducted on October 21st, 2023. The method used was systematic sampling for collecting samples and directly measuring physicochemical parameters. The calculated index of species diversity used is Shannon-Wiener's formula. The result showed that seventeen species of macroalgae were identified, consisting of six species from Chlorophyta, two species from Phaeophyta, and nine species from Rhodophyta. The macroalgal diversity index in the intertidal zone of Mbuluk Beach is 1,9, which means that the level of species diversity is moderate. The type of substrate which is mostly rocky substrate and the physicochemical parameters obtained including air temperature (22°C), water temperature (21.3°C), pH (7.4), salinity (35.1 ppt), light intensity (5219.5 Lux), and rocky substrate characterized the environmental conditions in which the identified macroalgae species were present in the intertidal zone of Mbuluk beach.

Keyword: Diversity, macroalgae, intertidal zone, systematic sampling

ABSTRAK

Pantai Mbuluk merupakan salah satu pantai wisata baru di Kabupaten Gunungkidul, D. I. Yogyakarta. Pantai Mbuluk merupakan pantai kecil yang memiliki ciri khas substrat berbatu di sepanjang pesisir pantai dan ditumbuhi makroalga. Meskipun memiliki kekhasan substrat yang kondusif untuk pertumbuhan makroalga, eksplorasi keanekaragaman makroalga di sepanjang pantai ini belum pernah diteliti. Penelitian ini bertujuan untuk mempelajari keanekaragaman makroalga di zona intertidal Pantai Mbuluk dan mengetahui parameter fisikokimia yang menjadi karakter kondisi lingkuangan tersebut. Penelitian ini dilakukan pada tanggal 21 Oktober 2023. Metode yang digunakan adalah sampling sistematis untuk pengambilan sampel dan pengukuran parameter

fisikokimia secara langsung. Perhitungan indeks keanekaragaman jenis yang digunakan adalah rumus Shannon-Wiener. Hasil penelitian menunjukkan bahwa tujuh belas spesies makroalga teridentifikasi, yang terdiri dari enam spesies dari Chlorophyta, dua spesies dari Phaeophyta, dan sembilan spesies dari Rhodophyta. Indeks keanekaragaman makroalga di zona intertidal Pantai Mbuluk sebesar 1,9 yang berarti tingkat keanekaragaman jenisnya sedang. Jenis substrat yang sebagian besar berupa substrat berbatu dan parameter fisikokimia yang diperoleh meliputi suhu udara (22°C), suhu air (21,3°C), pH (7,4), salinitas (35,1 ppt), intensitas cahaya (5219,5 Lux), dan substrat bebatuan merupakan karakteristik kondisi lingkungan dimana spesies makroalga yang teridentifikasi hadir di zona intertidal Pantai Mbuluk.
Keyword: Keanekaragaman, Makroalga, Zona intertidal, *Systematic sampling*

1. Introduction

Macroalgae are autotrophic organisms that are usually found in water or moist places. They can be divided into several groups based on taxonomy, namely Rhodophyta (red algae), Chlorophyta (green algae), and Phaeophyceae (brown algae). Rhodophyta has various photosynthetic pigments such as chlorophyll a and d, phycobilin, and several carotenoids such as β-carotene, myxoxanthophyll, and zeaxanthin. Chlorophyta have chlorophyll a and b, as well as carotenoids such as β-carotene, lutein, neoxanthin, violaxanthin, and zeaxanthin. Phaeophyceae have chlorophyll a and c, and carotenoids such as β-carotene, fucoxanthin, and violaxanthin, with fucoxanthin as the dominant pigment that gives the brown color of these algae (Pereira, 2021; Spalding et al., 2019).

Algae play an important role both for the environment and in the fields of nutrition and medicine. In the intertidal ecosystem, algae act as a habitat and food source for other marine biota and can be used as a bioindicator of polluted water. Algae can provide a primary source of sustenance, materials for producing polysaccharides, fertilizers, and antibiotics, and for conducting biological research and waste management (Mathimani & Pugazhendhi, 2019). In their growth, macroalgae are influenced by environmental factors, such as temperature, salinity, light intensity, nutrient sources, and substrates (Susrini et al., 2023). Different species of macroalgae can require different conditions to thrive. Therefore, studying the diversity of macroalgae in coastal areas is very important to maintain the sustainability of the ecosystem and explore its potential utilization.

Mbuluk Beach is a karst beach located in Kemadang village, Tanjungsari sub-district, Gunungkidul Regency, D.I. Yogyakarta, Indonesia. This beach became a tourist destination and is usually visited by tourists. Mbuluk Beach is characterized by rocky substrates and corals in deeper areas. The rocky substrate is a substrate that supports most types of macroalgae to attach and prevent them from being carried away by waves or high current speed of the beach (Erniati et al., 2022; Widyartini et al., 2023). Despite the distinctiveness of the substrate conducive to macroalgae growth, the exploration of macroalgae diversity along this particular beach has never been studied. Therefore, this research was conducted with the aim of studying the diversity of macroalgae in the intertidal zone of Mbuluk Beach and determining the environmental factors as the characteristics of environmental conditions where macroalgae can live and grow. This study can also provide valuable insights into Indonesia's macroalgal diversity database, baseline monitoring, and strategies for conservation and sustainable management.

2. Method

2.1. Study Area and Sampling Time

This research was carried out on October 21st, 2023, in the intertidal zone of Mbuluk Beach, Kemadang Village, Tanjungsari District, Gunungkidul Regency, D.I. Yogyakarta (8°08'00.4 "S 110°33'07.7 "E) at 5.00 until 7.00 am during low tide.

2.2. Materials and Tools

The Materials used in this study are macroalgae samples from Mbuluk Beach and identification books, FAO vol. 1: Species Identification Guide for Fishery Purposes. Furthermore, the tools used in this study are three quadrat plots with a size of 1×1 m (Figure 2a), a roll meter, refractometer, pH meter, thermometer, lux meter, and cameras.

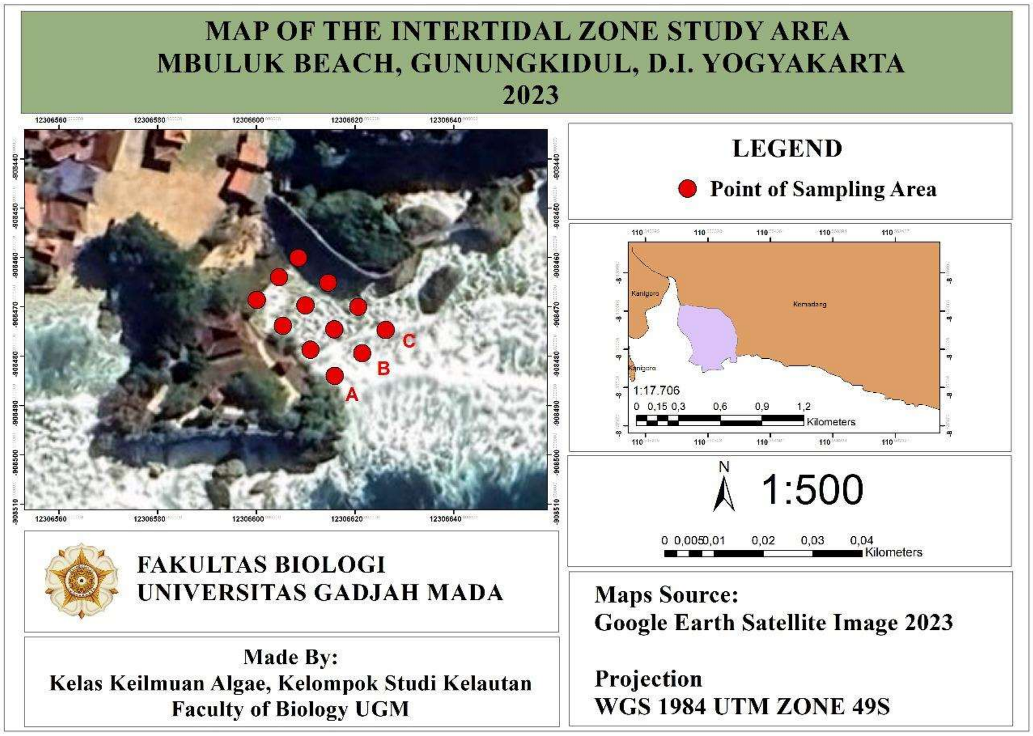


Figure1. Map Illustration of the Intertidal Zone of Mbuluk Beach

2.3. Sampling Method

Systematic sampling is a well-established method for selecting random samples from a population. This method is easier to implement in the field compared to simple random sampling, especially when dealing with large areas of difficult terrain. When there is an underlying structure or stratification in the population, systematic sampling can provide more precise estimators and ensure good spatial coverage (Abi et al., 2017).

The systematic sampling with plots method used in this study was to measure the entire intertidal zone of Mbuluk Beach during low tide using a roll meter. Afterwards, 1% of the total intertidal zone area was measured to determine the sampling area, which is the same as the total of sample plots. The twelve sampling plots we obtained after calculating were divided into 3 vertical transects, each consisting of 4 sample areas. Data collection was done by recording each sample plot using the cameras, and the sample of macroalgae was collected to be identified.

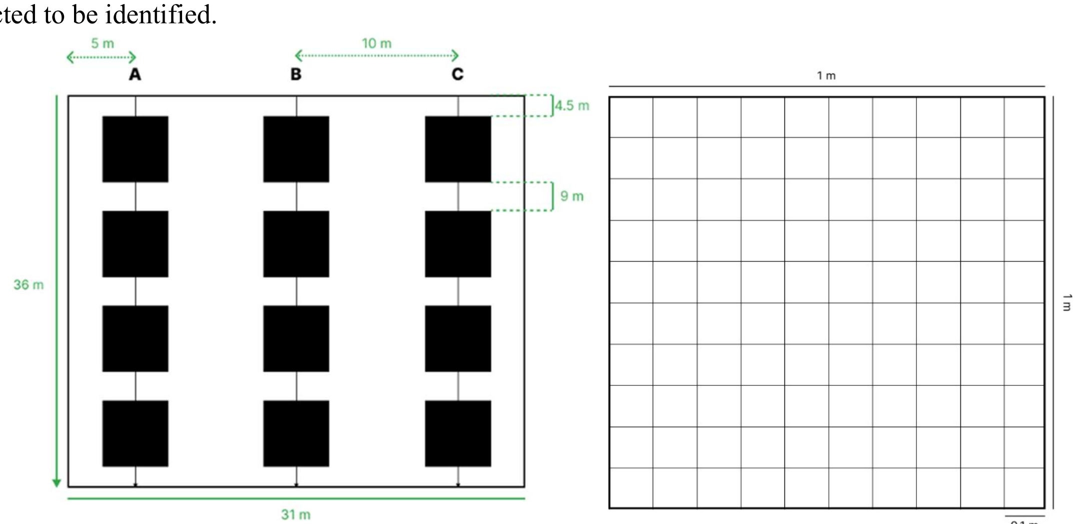


Figure 2. systematic sampling design (1×1 m) (a) and Illustration of the quadrat plot (b)

2.4. Measurement of Physicochemical Parameters

The measurement of physicochemical parameters was done simultaneously with the data collection of macroalgae for each sample plot, except light intensity, which was measured at the beginning and end of the data collection. Water temperature and air temperature, light intensity, water pH, and salinity were measured using thermometer, lux meter, pH meter, and refractometer.

2.5. Identification

The collected macroalgal samples were placed on a millimeter block and documented using a camera. Afterward, macroalgae were identified by morphological observation using the identification books FAO vol. 1: Species Identification Guide for Fishery Purposes. Additional sources such as previous researchs and documentations were also used to confirm the identified species.

2.6. Data Analysis

The diversity index of macroalgae was calculated and analyzed using the Shannon-Wiener index. The qualitative interpretation of the diversity index is as follows: H' ≤ 1 indicates low diversity, 1 < H' < 3 indicates moderate diversity, and H' > 3 indicates high diversity (Hauer & Lamberty, 1996). The diversity index was calculated by the following formula:

$$H' = -\Sigma(pi \times ln\,(pi)) \text{ (I)}$$

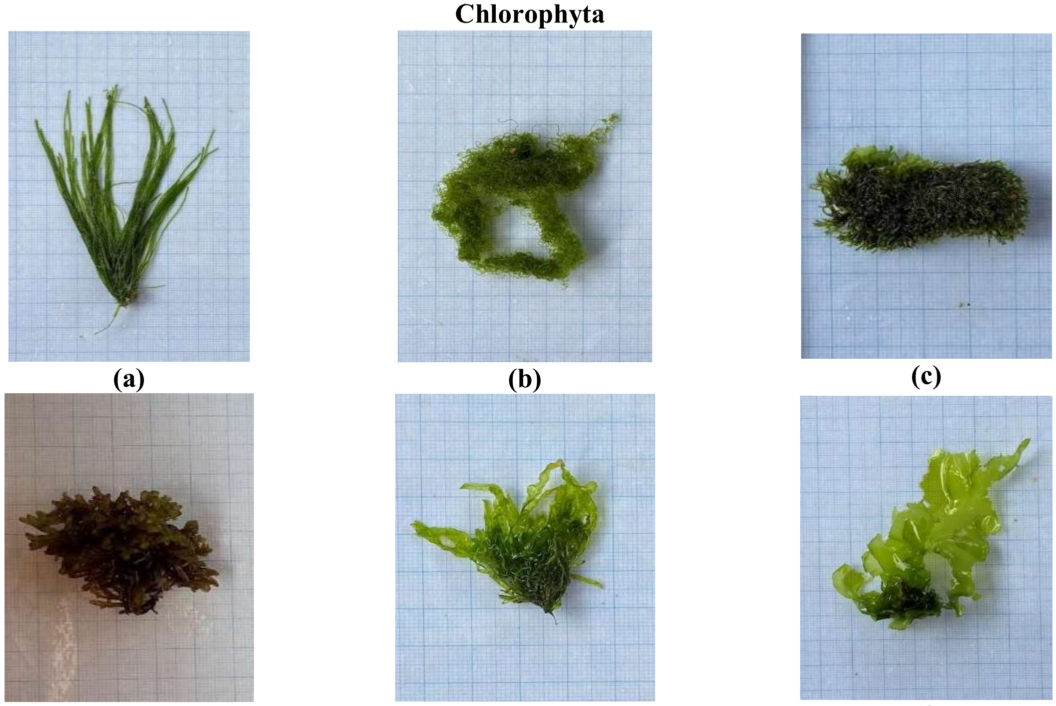
(Odum, 1995)

H’ = Shannon-Wiener diversity index
Pi = Ni/N
Ni = Number of individuals of the species
N = Number of individuals of the entire species

3. Result and Discussion

3.1. Result

Chlorophyta



(a) **(b)** **(c)**

(d) **(e)** **(f)**

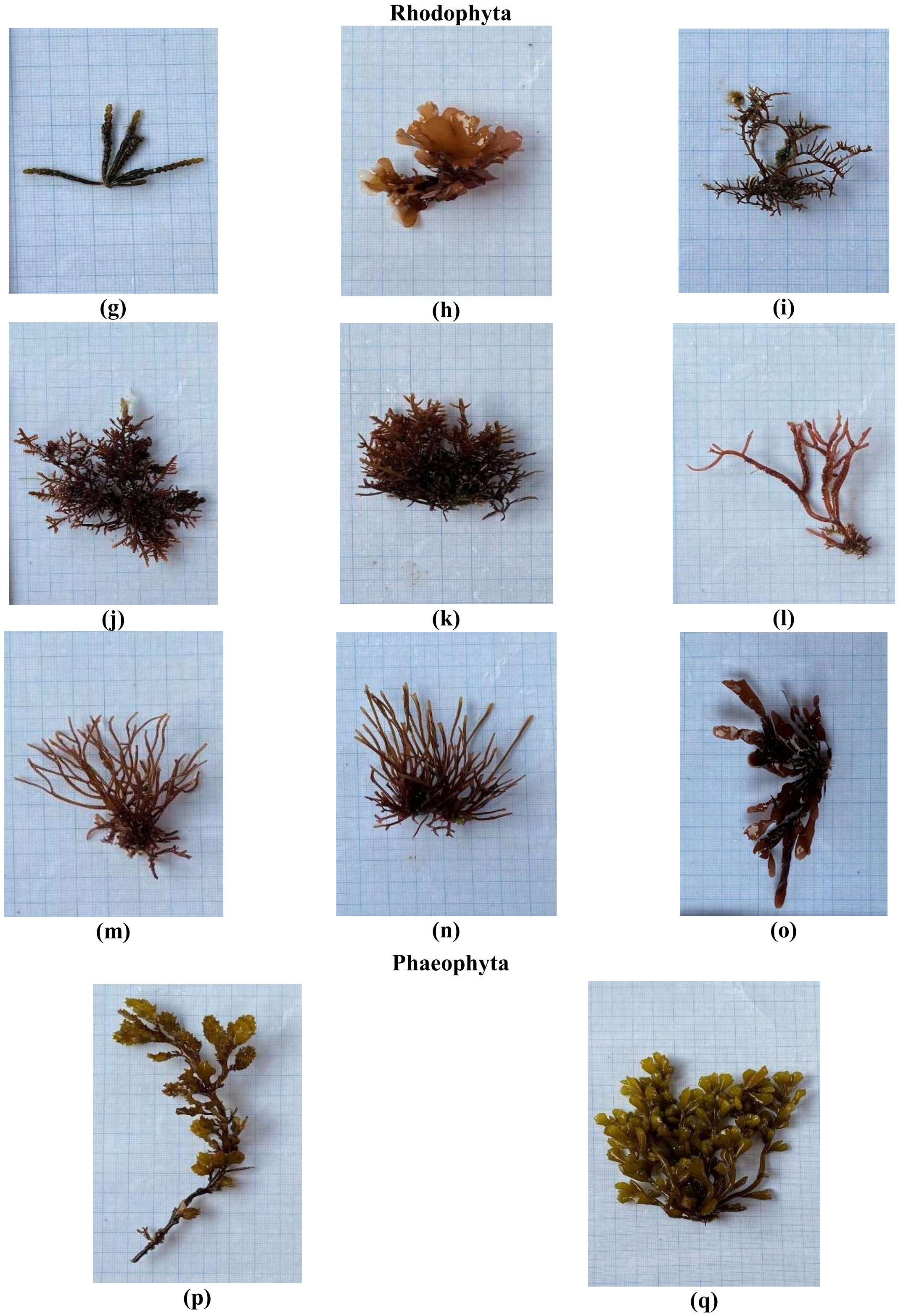


Figure3. Macroalgal Species in Intertidal Zone of Mbuluk Beach, *Chaetomorpha antennina* (a), *Chaetomorpha crassa* (b), *Cladophora catenata* (c), *Codium edule* (d), *Ulva intestinalis* (e), *Ulva lactuca* (f), *Acanthophora muscoides* (g), *Chondrus crispus* (h), *Eucheuma denticulatum* (i), *Gelidiella acerosa* (j), *Gelidium purpurascens* (k), *Gracilaria arcuata* (l), *Hydropuntia edulis* (m), *Gracilariopsis longissima* (n), *Palmaria decipiens* (o), *Sargassum ilicifolium* (p), *Sargassum turbinuroides* (q).

Based on the results of macroalgae species identification, 17 species of macroalgae were identified, consisting of 6 species from Chlorophyta, 9 species from Rhodophyta, and 2 species from Phaeophyta, as shown in Figure 3. Based on the results in Table 1., it can be seen that the air temperature average is 22°C with 0.56 as the standard deviation, water temperature average is 21.3 °C with a standard deviation of 0.62, water pH average is 7.4 with 0.10 as the standard deviation, water salinity average is 35.1 ppt with a standard deviation of 0.29, and for the light intensity average is 5210.5 Lux.

Table 1. Physicochemical parameters at Mbuluk Beach

No	Physicochemical Parameters	Average	Std. Dev
1	Air temperature (°C)	22	0.56
2	Water temperature(°C)	21.3	0.62
3	Water pH	7.4	0.10
4	Salinity (ppt)	35.1	0.29
5	Light intensity (Lux)	5210.5	-

3.2. Discussion

A total of 17 species of macroalgae were obtained. There were 6 species of Chlorophyta, 2 species of Phaeophyta, and 9 species of Rhodophyta. The highest species diversity was shown by Rhodophyta because they have a multicellular holdfast that can make them stick firmly to the substrate. Besides that, Rhodophyta has the biggest species diversity in the world (Hadisusanto et al., 2013). These results are in accordance with the substrate obtained in this study, where the substrate type of Mbuluk Beach is dominated by rocky substrate approximately 27 meters along the upper and middle zone. Besides rocks, the substrates found in this study were sand along the upper zone, at a distance of 9 meters from the upper zone, and corals along the lower zone, starting from a distance of 27 meters and upward from the upper zone sampling area. The characteristics of substrate can affect the growth and population of macroalgae, including species diversity, because some species of macroalgae can only grow in a specific substrate (Zhao et al., 2016; Handayani, 2017). Most species are found on coral and rocky substrates because they are stable, so that the macroalgae can stick firmly to the substrate (Riswanti & Santosa, 2017).

Based on the physicochemical parameter results we obtained, the average water and air temperatures were in a suitable range for macroalgae growth, although they were at a low range. There are some areas that have lower or higher temperatures than other areas, but not in a significant difference. Water temperature plays an important role in macroalgae metabolism, as high temperature causes higher metabolism. However, there is a temperature range that can inhibit the growth of macroalgae because it is too high (Riswanti & Santosa, 2017). Salinity will affect the distribution and productivity of macroalgae. Optimum salinity for macroalgae growth ranges from 33-40 ppt (Riswanti and Santosa, 2017; Ulfah et al., 2017), and the result obtained indicates that the salinity is within the range suitable for macroalgae growth. The pH does not really affect macroalgae growth because they are able to grow in a wide range of pH, even though there are ranges of pH that could affect their growth (Ulfah et al., 2017). The diversity index (H') that was obtained in this research is 1.9, which indicates moderate diversity. The moderate diversity index is supported by suitable environmental conditions. It can be seen from the physicochemical parameters and the substrate in the study area that are suitable for the growth of the macroalgae species found. The diversity index can also be used as a measure to assess environmental conditions (Aziz & Chasani, 2020). The moderate category of macroalgae species diversity indicates a healthy and unexploited ecosystem. These can be used as a diversity database for macroalgae utilization based on sustainable policies to maintain conservation and avoid exploitation. The following is an explanation and description of the species identified in this research.

3.2.1. *Chaetomorpha antennina* (Bory) Kützing, 1847

Chaetomorpha antennina belongs to the Cladophoraceae family and can be found in both marine and freshwater environments. This filamentous and rigid alga typically forms dense clusters on rocky substrates in intertidal and sublittoral zones, reaching heights of 5-7 cm. It exhibits a strong attachment to wooden surfaces, likely due to the powerful ocean currents in its habitat. *C. antennina* has thick-walled, club-shaped holdfast cells that have ring-like constrictions near the base, measuring 400–700 µm in diameter and up to 7.5 mm in length. Other cells are subcylindrical, 400–750 µm wide and 700–1000 µm long, widening into a barrel-like shape toward the top (Leliaert et al., 2011). One of the distinguishing features of *C. antennina* is its unique appearance, characterized by an upright, brush-like tuft formed by the straight and proximal end of its holdfast cell. This distinct morphology makes it easily identifiable (Jebamalar & Sumathy, 2018; Abishek et al., 2018; Gazali et al., 2020). In this study, the species *C. antennina* was frequently found in the lower zone, attached to rocky substrates. Its size varies from small to medium. This species plays a role in controlling water quality by absorbing excess nutrients such as nitrates and phosphates, and also serves as a habitat for aquatic microfauna (Jebamalar et al., 2018).

3.2.2. *Chaetomorpha crassa* (C.Agardh) Kützing, 1845

Chaetomorpha crassa is a green macroalgae, and the thallus is shaped like long strands of hair with fairly strong segments. Thallus filamentous, unbranched, with bright green color. The thallus grows as an entangled form with other seaweeds as epiphytes. This species is mostly found in shallow waters and usually forms dense mats (Faradilla et al., 2022). In this study, *C. crassa* was not found much, and its presence was dominant in the upper sampling area. Like *C. antennina*, this species also plays an important role in improving water quality by preventing eutrophication through the absorption of excess nutrients, especially nitrogen. (Gao et al., 2018).

3.2.3. *Cladophora catenata* Kützing, 1843

Cladophora catenata is a species of green algae that is characterized by a uniseriate, filamentous, branched thallus with multinucleated cells (Alves et al., 2012). *C. catenata* has a dark-green to blackish color with a size of approximately 2,5 cm in height and 3-14 cm in diameter. *C. catenata* has rhizoids emanating form basal cells to stick on the substrate, which is characterized by irregular, branched, and septated (Faradilla et al., 2022). Thallus growth is by division of prominent apical cells, which is followed by cell enlargement. The type of branch is unilateral with a laterally inserted branch in the apical pole of the cell, separated by a sloping wall at the base (Alves et al., 2012). Based on the sampling results, the species *C. catenata* is found in the upper region and is generally attached to rock substrates. At the time of sampling, this species formed a structure that covered the rocks. This is in accordance with the general habitat of *C. catenata*, namely on hard substrates, such as rocks and corals. This macroalgae is generally a habitat for various epiphytes and motile animals because it can provide protection from predators or water flow, and can be a food producer for organisms that live around it. (Dodds & Gudder, 1992).

3.2.4. *Codium edule* P.C.Silva, 1952

Codium edule is a green alga with an intertwined thallus that forms a spongy mass. The thalli of this species are erect, ranging from 3.4 to 16.7 cm in height and 3.2 to 18.2 cm in diameter, displaying shades of yellowish green to dark green. They attach to substrates through spongy disc-like holdfasts. The branches that originate from the holdfast are dichotomously branched and compressed, with diameters varying between 1 to 27 mm. The thallus consists of numerous finely woven medullary filaments, each with a diameter of 50-30 µm, originating from the lower part of individual utricles. C. edule primarily thrives in the intertidal zone, where it experiences temperatures between 10-20°C, pH levels ranging from 7.5-8.5, and salinity levels between 20-30 ppt (Ragasa et al., 2016; Wai et al., 2009). The species *C. edule* was only found in one plot in the upper region. The species found has a dense sponge structure attached to the rock substrate. The structure of the *Codium* group macroalgae plays an important role in the structure of an aquatic community. The thallus network forms a permanent belt that influences the dominance of the substrate and community structure (Gonzalez et al., 2012).

3.2.5. *Ulva intestinalis* Linnaeus, 1753

Ulva intestinalis is a bright green macroalgae that can be found in a variety of habitats on all coastal plains. Under suitable conditions, *U. intestinalis* can grow on rocks and sand substrates. This species has a structure resembling tube-shaped leaves that swell and narrow irregularly. This structure grows from a small disc at the base. Fronds are usually unbranched, the tips are usually rounded, the length is 10-30 cm, and the diameter is 6-18 mm (Mohibbullah et al., 2023). The distribution of *U. intestinalis* is influenced by salinity. Variations in salinity can cause osmotic, ionic, and oxidative stress that affects the cellular function of *U. intestinalis* (Simon et al., 2022). In this study, *U. intestinalis* was found mostly in the upper region, precisely on the sandy rock substrate. This macroalgae is attached to the substrate and sometimes associated with other species of macroalgae. *Ulva intestinalis* acts as a producer for aquatic organisms and facilitates the reproduction process by providing a place to grow and develop (Soufi et al., 2024).

3.2.6. *Ulva lactuca* Linnaeus, 1753

Ulva lactuca is a green macroalgae (Chlorophyceae) that can be found easily in Indonesian waters and has a wide distribution (Rao et al., 2018). In this study, *U. lactuca* was found in the sampling area in the upper, middle, and lower areas. The habitat where this species was found during sampling was on sandy coral substrates. This is in accordance with previous studies, which stated that they can be found in coastal areas of intertidal zones and grow by attaching to dead coral, sand, or coral fragments mixed with sand (Isham et al., 2018; Rao et al., 2018). *U. lactuca* has a fresh green color with a thin and smooth thallus (Handayani, 2016; Kepel et al., 2016). Because of the thallus that looks like lettuce, they are called a sea-lettuce. The salinity range where *U. lactuca* can grow is between 29-31.5 ppt, and it lives in the temperature range of 28-31^{o}C (Jasmadi et al., 2023). This species was the most frequently found during the sampling process. In aquatic ecosystems, *U. lactuca* acts as a producer that provides food and serves as a habitat for various organisms. However, an excessive amount of it can lead to environmental problems such as a decline in biodiversity and the production of harmful components in the water. For example, the decomposition of *U. lactuca* releases acidic vapors that can be hazardous to animals and humans (Peter et al., 2024).

3.2.7. *Acanthophora muscoides* (Linnaeus) Bory de Saint-Vincent, 1828

Acanthophora muscoides is a genus of marine red algae in the family Rhodomelaceae. A. *muscoides* has a brittle, compact, bushy, cartilaginous thallus type, 7.5-18 cm high, dark brown-red, greenish or yellowish, to almost black, branching irregularly, more crowded (near to verticillate) in the upper portions. Main axes cylindrical, to 0.7(-2.5) mm. Short spines are present on both main and determinate branches. The determinate branches are spirally arranged. Sporangia in very spiny branchlets and tetrahedrally divided (Rodrigues et al., 2016). The majority of the samples found at the sampling sites have a small size (juvenile) with an incomplete structure. This could be due to the contribution of fauna in the environment that eat this alga, or damage due to heavy ocean currents. As an invasive alga, *A. muscoides* significantly impacts biodiversity and ecosystem structure by disrupting native species' mutualistic interactions, leading to declines in native flora and altered community dynamics, while reducing ecosystem resilience (Traveset, 2015). Its invasion can simplify food webs, diminishing primary production, decomposition rates, and nutrient cycling, which compromises habitat complexity (O'Gorman, 2021). Although some invasive species may coexist with natives with minimal immediate effects, subtle long-term impacts on population dynamics and community structure persist, as evidenced by the recovery of native species abundance and health following invasive removal, underscoring the often-underestimated ecological consequences of invasions (Epstein et al., 2019).

3.2.8. *Chondrus crispus* Stackhouse, 1797

Chondrus crispus is a marine red alga with carrageenans in its extracellular matrix. They have a red-brown color (Oryza et al., 2017). *C. crispus* can be found on rocky shores and in a pool, and can be adapted to some reduced salinity. They can tolerate a wide range of salinities, from 10-58 ppt, but their growth significantly reduces below 30 ppt (DFO, 2009). This species has a complex haplodiplontic life cycle. *C. crispus* has a thallus with a discoid holdfast and erect fronds. The stalk is not branched but forms fan-like blades. Environmental factors can influence variations in shape (Rayment & Pizzola, 2008). *C. crispus* enhances habitat complexity in low intertidal zones, supporting local biodiversity by providing shelter and food for marine organisms, with its cover positively correlated with invertebrate species richness (Scrosati, 2016). However, high cover levels may reduce algal diversity, highlighting a trade-off in its ecological influence. By fostering invertebrate populations, *C. crispus* can modify predator-prey interactions and nutrient cycling, thereby shaping ecosystem dynamics (Scrosati, 2016).

3.2.9. *Eucheuma denticulatum* (N.L.Burman) Collins & Hervey, 1917

Eucheuma denticulatum (Burman) Collins and Hervey, 1917 is one of the most commonly found species of red algae. Mostly, *E. denticulatum* grows naturally on hard substrates and is rarely found deeper. *E. denticulatum* has a body shape resembling a leaf with long and flat leaf blades. The thalli have cylindrical or flat branches, with sizes up to 30 cm in height, and are cartilaginous. Carrageenan from *E. denticulatum* is a raw material for various industries. *E. denticulatum* growth is affected by substrate, salinity, temperature, nutrient availability, and light intensity (Munawan et al., 2021). *E. denticulatum* enhances habitat structure by creating a three-dimensional environment that supports diverse marine life, with its structural complexity directly linked to increased invertebrate biodiversity, forming critical foundations for marine food webs (Gibbons & Quijón, 2023; Dijkstra et al., 2017). However, its introduction can shift community composition, displacing native species and altering trophic interactions (Dijkstra et al., 2017). While elevated biodiversity at lower trophic levels may bolster ecosystem resilience, such changes risk disrupting established species relationships, potentially triggering unforeseen ecological consequences (Fouw et al., 2023).

3.2.10. *Gelidiella acerosa* (Forsskål) Feldmann & Hamel, 1934

Gelidiella acerosa (Forsskål) Feldmann and Hamel, 1934 is one of the most common species of red algae. Because of variations in light intensity and the presence of certain chemicals, *G. acerosa* sometimes has a reddish-brown color. *G. acerosa* has a body resembling fine and dense branches, with branch lengths ranging from 10-30 cm. *G. acerosa* is abundantly found in the intertidal and upper subtidal zones and grows at a depth of 0 – 47 m. *G. acerosa* has an important role in aquatic ecosystems for maintaining sustainability because *G. acerosa* serves as an oxygen producer and balancer of the nutrient cycle. This species also contains antimicrobial, antioxidant, antifungal, anticoagulant, and antifertility properties. Because of that, *G. acerosa* is widely utilized for the food and pharma industry (Begum et al., 2018).

3.2.11. *Gelidium purpurascens* N.L.Gardner, 1927

Gelidium purpurascens N.L.Gardner, 1927 has characteristcs thallus 8-30 cm high, mostly with rather regular distichous branching, sometimes markedly polystichous, alternate or opposite, with or without geniculate branching; axes basally nearly cylindrical or compressed, usually more compressed above; ultimate sterile branchlets occasionally terete, with acute apices; branching highly variable; lower axes unbranched, or with branching near base; distal branching sparse to dense; main axes 0.5-2 mm wide, 0.25-1.2 mm thick near base; ultimate branches 0.27-0.95 mm wide, 0.12-0.6 mm thick (Abbott & Norris, 1985). *G. purpurascens* acts as a foundational species in coastal ecosystems, enhancing habitat complexity by providing substrate for marine organisms and directly supporting invertebrate biodiversity, which underpins marine ecosystem health (Ramus et al., 2024). Its presence correlates with increased macroalgal diversity and higher invertebrate biomass, reinforcing its critical role in sustaining consumer communities (Ramus et al., 2024). While *G. purpurascens* strengthens food web dynamics by boosting food availability for higher trophic levels, its populations are vulnerable to environmental stressors like pollution and climate change, which risk disrupting these ecological networks and triggering declines in dependent species (Miloslavich et al., 2019). Consequently, the degradation or loss of *G. purpurascens* could destabilize coastal ecosystems, emphasizing the urgency of conservation efforts to protect its vital ecosystem services.

3.2.12. *Gracilaria arcuata* Zanardini, 1858

Gracilaria arcuata Zanardini, 1858 is a red macroalgae and sometimes has a reddish brown color when fresh. The holdfast is disc-shaped, while the branches are cylindrical, irregular, and slightly narrow at the base, enlarged in the middle, and thinner at the tip. The branch tips have 2-5 short, spinose branches. *G. arcuata* generally lives attached to coral or rocks and grows in shallow areas (Othman et al., 2015). *G. arcuata* is a macroalgae source that provides several bioactive compounds such as antioxidants, antibacterials, and anti-inflammatories (Hidayati et al., 2020). *G. arcurata* thrives in tropical and subtropical coastal regions, providing a habitat for and serving as a food source for marine life. However, its accelerated proliferation in nutrient-rich environments (eutrophication) frequently results in dense blooms, which perturb ecosystems by shading seagrasses and corals, reducing biodiversity, and causing hypoxia. Its proliferation is a key indicator of nutrient pollution from sources such as agriculture, sewage, or aquaculture. Despite its disruptive potential, it is also studied for bioremediation purposes, that is, to absorb excess nutrients in polluted waters.

3.2.13. *Hydropuntia edulis* (S.G.Gmelin) Gurgel & Fredericq, 2004

Hydropuntia edulis (S.G.Gmelin) Gurgel & Fredericq, 2004 is a red algae in the family Gracilariaceae. *H. edulis* has the characteristics of a thick and fleshy thallus. The thallus generally has a width of 2-5 cm with a length of 10-30 cm and is equipped with small branches. Sometimes, *H. edulis* has a dark purplish red and appears shiny. This red algae species is distributed in tropical to subtropical areas. In this research, *H.edulis* was only found in the lower intertidal zone on sandy-rocky substrates. Based on its distributrion, *H. edulis* can thrives in diverse ecological settings, encompassing both intertidal and subtidal zones. This species also can withstand a wide range of salinity levels and temperatures (Bhushan et al., 2023).

3.2.14. *Gracilariopsis longissima* (S.G.Gmelin) Steentoft, L.M.Irvine & Farnham, 1995

Gracilariopsis longissima (S.G.Gmelin) Steentoft, L.M.Irvine & Farnham, 1995 is a type of red algae. Its structure includes an upright thallus that can reach lengths of up to 20 cm (for depths less than 1 m) or 100 cm (for depths greater than 1 m). Unlike other algae, it doesn't have a holdfast and is instead anchored in sediment. The thallus is intricately branched, with branches that are cylindrical, measuring up to 2 mm in width. The base of these branches is often narrowed down to 0.8 mm in diameter, and their tips come to a sharp point. In its fresh state, this alga is cartilaginous and displays dark red to purple hues (Iyer et al., 2004). *G. longissima* can provides habitat for other marine species, such as fish and invertebrates. Its primary production of oxygen also plays a important role in nutrient cycling. In this research, *G. longissima* were only found in lower habitats as this species prefers rocky substrates and shallow waters but can also be found deeper and tolerate a variety of salinities.

3.2.15. *Palmaria decipiens* (Reinsch) R.W.Ricker, 1987

Palmaria decipiens (Reinsch) R.W.Ricker, 1987 is a species from Rhodophyta which have characteristics flattened thallus and the erect frond of dulse grows attached by its discoid holdfast and a short inconspicuous stipe epiphytically onto the stipe to rocks. The habitat is usually epilithic, although sometimes epiphytic (Nelson et al., 2022). The fronds are variable in shape and colour from deep rose to reddish purple and are rather leathery in texture. *P. decipiens* is highly abundant in the intertidal and upper subtidal zones. Consequently, it plays a significant role in ecosystem structure and function by providing habitat, food, and shelter for associated marine organisms. *P. decipiens*, known as the seasonal anticipator, develops new blades in August and then prepares to grow and reproduce in late winter or spring (Robinson et al., 2022).

3.2.16. *Sargassum turbinarioides* Grunow, 1915

Sargassum turbinarioides Grunow, 1915 is a brown-yellow Phaeophyceae that is commonly found in tropical to subtropical coastal waters (Triastinurmiatiningsih, 2011). They can grow in waters at a depth of 0.5-10 m, typically in high-energy environments with strong currents and wave action. This species attaches to hard substrates such as coral or dead coral and forms large clumps (Kadi, 2005). The condition of the coastal waters where they grow must be clear, as turbid water hinders photosynthesis by limiting sunlight penetration (Lestari et al., 2023).

3.2.17. *Sargassum ilicifolium* (Turner) C.Agardh, 1820

Sargassum ilicifolium (Turner) C.Agardh, 1820 is a phaeophyta macroalgae that has a cylindrical and smooth axis. The thallus is ovate to spatulate with denticulate or biserrate edges. It resembles a thin leaf midrib and spreads toward the top. The vesicles are round or ovoid, smooth, and occur singly or in pairs, sometimes winged, measuring 5-12 cm (Zip et al., 2018). *S. ilicifoium* is a type of canopy-forming algae that belongs to the Famili Sargassacecae and Ordo Fucales. In this study, *S. ilicifolium* was mostly found in the lower zone with coral substrate which made it easy for it to attach steadily using holdfasts. *S. ilicifolium* in the ecosystem acts as shelter and food sources for reef associated species. However, its abundant presence can also be a competitor for other benthic organisms for sunlight and space (Oh et al., 2021).

4. Conclusion

Based on the research conducted, a total of 17 macroalgae species were found, consisting of 6 species classified as Chlorophyta, 2 species classified as Phaeophyta, and 9 species classified as Rhodophyta. The macroalgae diversity index in the intertidal zone of Mbuluk Beach is 1.9, which indicates a moderate level of species diversity. Physicochemical parameters indicate that air temperature (22°C), water temperature (21.3°C), pH (7.4), salinity (35.1 ppt), light intensity (5219.5 Lux), and rocky substrate characterized the environmental conditions in which the identified macroalgae species were present in the intertidal zone of Mbuluk beach.

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6. Conflict of Interest

The authors declare that there is no conflict of interest regarding the research.

References

Abbott, I. A. & Norris, J. N. (1985). Taxonomy of economic seaweeds: with reference to some Pacific and Caribbean species. UC San Diego: Scripps Institution of Oceanography.

Abishek, D., Jyoti, P., Savan, D. & Sumitra, C. (2018). Pharmacognostic standardization of *Chaetomorpha antennina* and *Ulva lactuca*, green seaweeds from Gujarat coast. Journal of Pharmacognosy and Phytochemistry, 7(2), 3863–3870.

Abi, N., Moradi, M., Salehi, M., Brown, J., Al-Khayat, J.A. & Moltchanova, E. (2017). Application of balanced acceptance sampling to an intertidal survey, 1(10), 97-107.

Alves, A. M., Gestinari, L. M., Oliveira, I. S. D., Brito, K. L. M. & Moura, C. W. D. N. (2012). The Genus *Cladophora* (Chlorophyta) in The Littoral of Bahia, Brazil. Nova Hedwigia, 3(4), 337–372. DOI: 10.1127/0029-5035/2012/0025

Aziz, L. & Chasani, A. R. (2020). Perbandingan Struktur dan Komposisi Makroalga di Pantai Drini dan Pantai Krakal. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, 13(2), 75-86. DOI: 10.21107/jk.v13i2.6263

Begum, F. M., Chitra, K., Joseph, B., Sundararajan, R. & Hemalatha, S. (2018). *Gelidiella acerosa* inhibits lung cancer proliferation. BMC Complementary and Alternative Medicine, 18(104), 1–14. DOI: 10.1186/s12906-018-2165-1

Bhushan, S., Veeragurunathan, V., Bhagiya, B. K., Krishnan, S. G., Ghosh, A. & Mantri, V. A. (2023). Biology, farming and applications of economically important red seaweed *Gracilaria edulis* (S. G. Gmelin) P. C. Silva: A concise review. Journal of Applied Phycology, (35), 983–996. DOI: 10.1007/s10811-023-02955-8

DFO. (2009). Ecological Assessment of Irish Moss (*Chondrus Crispus*) in Basin Head Marine Protected Area. Canadian Science Advisory Secretariat, 1–16.

Dijkstra, J. A., Harris, L. G., Mello, K., Litterer, A., Wells, C. D., & Ware, C. (2017). Invasive seaweeds transform habitat structure and increase biodiversity of associated species. *Journal of Ecology*, 105(6), 1668–1678. DOI: 10.1111/1365-2745.12775

Dodds, W. K. & Gudder, D. A. (1992). The ecology of *Chladophora*. Journal of Phycology, 28(4): 415-427. DOI: 10.1111/j.0022-3646.1992.00415.x

Epstein, G., Foggo, A., & Smale, D. A. (2019). Inconspicuous impacts: Widespread marine invader causes subtle but significant changes in native macroalgal assemblages. *Ecosphere*, 10(7). DOI: 10.1002/ECS2.2814

Erniati., Erlangga., & Yudho Andika. (2022). Buku Rumput Laut (Perairan Aceh). KBM Indonesia. ISBN: 978623-499-193-2.

Faradilla, F., Nikmah, F., Putri, A. D., Agustin, G. A., Nurkaromah, L., Febrianti, M. W., Budiman, M. A., Salamah, U. & Chasani, A. R. (2022). Macroalgae Diversity at Porok Beach, Gunungkidul, Yogyakarta, Indonesia. Journal of Agriculture and Applied Biology, 3(1), 50–61. DOI: 10.11594/jaab.03.01.06

Fouw, J., Holmer, M., Beca-Carretero, P., Boström, C., Brun, F. G., Cruijsen, P. M. J. M., Govers, L. L., Garmendia, J. M., Meysick, L., Pajusalu, L., Richir, J., Robroek, B. J. M., Valle, M., van der Ven, P. J. P., Eklöf, J. S., & van der Heide, T. (2023). A facultative mutualism facilitates European seagrass meadows. *Ecography*, 2023 (5). DOI: 10.1111/ecog.06636

Gao, X., Endo, H. & Agatsuma, Y. (2018). Seasonal changes in photosynthesis, growth, nitrogen accumulation, and salinity tolerance of *Chaetomorpha crassa* (Cladophorales, Chlorophyceae). Journal of Applied Phycology, 30(1): 1905–1912. DOI: 10.1007/s10811-017-1381-2

Gazali, M., Nurjanah, Zamani, P. N., Zuriat & Nasution M. A. (2020). A study on a potential bioactive compound in green seaweed *Chaetomorpha antennina* Kützing (1847) extract as antioxidant from the Gosong Telaga Coast, Aceh Singkil. The 3rd International Symposium Marine and Fisheries (ISMF), 1–9. DOI: 10.1088/1755-1315/564/1/012058

Gibbons, E. G., & Quijón, P. A. (2023). Macroalgal features and their influence on associated biodiversity: implications for conservation and restoration. *Frontiers in Marine Science*. DOI: 10.3389/fmars.2023.1304000

Gonzales, A. V., Chacana, M. E. & Silva, P. C. (2012). Codium bernabei sp. nov. (Bryopsidales, Chlorophyta), a coalescing green seaweed from the coast of Chile. Phycologia, 51(6): 666-671. DOI: 10.2216/12-025.1

Hadisusanto, S. Dewi, S. C., Meilianda, A., Haryatfrehni, R. & Sari, I. Z. R. (2015). Macroalgal abundance in intertidal zone of Sarangan Beach, Gunungkidul, DIY. The 3rd International Conference on Biological Science 2013, 2, 518–521. DOI: 10.18502/kls.v2i1.207

Handayani, T. (2016). Karakteristik dan Aspek Biologi Ulva spp. (Chlorophyta, Ulvaceae). Oseana, XLI, 1, 1–8.

Handayani (2017). The Potency of Macroalgae in the Reef Flat of Lampung Bay. Oseanologi dan Limnologi di Indonesia, 2(1), 55–57. DOI: 10.14203/oldi.2017.v2i1.15

Hauer, F. R., & Lamberty, G. (1996). Methods in Stream Ecology. Academic Press, Inc.

Hidayati, J.R., Yudiati, E; Pringgenies, D., Oktaviyanti, D.T. & Kusuma, A.P. (2020). Comparative Study on Antioxidant Activities, Total Phenolic Compound and Pigment Contents of Tropical *Spirulina platensis*, *Gracilaria arcuata* and *Ulva lactuca* Extracted in Different Solvents Polarity. E3S Web of Conference, 147(03012), 1–9. DOI: 10.1051/e3sconf/202014703012

Isham, Kasim, M. & Arami, H. (2018). Komposisi Jenis dan Kepadatan Makroalga Di Perairan Desa Ulunipa Kecamatan Menui Kepulauan Kabupaten Morowali Sulawesi Tengah. Jurnal Manajemen Sumber Daya Perairan, 3(3), 199–207.

Iyer, R ., Clerck, O. D., Bolton, J. J. & Coyne, V. E. (2004). Morphological and taxonomic studies of *Gracilaria* and *Gracilariopsis* species (Gracilariales, Rhodophyta) from South Africa. South African Journal of Botany, 70(4), 521–539. DOI: 10.1016/S0254-6299(15)30192-7

Jasmadi, Poeloengasih, C. D., Novianty, H., Rakhmi, A., Sefrienda, Permadi, S., Suryaningtyas, I. T., Kumayanjati, B. & Setyono, D. E. D. (2023). Characteristics of *Ulva lactuca* Freshness Under Different Temperatures at Short-term Storage. Journal of Aquaculture and Fish Health, 12(2), 246–258. DOI: 10.20473/jafh.v12i2.33710

Jebamalar, J. & Sumathy, J. H. (2018). A Study on the Antioxidant Potential of *Chaetomorpha antennina*. International Journal of Engineering and Techniques, 4(1), 405–413.

Kepel, R. C., Mantiri, D. M. H., Rumengan, A. & Nasprianto. (2016). The Biodiversity of Macroalgae in The Coastal Waters of Blongko Village, Sub-District of Sinonsayang, District of South Minahasa. Platax Scientific Journal, 6(1), 174–187. DOI: 10.35800/jip.6.1.2018.19583

Leliaer, F., D'hondt, S., Tyberghein, L., Verbruggen, H. & De Clerck, O. (2011). Atypical development of Chaetomorpha antennina in culture(Cladophorales, Chlorophyta). Phycological Research, 59: 91–97. DOI: 10.1111/j.1440-1835.2010.00604.x

Lestari, P.A., Siregar, Z.S., Putri, F. & Fitri, R. (2023). Identifikasi Alga Makroskopis di Kawasan Pantai Carolina Kota Padang. Prosiding SEMNAS BIO 2023, 967–976. DOI: 10.24036/prosemnasbio/vol3/667

Miloslavich, P., Johnson, C. R., & Benedetti-Cecchi, L. (2019). Keeping a watch on seaweeds: the forests of the world's coasts. *Eos*, 100. DOI: 10.1029/2019EO113401

Mathimani, T. and Pugazhendhi, A., (2019). Utilization of algae for biofuel, bio-products and bio-remediation. Biocatalysis and agricultural biotechnology, 17, pp.326–330. DOI: 10.1016/j.bcab.2018.12.007

Mohibbullah, M., Amin, A., Talha M.A., Baten, M. A., Rana, M. M., Sabuz, A. A., Newaz, A. W. & Choi J. S. (2023). Physicochemical and Nutritional Characteristics of Cookies Prepared with Untapped Seaweed *Ulva intestinalis*: An Approach to Value Addition as a Functional Food. Foods, 12(205), 1–15. DOI: 10.3390/foods12010205

Munawan, Kasim, M. & Ruslaini. (2021). Growth rate of *Eucheuma denticulatum* cultivated in horizontal net and vertical net. IOP Conf. Series: Earth and Environmental Science, 925, 1–10. DOI: 10.1088/1755-1315/925/1/012018

Nelson, W. A., Neill, K. F., D'Archino, R. & Sutherland, J. E. (2022). Marine macroalgae of the Balleny Islands and Ross Sea. Antarctic Science, 34(4), 298–312. DOI: 10.1017/S0954102022000220

Odum, E. P. (1995). Fundamental of Ecology (3rd ed.). Toppan Compani, Ltd.

O'Gorman, E. J. (2021). Multitrophic diversity sustains ecological complexity by dampening top-down control of a shallow marine benthic food web. *Ecology*, *102*(3). DOI: 10.1002/ECY.3274

Oh, R. M., Bollati, E., Maithani, P., Huang, D., & Wainwright, B. J. (2021). The Microbiome of the Reef Macroalga Sargassum ilicifolium in Singapore. *Microorganisms*, 9(5), 898. DOI: 10.3390/microorganisms9050898

Oryza, D., Mahanal, S. & Sari, M. S. (2017). Identifikasi Rhodophyta sebagai Bahan Ajar di Perguruan Tinggi. Jurnal Pendidikan, 2(3), 309–314. DOI: 10.17977/jptpp.v2i3.8582

Othman, M. N. A., Hassan, R., Harith, M. N. & Sah, A. S. R. (2015). Red Seaweed *Gracilaria Arcuata* in Cage Culture Area of Lawas, Sarawak. Borneo Journal of Resource Science and Technology, 5(2), 53–61. DOI: 10.1155/2019/3430968

Pereira, L. (2021). Macroalgae. Encyclopedia, 1(1), 177–188.

Peter, N. R., Raja, N. R., Rengarajan, J., Pillai, A. R., Kondusamy, A., Saravanan, A. K., Paran, B. C. & Lal, K. K. (2024). A comprehensive study on ecological insights of *Ulva lactuca* seaweed bloom in a lagoon along the southeast coast of India. Ocean & Coastal Management, 248: 106964. DOI: 10.1016/j.ocecoaman.2023.106964

Ragasa, C.Y., Antonio, C. & Shen, C. 2016. Chemical Constituents of *Codium edule*. Der Pharma Chemica, 8 (10): 83-87.

Ramus, A. P., Lefcheck, J., & Long, Z. T. (2024). Foundational biodiversity effects propagate through coastal food webs via multiple pathways. *Authorea.* https://doi.org/10.22541/au.170668098.89188501/v1

Rao, P. V. S., Periyasamy, C., Kumar, K. S., Rao, A. S. & Anantharaman, P. (2018). Seaweeds: Distribution, Production and Uses. In M.N. Noor, S.K. Bhatnagar, and S.K. Sinha (Eds.), India: Society For Plant Research India, pp.59-78.

Rayment, W. & Pizzola, P. (2019). Carrageen (*Chondrus crispus*). MarLIN - Marine Life Information Network, 1-22.

Riswanti, D. & Santosa, G.W. (2017). Struktur komunitas rumput laut di Pantai Krakal bagian barat Gunung Kidul Yogyakarta. Prosiding Seminar Nasional Hasil-Hasil Penelitian Perikanan dan Kelautan ke-VI. 434–442

Robinson, B.J.O., Morley, S.A., Rizouli, A., Sarantopoulu, J., Gkafas, G. A., Exadactylos, A. & Kupper, F. C. (2022). New confirmed depth limit of Antarctic macroalgae: *Palmaria decipiens* found at 100 m depth in the Southern Ocean. Polar Biology, 45, 1459–1463. DOI: 10.1007/s00300-022-03071-y

Scrosati, R. A. (2016). The clonal seaweed *Chondrus crispus* as a foundation species. *Algae*, 31(1), 41–48. https://doi.org/10.4490/ALGAE.2016.31.2.10

Simon, C., McHale, M. & Sulpice, R. Applications of *Ulva* Biomass and Strategies to Improve Its Yield and Composition: A Perspective for Ulva Aquaculture. Biology, 11(11), 1–17. DOI: 10.3390/biology11111593

Soufi, J., El Hammoudani, Y., Haboubi, K., Hanafi, I. & Dimane, F. (2024). *Ulva* spp (*Ulva intestinalis, U. fasciata, U. lactuca*, and *U. rigida*) composition and abiotic environmental factors. BIO Web of Conferences, 109(01012): 1-10. DOI: 10.1051/bioconf/202410901012

Spalding, H. L., Gilberto, M. A. F., Ricardo, G. B., David, L. B., Suzanne, F., James, J. L., Wendy, A. N., Marc, S., & Roy, T. T. (2019). Macrolgae. Springer Nature, 2, 507-536. DOI: 10.1007/978-3-319-92735-0_29

Susrini, P. D., Nurdiansyah, S. I., Sofiana, M. S. J., Kushadiwijayanto, A. A. & Safitri, I. (2023). Macroalgae Community Structure in the Waters of Temajo Island, Mempawah Regency, West Kalimantan. Jurnal Ilmiah PLATAX, 11(1), 259–268. DOI: 10.35800/jip.v10i2.48011

Traveset, A. (2015). Impacto de las especies exóticas sobre las comunidades mediado por interacciones mutualistas. *Ecosistemas,* 24(1), 67–75.

Triastinurmiatiningsih, Ismanto, & Ertina. (2011). Variasi Morfologi dan Anatomi *Sargassum* spp. di Pantai Bayah, Banten. Ekologia, 11(2), 1–10. DOI: 10.33751/ekol.v11i2.255

Ulfah, S., Agustina, E. & Hidayat, M. (2017). Struktur komunitas makroalga ekosistem terumbu karang perairan Pantai Air Berudang Kabupaten Aceh Selatan. Prosiding Seminar Nasional Biotik 2017, 237–244.

Wai, M. K., Nyunt, T., Kyaw, S. P. P. & Soe-Htun, U. (2009). The Morphology and Distribution of the Genus *Codium* (Bryopsidales, Chlorophyta) from Myanmar. Jour. Myan. Acad. Arts & Sc, 7(9), 1–11.

Widyartini, D. S., Insan, A. I. & Hidayah, H. A. (2023). Diversity and Distribution of Phaeophyta Macroalgae in Pedalen Coastal Waters, Kebumen. Jurnal Ilmu Pertanian Indonesia (JIPI), 28(1), 65–71. DOI: 10.18343/jipi.28.1.65

Yip, Z. T., Quek, R. Z. B., Low, J. K. Y., Wilson, B., Bauman, A. G., Chou, L. M., Todd, P. A., & Huang, D. (2018). Diversity and phylogeny of *Sargassum* (Fucales, Phaeophyceae) in Singapore. Phytotaxa, 369(3), 200–210. DOI: 10.11646/phytotaxa.369.3.3