JOURNAL OF AGRICULTURE AND APPLIED BIOLOGY
2022, Vol. 3, No. 1, 50 - 61
http://dx.doi.org/10.11594/jaab.03.01.06
E-ISSN: 2723-5106

Research Article

Macroalgae diversity at Porok Beach, Gunungkidul, Yogyakarta, Indonesia

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Article history:
Submitted 06 February 2021
Accepted 05 October 2021
Published 18 April 2022

Keywords:
Diversity
Macroalgae
Porok Beach

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Abstract

Indonesia is one of the world's richest nations in terms of its biodiversity. One of the biological resources that has an important role in marine life is macroalgae. As a primary producer, macroalgae play an important role in the coastal environment. Porok Beach is a beach in the Gunungkidul district of Yogyakarta, Java Island, Indonesia. Porok beach is dominated by a rocky substrate, which would be the ideal substrate for macroalgae. The development of coastal areas as a tourism destination is feared to have an impact on macroalgae biodiversity. Comprehensive efforts are required to protect the coastlines of Porok Beach as sources of macroalgae germplasm that will ensure the survival of coastal biodiversity in Gunungkidul. So, it is necessary to study macroalgae diversity in Porok Beach to obtain a preliminary data to conserve. the macroalgae in the area. This study aims to monitor the presence of the macroalgae on Porok Beach. Purposive random sampling was used in the study, which took place on October 17th, 2020. Water temperature and pH are the ecological parameters that are measured. Seaweed specimens were collected only from those that were attached to the substrate (no floating specimens were collected) during low tide and then placed in ziplock plastic bags. Macroalgae species were identified to determine macroalgae species based on taxonomic keys using FAO species identification Guide for Fishery From the results of the study, Porok Beach was home to 17 species of macroalgae, eight of which were classified as Chlorophyta, 3 species are classified as Phaeophyta, and 6 species are classified as Rhodophyta.

Introduction

Macroalgae popularly known as seaweed, is an important biological resource of the ocean. Macroalgae have a major influence on the nature and distribution patterns of marine life. Macroalgae can cover benthos in large

How to cite:
Faradilla, F., Putri, A. D., Agustin, G. A., Nurkaromah, L., Febrianti, M. W., Budhiman, M. A., Salamah, U., Chasani, A. R., & Nikmah, F. (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

intertidal areas, and also undergo seasonal cycles that change the physical structure of the habitat (Wilson et al., 2014). They are found on coastal waters areas up to 180-meter depth, attached to the substrate, such as rocks, dead corals, shells, pebbles, and plants (Sahayaraj et al., 2014). Macroalgae are classified according to their pigmentation as Green Algae (Chlorophyte), Brown Algae (Phaeophyte), and Red Algae (Rhodophyte). Chlorophyll, carotenoid, and phycobilin are the three types of macroalgae pigments. Chlorophyll and carotenoid are water-insoluble pigments, whereas phycobilin is a protein group that dissolves in water (Haryatfrehni et al., 2014). Porok beach is one of the beaches in Gunung Kidul Regency, Yogyakarta, Indonesia, whose beaches are dominated by corals. The coral rock in Porok beach was mostly covered by algae. There are many human activities on Porok Beach, both tourism activities and activities of residents. The development of coastal areas in Gunung Kidul, Indonesia as a tourism destination is feared to have a negative impact on macroalgae biodiversity. Comprehensive efforts are required to protect the coast of Porok Beach as a source of macroalgae germplasm that will ensure the conservation and restoration of coastal natural assets in Gunungkidul, Indonesia. As a result, macroalgae diversity research is needed to acquire preliminary data for the research of Porok Beach as a conservation area. Based on the study of Sartika et al. (2021) in 2019, 29 species of macroalgae were found, making Porok Beach one of the beaches in Gunungkidul with the highest diversity of macroalgae. But the diversity of macroalgae may decrease due to the rampant human activities in the last 2 years. So, this study is important to explore further the diversity of macroalgae, especially chlorophyte, rhodophyte, phaeophyte, and the specific characters of each species. This research aims to monitor the presence of macroalgae on Porok Beach, Yogyakarta, Indonesia.

Materials and methods

Research location and design

This study was conducted on October 17th, 2020 during low tide, when macroalgae was exposed on Porok Beach, Gunungkidul, Yogyakarta, Indonesia. Porok Beach GPS coordinate point as follows: -8° 08'02.8 "S and 110 ° 33'28.8" E (Figure 1). Purposive random sampling was used to collect samples of macroalgae managed to find with in intertidal zone of Porok Beach. For identification, each sample was completely removed from the substrate. Whereas the tools used in this study included zip-lock plastic for storage, a digital camera for documentation, the FAO Species Identification Handbook for Fishery Purposes for Identification, and a thermometer for measuring water temperature, universal indicator for measuring the water pH, hygrometer for measuring the air humidity. Sampling on this research used transect quadrat methods with 1x1 meters plot. (Yusron, 2010). The transect line is pulled perpendicular to the shoreline in the direction of 110 meters of sea at low tide or near low tide, with 3 times observation point in each station. Transect have been observed, for example calculating the sample from each species, and observation about the substrate (Tarigan, 2015). This study has been held in the morning on 17 October 2020.

Figure 1. The study site, Intertidal Zone of Porok Beach

Data collection and analysis

The macroalgae were cleaned under running water and documented using millimeter blocks for identification. Identification of macroalgae species using FAO species identification Guide for Fishery Purpose 1998 for identifying various species of macroalgae based on taxonomic key. Environmental parameters were measured using a thermometer for measuring the water temperature and universal indicator for measuring the water pH.

Result and discussion

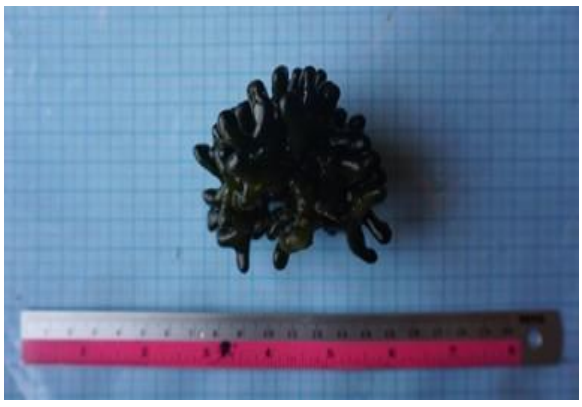
Diversity of macroalgae of Porok Beach

Based on the results of macroalgae species identification, 17 species macroalgae were identified consisting of 8 Chlorophyta species, 3 Phaeophyta species, and 6 Rhodophyta species as shown in Table 1.

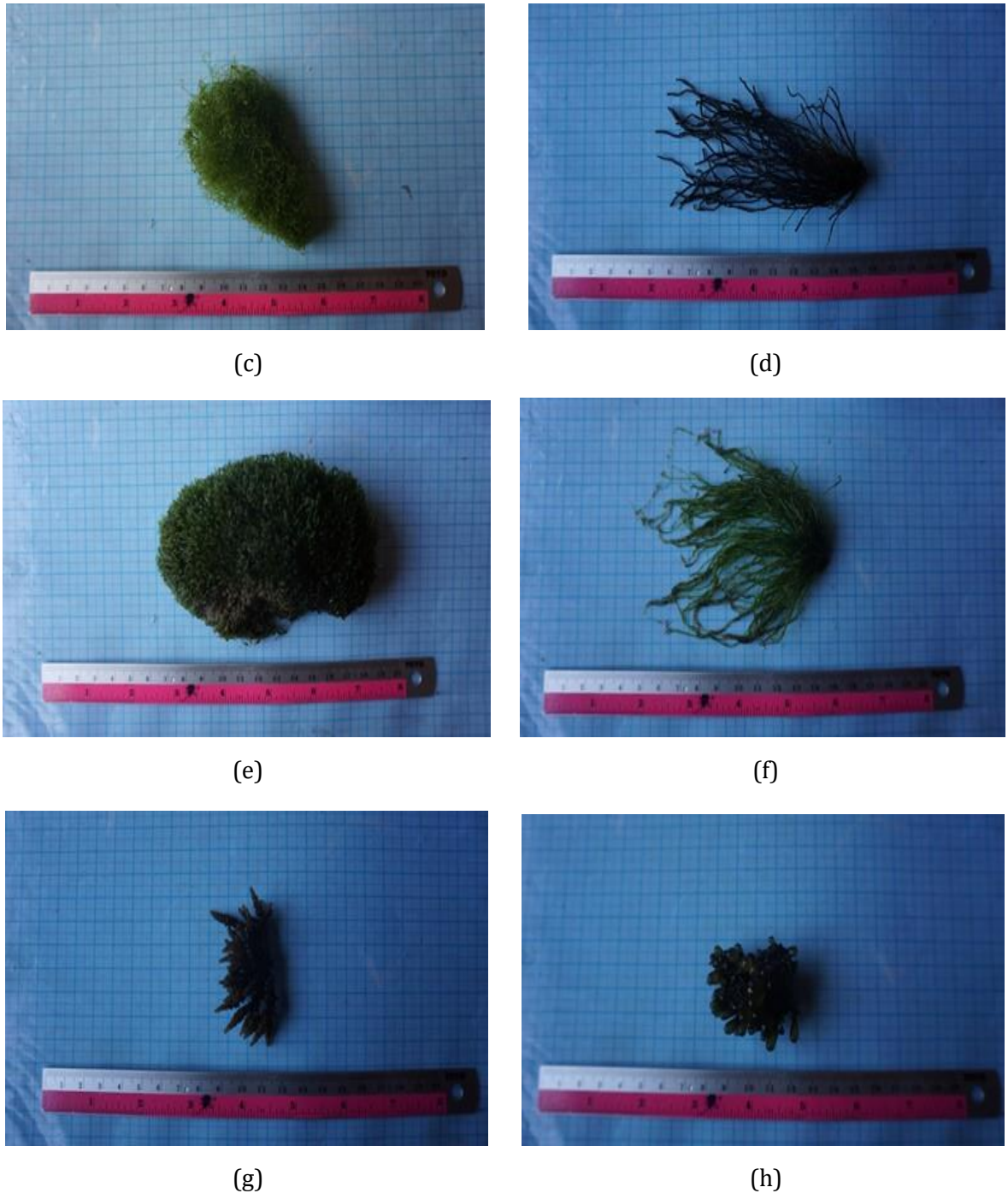
Table 1. Diversity of macroalgae in intertidal zone of Porok Beach

No.	Division	Macroalga species
1	Chlorophyta	*Ulva lactuca*
		Codium intricatum
		Chaetomorpha crassa
		Chaetomorpha antennina
		Cladophora catenata
		Enteromorpha flexuosa
		Caulerpa lentillifera
		Halicystis sp.
2	Phaeophyta	*Sargassum cristaefolium*
		Sargassum turbinarioides
		Padina minor
3	Rhodophyta	*Gigartina papillata*
		Gracilaria canaliculata
		Gracilaria edulis
		Gracilaria lemaneiformis
		Gelidium pusillum
		Palmaria palmata

(a)



(b)



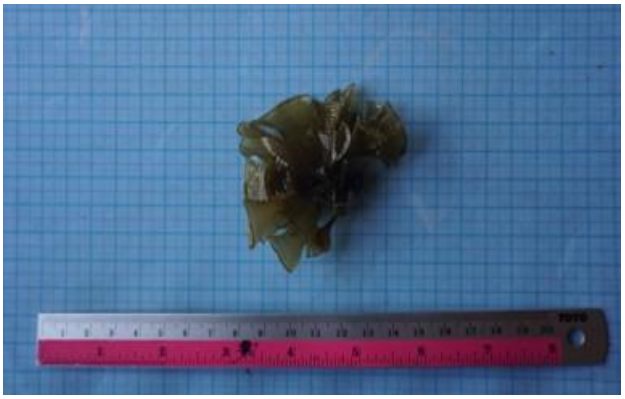
(c) (d)

(e) (f)

(g) (h)

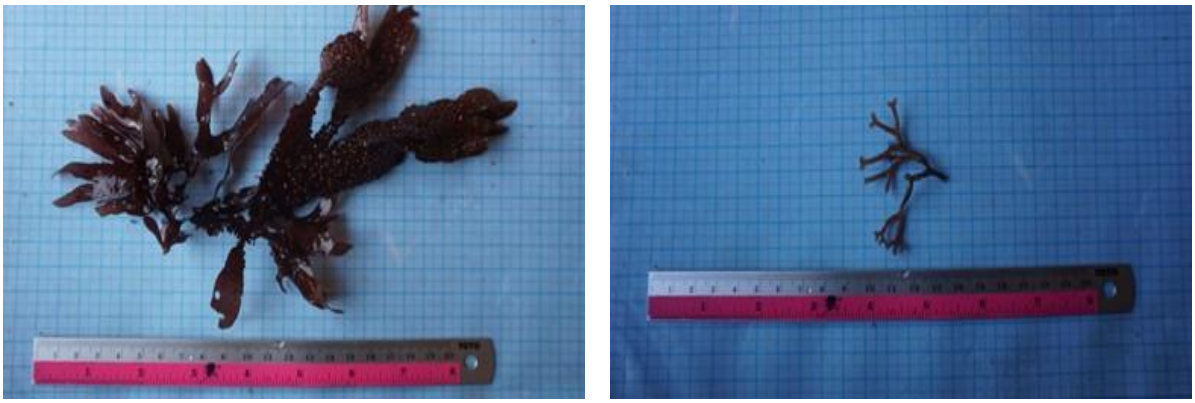
Figure 2. ***Chlorophyta*** *(a. Ulva lactuca, b. Codium intricatum, c. Chaetomorpha crassa, d. Chaetomorpha antennina, e. Cladophora catenata, f. Enteromorpha flexuosa, g. Caulerpa lentillifera, h. Halicystis sp.)*

(a) (b)

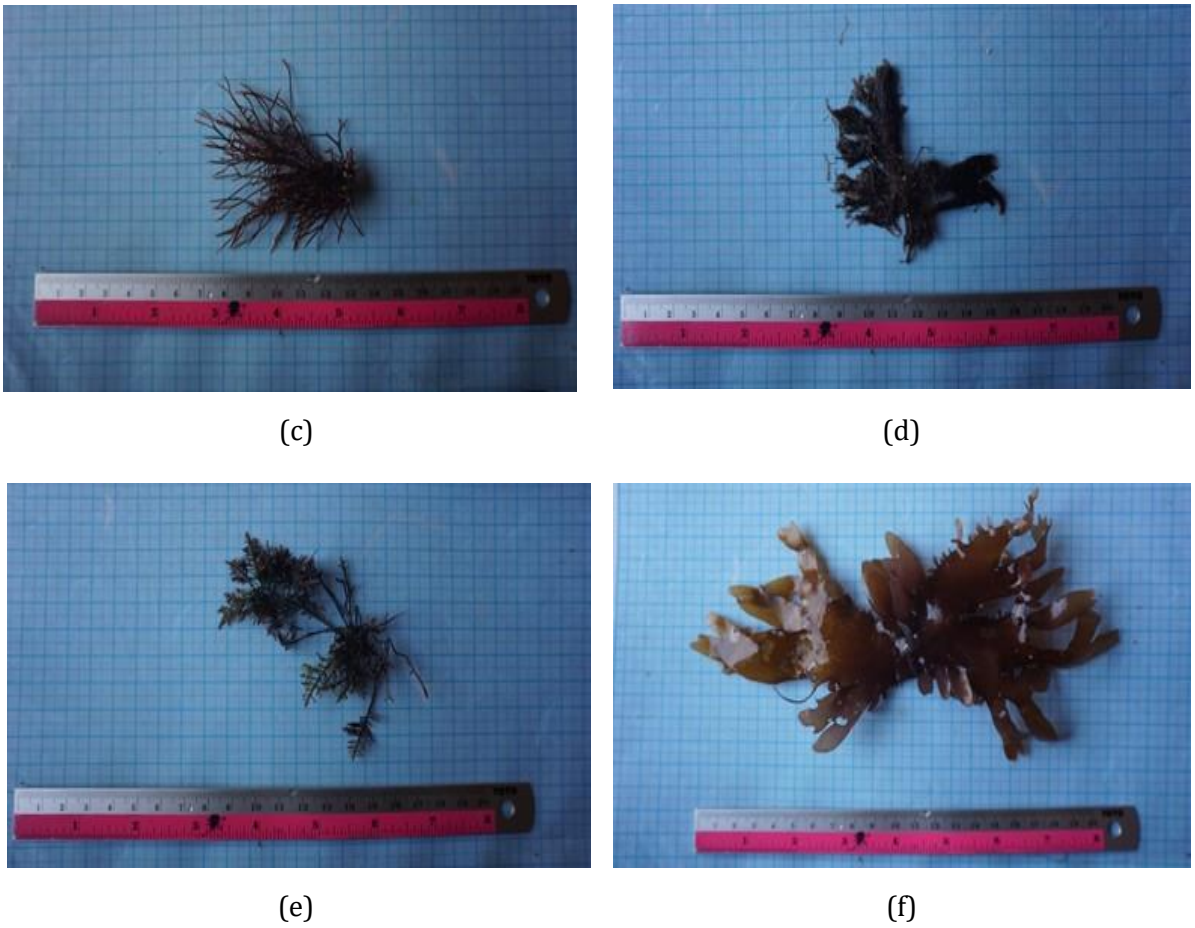


(c)

Figure 3. ***Phaeophyta*** *(a. Sargassum cristaefolium, b. Sargassum turbinarioides, c. Padina minor)*



(a) (b)



(c) (d)

(e) (f)

Figure 4. ***Rhodophyta*** *(a. Gigartina papillata, b. Gracilaria canaliculata, c. Gracilaria edulis, d. Gracilaria lemaneiformis, e. Gelidium pusillum, f. Palmaria palmata)*

Chlorophyta

The diversity of Chlorophyta in Porok Beach consists of 8 species, they are *Ulva lactuca, Codium intricatum, Chaetomorpha crassa, Chaetomorpha antennina, Cladophora catenata, Enteromorpha flexuosa, Caulerpa lentillifera*, and *Halicystis* sp. The diversity of Phaeophyta that consists of 3 species are *Sargassum cristaefolium, Sargassum turbinarioides*, and *Padina minor*. The diversity of Rhodophyta that consists of 6 species are *Gigartina papillata, Gracilaria canaliculata, Gracilaria edulis, Gracilaria lemaneiformis, Gellidium pusillum*, and *Palmaria palmata*.

Chlorophyta has a higher diversity compared to other divisions as Chlorophyta has a good adaptability to the local environment. One example of the adaptability of macroalgae from the Chlorophyta division is easy to attach to various types of substrates so that chlorophyta can withstand various types of environmental conditions, such as strong water currents (Srimariana et al, 2020).

In general, the habitat has a close relationship with algae, where the habitat is very influential on the phycocolloid content of a macroalgae. If the growth of macroalgae in a water is quite good with a high phycocolloid content, it can be concluded that the characteristics of the waters are good for the growth and development of macroalgae. Seawater quality, non-algae marine biota, growth position and other habitat aspects are factors that make up a habitat characteristic. Habitat also greatly affects the diversity of macroalgae, because each type of macroalgae is only able to grow on its own substrate (Litaay, 2014).

Ulva lactuca is a macroalgae that belongs to the Chlorophyta division and was discovered by Linnaeus in the Baltic Sea in the late 1700s. The *Ulva lactuca* is characteristized by its green thallus, expanded into thin, glossy broad sheets with a lobed or undulate to ruffled and more or less spinulosus, attached by circular disc, with or without a small stipe (Figure 2a). The thallus was deeply divided with lanceolate lobes, broadly expanded or with less divided lanceolate to irregular lobes (Kazi et al, 2016). This species is also known as sea lettuce because the morphology This species also known as sea lettuce because the morphology of thallus like lettuce leaf with light green, slimy, and soft to touch. *Ulva lactuca* mostly found in the nearest area from land. The natural habitat of *Ulva lactuca* is attaches to rocks and also can associated with other algae like *Cladophora* sp. (Baweja et al, 2016).

Codium intricatum is characterized by a spongy, creeping, erect, dark to dull green siphonous thallus (Uragami et al., 2014). The thallus is often entwined forming hemispherical masses of densely fusing branches. The branching of the thallus is irregular, sub dichotomous, cervicorn (dichotomous with one arm of the dichotomy suppressed) (Figure 2b). *Codium intricatum* has branches firm, cylindrical, slightly compressed. The branches are entwined together into a clump. Utricles was club-shaped, cylindrical. Apices rounded. *Codium intricatum* grows on lower intertidal and upper subtidal hard substrate on semi-protected and open shores (Okamura, 1913). *Codium intricatum* is one of edible green algae that has high potential antioxsidant and antibactery activities. This species live attaches on rock or associated with *Chaetomorpha crassa* (Arguelles, 2020).

Chaetomorpha crassa is green in color and the thallus is shaped like long strands of hair with a fairly strong segment when and observation under a microscope with a fairly strong segment (Figure 2c). The thallus grows as an entangled form with other seaweeds as epiphyte (Ghazali et al., 2018). Thallus filamentous unbranched with bright green color (Leliaert and Coppejans, 2004). This species is mostly found in shallow water and usually denses to be mats form (Bolton et al, 2007; Gao et al, 2018). According to Gao, Endo, and Agatsuma (2018), the value of photosynthetic process and the growth of *Chaetomorpha crassa* higher in the dry season or summer.
Chaetomorpha antennina is 2-3 inches tall, has a rigid structure, and the filaments are bright green (Figure 2d). This alga lives on rocky substrates in the intertidal zone. *Chaetomorpha antennina* can grow at temperatures of 27-30°C with a pH of 6-9 (Leliaert et al., 2011).

Cladophora catenata is a dark-green to blakcfhish macroalgae. make a compact pads. This macroalgae also erect to prostrated. *Cladophora catenata* has 2.5 cm in height and 3-14 cm in diameter, fixed to the substrate by rhizoids originating from the basal cell, irregular branched and septated, and by rhizoids forming from the tip of apical cells, with hapteroid apices (Figure 2e). Thallus growth by division of conspicuous cylindrical apical cells, followed by cell enlargement. Apical cells are long, with rounded tip, main axis curved. Unilateral branching, with branches inserted laterally in the apical pole of the cell, septated by an oblique wall at the base. Cells with tetrahedral crystalline protein inclusions. Fertile cells with lateral papilla, from which the zoids are released. Habitat of *C. cantenata* observed in the intertidal zone in dense populations forming compact carpets (Alves et al., 2012).

In certain species of the Flexuosa Group of Enteromorpha the young filament of 3-5 cells has not rarely longitudinal cell-divisions and becomes hook-shaped. Plants typically slender, of soft fragile consistency, not proliferous, mostly without. secondary ramification, sometimes simple. Cells arranged in longitudinal series and, at least. in young parts, in transverse rows. In greater or smaller regions of the main axis the regularity can be disturbed by the fact that new cells are separated by oblique walls (Guiry and Guiry, 2021).

The larger tubular portions may or may not branched, if they are branched, the branches are narrow filamentous branchlets. *Enteromorpha flexuosa* has a rhizoid attached to rocky substrates. Rhizoid grows from basal cells of the tube. Habitat of *Enteromorpha flexuosa* on high intertidal to mid-intertidal. Will

often be exposed at low tide and often found near freshwater intrusion (Beach et al, 1995).

Caulerpa lentillifera has a structure that resembles "grapes" and it is an edible species. It has a branching horizontal stolon that gives rise to numerous assimilators and rhizoids at its ventral side for attachment (Figure 2g). This species is found in tropical areas, mostly inhabiting saddy or muddy sea bottoms in shallow protected areas (Paul et al., 2013). *Caulerpa lentillifera* is characterized as having ramuli with globose tips, which are constricted at the base and arranged imbricated in rows of four (Estrada et al., 2020).

The characteristic of *Halicystis* sp. is a plant-like gametophyte consisting of ovoid vesicles with a diameter of about 3 cm. The characteristics of *Halicystis* sp. is a plant-like gametophyte consisting of an ovale vesicles with a diameter of about 3 cm arising from a slender branched tuberous rhizoid embedded calcareous and growing at low tide (Figure 2h). The growth of *Halicystis* sp. vesicle is very slow, new vesicles arising later from the parennating rhizoid and regeneration may go on for several days (Chapman and Chapman, 1973).

Rhodophyta

Macroalgae from the Rhodophyta division found in Porok Beach consist of six species. The order that has the most members is Gracilariales with three species, there are *Gracilaria edulis, Gracilaria canaliculata*, and *Gracilaria lemaneiformis*. *Gracilaria edulis* are characterized by the erect, cartilaginous, greenish brown to dark brown, or purple in colour, attached by a small discoid holdfast (Figure 4c). In terms of male and female gametangia, plants can be monoecious or dioecious. Following fertilization, the carpogonium merges with one of the nutritive cells acting as an auxiliary cell. Cystocarp is a dome-shaped protuberant structure that develops on female gametophytes upon fertilization and continues to give the thallus a rough texture. This species live in salinities ranging from 5 to 34ppt, making this a common seaweed of brackish water, mangrove swamps, and the sea. *Gracilaria* edulis is primarily cultivated for agar production, responsible for more than half of the world's agar supply (Baweja et al, 2016).

Gracilaria canaliculata forms large tufts on rocks and dead reef debris over time. This alga is cylindrical and sometimes constrained with club-shaped or oblong articulations, succulent to mildly cartilaginous in texture, infrequently or dichotomously to trichotomously decided to branch, with blunt apices at the ends of its ultimate branches (Figure 4b). The fronds can expand to be up to 9.4 cm long and 3-5 mm wide, are prostrate or decumbent in shape, form clumps, dense cushions on the substratum, and are also very prone to cracking when young (Selvavinayagam and Dharmar, 2018).

The diagnostic characters of *Gracilaria lemaneiformis* has a solitary thallus with a height of 40 cm and a width of 0,5-2,0 mm diameter. Tetrasporangia are moon-shaped to ellipsoidal with anti-clinically elongated cell cortex. The branching is irregularly and sparingly, mostly with abundant and short lateral branches (Figure 4d).

The 3 other species of macroalgae from the Rhodophyta division are *Gelidium pusillum, Gigartina papillata*, and *Palmaria palmata.* The characters of *Gelidium pusillum* are cartilaginous, blackish-red color when slightly dry, forming turf, erect thalli, and branches develop irregularly branching of up to three (Kim and Boo, 2012; Zin and Ei, 2020). This species is found on a rocky substrate in the intertidal zone of Porok Beach. *Gigartina papillata* commonly known as *Mastocarpus papillatus* grows has gametophytic thallus upright, crisp, up to 9 cm tall. Stipe terete, unbranched. Thallus is reddish black all over. The apophysis margin is slightly swollen, giving the thallus a canaliculate appearance; the blade margin is slightly wavy and rarely proliferous. Branching is highly variable, commonly subdichotomous, to three orders, and sometimes unbranched. Apices that are rounded, crenate, or irregular Cortex of 6–8 cell layers in section, occupying roughly half the width of the section. Male thalli are smooth and free of papillae. Female thalli have simple papillae that are initially nipple-like but eventually become subspherical; papillae are restricted to the blade surface (not along margins); larger papillae occur in discrete patches on older (lower) parts of the thallus Distinguished from those other Mastocar-

pus organisms by variations in molecular sequence (Lindstrom et al, 2011). The characters of *Palmaria palmata* are thallus of dulse that is upright, elongated, wedge-shaped, and often ending in forks (Figure 4f). The colors of the wet fronds are purple, crimson, or brownish red, which turns to a pinky–red after drying and bleaching in the sun (Mouritsen et al., 2013). *Palmaria palmata* is usually used by other plants as a basiphyte, also this species contain of valuable biological substances such as vitamins, amino acids macro-and microelements that used in medical industry (Dobychina et al., 2020). This species is also found on a rocky substrate in the intertidal zone of Porok Beach rows of four (Estrada et al, 2020).

Phaeophyta

Furthermore, the brown algae found in Porok beach, Gunung Kidul, come from two genera, Sargassum and Padina. Then there are three species of brown algae, *Sargassum cristaefolium, Sargassum turbinarioides,* and *Padina minor*. *Sargassum* (genus) is a tropical and subtropical brown seaweed, commonly found in subtidal and intertidal zone (Dewinta et al., 2020). *Sargassum cristaefolium* is a brown-algae that is widely used by coastal communities for food. Its habitat is in the middle tidal zone to the subtidal zone, it is found attached to rocks and forms a colony (Figure 3b). Morphological characteristics are having a thallus that is round on the main stem but slightly flattened at the branch, the blades are oval round, the edges are serrated and thick, the vesicles are ovoid or elliptical which is attached to the stem (Pansing et al., 2017). Thalli can grow to be up to 90 cm tall, with a discoid holdfast. The primary and secondary branches are terete and smooth. Cryptostomata can be found on the main branches. The leaves of the main branches are coriaceous, with broad oblanceolate-lanceolate to ovate-obovate leaves up to 18 mm long and 6 mm wide. The midrib is distinct and runs halfway down the length of the leaf; the margin is duplicated. Obtuse apex. Cryptostomata are dispersed at random. The leaves on the primary branches are coriaceous, ovate to obovate, up to 12 mm long and up to 5 mm broad. The midrib is distinct and runs halfway down the length of the leaf; the margin is duplicated. Obtuse apex. Cryptostomata were scattered. Vesicles are spherical, with a diameter of up to 1 mm, an obtuse apex, and a short pedicel (Shams, Afsharzadeh, and Balali, 2015).

The second species found is *Sargassum turbinarioides*, it lives attached to rocks and other rocky substrates in the tidal zone. The thallus is brown, flattened, and at the ends there are short, sharp, and irregular ramuli (Figure 2b). The blades are thick, rather short, and round with a diameter of 1.0 - 1.3 cm and a length of 1.2 - 1.7 cm. This alga has irregular branching with a total height of between 25-30 cm (Kepel and Mantiri, 2019). Air bladders (vesicles) normally present, subspherical to ovoid, petiolate, mutic or apiculate, replacing ramuli or axilliary to the laterals (Guiry and Guiry, 2021).

The last phaeophyta species discovered was *Padina minor*. Species of the marine brown algal genus Padina are widely distributed throughout the tropics and are very easy to recognize in the field (Geraldino et al, 2005). This alga has a yellowish-brown color that sometimes turns white due to calcification, has a thallus that looks like a fan, has thin segments, and radial stripes (Figure 3c). It can reach 7 cm in height, it also has lobeline from the blade to the blade surface of 7-12 pieces. The habitat of this algae is a sandy substrate (Tampubolon et al., 2013). The erect thalli are semicircular with entire margin, small, up to 8 cm wide and 6 cm tall, and attached by a discoidal holdfast. The stipe is short and cylindrical, up to 6 mm long and 2 mm wide (Win et al., 2013). The diversity and distribution of macroalgae in Porok Beach, Gunungkidul is influenced by several environmental factors such as temperature depth zones, salinity, substrate, nutrients, season, and climate. Among these factors, the most common factors affecting the diversity and distribution are different depth zones, season, and type of substrate, because each type of macroalgae usually has its own season and different substrates (Hadi et al, 2016).

The most widely found macroalgae in Porok beach are Chlorophyta, Rhodophyta and the last is Phaeophyta. The difference in diversity is due to the fact that Chlorophyta habitats

are in the intertidal zone, where the sampling was conducted, that's the reason it is the most widely found. In addition, differences in diversity and distribution can also be caused by seasons and types of substrates. Each type of macroalgae in Porok Beach has a certain life season, while the majority of macroalgae are found on rocky and sandy substrates.

The temperature of the water, the temperature of the air, and the ph level are all measured. The water temperature is 26°C, the average air temperature is 24°C, and the water's pH is 7. The water pH is neutral that indicates the water is not polluted because Porok Beach is not used as a tourism destination. This pH indicates a good pH level for macroalgae growth. A pH decrease of sea water in saturation state has negative effects on the calcification of the primary producers, that has an important role in the carbon cycle, habitat structure and rocky beach habitat stability (Setyorini et al, 2021). For this reason, Porok Beach is still natural. Chlorophyta has an optimum temperature of 15-30°C. Therefore, chlorophyta has the most abundance macroalgae in the area.

Substrate type affects the presence of certain species in the area. The substrate in Porok Beach is the rocky and sandy substrate. Rocky substrate is suitable for growth Phaeophyta, sandy substrate is suitable for growth Rhodophyta, while the rocky and sandy substrate is suitable for growth Chlorophyta. The role of substrate depth in sediment stability includes protecting macroalgae from seawater currents and nutrient supply.

Conclusion

According to this study, there are 17 species of macroalgae than can be found in Porok Beach, Gunungkidul, Yogyakarta, Indonesia. Those macroalgae are classified as Chlorophyta (8 species), Phaeophyta (3 species), and Rhodophyta (6 species). Thus, this identification will be useful for the further research.

Acknowledgement

The authors are thankful to Kelompok Studi Kelautan and Plant Systematic Laboratory, Faculty of Biology, Universitas Gadjah Mada for facilitating this research.

Author's declaration and contribution

The authors declare that there is no conflict of interest. FF and FN were designing this study. ADP, MWF, LN, and US were collecting sample and analyzing data. MAB, ARC, and GAA conduct manuscript proofreading before submission. All authors write, read, and approve the final version of the manuscript.

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