Distribution pattern of macro algae at Jungwok Beach, Gunungkidul District, South Java, Indonesia

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Abstract. Jungwok Beach is a rocky beach with white sands, supporting the growth of various genera of macro algae. The study aims to identify the distribution patterns of macro algae at Jungwok Beach, South Java. The method used in the present study was a survey method with a descriptive approach. The data collection of the distribution of macro algae was conducted by sampling exploration technique that starts from the east to the west area of Jungwok Beach, 10 m above the coastline. The analysis of the distribution patterns of macro algae was conducted spatially using the GIS software, producing a map. The study showed that macro algae found in Jungwok Beach were *Ulva* sp., *Gracilaria* sp., *Boergesenia* sp., *Euchema* sp., and *Enteromorpha* sp. The macro algae were more dense in the east part of Jungwok Beach, at 4-7.5 m above the coastline to the sea. This result is supported by topography forms and presence of dead coral structures in the eastern area of Jungwok Beach that provides growth medium for macro algae.

Key Words: abundance, GIS, intertidal zone, rocky beach, spatial distribution macro algae.

Introduction. South Java coast has several zones with unique features, one of them are Gunung Sewu Karst area. As explained by Haryono et al (2008), the Gunung Sewu area is located on the South Java coast and is adjacent to the Indian Ocean. Geologically, the Gunung Sewu area also has coral reef limestone which are dominated by rudstones, packstones and framestones (Haryono et al 2008). As a part of the South Java Coast, the Jungwok coastal area is known to have rocky steep cliff coast and sandy beaches, being a tourism destination. Part of it is a habitat of various marine organisms, such as macro algae in its intertidal zone. The existence of various genera of macro algae in Jungwok Beach is also due to the ability of macro algae to grow in shallow, rocky and tidal zone. According to Kadi (2017), macro algae can grow as phytobenthic in coastal water, attached on dead coral reefs. Community structure of macro algae was also influenced by the geomorphological variables such as active tidal processes, hard rocky substrate, coastal orientation and lithology (Ramos et al 2016).

Fundamentally, macro algae has an important role as one of the primary producers in the coastal ecosystem. According to Takolander et al (2017), estuarine macro algae has an important role as primary producer in the aquatic ecosystems and can provide a complex habitat. The epifauna and infauna macrobenthic organisms found in association with macro algae presence at Jungwok Beach are: *Eurythoe complanata*, *Pherecardia striata*, *Ophiocomina nigra* and *Turbo sparverius*. A study of Lutz et al (2019) also showed that the abundance of epifauna in *Codium* holdfast is dominated by gastropods (*Alaba opiniosa*) and gammarid amphipods. These species contributed to differentiate the infauna composition mainly between native and non-indigenous infauna in its holdfast (Lutz et al 2019). Their abundance was also influenced by the number of branch and epiphyte (Lutz et al 2019). Gestoso et al (2010) underlined that there is a

difference in the composition of epifauna associated with *Bifurcaria bifurcata* and *Sargassum muticum*. Furthermore, *S. muticum* supplies a new and additional habitat to the native epifauna, contributing to the increase of the spatial and temporal variability of the epifauna assemblages (Gestoso et al 2010).

As explained by Salosso & Jasmanindar (2018), the abundance and distribution pattern of macro algae were influenced by: the season, the seawater quality, the ability of macro algae to adapt to the environment and the spore distribution in the seawater. Temperature and salinity are important sea water quality parameters that influence the life of macro algae. Temperature is the main factor that influences the dynamics of macro algae, mainly in terms of spatial context (Fulton et al 2014). Furthermore, an increase of temperature is expected to encourage coastal eutrophication and the growth of green algae, while a decline of salinity can change the distribution of marine species in Baltic sea (Takolander et al 2017).

Thus, it can be inferred that a study on the distribution of macro algae in Jungwok Beach is needed, providing information and data about various genera and distributions of macro algae. The current research aimed to explore the distribution of macro algae at Jungwok Beach, Gunungkidul district, South Java, in terms of macro algae genera and sea water quality. The results can be used as preliminary information on the interaction of the environmental factors with the presence and distribution patterns of various genera of macro algae, in support of further management and development of macro algae at Jungwok Beach.

Material and Method

Description of the study sites. This study was conducted in Jungwok Beach, Jepitu village, Girisubo sub-district, Gunungkidul district, Special Region of Yogyakarta, South Java, Indonesia in May 2019, where east monsoon occurs. Figure 1 shows the map of the research location. The topography of the open sea near the Jungwok Beach is characterized by curved and steep coastlines. Nurhayati (2012) noted that most of the beaches in the south coast of Gunungkidul were categorized as open sea next to the Indian Ocean, so the energy of the wave's motion towards the beach will greatly influence the process of beach morphogenesis.

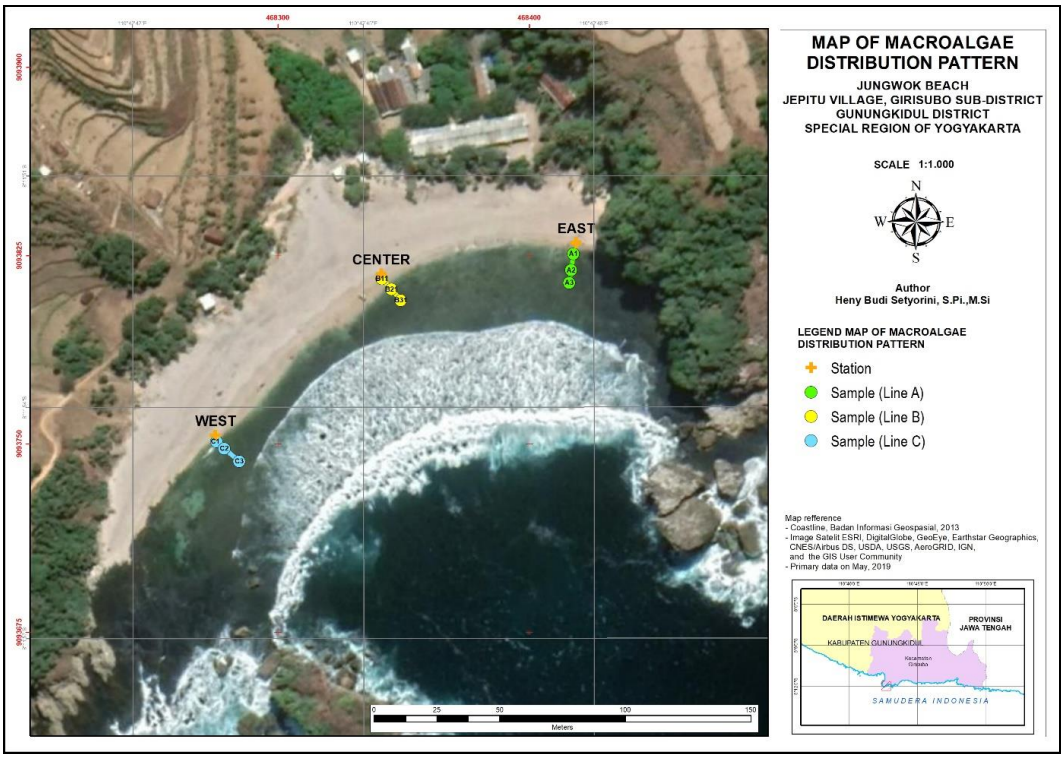

Figure 1. Research location of macro algae at Jungwok Beach, South Java.

Material of the study. The material of this study is constituted of various genera of macro algae and sea water from Jungwok Beach, for its quality variables determination: temperature, depth, substrate, pH, salinity and dissolved oxygen. This considers the connection between the substrate type, depth and water quality of Jungwok Beach, and the macro algae population (existence and abundance).

Method of the study. The method used in this study is a survey with a descriptive approach. Surveys consist of collecting characteristic information from a sampling population in order to elaborate descriptive statistics (Yusuf 2014). The determination of the sampling location uses a purposive sampling.

The data collection of macro algae distribution. The data collection of macro algae distribution was conducted in low tide period by exploring the Jungwok Beach from east to west, each 0-10 m seaward to the coastline with three units of GPS Garmin simultaneously. The characteristics and sampling coordinates of macro algae were noted during the exploration. The genera of macro algae were documented using a digital camera.

The data collection of sea water quality. The sampling was conducted using a line transect method. The east (A), center (B) and west (C) parts of Jungwok Beach were sub-divided into three groups of sites (1, 2 and 3), at 0, 5 and 10 m, respectively, as shown in Figure 2, at a distance of 25 m from the coastline, towards the sea. The position of the sampling station was done in consideration of the topography at Jungwok Beach and the potential penetration of the rip current, to ensure researchers safety during data collection.

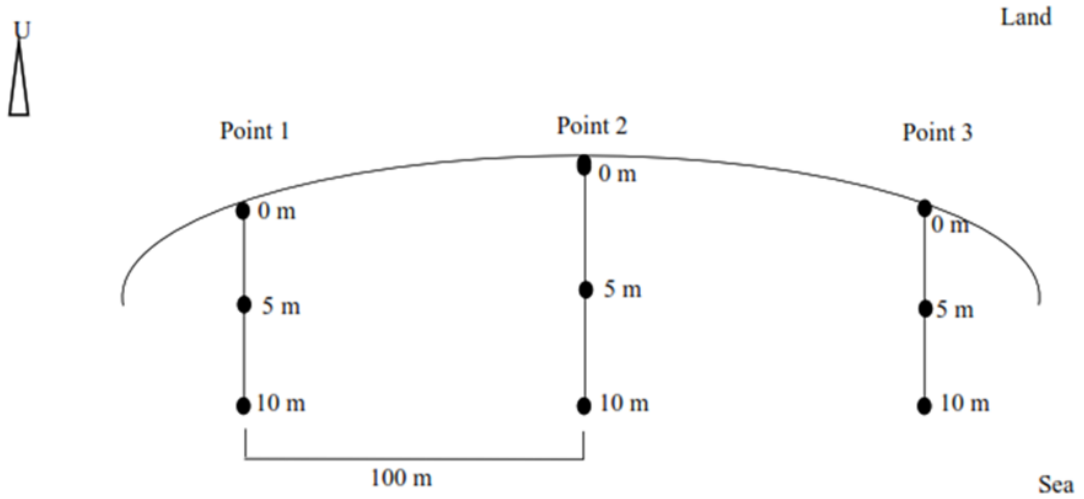

Figure 2. Sampling points with line transect method at Jungwok Beach, South Java.

Variables of seawater quality (temperature, DO, pH and salinity) were measured in situ at each sampling point, using a water quality checker AZ 8693. The measurement of water depth and observation of substrate types were conducted in situ along with the water quality variables measurement, at each of the 3 stations of the eastern, central and western areas of the Jungwok Beach.

Data analysis. The genera of macro algae and sampling coordinate were spatially plotted onto the Landsat 8 image using the GIS software to obtain the macro algae distribution pattern (Hartoko et al 2015). Data from the observation of the temperature, DO, pH, salinity, depth of water and types of substrate were analyzed descriptively by comparing with references.

Results

Distribution of macro algae. The result of number of macro algae genera at Jungwok Beach is shown in Figure 3. Based on the figure, it is known that several genera of macro algae found in Jungwok Beach are *Ulva* sp., *Gracilaria* sp., *Boergesenia* sp., *Euchema* sp., and *Enteromorpha* sp. The density of *Enteromorpha* sp. was found to be the highest, followed by *Gracilaria* sp., *Ulva* sp., *Euchema* sp. and *Boergesenia* sp. Based on the dominant pigment content of macro algae, *Ulva* sp., *Boergesenia* sp. and *Enteromorpha* sp. are included in the *Chlorophyta* phylum, while *Gracilaria* sp., and *Euchema* sp. are included in *Rhodophyta* (Haryatfrehni et al 2015).

The result of macro algae distribution pattern is shown in Figure 4. Macro algae spread thoroughly in the intertidal zone of Jungwok Beach. Their maximum density was found over the eastern site, at 4-7.5 m above the coastline, as shown in Figures 3 to 8, their distribution was dominated by *Enteromorpha* sp., followed by *Gracilaria* sp., *Ulva* sp., *Euchema* sp. and *Boergesenia* sp. The central site of Jungwok Beach was dominated by *Gracilaria* sp., *Ulva* sp., *Boergesenia* sp., and *Enteromorpha* sp. The western site of Jungwok Beach was dominated by *Ulva* sp., *Gracilaria* sp., *Enteromorpha* sp., *Euchema* sp. and *Boergesenia* sp. Figures 10 to 14 show specimens of the macro algae genera found at the sampling stations.

The abundance and distribution of macro algae in Jungwok Beach is strongly influenced by the season, the hydro-oceanographic factors and the sea water quality. This is supported by the results of a survey in early July 2019, showing that the abundance of macro algae at Jungwok Beach was increased from July to August. On the contrary, the study of Putri et al (2017) showed that the percent cover of *Ulva* sp. found in Krakal Beach in the rainy season only reached 0.65%. The result is also strongly related to the substrate type, on what *Ulva* sp. was found in each transect (Putri et al 2017). Williams et al (2013) further explain how the abundance and diversity (including cover, biomass, species richness, diversity, homogeneity and community composition) of macro algae are influenced by the tidal height, physical pressure and existence of herbivores.

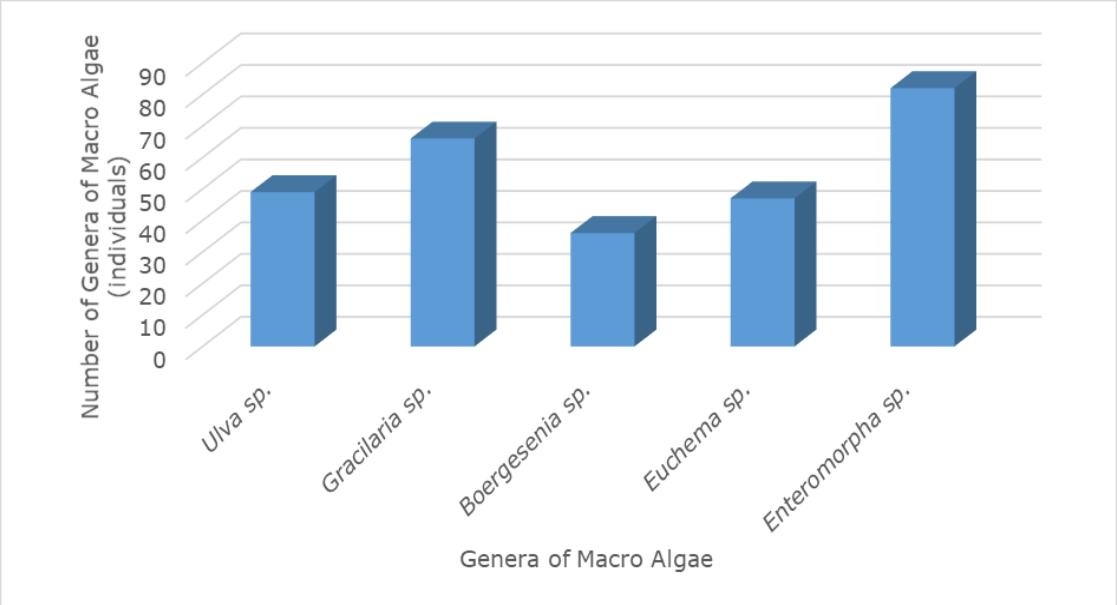

Figure 3. Number of macro algae at Jungwok Beach, South Java.

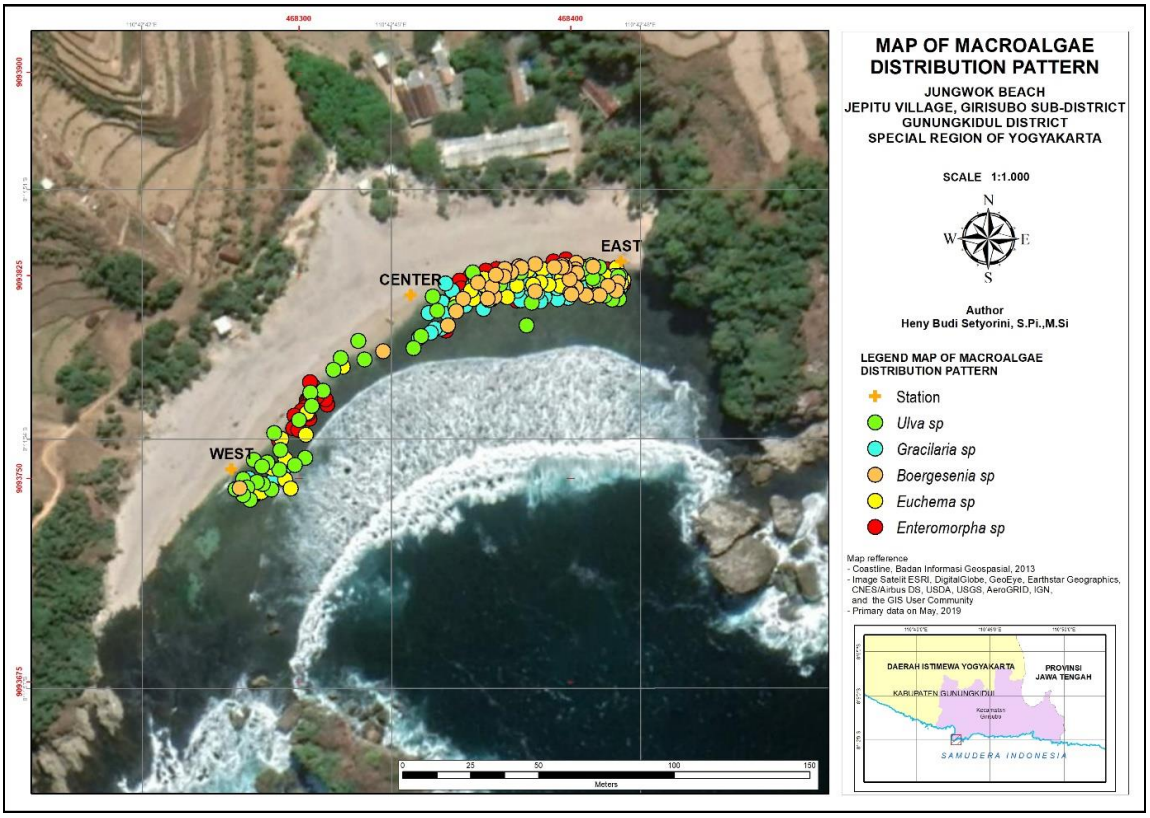

Figure 4. Multi genera of macro algae distribution pattern at Jungwok Beach, South Java.

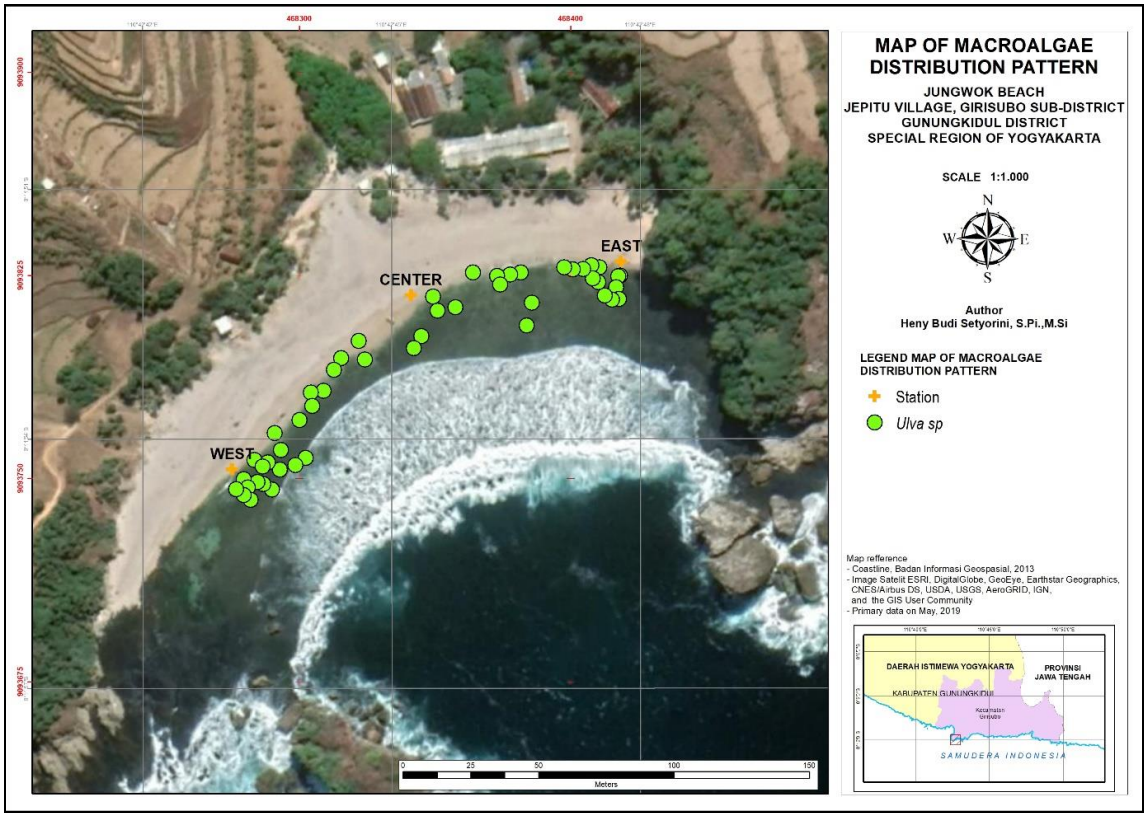

Figure 5. Distribution pattern of *Ulva* sp. at Jungwok Beach, South Java.

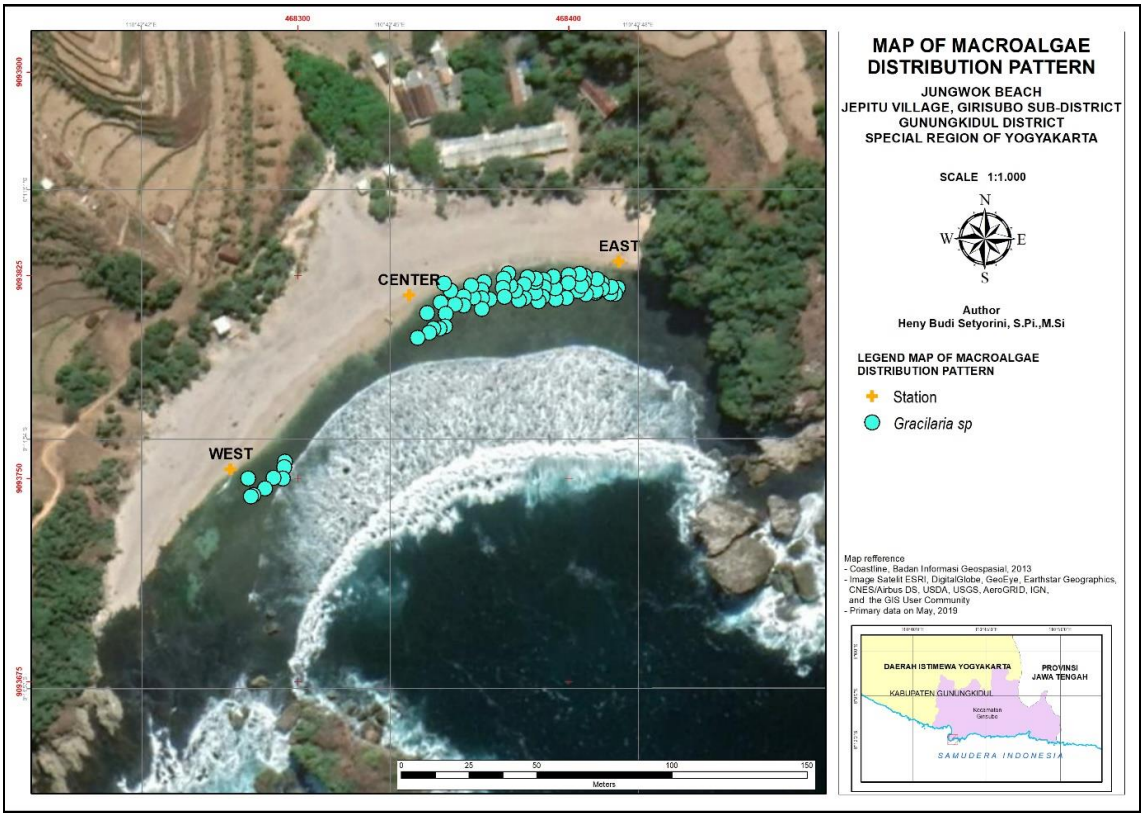

Figure 6. Distribution pattern of *Gracilaria* sp. at Jungwok Beach, South Java.

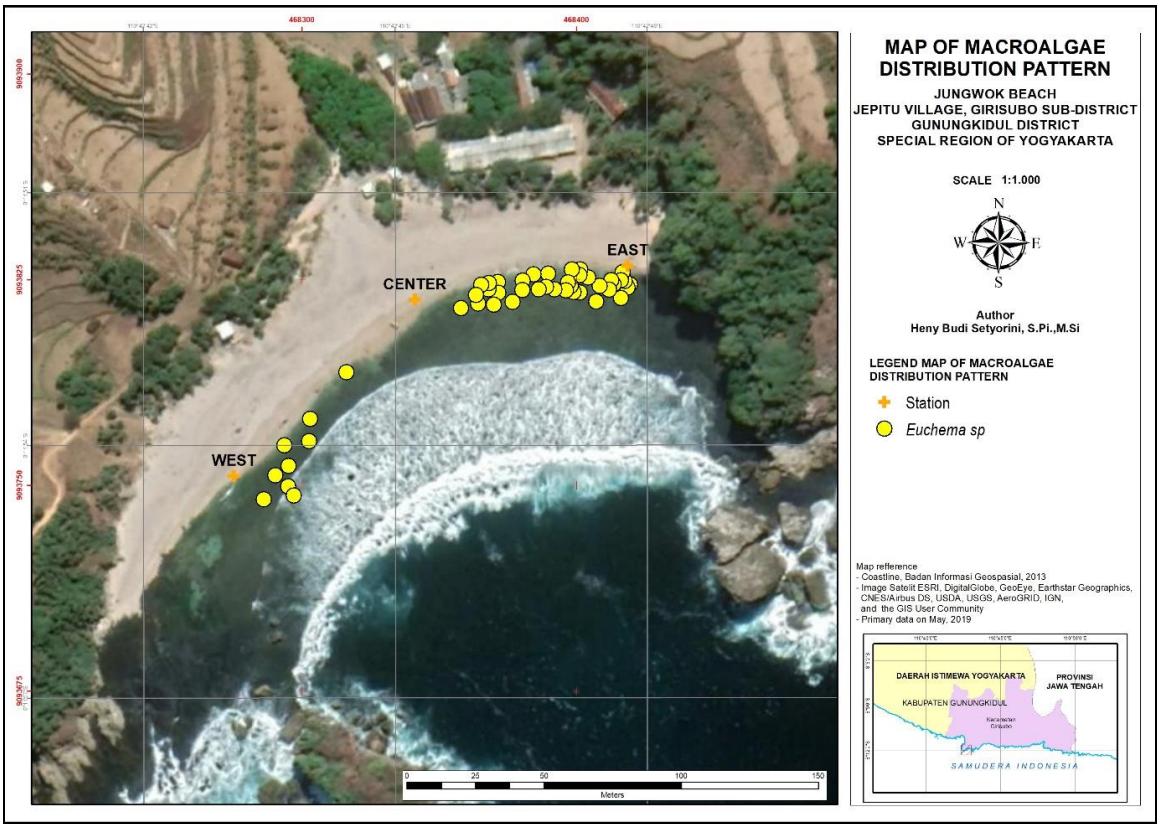

Figure 7. Distribution pattern of *Euchema* sp. at Jungwok Beach, South Java.

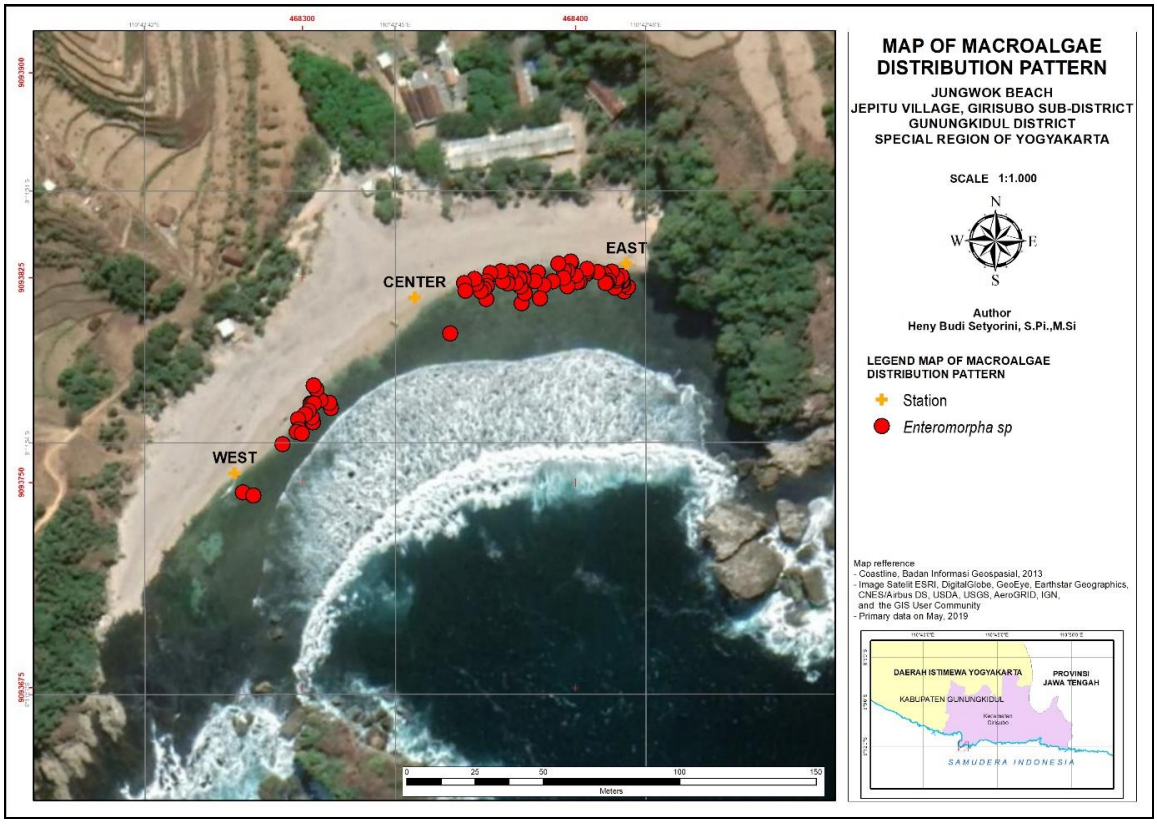

Figure 8. Distribution pattern of *Enteromorpha* sp. at Jungwok Beach, South Java.

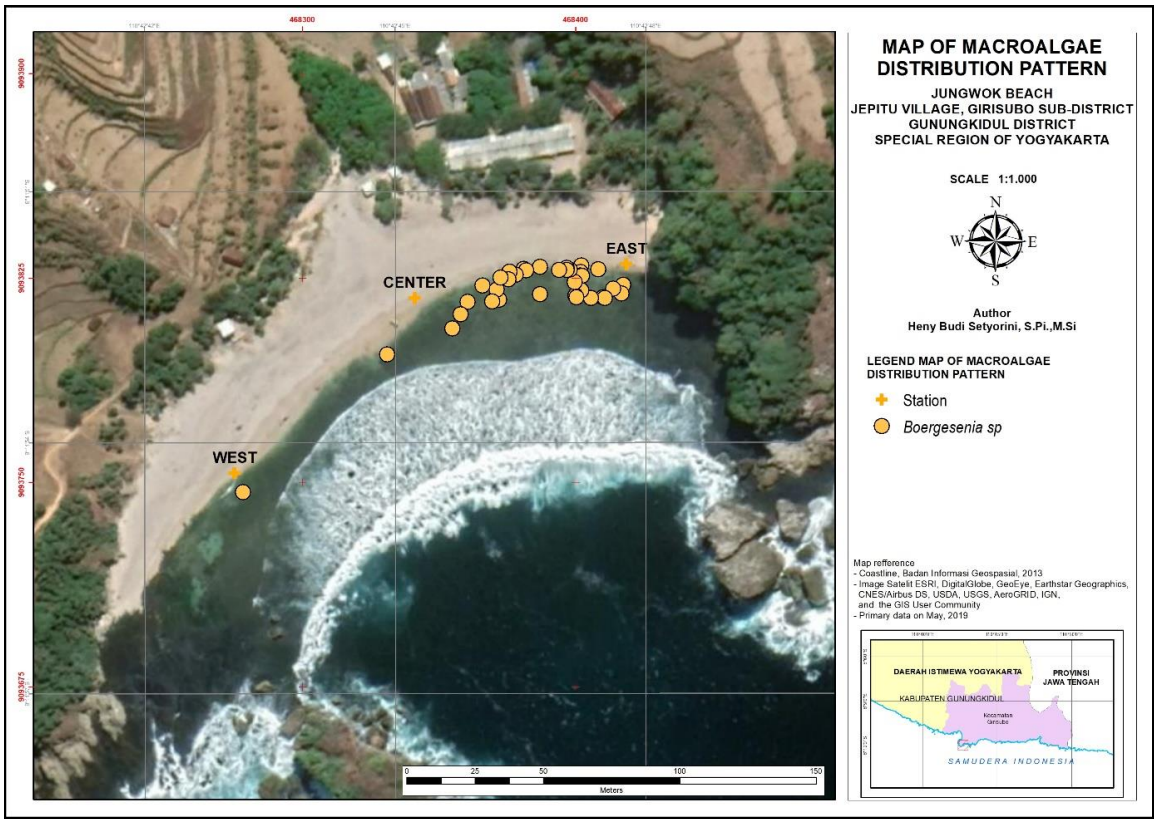

Figure 9. Distribution pattern of *Boergesenia* sp. at Jungwok Beach, South Java.

Figure 10. *Ulva* sp. (original)

Figure 11. *Gracilaria* sp. (original)

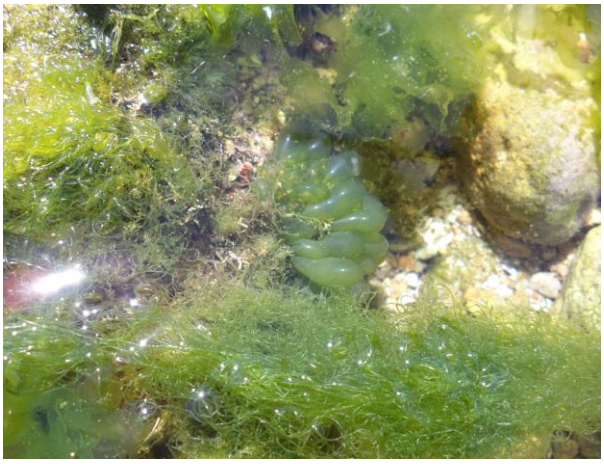

Figure 12. *Boergesenia* sp. (original)

Figure 13. *Euchema* sp. (original)

Figure 14. *Enteromorpha* sp. (original)

Sea water quality variables. The differences of macro algae composition in the eastern, central and western areas of Jungwok Beach were associated to the variability of the substrates and of the sea water quality. The dead coral structures in the eastern area were prevalent and more robust, compared to the central and western areas. The result of the in situ measurements is showed in Table 1.

Table 1

Sea water quality variables at Jungwok Beach

Variables	*Results*	*Standard*	*References*
Depth (m)	0.025-0.275	>3	Ministry of Environment of Indonesia (2004)
Substrate	Dead corals and sand	Sand and corals	National Standardization Agency of Indonesia (2010)
Temperature (^{o}C)	29.90-32.90	28-32	Ministry of Environment of Indonesia (2004)
		26-32	National Standardization Agency of Indonesia (2010)
DO (mg L^{-1})	5.70-10.70	>5	Ministry of Environment of Indonesia (2004)
pH	8.83-9.40	7-8.5	Ministry of Environment of Indonesia (2004), National Standardization Agency of Indonesia (2010)
Salinity (ppt)	34.30-35.20	33-34	Ministry of Environment of Indonesia (2004)
		28-34	National Standardization Agency of Indonesia (2010)

Source: Setyorini & Maria 2019, 2020.

Discussion. Macro algae plants, classified into red, brown and green, are characterized by simple internal structures and their communities commonly live in the coastal areas (Hamed et al 2018). As stated by Lalegerie et al (2019), marine macro algae attach to the substrate, and their existence is conditioned by the tide cycle. The diversity of macro algae in this study is similar to the previous studies of Nurmiyati (2013), where 13 species were found in total, with 6 species from the *Chlorophyceae* class, 5 species from *Rhodophyceae*, and 2 species from *Phaeophyceae* in Sepanjang Beach, Gunungkidul, with *Boergesenia forbesii* as the most evenly distributed species. The of study of Pratama et al (2015) showed that the number of macro algae species found in Drini Beach, Gunungkidul, is of 9 *Rhodophyta*, 7 *Chlorophyta* and 2 *Phaeophyta*, with *Rhodophyta* as the species with the highest abundance, around 50.76%.

Hadisusanto et al (2015) noted that the macro algae number of species found in the intertidal zone of Sarangan Beach, Gunungkidul, is of 14 *Chlorophyta*, 4 *Phaeophyta*, 17 *Rhodophyta*, with *Enteromorpha intestinalis* as the species the most abundant, followed by *Ulva fasciata* and *Cladophora catenata*. The study of Putri et al (2017) mentioned that the *Chlorophyta* found in Krakal Beach, Gunungkidul, are *Chaetomorpha* sp., *Boergesenia* sp., *Ulva* sp., *Cladophora* sp., *Enteromorpha* sp. and *Halicystis* sp., with 9.88% as the highest percentage cover of *Enteromorpha* sp. and 0.14% as the lowest percentage cover of *Halicystis* sp.

As explained by Haryatfrehni et al (2015), macro algae were classified into 3 groups *Chlorophyta*, *Phaeophyta*, and *Rhodophyta* based on the dominant pigment among chlorophyll, carotenoids or phycobilin, respectively. Pigments facilitate macro algae adaptation to the environment and optimize the sunlight absorption for photosynthesis at various levels of water depth (Haryatfrehni et al 2015). The study of Haryatfrehni et al (2015), shows that the samples of macro algae found in Porok beach, Gunungkidul, are of the genus *Chlorophyta*, containing chlorophyll and carotenoids, and *Rhodophyta*, containing chlorophyll and phycoerythrin. Moreover, Vega et al (2020) observed that among the species found in the Canaries, *T. abies-marina*, *Codium intertextum* and *F. spiralis* Islands contain the highest concentrations of chlorophyll *a* and carotenoids, while *H. incurva* and *P. capillacea* contains the higher concentrations of phycoerythrin (PE). Some of carotenoids are produced by cyanobacteria present in macro algae (Markov et al 2018).

Macro algae from the Jungwok beach, particularly in the eastern area, tend to be distributed in the intertidal zone, at a distance of about 4-7.5 m away from the coastline, whose richness in nutrients and oxygen increases from the highest to the lowest tidal zone (Nugroho 2012). Moreover, according to Hamed et al (2018), the intertidal, sublittoral and littoral zones on rocks or another hard substrate are often occupied by marine macro algae. Lalegerie et al (2019) also explained that some species of macro

algae are present within the intertidal or subtidal zones, where the abiotic parameters can be altered during the tide cycle.

The distribution of macro algae communities was also influenced by abiotic variables such as: water temperature, air temperature and significant wave height (Ramos et al 2020). Moreover, Lalegerie et al (2019) noted that the distribution of macro algae is also influenced by abiotic parameters (such as sunlight, temperature, and salinity) and biotic parameters (such as grazing, fouling and pathogens). The abundance of macro algae in the intertidal zone is also influenced by the level of visibility and accessibility. The level of visibility at Jungwok beach is around 2.50 cm up to more than 27.50 cm, tend to be clear. This value can optimize the sunlight penetration that supports the photosynthesis process and growth of macro algae in Jungwok beach. The level of accessibility can be seen from the easiness of access to discover the macro algae. This statement is supported by the presence of macro algae at Jungwok beach mostly found in the intertidal zone that is also accessed by tourists.

Kokabi et al (2016) further explained the vertical distribution of macro algae: in the lower intertidal zone red algae tend to be more abundant and localized, while in the other intertidal zones the green and brown algae are more homogenously distributed on three levels. This explanation is supported by the result of the study of Heo et al (2011), that showed that macro algae biomass in the intertidal zone is more abundant than in the subtidal zone in Jusamdo and Woejodo Island, but different from the pattern in Ongdo, Korea. The macro algae biomass gross weight in the intertidal zone in Ongdo Island is around 41.40 g m^{-2} and in Jusamdo around 129.56 g m^{-2}, while in the subtidal zone of Jusamdo Island it is around 27.67 g m^{-2} and in Ongdo around 91.70 g m^{-2}, calculated from 1 to 5 m depth (Heo et al 2011). The macro algae biomass density is related to the condition of intertidal zone: when the sea recedes, sunlight exposure increases, the temperature rises and the area tends to dry (Nugroho 2012). Fulton et al (2014) showed that the *Sargassum* biomass variation at Ningaloo was strongly influenced by the sea temperature and by the spatial factor at the location.

Macro algae adaptation and vertical distribution in intertidal zone are also influenced by the difference in photosynthetic pigments and by the tolerance towards dryness (Kokabi et al 2016). Considering the vertical distribution, *Ulva pertusa* macro algae tend to be found in the central intertidal zone in Jusamdo Island and in the lower intertidal zone in Woejodo Island, while in the subtidal zone the pattern was different: *Ulva pertusa* and *Gracilaria textorii* macro algae were precisely found at depths of 1 m in Woejodo Island, 5 m in Ongdo and Jusamdo Island and 10 m in Ongdo Island particularly for *Gracilaria textorii* (Heo et al 2011).

Genera variety of macro algae in Jungwok Beach was also influenced by seasons. This condition can be seen in May (summer), when the abundance of macro algae at Jungwok Beach in summer tends to be higher than in the rainy season. This statement is supported by the observations of Duran et al (2016): in summer the growth of macro algae is higher, when the abundance of herbivore fishes also controls the recruitment and succession of the macro algae. The result of the study undertaken by Putri et al (2017) showed that the percent cover of *Enteromorpha* sp. found in Krakal beach in March 2017 (rainy season) was 9.88% as the highest of *Chlorophyta* genera in the location. Ojeda et al (2019) also concluded that the taxa richness and wet biomass of macro algae found in Robalo Bay is higher in the summer than in the winter, also depending on the intertidal sites and levels.

The presence of macro algae in the eastern area of Jungwok beach is also related to the basic substrate of the water, size of sediment particles, current and wave energy in the area. Ayhuan et al (2017) explained that sediment types such as rough sands, faults and shards of corals provide the opportunity of nutrients migration from pore water to the water column while the currents in the area will also bring beneficial nutrients for the growth and development of macro algae. Furthermore, as one of the environmental parameters, the current also has an important role to prevent the occurrence of *silt* accumulation and epiphytic attachment in *thallus* that can inhibit the growth of macro algae (Ayhuan et al 2017). The study of Nurhayati (2012) showed that the wave height at Kukup, Krakal, Drini, Sepanjang and Sundak beaches in March 23-27, 2012, was in

the range of 0.3 to 3 m. Overall, the wave height in Gunungkidul coastal waters also affect the presence and survival of macro algae. The study of Jonsson et al (2006) showed that waves in the range >2 m s^{-1} can reduce the persistence of *Fucus* spp. Martone et al (2012) further explained how the adaptation strategy of bladed intertidal macro algae to wave was done by reducing drag coefficients, while branched intertidal macro algae was done by reducing projected area in flow of wave.

The topography of eastern area of Jungwok Beach, which is more protected by corals compared to the central and western areas: the wave energy is dampened, giving macro algae the opportunity to grow and develop abundantly. Environmental variables like depth, temperature, pH, DO and salinity also cause variances in the macro algae growth and distribution, which are controlled and maintained by the environmental stability (Wong et al 2012).

According to Table 1, temperatures are different in the rainy season, thereby influencing the abundance of macro algae. Fulton et al (2014) showed that temperature is a main factor in the seasonal fluctuation of *Sargassum* biomass in the sea-grass meadow of the Ningaloo lagoon, where the biomass peak occurs at the end of the Austral summer (February). Furthermore, Fulton et al (2014) showed that larger *Sargassum* biomass occurred in 2011, with warmer summer temperatures, than in 2012, when the summer was cooler.

According to Hofmann & Bischof (2014), 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. The measured pH in the present study tended to be alkaline. Dissolved oxygen is one of determinants in the growth of macro algae because it has an important effect on the photosynthesis process (Melsasail et al 2018). The recorded dissolved oxygen at an optimal value for macro algae would be around 2.0-3.5 mg L^{-1} (Melsasail et al 2018).

Similarly to the temperature, salinity values will be different in the rainy season. Macro algae abundance in the rainy season tend to lower than in summer, due to the salinity decrease, but they are rather tolerant to salinity variations (Wong et al 2012). Some other environment variables, in particular the conductivity and total suspended solids, also influence the growth of macro algae (Wong et al 2012). As a comparison, Prasetyaningsih & Rahardjo (2016), reported temperatures of 25-26^{o}C, a pH of 7.5-7.8, a salinity of 28-30 ppt, a DO of 5.5-6.7 mg L^{-1}, a nitrate of 0.324-1.47 mg L^{-1} and a phosphate of 0.066-0.455 mg L^{-1} in Wediombo Beach. These results tend to be lower mainly in temperature, pH, DO and salinity than in the present study. The differences of time measurement and season contributed to the results obtained. Overall, according to the Ministry of Environment of Indonesia (2004) and National Standardization Agency of Indonesia (2010), both the results of measurement fulfilled the quality requirements for marine biota and supported for the growth of macro algae.

Seawater nutrient content at Jungwok Beach might also influence the abundance and distribution of macro algae. The nutrient content is also related to the sampling location in the intertidal zone of Jungwok Beach. The tidal cycle in intertidal zone also influences the physiology and life sustainability of macro algae. During high tides, macro algae will experience a decrease in water brightness and temperature, while in low tides macro algae will be exposed to light and higher air temperatures (Guenther & Martone 2014).

Conclusions. Macro algae found in Jungwok Beach are: *Ulva* sp., *Boergesenia* sp. and *Enteromorpha* sp., from the Chlorophyta genus, and *Gracilaria* sp. and *Euchema* sp., from the Rhodophyta genus. Overall, the macro algae tend to spread in the intertidal zone of Jungwok Beach particularly in the eastern site, at a distance of about 4-7.5 m away from the coastline. In the latter location the waves are obstructed by the corals and the substrate (dead corals and sand) is offering the appropriate habitat for macro algae.

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