

Influence of physicochemical environmental factors on morphometric characteristics of macroalgae from Ambon Island, Indonesia

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Abstract. Liline S, Rumahlatu D, Zubaidah S, Salmanu S, Sangur K. 2024. Influence of physicochemical environmental factors on morphometric characteristics of macroalgae from Ambon Island, Indonesia. *Biodiversitas* 25: 1436-1453. Macroalgae are an essential part of the marine biodiversity of Ambon Island, requiring thorough investigation for conservation and cultivation purposes. Therefore, this study aimed to identify macroalgae and analyze the relationship of environmental physicochemical factors to morphometric characteristics of macroalgae from the coastal waters of Ambon Island, Maluku Province, between June and July 2023. Sampling was performed at four locations, i.e., Hutumuri, Alang, Aer Low, and Suli Villages, followed by laboratory morphometric identification and measurements. The results showed significant variations in the physicochemical environmental factors of the four locations, featuring temperatures ranging from 25.00-30.05°C, pH of 7.00-8.34, salinity of 31.00-32.00, and dissolved oxygen (DO) of 6.00-15.27. Furthermore, the substrate in each location differed, presenting sequentially as sandy coral, coral, sandy coral, and mud sand. 11, 10, 6, and 25 species were found in Hutumuri, Alang, Aer Low, and Suli, respectively. Each species, with distinct morphological characteristics and morphometric sizes, was distributed across the Chlorophyta, Ochrophyta, and Rhodophyta classes. These observations provided crucial insights into the intricate relationship between environmental factors and morphometric characteristics, including full length, thallus width, and length, as well as holdfast length and width of both same-species and different macroalgae populations in Ambon Island.

Keywords: Ambon Island, macroalgae, morphometric, physicochemical environment

INTRODUCTION

Ambon Island, situated between the Seram and Banda seas, is renowned for its rich marine biodiversity in the Maluku Province. Geographical positioning significantly influences the presence of diverse marine organisms, including macroalgae (Lumuindong et al. 2023; Limmon et al. 2023; Pattikawa 2018). Macroalgae, multicellular eukaryotes capable of photosynthesis, generate over 40% of the world's oxygen needs (Guo et al. 2022; Kumar et al. 2022; Florez et al. 2017). Its significant role is played in the water ecosystem by serving as a food source (Sheikhzadeh et al. 2022), functioning as a habitat and a source of nourishment for epifauna (Navarro-Barranco et al. 2019), providing essential sustenance for fish (Manikandan et al. 2022; Rouhani et al. 2022), sources as pigments, proteins, polysaccharides, and lipids (Arias et al. 2022; Pereira et al. 2017), function as economic value and benefit humans as medicine, foodstuffs, and industrial raw materials (Afreen et al. 2023; Srimariana et al. 2020), and natural fertilizers, and liquid waste treatment (Kustantinah et al. 2022; EL Boukhari et al. 2020; Barbot et al. 2016). Macroalgae reside in coastlines and oceans, extending from intertidal zones to depths exceeding 200 meters (Duarte et al. 2022). Indonesia contains 6.42% of the total macroalgae biodiversity worldwide, covering 1.2 million hectares (Sofiana et al. 2022; Melsasail et al. 2018).

Environmental factors greatly influence the life of macroalgae in marine waters. Warm tropical waters, enriched with sunlight and physicochemical factors, contribute to the abundance of organisms (Mushlihah et al. 2021). Sangil et al. (2018) stated the significant impact of temperature variations on subtidal macroalgae community structure in the Eastern Atlantic Islands. According to Wahl et al. (2021), temperature, salinity, and oxygen availability constantly fluctuate, causing stress that affects marine organisms' interaction with the environment. Seawater's acidity or pH level ranging from 6.87-8.12 and a temperature of 25.9-26.6°C are crucial for photosynthesis (Fitrihastuti et al. 2023; Rugebregt et al. 2020). Salinity and CO₂ levels also play important roles in determining growth rate (Fabricius et al. 2023; Pei et al. 2021). Handayani et al. (2023) found that the diversity of macroalgae in the Seribu Islands was influenced by salinity, temperature, brightness, depth, and current speed (physical factors), as well as nitrate, orthophosphate, heavy metal levels, and pH (chemical factors). Apart from environmental factors, the substrate performs an essential role by serving as a surface for macroalgae attachment by holdfasts, promoting efficient growth. Furthermore, the substrate's type, size, and stability significantly influence these organisms' presence and diversity (Sangil et al. 2021; Lin et al. 2018).

Studying morphometric characteristics is crucial for the breeding of macroalgae and assessing genetic traits (Umanzor et al. 2021). Research studies on macroalgae morphometrics in Indonesian marine waters have been conducted Raza'I et al. (2021) reported the morphometrics of *Caulerpa racemose* on Bintan Island for tallus length, stolon length, and stolon grains. Sumandiarsa et al. (2021) reported a correlation of DO and salinity to the distance from holdfast to talus branching and a correlation of temperature and brightness to the diameter of the holdfast *Sargassum polycystum* of Tidung, Sebesi, and Bintan Island. Kase et al. (2019) reported that the environment influences morphometrics of several macroalgae from Chlorophyta, Ochrophyta, and Rhodophyta in the Dara Mara marine. The study of macroalgae morphometrics in Ambon Island waters is crucial, backed by morphological studies of the macroalgae species found in the island's waters. The morphological characteristics of macroalgae observed are types of thallus in the form of sheets, tubes, fibers, grapes, stolons, and holdfasts. Morphometric measurements are crucial for understanding macroalgae's morphological variation, but the relationship between physical environmental factors and their characteristics remains unexplored.

Administratively, Ambon Island consists of two regencies, namely Ambon City and Central Maluku, which comprise the waters of Hutumuri, Aer Low, Alang, and Suli Villages, respectively. Varying elevation, slope

characteristics, and substrate in these locations influence macroalgae biodiversity (Sangil et al. 2021; Steigleder et al. 2019). Therefore, this study aimed to analyze the biodiversity of macroalgae from the coastal waters of Ambon Island, Maluku Province, and the relationship of physicochemical factors to their morphometrics. Morphological studies on Ambon Island macroalgae can enhance their economic value and facilitate structural studies between species, making them valuable for food and industry. Hence, this study reveals environmental physicochemical factors, macroalgae identification, and macroalgae morphometric measurements.

MATERIALS AND METHODS

Study locations

This study was carried out from June to July 2023 in the waters of Hutumuri (H), Aer Low (AL), Alang (A), and Suli (S) Villages of Ambon Island, Maluku, Indonesia. The geographical conditions of the four data collection locations are presented in Figure 1 and Table 1. The sampling location using probability sampling techniques is according to the researchers' considerations. The intended consideration is that the location has a lot of macroalgae diversity; the location is easy to reach and is safe for sampling.

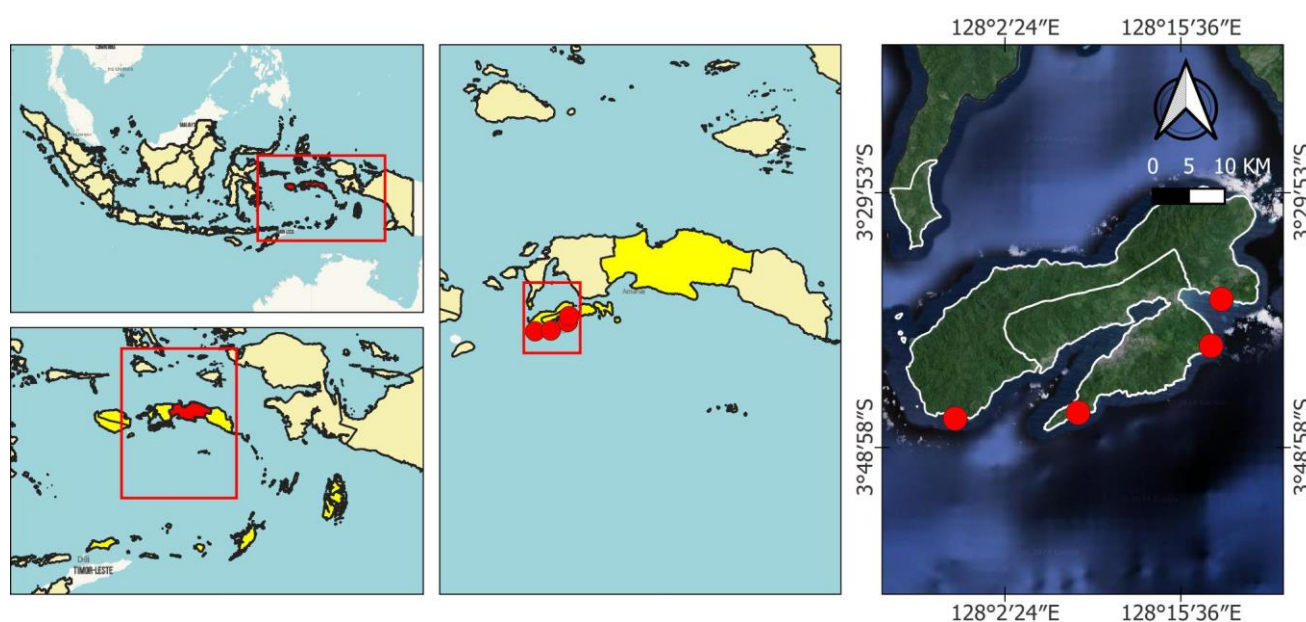


Figure 1. Study locations in Ambon Island, Maluku, Indonesia [Red dots indicate four locations]

Table 1. Geographical conditions of waters in this study in Ambon Island, Maluku, Indonesia

Location	Slope	Range (m)	Latitude	Longitude	Height	Coordinate point
Aer low	60.0000111 ⁰	1.107.00368	-3.7748585 ⁰	128.1321497 ⁰	7.1234675	3°46'40"S, 128°07'55"E
Suli	59.961602 ⁰	809.2938129	-3.6373316 ⁰	128.3181125 ⁰	-0.1887869	3°38'22"S, 128°19'05"E
Alang	44.996677 ⁰	531.3485977	-3.7816083 ⁰	127.9770405 ⁰	0.1014395	3°46'57"S, 127°58'37"E
Hutumuri	-	909.144487	-3.6873857 ⁰	128.2997294 ⁰	6,9827965	3°41'14"S, 128°17'59"E

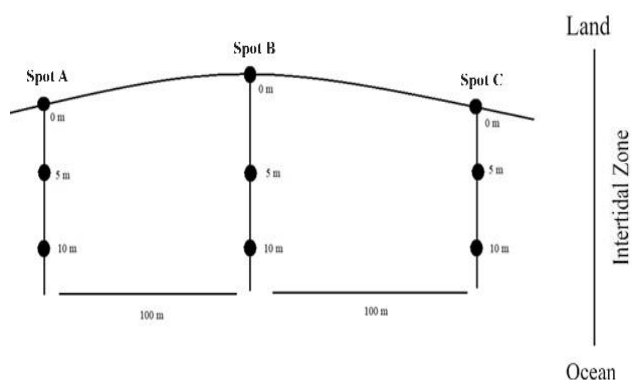


Figure 2. Line transect method

Procedures

Sample preparation

The locations to be explored were determined before commencing this study, and then physical and chemical environmental factors, including temperature, pH, salinity, and DO, were measured (Handayani et al. 2023). Figure 2 shows algae samples were collected during low tide using the line transect method. Those macroalgae found were stored in labeled plastic containers and transported to the laboratory for washing with running water, eliminating sand and dirt attached to the surface.

Sample identification

The sample images were captured using a Canon EOS 700D camera, followed by observing morphological characteristics such as color/thallus pigments, general thallus shape, blade shape, blade tip shape, and blade edge shape. Others included holdfast, main axis shape, holdfast shape, stipe, presence of ribs on the stipe, thallus branching shape, blade position, midrib, ramuli, phylloid, frond, phylloid shape, frond shape, receptacle (spore-bearing branch), and receptacle shape. Subsequently, the samples were preserved in a 10% formalin and water solution and identified by comparing observed characteristics with descriptions provided by AlgaBase (2023) and Gakken (1979).

Morphometric measurements

Morphometric measurements of thallus and holdfast length and width were conducted on all algae samples (Figure 3) for macroalgae resembling sheets, phylloid width and length were estimated, while those with a cylindrical shape were subjected to branch measurements. The overall length measurement covered the distance from the holdfast to the longest thallus tip. Furthermore, morphometric measurements were performed using the Raster image processing application.

Data analysis

The collected macroalgae exploration data were analyzed qualitatively through image interpretation and morphological characterization and quantitatively by calculating mean and standard deviations for measurements of physicochemical environmental factors. Subsequently, relationship analysis was conducted using Raster version 4.3.1, and the effective contribution standard error (SE) was estimated with the formula from Hadi (2004):

$$EC\%X_n = RC\%X_n \times R^2$$

RESULTS AND DISCUSSION

Physicochemical environmental factors

The measurements of physicochemical environmental factors showed variations in temperature, pH, salinity, and DO, as presented in Table 2. Macroalgae species thriving in the four study locations manifested adaptation ability towards the environment, suggesting that the physical and chemical factors were optimal. However, high temperatures could be a stress factor, affecting pigment color and macroalgae distribution across specific locations (Menaa et al. 2020; Takolander et al. 2017; Wernberg et al. 2016). Roleda and Hurd (2019) stated that an optimal temperature was crucial for macroalgae survival, regulating enzyme activity, chemical reaction rate constants, and nutrient uptake rates. Hyposaline or hypersaline conditions were found to influence the biochemistry and biodiversity of these organisms (Monteiro et al. 2021; AbouGabal et al. 2022).

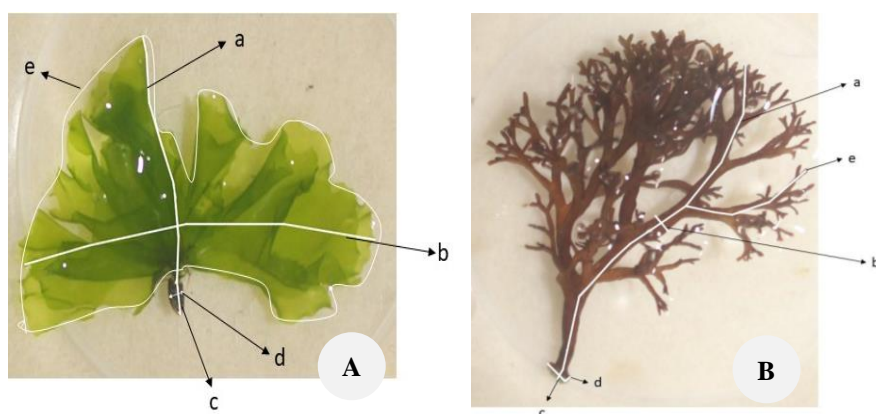


Figure 3. Morphometric visualization of macroalgae. A: a. thallus length; b. thallus width; c. holdfast length; d. holdfast width; e. phylloid width. Image B: a. thallus length; b. thallus width; c. holdfast length; d. holdfast width; e. branch length

Table 2. Data on physicochemical environmental factors in study sites of Ambon Island, Maluku, Indonesia

Location	Measurement results of physicochemical environmental factors				
	Temperature (°C)	pH	Salinity (‰)	DO (mg/l)	Substrate
Hutumuri (H)	30.05±0.041	8.34±0.005	32.00±0.082	8.00±0.0471	Sandy coral
Alang (A)	25.00±0.082	7.00±0.044	34.00±0.0471	6.00±0.0471	Sandy coral
Aer Low (AL)	29.50±0.368	7.53±0.042	35.00±0.0471	7.70±0.0943	Coral
Suli (S)	25.00±0.082	7.50±0.0471	31.00±0.0471	15.27±0.0420	Sandy coral and mud sand

Previous studies described ideal environmental conditions for macroalgae; for example, optimal pH for the genus *Gracilaria* was identified as 6.61, and an increase to 9.30 led to growth decline, while optimal salinity ranged from 20-50 ppt (Lee et al. 2019; Alves et al. 2021). The optimal pH and salinity for proper growth of the genus *Caulerpa* were 8.42-9.41 and 29.13-31.54 ppt, respectively (Sompong et al. 2020). Pereira et al. (2023) reported salinity as a determining factor for macroalgae distribution in a water body, with *Acanthophora spicifera* tolerating values between 25-40 PSU whereas 15 and 50 PSU salinity values induced biochemical changes such as color loss and biomass alterations. Average environmental factors for the genus *Porphyra* included temperature, pH, and salinity ranging from 25.36-27.5, 7.96-8.10, and 20.6-25.3 PSU, respectively (Pise et al. 2013). *Hypnea cervicornis* J. Agardh lives at an ideal salinity of 250/00 conditions and temperature 25°C (Ding et al. 2013). Environmental factors exceeding limits, such as high salinity concentrations, can inhibit photosynthesis, disrupting productivity, cell biochemical composition, and cell structure (Gani et al. 2019). Each species of macroalgae can live on ideal physicochemical factors but can survive in different conditions due to good adaptability.

The substrate was found to be a source of nutrients and a place for macroalgal growth to attach, significantly influencing the type of organism. Suli Beach consists of a substrate in the form of sandy coral and muddy sand, contributing to various types of macroalgae morphology. Coral rocks containing sediment are suitable for the growth of macroalgae because they have the ability to store organic and inorganic compounds without causing ecosystem harm to coral reefs (Guo et al. 2022; Widayartini et al. 2021; Rahardjanto et al. 2020). Some macroalgae species such as *Halimeda* and *Caulerpa* thrive on the substrate of mud, sand, and coral fragments, while *Padina*, *Sargassum*, and *Gracilaria* can be found on dead coral (Melsasail et al. 2018).

Whereas several studies show the types of macroalgae that live in various substrates, including Arsianti et al. (2020) reported that *S. polycystum* from Dompu Beach, Lombok Nusa Tenggara Barat thrives on coral reefs, dead coral, and volcanic rocks, with the ideal surface being coral reefs. Carreira-Flores et al. (2023) reported the presence of the *Sargassum* group, which is more commonly found on rocky substrates on the southwest coast of the Bay of Biscay. Kepel et al. (2019) reported the distribution of macroalgae on Mantehage Island, North Sulawesi, based on rocky substrates consisting of the species *Dictyosphaeria cavernosa*, *S. cristaeifolium*, *C. serrulata*,

C. sertularioides, *P. australis*, *H. opuntia*, *C. racemosa*; muddy sand substrate consisting of the species *Boergesenia forbesii*, *C. crassa*; sandy substrate consisting of the species *G. salicornia*, *G. edulis*. Veeragurunathan et al. (2022) found that corals exposed to strong wave pressure had limited macroalgae species. In addition, the mixture of sand and mud causes a reduction in species diversity because the sediment that settles next to the sand interferes with sunlight absorption.

Macroalgae identification

Several interesting species, including *Dictyosphaeria versluisii*, *Sargassum polycystum*, *Galaxaura rugosa*, and *G. salicornia*, were identified during this study in Hutumuri and Suli Villages. *Gymnogongrus flabelliformis* and *Ceramium kondoi* were found on Aer Low and Alang coral substrates. *Boodlea coacta* was detected in Hutumuri and Alang, while *U. lactuca* and *P. australis* were found in Alang and Suli. *Amphiroa fragilissima*, *T. ornata*, and *C. racemosa* var. *peltata* were distributed across Hutumuri, Suli, and Alang (Table 4), while other species were present in only one location.

Morphologically, the *Caulerpa* genus consists of rhizoids, stolons, and assimilators (parts resembling a leaf) with a branch arrangement that characterizes each species (Belton et al. 2019; Wirawan et al. 2022). The assimilators differ depending on the species, with some being fan-shaped, spiral-shaped, or similar to grapes. Moreover, macroalgae belonging to sheet thallus included *U. lactuca*, *Porphyra crispata*, genus *Sargassum*, and genus *Padina*. The narrow sheet thallus group comprised *B. coacta*, *Bryopsis ryukyuensis*, *C. crassa*, *Enteromorpha prolifera*, *Dictyota bartayresiana*, and *Ectocarpus siliculosus*. The group with triangular thallus includes *T. ornata* and *H. opuntia*. Those classified as cylindrical thallus were *Galaxaura rugosa*, *Jania adherens*, *Gigartina affinis*, *Gymnogongrus flabelliformis*, *Hypnea cervicornis*, as well as the genera *Acanthophora*, *Amphiroa*, and *Gracilaria*. According to Kepel et al. (2020), the *Enteromorpha* genus possessed light green thallus shaped as hollow filaments resembling hair.

Meinita et al. (2021) and Kongkittayapun and Chirapart (2011) reported that *Gracilaria* belonged to Rhodophyta group. However, *G. salicornia* and *G. coronopifolia* are dark green to brown green and yellowish to brownish. The Chlorophyta group has a filamentous, sheet, and cylindrical thallus, primarily used in shallow waters to absorb sunlight. Phaeophyta features a fan-shaped thallus with sheets and contains radial, cylindrical concentric lines. Furthermore, the leaf morphology resembles a trumpet with serrated

edges, and thallus is similar to Cormophyta plants. Rhodophyta has strong holdfasts firmly anchored in the substrate with thallus some appear cylindrical, spiny, and bear intermittent branches, while others contain lime and are herbaceous (Erniati et al. 2023).

Moreover, 37 macroalgae species were identified, with 12, 7, 17, and 1 belonging to Ulvophyceae, Phaeophyceae, Florideophyceae, and Bangiophyceae classes. This number exceeded the 21 species reported by Litaay (2014) from Salobar Water, Hative Besar, Tantui, Halong, and Lateri, from Ambon Island, ordered as Rhodophyceae> Chlorophyceae> Phaeophyceae. Litaay et al. (2021) reported 22 species originating from Tantui, Hative Besar, and Alang, with a distribution of Rhodophyta> Phaeophyta> Chlorophyta. Previous results and this current study showed the prevalence of macroalgae from Rhodophyta class in Ambon Island waters. This observation was supported by Titlyanov et al. (2018), stating that red algae (Rhodophyta) constituted the largest group of macroalgae, with 4,000 identified species exceeding Chlorophyta and Phaeophyta. Kokabi et al. (2016) reported similar results on the east coast of Qeshm Island in the Persian Gulf, Iran, where Rhodophyta dominated but had a small biomass due to the small filamentous algae such as the genera *Jania*, *Hypnea*, *Gracilaria*, *Acanthophora*, and *Ceramium*.

Therefore, from highest to lowest, Macroalgae diversity observed in sequence included 25, 12, 8, and 7 species in the waters of Suli, Hutumuri, Alang, and Aer Low Villages, respectively (Table 3). These differences were influenced by substrate factors, where Suli waters contained more species due to muddy sand and sandy coral. Zulpikar and Handayani (2021) reported a similar result in the Mangaitan, Setuga, Padar, and Muntia Islands, attributing the high species biodiversity to soft and hard substrate presence. This current study showed that *A. fragilissima* adapted to the environment through attachment to other macroalgae, particularly *Caulerpa racemosa* var. *peltata*, as a substitute for hard coral in Sungai Pulai, Johore (Harah et al. 2014).

This study found the genus *Caulerpa* in rock substrates in Alang, Hutumuri, and Suli villages. *Sargassum* has a wide habitat because it can be attached to sand substrates and corals. In contrast, *U. lactuca*, *D. versluysii*, *P. crispata* and *Amphiroa* spp. have specific substrates, namely hard substrates such as corals. *Caulerpa* types with rhizoid types were more developed on sand substrates or not compact rocks, such as gravel (Costa et al. 2001; de Carvalho et al. 2013). *Gracilaria salicornia* and *H. macrolaba* are the most common species found in sand habitats; this is also because the holdfast of *Halimeda* is round-type, while the genera *Padina* spp. and *S. polycystum* are very suitable for growing in rocky substrates because holdfast type attaches laterally to strong and stable substrates, filamentous algae such as *Chaetomorpha* spp. are very suitable on rocky substrates and form green "mats" in rocks (Zainee et al. 2019; de Maria César Ferreira et al. 2022). Genus *Porphyra* is a macroalgae with a narrow ecological niche only found in coral substrates (Meynard et al. 2019). Moreover, this study shows *C. crassa*, *U. lactuca*, *A.*

fragilissima, *A. misakiensis*, and *D. versluysii* grow on coral substrates; the genus *Sargassum* on coral and sand substrates in the Suli and Hutumuri area.

Macroalgae morphometric characteristics

Morphometric measurements of macroalgae in this study were conducted based on the species observed. Those resembling sheets, namely the genera *Padina* and *Ulva*, were evaluated for overall length, thallus width and length, holdfast length, and width, as well as phylloid width. The cylindrical types had additional characteristics, including phylloid length and branching. Additionally, macroalgae similar to higher plants, such as *Sargassum* and *Turbinaria*, were assessed for all morphometric characteristics (Table 5). The results showed that morphometric measurements differed among the same species in different environments. Examples of these variations were observed in *Boodlea coacta* (Dickie) G. Murray & De Toni 1889, *Dictyosphaeria versluysii* Weber Bosse 1905, *C. racemosa* var. *peltata*, *U. lactuca* Linnaeus 1753, *Padina australis* Hauck 1887, *Sargassum polycystum* C. Agardh 1824, *T. ornata* (Turner) J. Agardh 1848, and *Galaxaura rugosa* (J. Ellis & Solander) J.V. Lamouroux 1816. Other species including *Ceramium kondoi* Yendo 1920, *Amphiroa fragilissima* (Linnaeus) J.V. Lamouroux 1816, *Gracilaria salicornia* (C. Agardh) E.Y. Dawson 1954, and *Gymnogongrus flabelliformis* Harvey 1857 were used for monitoring the variations.

The study aligns with several studies, including by Díaz-Tapia et al. (2020), suggesting that morphometric analysis of macroalgae species produced diversity due to environmental influences; Santiañez and Trono (2013) reported morphotypes differences among *Sargassum* from the Philippine Islands of Alabat, namely *S. crassifolium* J. Agardh, *S. cristaefolium* Agardh, *S. kushimotoense* Yendo, *S. gracillimum* Reinbold, *S. myriocystum* J. Agardh, and *S. polycystum* C. Agardh. According to Yap-Dejeto et al. (2022), the morphological plasticity ability of *Sargassum* was very high due to environmental influences. Belton et al. (2019) stated the significance of morphology exploration due to the very high level of plasticity among the species *C. racemosa* var. *peltata*. Moreover, the study conducted on macroalgae morphometrics by Estrada et al. (2020) showed morphometric variations in branching, assimilator height, distance between assimilators, ramulus diameter, and number of holdfasts in *C. racemosa* at 13 aquatic locations. The same results were also found in the *C. racemosa* variation, namely, the overall length, length and width of the holdfast and branching were found in the Alang, Hutumuri, and Suli locations, while the length and width of the thallus and the length and width of the phylloid were found in the Hutumuri and Suli areas.

Neustupa and Nemcova (2020) reported morphometric variations in the segments and branches of the *Halimeda tuna* species. Verbruggen et al. (2005), Neustupa and Nemcova (2018), and Kase et al. (2019) further reported *H. opuntia* species with different morphological characteristics in terms of thallus segments due to variations in environmental factors. Moreover, Kim et al. (2022) reported that environmental adaptations impact the

size of *S. thunbergia*, showing the potential of morphometrics to provide insights into environmental quality. These studies can serve as a reference that environmental factors can affect the morphological and morphometric characteristics of a macroalgae species. In comparison, a brief morphological description of macroalgae from Ambon Island is presented in Table 4. Morphometric measurements of macroalgae from Ambon Island are presented in Table 5.

Relationship between physicochemical and morphometric factors

Physical and chemical environmental factors have a relationship with the morphometric characteristics of macroalgae but do not have a uniform impact on all morphometric characteristics. This is indicated by the negative value in the Adjusted R-squared, which means that the physical and chemical environmental factors have a negative relationship with several morphometric characteristics with a significance level of $p < 0.05$ (Table 6). Meanwhile, there is also a positive relationship between physical and chemical environmental factors and several morphometric characteristics with a significance level of $p < 0.05$ (Table 6).

The relationship between physical and chemical environmental factors to these characteristics was recorded respectively as Holdfast Length > Holdfast Width > Full Length > Thallus Width > Thallus Length in Hutumuri, Holdfast Length > Thallus Width > Thallus Length > Full Length > Holdfast Width in Alang, Thallus Width > Full Length > Thallus Length > Holdfast Width > Holdfast Length in Aer Low, and Holdfast Width > Thallus Length > Full Length > Holdfast Length > Thallus Width in Suli (Table 6). Some research aligns with the study's results; for example, Tiwari and Troy (2015) reported a relationship between environmental factors, such as temperature, radiation, nutrition, water movement, and thallus regeneration capacity during cultivation. Erlania and Radiarta (2015) found that macroalgae biomass and yield of *Kappaphycus alvarezii* var. Tambalang and Maumere, *K. striatum*, and *E. denticulatum* were related to turbidity, nutrition, and seawater temperature. Roleda and Hurd (2019) described the abiotic factors influencing macroalgae productivity. Seawater temperature plays a significant role in determining morphometric characteristics of *E. cava* (Laminariales, Phaeophyta) in two distinct locations (Serisawa et al. 2002).

Three species *Halimeda tuna*, *H. opuntia*, and *Dictyota* sp. have diverse morphometric sizes in four locations featuring different light conditions, temperatures, nutrients, and hydrodynamics (Yñiguez et al. 2010). Furthermore, Sissini et al. (2022) reported coralline red algae thriving in ecoregions with tropical and warm climates, where temperature, nutrient levels, and water current speed facilitated growth and development. These factors included the effect of seawater movement on the DO diffusion process and the impact of light absorption on the photosynthesis rate. Furthermore, temperature greatly affects enzyme activity, metabolic reaction rates, and macroalgae nutrient diffusion. An increase in CO_2

concentration increases the activity of the enzyme nitrate reductase, while low salinity concentration positively influences nutrient absorption.

Nevertheless, many of these relationships had negative values in this study, showing a lack of correlation with physical and chemical environmental factors. A similar result by Lemesle et al. (2023) stated that environmental factors such as solar radiation had a negative relationship with the location of macroalgae deposits, while air temperature and wave size showed a positive relationship on Luc-sur-Mer Beach in Normandy, France. This analysis of Ambon Island waters would be a beneficial resource for cultivating potential macroalgae species in the future.


The relationship of physicochemical and environmental factors to the morphometrics of the same species at different locations can only be explained by a few species. This is because not all species live in these four locations. As for species that can be compared morphometrically to the relationship of physical, chemical, and environmental factors, only a few of them include *Boodlea coacta* (Dickie) G. Murray & De Toni 1889, *Dictyosphaeria versluysii* Weber Bosse 1905, *Caulerpa racemosa* var. *peltata*, *Ulva lactuca* Linnaeus 1753, *Padina australis* Hauck 1887, *Sargassum polycystum* C. Agardh 1824, *Turbinaria ornata* (Turner) J. Agardh 1848, *Galaxaura rugosa* (J.Ellis & Solander) J.V. Lamouroux 1816, *Ceramium kondoi* Yendo 1920, *Amphiroa fragilissima* (Linnaeus) J.V. Lamouroux 1816, *Gracilaria salicornia* (C.Agardh) E.Y. Dawson 1954, *Gymnogongrus flabelliformis* Harvey 1857 (Table 5).

The results showed differences in morphometric size in the same macroalgae species due to different physicochemical factors (Table 5 and Table 6). According to Karsten (2012), the same macroalgae species but growing in different salinity conditions can show different tolerances because salinity is one factor affecting the growth of fine grains and the distribution of macroalgae. Different physicochemical and environmental factors at the location of Aer Low and Alang affect the morphometrics of both types of macroalgae, namely *Ceramium kondoi* Yendo 1920 and *Gymnogongrus flabelliformis* Harvey 1857 (See in Table 2). The results showed variations in the morphometric size of the species *Ceramium kondoi* Yendo 1920 living at the location of Aer Low > Alang, in contrast to the morphometric size of the species *Gymnogongrus flabelliformis* Harvey 1857 living at the location of Alang > Aer Low. Some macroalgae species such as *Dictyosphaeria versluysii* Weber Bosse 1905, *Padina australis* Hauck 1887, *Sargassum polycystum* C. Agardh 1824, *Turbinaria ornata* (Turner) J. Agardh 1848, *Galaxaura rugosa* (J.Ellis & Solander) J.V.Lamouroux 1816, and *Gracilaria salicornia* (C.Agardh) E.Y. Dawson 1954 have morphometric variations, namely morphometric at the location of Suli > Hutumuri. Especially for *Sargassum* types, it is reported that high salinity and temperature affect the growth of *Sargassum* (Li et al. 2019; Graba-Landry et al. 2020).

Table 3. Composition of macroalgae taxa found in the study locations in Ambon Island, Maluku, Indonesia

Class	Ordo	Family	Genus	Species	Data collection locations				Total species
					H	A	AL	S	
Ulvophyceae	Cladophorales	Boodleaceae	Boodlea	<i>Boodlea coacta</i> (Dickie) G.Murray & De Toni 1889	+	+	-	-	12
		Siphonocladaceae	Boergesenia	<i>Boergesenia forbesii</i> (Harvey) Feldmann 1938	-	-	-	+	
		Cladophoraceae	Chaetomorpha	<i>Chaetomorpha crassa</i> f. <i>genuina</i> Schiffner nom. inval. 1938	-	-	+	-	
		Siphonocladaceae	Dictyosphaeria	<i>Dictyosphaeria versluysii</i> Weber Bosse 1905	+	-	-	+	
	Bryopsidales	Bryopsidaceae	Bryopsis	<i>Dictyosphaeria cavernosa</i> (Forsskål) Børgesen 1932	-	-	-	+	
				<i>Bryopsis ryukyuensis</i> Yamada 1934	-	-	+	-	
		Halimedaceae	Halimeda	<i>Halimeda opuntia</i> (Linnaeus) J.V.Lamouroux 1816	-	-	-	+	
		Caulerpaceae	Caulerpa	<i>Caulerpa racemosa</i> var. <i>peltata</i>	+	+	-	+	
				<i>Caulerpa sertularioides</i> f. <i>farlowii</i> (Weber Bosse) Børgesen 1907	-	-	-	+	
				<i>Caulerpa serrulata</i> (Forsskål) J.Agardh 1837	-	-	-	+	
		Ulva	Enteromorpha	<i>Enteromorpha prolifera</i> (O.F.Müller) J.Agardh, 1883	-	-	-	+	
				<i>Ulva lactuca</i> Linnaeus 1753	-	+	-	+	
Phaeophyceae	Dictyotales	Dictyotaceae	Dictyota	<i>Dictyota bartayresiana</i> J.V.Lamouroux 1809	-	-	-	+	7
			Padina	<i>Padina australis</i> Hauck 1887	-	+	-	+	
			Padina	<i>Padina crassa</i> Yamada 1931	+	-	-	-	
	Ectocarpales	Ectocarpaceae	Ectocarpus	<i>Ectocarpus siliculosus</i> (Dillwyn) Lyngbye, 1819	-	-	+	-	
	Fucales	Sargassaceae	Sargassum	<i>Sargassum crassifolium</i> J.Agardh 1848	-	-	-	+	
			Sargassum	<i>Sargassum polycystum</i> C.Agardh 1824	+	-	-	+	
Florideophyceae	Nemaliales	Galaxauraceae	Turbinaria	<i>Turbinaria ornata</i> (Turner) J.Agardh 1848	+	+	-	+	17
			Galaxaura	<i>Galaxaura rugosa</i> (J.Ellis & Solander) J.V.Lamouroux 1816	+	-	-	+	
	Ceramiales	Rhodomelaceae	Acanthophora	<i>Acanthophora spicifera</i> (M.Vahl) Børgesen 1910	+	-	-	-	
				<i>Acanthophora muscoides</i> (Linnaeus) Bory 1828	-	-	-	+	
				<i>Acanthophora dendroides</i> Harvey 1855	-	-	-	+	
				<i>Ceramium kondoi</i> Yendo 1920	-	+	+	-	
	Corallinales	Lithophyllaceae	Amphiroa	<i>Amphiroa misakiensis</i> Yendo 1902	+	-	-		
				<i>Amphiroa fragilissima</i> (Linnaeus) J.V.Lamouroux 1816	+	+	-	+	
				<i>Jania adherens</i> Lamouroux 1816	-	+	-	-	
	Gracilariales	Gracilariaceae	Gracilaria	<i>Gracilaria arcuata</i> Zanardini 1858	-	-	-	+	
				<i>Gracilaria coronopifolia</i> J.Agardh 1852	-	-	-	+	
				<i>Gracilaria lichenoides</i> f. <i>coronopifolia</i>	-	-	-	+	
				<i>Gracilaria salicornia</i> (C.Agardh) E.Y.Dawson 1954	+	-	-	+	
	Gigartinales	Gigartinaceae	Gigartina	<i>Gigartina affinis</i> Harvey 1860	-	-	-	+	
				<i>Gymnogongrus flabelliformis</i> Harvey 1857	-	+	+	-	
				<i>Hypnea cervicornis</i> J.Agardh 1851	-	-	-	+	
	Halymeniales	Halymeniaceae	Halymenia	<i>Halymenia floresii</i> (Clemente) C.Agardh 1817	-	-	-	+	
				<i>Plocamium ovicorne</i> i	-	-	-	+	
Bangiophyceae	Bangiales	Bangiaceae	Porphyra	<i>Porphyra crispata</i> Kjellman 1897	-	-	+	-	1
Total					12	8	7	25	

Table 4. Identification of macroalgae from Ambon Island, Maluku, Indonesia

Species and morphology	Specimen		
Ulvoephyceae			
<i>Boodlea coacta</i> Thallus is green, smooth, small, and cylindrical. It attaches to dead coral to form a carpet.		<i>Bryopsis ryukyuensis</i> Thallus is dark green, has a smooth cylinder form, is dense at the base, and resides in coral habitats.	
<i>Boergesenia forbesii</i> Thallus is dark green, soft, cylindrical, enlarged from the middle to the tip, and arranged as a floret, inhabiting coral rocks.		<i>Halimeda opuntia</i> The light green thallus consists of segments similar to small triangles and lime. It is hard, rigid, overlapping each other, and found in sand habitats.	
<i>Chaetomorpha crassa</i> f. <i>genuina</i> Thallus is light green, slender, cylindrical, and long, forming a carpet on dead coral.		<i>Caulerpa racemosa</i> var. <i>peltate</i> Thallus is light green, in the form of an elongated stolon, with rhizoids, and has an assimilator (similar to a phylloid) with a button-shaped protrusion. It resides in coral and sandy coral habitats.	
<i>Dictyosphaeria versluisii</i> Thallus is dark green, the surface is hard with small pores, and it attaches to coral rocks.		<i>Caulerpa sertularioides</i> f. <i>farlowii</i> Thallus is light green, in the form of an elongated stolon, contains rhizoids, and has a fan-shaped assimilator (similar to a phylloid). It is found in coral habitats.	
<i>Dictyosphaeria cavernosa</i> Thallus is light green, with small protrusions on the surface, and attaches to rocks.		<i>Caulerpa serrulata</i> Thallus is light green in the form of an elongated stolon and contains rhizoids. It also has a spiral-shaped assimilator (similar to a phylloid) and resides in coral habitats.	

Enteromorpha prolifera

Thallus is light green, the strands from the middle to the tip are rolled up in a spiral shape, and it thrives in coral habitats.

*Ulva lactuca*

Thallus is light green and in flat sheets arranged in a fan shape. It is found in coral habitats.

**Phaeophyceae***Dictyota**bartayresiana*

Thallus is brown, with a flat and narrow sheet, and a slit at the tip.

*Padina crassa*

Thallus is brown and in the form of thin as well as easily tearable sheets resembling a fan. It has a short stipe, with short hair around the holdfast, and inhabits coral habitats.

*Padina australis*

Thallus is brown and in the form of thin as well as easily tearable sheets. It has a long stipe with long hair around the holdfast and inhabits coral habitats.

*Ectocarpus siliculosus*

Thallus is brown, in the form of smooth strands, and resides in coral rock habitats.

*Sargassum crassifolium*

Thallus is brown, with a smooth stipe (organ similar to stem) and a thick, oval-shaped phylloid (organ resembling leaf). The edges of the phylloid are serrated, the tip is pointed, and the vesicles are round, as commonly found in coral habitats.

*Sargassum polycystum*

Thallus is brown, with a rough, blunt protrusion on the stipe (organ resembling a rod). The phylloid is oval to elliptical, with serrated edges and a pointed tip. It also has thin, round vesicles found in sand and coral habitats.

*Turbinaria ornata*

The brown thallus comprises triangular phylloids and has a holdfast with long branches. It resides in coral habitats.

**Florideophyceae***Galaxaura rugosa*

Thallus is red, very hard, segmented, branched, and thrives in coral habitats.



Acanthophora spicifera

Thallus is reddish-brown and cylindrical. It has a surface covered with blunt protrusions and lives on coral.

*Acanthophora muscoides*

Thallus is reddish-brown, with branches at the tip and occasionally in the middle. The surface has blunt protrusions, and it thrives on muddy sand.

*Acanthophora dendroides*

Thallus is reddish-brown, with few branches and blunt protrusions on the surface. Its habitat is muddy sand.

*Ceramium kondoi*

Thallus is dark red in fine strands arranged as a carpet on the surface of coral rocks.

*Amphiroa misakiensis*

Thallus is dark red, with a hard tube, and lives in coral habitats.

*Amphiroa fragilissima*

Thallus is blackish-red and slightly stiff while it inhabits coral habitat.

*Jania adherens*

Thallus is dark red, slightly stiff, and resides in coral habitats.

*Gracilaria arcuata*

Thallus is green, in the form of stolons, with soft branches along its length, and thrives in muddy sand habitat.

*Gracilaria coronopifolia*

Thallus is light green, in the form of stolons, and has soft branches. Branching converging towards the base, repetitive, and irregularly alternating. It is found in muddy sand habitats.

*Gracilaria lichenoides f. coronopifolia*

The red thallus is in the form of stolons with soft branches. Branching converging towards the base, repetitive, and irregularly alternating. It resides in muddy sand habitats.

*Gracilaria salicornia*

Thallus is yellowish-green, cylindrical, and smooth with septa. The branches are cylindrical, with the tip enlarged and rounded and the base slightly smaller. It has fine hair follicles on the septa and is found in rock and sandy habitats.

*Gigartina affinis*

Thallus is yellowish-green, cylindrical, and intertwined with one another. The surface is smooth but features many branches and is found in sand habitats.

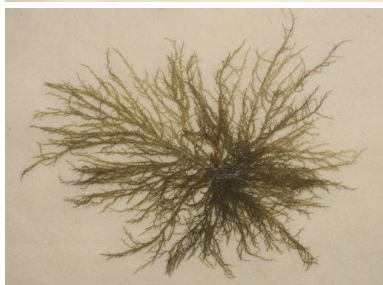


Gymnogongrus flabelliformis

Thallus is red and cylindrical, with soft branches on the tip, and resides in coral habitats.

*Hypnea cervicornis*

Thallus is green, in a small cylinder form, with irregular branches along it, and is found in muddy sand habitats.

*Halymenia floresii*

Thallus is dark red, flat, soft, with many branches, and often resides on coral surfaces.

*Plocamium ovicorne*

Thallus is bright red, in a small cylinder form, with small branches along its length, and is often found in coral habitats.

**Bangiophyceae***Porphyra crispata*

Thallus is brown in the form of sheets overlapping at the base and thrives on coral surfaces.



Borburema et al. (2021) also explain various studies on high temperatures that high seawater temperatures cause growth decline; high temperatures favor the evaporation rate, thus affecting the photosynthesis of macroalgae (Lamote et al. 2012). Moreover, temperature can affect photosynthesis and other metabolic pathways of seaweed since enzymatic activity depends on temperature (Lalegerie et al. 2015). Furthermore, according to Eggert (2012), seaweed responds to temperature in three ways: genetic adaptation to constant living ambient temperature, phenotypic acclimatization, or short-term physiological regulation in response to temporal temperature shocks.

High pH values cause the growth response of coralline macroalgae thallus to slow down (Cornwall et al. 2013). This is in line with the results of research that the morphometric type of Coralline macroalgae, namely *Galaxaura rugosa* (J.Ellis & Solander) J.V.Lamouroux 1816, which grows in locations with high seawater pH values, namely Hutumuri<Suli. Furthermore, Ji et al. (2016) explained that fluctuations in the pH of seawater against macroalgae specific to certain types and regions depend on their microhabitat. In general, it can be explained that macroalgae with the same species can have morphometric characteristics such as the full length of the whole body, length and width of the thallus, and branching, length, and width of holdfast have different characteristics due to exposure to different physicochemical environmental factors, this depends on the ability of the species to adapt and survive in these conditions. However, the species' distinctive features remain a species identity.

Although this study did not investigate the impact of biotic factors on morphometric characteristics, it is important to note that these factors play a significant role. Grazing pressure is one of them to be an influential biotic factor (Flores et al. 2015; Sampaio et al. 2017). There is a symbiotic relationship between macroalgae and coral reefs (Fulton et al. 2019; Monteil et al. 2020; Sura et al. 2021), as well as releasing exudates from macroalgae containing toxic substances to deter herbivores, larvae, or other macroalgae (Fong et al. 2019; Lenzo et al. 2023; Pezzolesi et al. 2021; Alvarez-Hernandez et al. 2019) are also important factors. Although these were not part of the scope of this study, they form the basis for future research.

Table 5. Morphometric measurements of macroalgae from Ambon Island, Maluku, Indonesia

Species	Location	Full length (µm)	Thallus width (µm)	Thallus length (µm)	Holdfast length (µm)	Holdfast width (µm)	Phylloid length (µm)	Phylloid width (µm)	Branching (µm)
<i>Boodlea coacta</i> (Dickie) G.Murray & De Toni 1889	Hutumuri	9736.41	6149.46	5460.79	3743.78	3546.51	nm	nm	nm
	Alang	7171.04	12632.72	7171.04	nm	nm	nm	nm	nm
<i>Boergesenia forbesii</i> (Harvey) Feldmann 1938	Suli	13755.52	5151.20	10041.24	2283.99	3272.16	nm	nm	nm
<i>Chaetomorpha crassa</i> f. <i>genuina</i> Schiffner nom. inval. 1938	Aer Low	936407.47	94861.33	930824.99	6481.55	7486.90	nm	nm	nm
<i>Dictyosphaeria versluysii</i> Weber Bosse 1905	Hutumuri	68146.38	14787.12	21962.15	19447.93	11555.98	nm	nm	nm
	Suli	93126.14	25852.37	29733.09	22684.46	24017.56	nm	nm	nm
<i>Dictyosphaeria cavernosa</i> (Forsskål) Børgesen 1932	Suli	105950.66	19922.60	27463.64	29835.84	29152.50	nm	nm	nm
<i>Bryopsis ryukyuensis</i> Yamada 1934	Aer low	918464.54	1090175.42	909152.12	4783.56	8128.96	nm	nm	nm
<i>Halimeda opuntia</i> (Linnaeus) J.V.Lamouroux 1816	Suli	143162.78	47485.22	139580.40	4144.77	5189.38	3462.53	2548.45	9867.78
<i>Caulerpa racemosa</i> var. <i>peltata</i>	Hutumuri	112003.38	1178.47	103817.97	6320.31	1131.33	5503.34	6637.33	32938.71
	Alang	798707.75	nm	nm	54038.35	5099.02	nm	nm	258489.76
	Suli	108497.98	1054.386	133074.73	11156.85	400.70	2567.33	2457.82	27221.70
<i>Caulerpa sertularioides</i> f. <i>farlowii</i> (Weber Bosse) Børgesen 1907	Suli	168732.99	1647.89	138378.78	47768.47	3134.13	25584.18	7603.53	49224.02
<i>Caulerpa serrulata</i> (Forsskål) J.Agardh 1837	Suli	176784.28	2353.99	169050.11	53367.57	3696.30	44061.36	41615.36	79621.75
<i>Enteromorpha prolifera</i> (O.F.Müller) J.Agardh, 1883	Suli	154202.41	1391.51	138980.21	13681.47	1447.77	nm	nm	nm
<i>Ulva lactuca</i> Linnaeus 1753	Alang	26523.25	40718.61	23690.60	3274.16	1730.05	nm	nm	nm
	Suli	30647.53	31189.60	28786.16	1710.689	842.76	nm	126063.77	
<i>Dictyota bartayresiana</i> J.V.Lamouroux 1809	Suli	42542.38	4491.29	33131.57	9320.41	5820.46	nm	nm	23786.00
<i>Padina crassa</i> Yamada 1931	Hutumuri	42502.53	45359.00	33460.45	8977.23	6529.90	nm	171422.57	nm
<i>Padina australis</i> Hauck 1887	Alang	25625.91	39591.63	23704.65	1534.36	3444.44	nm	113801.23	nm
	Suli	47767.66	50412.26	43435.26	4348.185	3974.33	nm	254767.04	nm
<i>Ectocarpus siliculosus</i> (Dillwyn) Lyngbye, 1819	Aer Low	49017.45	39935.90	46236.29	2773.62	3981.31	nm	nm	nm
<i>Sargassum crassifolium</i> J.Agardh 1848	Suli	121191.80	204196.10	111728.69	9338.13	11216.26	15887.21	9349.693	24043.48
<i>Sargassum polycystum</i> C.Agardh 1824	Hutumuri	33177.30	7919.85	27247.37	5424.43	361.55	nm	nm	6252.89
	Suli	77375.41	161429.50	72993.51	2593.91	5694.04	29799.37	8633.94	nm
<i>Turbinaria ornata</i> (Turner) J.Agardh 1848	Hutumuri	155015.41	55887.93	109556.75	54828.82	25403.09	22210.81	25216.40	nm
	Alang	1490756.02	1628562.98	694767.40	814102.59	40529.80	293265.37	480859.96	475697.84
	Suli	343735.44	96526.12	273656.71	63194.31	50478.49	20117.89	35947.33	47352.73
<i>Galaxaura rugosa</i> (J.Ellis & Solander) J.V.Lamouroux 1816	Hutumuri	16454.87	631.04	12826.68	511.95	882.55	nm	nm	8363.09
	Suli	26910.89	910.97	25750.56	954.67	1874.619	nm	nm	6031.73
<i>Acanthophora spicifera</i> (M.Vahl) Børgesen 1910	Hutumuri	36598.28	3826.96	34805.62	2009.35	1293.25	nm	nm	26704.71
<i>Acanthophora muscoides</i> (Linnaeus) Bory 1828	Suli	98297.9	5944.31	31663.96	3032.72	2969.34	nm	nm	19892.2
<i>Acanthophora dendroides</i> Harvey 1855	Suli	104731.26	5186.44	35367.62	7966.09	4752.01	nm	nm	15494.36
<i>Ceramium kondoi</i> Yendo 1920	Alang	17835.89	183.03	18519.44	1112.03	1026.09	nm	nm	1690.72
	Aer Low	46793.98	444.94	44799.22	1883.28	2717.58	nm	nm	40594.07
<i>Amphiroa misakiensis</i> Yendo 1902	Hutumuri	21695.81	572.52	20545.60	1296.72	1807.04	nm	nm	13202.54

<i>Amphiroa fragilissima</i> (Linnaeus) J.V.Lamouroux 1816	Hutumuri	22728.89	270.02	15110.94	1338.93	4004.69	nm	nm	8396.50
	Alang	49348.83	578.17	44449.05	2009.16	2008.36	nm	nm	5120.76
	Suli	15579.38	259.85	16058.92	2804.71	5208.27	nm	nm	6282.28
<i>Jania adherens</i> Lamouroux 1816	Alang	15268.29	13426.20	9847.57	12610.12	nm	2133.45	nm	1404.42
<i>Gracilaria arcuata</i> Zanardini 1858	Suli	106944.72	127239.57	17362.60	91515.27	3279.65	nm	nm	36810.56
<i>Gracilaria coronopifolia</i> J.Agardh 1852	Suli	203235.21	1593.82	18246.42	1321.01	879.96	nm	nm	59527.59
<i>Gracilaria lichenoides</i> f. <i>coronopifolia</i> (J.Agardh) V.May 1948	Suli	87531.24	1813.62	38609.70	1153.74	1449.07	nm	nm	46242.04
<i>Gracilaria salicornia</i> (C.Agardh) E.Y.Dawson 1954	Hutumuri	47877.46	2708.34	35986.25	4520.80	7722.54	nm	nm	18968.72
	Suli	57164	2941.67	21693.07	4115.87	2715.93	nm	nm	22337.72
<i>Gigartina affinis</i> Harvey 1860	Suli	72084.18	1182.14	10020.24	nm	nm	nm	nm	4943.35
<i>Gymnogongrus flabelliformis</i> Harvey 1857	Alang	50175.87	1578.09	48420.01	1469.69	3205.48	nm	nm	36509.41
	Aer Low	43239.89	1546.19	38713.05	3369.45	4564.10	nm	nm	13594.75
<i>Hypnea cervicornis</i> J.Agardh 1851	Suli	176147.04	1211.36	75683.39	742.97	495.66	nm	nm	63404.38
<i>Halymenia floresii</i> (Clemente) C.Agardh 1817	Suli	198836.27	10875.1	189415.06	9301.89	26223.50	nm	nm	nm
<i>Plocamium ovicorne</i> Okamura 1896	Suli	20071.21	863.77	18094.12	1828.40	1446.35	nm	nm	5993.23
<i>Porphyra crispata</i> Kjellman 1897	Aer Low	59926.31	56732.72	34063.60	2602.73	3293.75	nm	285086.93	nm

Note. Nm: not measured

Table 6. The relationship between physicochemical environmental factors to macroalgae morphometric characteristics in study sites of Ambon Island, Maluku, Indonesia

Morphometric characteristics	Multiple R-Squared	Adjusted R-Squared	F-value	p-value ($p < 0.05$)	Effective contribution
Hutumuri					
Full length	0.57	0.2833	1.988	0.022 ^(*)	28.33
Thallus width	0.4801	0.1336	1.385	0.034 ^(*)	13.36
Thallus length	0.1749	0.009875	1.06	0.040 ^(*)	0.9875
Holdfast length	0.7111	0.5185	3.692	0.050 ^(*)	51.85
Holdfast width	0.6161	0.3601	2.407	0.016 ^(*)	36.01
Alang					
Length	0.5688	0.2239	1.649	0.029 ^(*)	22.39
Thallus Width	0.6809	0.4256	2.667	0.015 ^(*)	42.56
Thallus Length	0.671	0.4077	2.549	0.016 ^(*)	40.77
Holdfast Length	0.6922	0.446	2.811	0.014 ^(*)	44.6
Holdfast Width	0.3802	-0.1156	0.7669	0.018 ^(*)	-11.56
Aer Low					
Length	0.7623	-0.1883	0.8019	0.037 ^(*)	-18.83
Thallus Width	0.9932	0.9661	36.61	0.013 ^(*)	96.61
Thallus Length	0.76	-0.1999	0.7918	0.016 ^(*)	-19.99
Holdfast Length	0.5861	-1.069	0.3541	0.032 ^(*)	-106.9
Holdfast Width	0.7117	-0.4417	0.617	0.028 ^(*)	-44.17
Suli					
Length	0.1939	0.03273	1.203	0.030 ^(*)	3.273
Thallus Width	0.1336	-0.03965	0.7712	0.050 ^(*)	-3.965
Thallus Length	0.671	0.4077	2.549	0.023 ^(*)	40.77
Holdfast Length	0.01578	-0.1811	0.08016	0.018 ^(*)	-18.11
Holdfast Width	0.9241	0.9089	60.87	0.006 ^(*)	90.89

In conclusion, this study identified 52 individuals from 37 species of macroalgae distributed across the coastal waters of Ambon Island, with various morphological and morphometric characteristics. Additionally, the physicochemical parameters of seawater, including temperature, salinity, pH, and DO, had significant simultaneous relationships with total length, thallus width, thallus length, holdfast length, and holdfast width, some being positive while others were negative. Other researchers have not previously reported findings on morphological and morphometric analysis of macroalgae from the island of Ambon. Therefore, current research recommends that future research focus on exploring macroalgae species on other islands in Maluku Province, utilizing macroalgae as raw materials for food, industry, and medicine, which will generate additional economic value. Therefore, it will increase macroalgae products into marine natural products and increase the sustainability and conservation of macroalgae typical of Maluku Province. Several types of macroalgae from Ambon island from the genera *Hypnea*, *Halymenia*, *Gymnogongrus*, *Gracilaria*, *Caulerpa*, and *Dictyosphaeria* have the potential to be studied and utilized. This is based on several studies that the use of *Saccharina japonica*, *Ulva rigida*, and *Porphyra dioica* as ingredients enriches the taste of chocolate in Portuguese (Salgado et al. 2023); *Laminaria* sp; *Sargassum muticum* and *Undaria pinnatifida* are sources of iodine (Badocco et al. 2017); *Gracilaria* sp. as artificial nori (Sari et al. 2019); *Sargassum polycystum*, *Turbinaria ornata* and *Padina boryana* are the sources of fucoidan, laminarin and alginate (Fauziee et al. 2023); Gelidiaceae,

Gracilariaceae, Gelidiellaceae and Pterocladaceae are groups of red macroalgae that are sources of alginate and carrageenan (Lee et al. 2017). Implications of the study's findings for conserving and cultivating macroalgae in Ambon Island are habitat maintenance (Swan et al. 2016), Reef to Ridge (R2R) (Vieira et al. 2021), while cultivation of macroalgae through fragmentation of talus or stolon (Moreira et al. 2022).

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