ABUNDANCE AND DIVERSITY OF SEAWEED IN THE COASTAL AREA OF SOUTH ACEH REGENCY, ACEH PROVINCE

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Abstract: The coastal area of South Aceh has a high level of biodiversity, one of which can be found in seaweed which plays an essential ecological and economic role. It is important to recognize the existence and diversity of seaweed as a source of data for optimal development. The present study aims to determine the composition, abundance and diversity of seaweed in the research area. It was conducted between February and October 2021. A combination of line transect and quadratic transect research methods was employed at six research locations across South Aceh's coastal area, i.e.: Keumumu Hilir, Paya Peulemat, Ujong Nibong, Ujong Seurudong, Gunong Cut, and Pulo Dua. The findings exhibit a total of 32 species of seaweed, consisting of 11 species of the *Chlorophyceae* class, 11 of the *Phaeophyceae* class, and 10 of the *Rhodophyceae* class. Several seaweed species are found in the highest abundance (>20%) on the coast of South Aceh, namely *Sargassum oligocystum*, *Amphiroa foliacea*, *Sargassum plagiophyllum*, *Amphiroa fragilissima*, and *Halimeda opuntia.* The environmental conditions in this coastal area, based on the water quality index measured using the pollution index method, indicate the quality status of light pollution. The diversity index values range between 1.500 and 2.327 with an average of 1.949, considered as the moderate category of community diversity and stability. The uniformity index values range from 0.721 to 0.891, with an average of 0.804, considered as the high category of uniformity. The dominance index values range between 0.138 and 0.306, with an average of 0.201, considered as the low category of dominance. These conditions represent that the level of stability of the seaweed community in the coastal area of South Aceh Regency is considered good and stable. This can be referred to as a data source for biodiversity information in science, development and sustainable management of coastal areas.
Keywords: abundance; diversity; seaweed; South Aceh

Abstrak: Pesisir Aceh Selatan memiliki potensi keanekaragaman hayati yang sangat beragam, salah satunya adalah rumput laut yang memiliki peranan dari sisi ekologi dan ekonomi. Keberadaan dan keragaman rumput laut sangat penting untuk diketahui sebagai sumber data untuk dikembangkan secara optimal. Penelitian ini bertujuan untuk mengetahui komposisi, kelimpahan, dan keragaman jenis rumput laut. Penelitian ini dilaksanakan pada bulan Februari hingga Oktober 2021. Metode yang digunakan adalah kombinasi metode transek garis dengan transek kuadrat pada enam lokasi penelitian di kawasan pesisir Aceh Selatan, yaitu: Keumumu Hilir, Paya Peulemat,

Ujong Nibong, Ujong Seurudong, Gunong Cut, dan Pulo Dua. Hasil penelitian ditemukan 32 spesies rumput laut, dengan komposisi kelas *Chlorophyceae* 11 spesies, kelas *Phaeophyceae* 11 spesies, dan kelas *Rhodophyceae* 10 spesies. Spesies rumput laut yang ditemukan dengan kelimpahan tertinggi (>20 %) di kawasan pesisir Kabupaten Aceh Selatan adalah *Sargassum oligocystum, Amphiroa foliacea, Sargassum plagiophyllum, Amphiroa fragilissima,* dan *Halimeda opuntia.* Kondisi lingkungan di kawasan pesisir Aceh Selatan berdasarkan hasil pengukuran indeks kualitas air dengan penentuan metode indeks pencemaran menunjukkan status mutu cemar ringan. Nilai indeks keanekaragaman berkisar antara 1,500-2,327 dan rata-rata 1,949 dengan kategori keanekaragaman dan kestabilan komunitas sedang. Nilai indeks keseragaman berkisar antara antara 0,721-0,891 dan rata-rata 0,804 dengan kategori keseragaman yang tinggi. Nilai indeks dominansi berkisar antara 0,138-0,306 dan rata-rata 0,201 dengan nilai kategori dominansi rendah. Kondisi ini menggambarkan tingkat kestabilan komunitas rumput laut di kawasan pesisir Kabupaten Aceh Selatan tergolong baik dan stabil untuk kehidupan rumput laut. Hal ini menjadi rujukan sumber informasi keanekaragaman hayati dalam ilmu pengetahuan, pengembangan dan pengelolaan kawasan pesisir yang berkelanjutan.

Keywords: kelimpahan: keanekaragaman; rumput laut; Aceh Selatan

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Introduction

The coastal area of South Aceh Regency is mostly in the form of exposed coral reefs which become the habitat of various marine biotas, one of which is seaweed (Fitria et al., 2019). South Aceh is part of southern Aceh's coastal areas which has a distribution of coral reefs (Herdiana et al., 2010). The types of coral reefs located in South Aceh waters include fringing reefs and flat reefs or charred reefs (DKP Aceh, 2020). The distribution of coral reefs in this area is classified as good, based on research that shows a high percentage of hard coral cover, i.e. 51–75% (Bahri et al., 2020). This condition strongly supports the life of seaweed. Seaweed is often found in locations with flat coral reefs, as its distribution and abundance depend on the type of bottomwater as the substrate. (Kasim, 2016). Seaweed grows wild and spreads in several coastal areas with coral reefs, and no seaweed cultivation activity has been found on the coast of South Aceh to date.

Previous research reveals 23 species of seaweed are discovered across the waters of South Aceh Bay, including in Pasar Lama Labuhan Haji, Lhok Pawoh Sawang, Pantai Bidari & Batee Tunggay Samadua, Batu Merah & Lhok Rukam Tapaktuan (Fitria et al., 2019) as well as 11 species in the waters of Air Berudang Tapaktuan *(*Ulfah et al., 2017), where the condition of the seaweed community is considered stable, with a medium diversity and low dominance index. However, South Aceh has a total beach length of ±169 km and has not been fully researched regarding the level of abundance and diversity of seaweed, despite not all locations being inhabited by seaweed. Only coastal areas with coral reefs become

seaweed habitats. Several coastal sub-districts in South Aceh Regency, according to the researchers' observations, have coral reef potential, with a total beach length of ±75 km, including Labuhan Haji, Labuhan Haji Timur, Meukek, Sawang, Samadua, Tapaktuan, Bakongan, and Bakongan Timur Sub-districts. Prior research was conducted in coastal villages with a total beach length of ±10.46 km (11% of the entire beach length that has the potential for coral reefs); while the coastal villages where the present research occurred have a total beach length of ±12.6 km (13% of the entire beach length with coral reef potential) using satellite imagery (Google Earth, 2022). The researchers focused on the spots that have never been studied so that the data obtained is more even. Thus, the locations on the coast of South Aceh that were selected as the present research object are areas that have coral reefs which are seaweed habitats, including Keumumu Hilir and Paya Peulemat Labuhan Haji Timur, Ujong Nibong Meukek, Ujong Seurudong Sawang, Gunong Cut Samadua, and Pulo Dua Bakongan Timur.

It is necessary to recognize the abundance and diversity of seaweed as well as environmental conditions that serve as seaweed habitats to be the basis for determining marine biodiversity in the coastal area of South Aceh, both from an ecological and economic perspective. Ecologically, the abundance and diversity of seaweed have an impact on the balance of marine ecosystems and indirectly impact humans, especially in the fisheries sector. High diversity of seaweed leads to high biological productivity in the ecosystem because seaweed acts as a primary producer as well as a shelter and spawning site for marine biota and plays a vital role as a carbon absorber. Economically, seaweed constitutes a superior fishery commodity since it is an excellent source of phycocolloids (jelly, alginate, and yeast) which are widely used to make products in food, cosmetics, pharmaceutical and other industries (Handayani, 2019). The nutritional content in seaweed, including polysaccharides and fibre, minerals, vitamins, proteins, lipids and fatty acids, vitamins, and polyphenols, is the basis for its use in the health sector (Suparmi & Sahri, 2013).

The information above can be a determining indicator for implementing policies related to maintaining the coastal environment from an ecological perspective and managing the use of coastal areas from an economic perspective sustainably. The present study aims at examining the abundance and diversity of seaweed in the coastal area of South Aceh Regency, Aceh Province so that it can be a reference in science, development and sustainable management of coastal areas.

Methodology

Research location and time

The study was conducted in February–October 2021. It took place in the coastal area of South Aceh Regency, Aceh Province (Figure 1). The station I was appointed on Pantai Keumumu Hilir, Labuhan Haji Timur Sub-district (N 03° 30'

49.90" E 097° 01' 11.63"); Station II on Pantai Paya Peulemat, Labuhan Haji Timur Sub-district (N 03° 29' 54.42" E 097° 01' 32.21"); Station III on Pantai Ujong Nibong, Meukek Sub-district (N 03° 25' 54.58" E 097° 03' 46.39"); Station IV on Pantai Ujong Seurudong, Sawang Sub-dictrict (N 03° 24' 57.64" E 097° 04' 23.22"); Station V on Pantai Gunong Cut, Samadua Sub-district (N 03° 19' 04.22" E 097° 07' 59.67"); and Station VI on Pantai Pulo Dua, Bakongan Timur Sub-district (N 02° 52' 58.94" E 097° 31' 03.71").

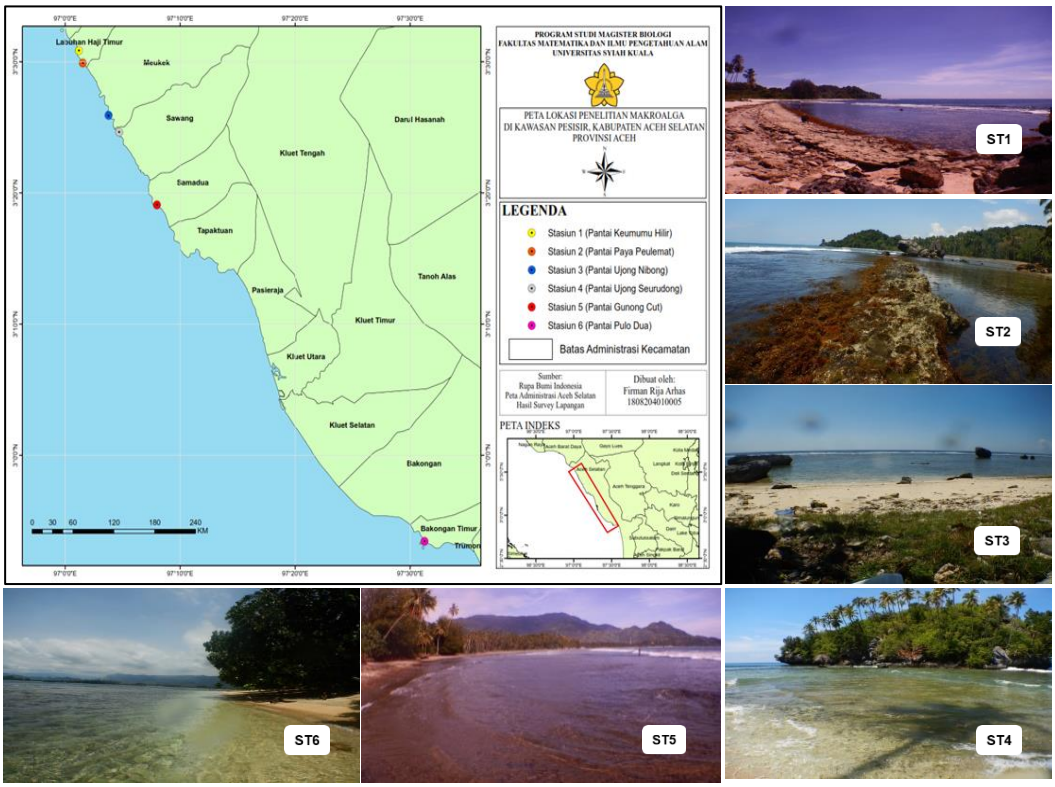

Figure 1. Map of research locations in the coastal area of South Aceh

The selection of research locations was focused on areas with coral beaches, especially flat reefs in the intertidal zone. Moreover, sampling points were determined based on the bottom substrate of the waters, which forms coral, rocky, marine sedimentation (coral fragments, gravel and sand), and other mixed substrates, sighted through direct or visual observations. All the locations studied have substrates suitable to support seaweed habitat.

Research method

Observation and sampling methods cover a combination of line transect and quadratic transect methods. Line transects were utilized to describe community structure; and quadrat transects to monitor marine biota communities (Fachrul, 2007). Line transects were placed perpendicular to the beach from the highest tide point to the lowest one, and measured using a roll meter; while quadrat transects

were placed along the line transects using observation plots. At each station, 4 observation transects were placed, with each transect line 50 m long located in the intertidal zone. Each transect was 20 m apart. Within the transect line, 5 quadrats with a size of 1x1 m^2 were determined, with a distance of 10 m from each square plot. Each station was equipped with 20 quadrat transects, so 120 of them were placed in South Aceh's coastal area.

Research tools and materials

The tools and materials employed in this research consist of physicochemical parameter measuring instruments, supporting equipment, and materials as presented in Table 1 below:

Table 1. Research Tools and Materials

Tool/Material	Specification (Brand)	Parameter	Unit	Test Method
Physical				
Thermometer	Lutron YK-2005WA	Temperature	^{0}C	SNI 06-6989.23-2005
Turbidity meter	Lutron TU-2016	Turbidity	NTU	Turbidimetry
Current meter	Flowatch FL-03	Current speed	m/s	SNI 3408:2015
Chemical				
Refractometer	ATC	Salinity	$^0/_{00}$	Refractometry
pH Meter	Lutron YK-2005WA	pH	-	SNI 6989.11-2019
Do Meter	Lutron DO-5512SD	Dissolved oxygen	Mg/l	Membrane Electrode
Spectrophotometer	AELAB	Nitrate & phosphate	Mg/l	Spectrophotometry
BOD Incubator	Wiggens	BOD	Mg/l	SNI 6989.72-2009
Supporting Equipment				
Garmin GPS maps	Garmis 64S	Location point	-	-
Winkler bottle	Pyrex	BOD sample bottle	-	-
Pipeline Plot	-	Quadrat transect	M	-
Roll meters	-	Line transect	M	-
Digital camera	Nikon D5100	Documentation	-	-
Underwater camera	Nikon Coolpix W300	Documentation	-	-
Diving goggles	TafSPORT	Pengamatan sampel	-	-
Microscope	Olympus SZ2-ILST	Sample identification	-	-
Sample bottle	-	Water sample container	-	-
Sample bag	Klip 20x12 cm	Sample container	-	-
Cooler box	Marina cooler 12S	Sample box	-	-
Styrofoam ice box	-	Water sample box		-
10 Liter plastic bucket	-	Sample washing container		-
Surgical tools	Gold cross	Sample incision	-	-
Material				
Formaldehyde 4%	Karchem	Sample preservation	-	-
Alcohol 70%	Local	Sample storage	-	-
Aquadest	Local	Equipment cleaner		-
Label	-	Sample naming	-	-
Nitrate reagent	HI3874	Sample test material	-	-
Phosphate reagent	HI3833	Sample test material	-	-

Data collection procedures

The seaweed species found in each observation plot at each station were recorded and counted for the number of individuals. Samples were taken selectively to represent the populations with the following characteristics: having complete thallus parts in the form of holdfast, stipe and blade. The selected seaweed specimens were then placed in a 10 liter plastic bucket containing seawater so that the particles at the bottom were released. The water was filtered with a sieve to make it clean and then used to wash the samples. After washing, the different specimens were separated from each other, and collected in a 20 x 12 cm clip sample bag and packaged with a label containing the specific date and location. The number of samples taken must be sufficient for identification and making a herbarium. Sample information and location coordinates were recorded in the observation table. Afterwards, the samples were given a 4% formalin solution in order to keep them from being easily damaged and then put in a cooler box for temporary storage. Next, the samples were taken to the laboratory and given a replacement solution in the form of 70% alcohol for storing the herbarium samples. Sample identification was undertaken at the Botany Laboratory of the Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala. It was carried out by examining various morphological characteristics and matching them with identification books, journals, web pages and other relevant references. The references used include *Seaweed of India* (Jha et al., 2009), *Sri Lankan Seaweeds* (Coppejans et al., 2009), *Field Guide of Marine Macroalgae of Kuwait* (Al-Yamani et al., 2014), *Useful Marine Plants of the Asia-Pacific Region Countries* (Titlyanov et al., 2018), Rumput laut Indonesia (Kasanah & Triyanto, 2015), and *Macoi Portuguese Seaweeds* (Pereira et al., 2014).

Environmental parameters were measured both in the field and in the laboratory. Measurements on each transect at each research location were conducted directly in the field, consisting of temperature measurement using the SNI 06-6989.23-2005 method, current speed using the SNI 3408:2015 method, pH Meter using the SNI 6989.11-2019 method, dissolved oxygen using the electrode membrane method, turbidity using the turbidimetric method in accordance with ISO 7027 standards, and salinity using the refractivity method. Meanwhile, the remaining parameters required laboratory tests, including biological oxygen demand using the SNI 6989.72-2009 method, and nitrate and phosphate test using the spectrophotometric method with a UV vis spectrophotometer.

Data analysis

The data obtained were analyzed qualitatively and quantitatively. The qualitative analysis includes examining seaweed species composition; and quantitative ones include species abundance index (K), Shannon-Winner diversity

index (H'), Evennes uniformity index (E), Simpson dominance index (C), and water quality index. The abundance index is calculated using the following formula:

$$\mathbf{D} = \frac{ni}{N} \mathbf{x\ 100\ \%} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where: D = relative species abundance (%), ni = number of individuals of each species, N = total individuals of all species. Abundance index criteria: high (>20%), medium (15%-20%), and low (<15%) (Ludwig & Reynolds, 1988). Seaweed diversity is calculated using the Shannon-Wienner index (H') as follows:

$$\mathbf{H' = -\sum (Pi)\ (lnPi)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where: H' = diversity index, Pi = ni/N, comparison of the number of individuals of the i-th species (ni) with the total number of seaweed individuals (N), ni = number of individuals of the I-th species, N = total number of individuals. Index criteria: H'< 1 = low diversity, 1< H'< 3 = medium diversity, H'>3 = high diversity (Ludwig & Reynolds, 1988). Uniformity index (evenness) is calculated using the formula below:

$$\boldsymbol{E = \frac{H'}{Hmax}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where: *E* = uniformity index (range: 0–1), *H'* = Shannon-Wienner uniformity index, *Hmax* = maximum species diversity (Ln *S*), *S* = number of species (Krebs, 1989). Criteria: E < 0.4 = low population uniformity, 0.4 < E < 0.6 = medium population uniformity, E > 0.6 = high population uniformity (Odum, 1996). The dominance index can be calculated with the Simpson dominance index formula:

$$\mathbf{D = \sum (ni / N)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where: n_i = number of individuals of the I-th species, N = total number of individuals, Dominance index ranges from 0 to 1, with criteria: $0.00 < D \leq 0.50$ = low dominance, $0.50 < D \leq 0.75$ = medium dominance, $0.75 < D \leq 1.00$ = high dominance (Odum, 1996).

For physicochemical environmental parameters, an analysis of the Water Quality Index was calculated through the Pollution Index (IP) method with the following formula:

$$\mathbf{PIj} = \sqrt{\frac{\mathbf{(Ci/Lij)M^2 + (Ci/Lij)R^2}}{\mathbf{2}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where: Ci = concentration of water quality parameters (i) obtained from the water sample analysis, Lij = concentration of water quality parameters included in the water allocation standards (j). (Ci/Lij)R value = average Ci/Lij value, and (Ci/Lij)M value = maximum Ci/Lij value. Therefore, Pij = pollution index for allocation (j) which is a function of Ci/Lij. The Pollution Index (IP) criteria include: $0 \leq PIj \leq 1.0$ = meets quality standards (good condition), $1.0 < PIj \leq 5.0$ = lightly polluted, $5.0 < PIj \leq 10$ = moderately dirty, PIj > 10 = heavily polluted (Keputusan Menteri Negara Lingkungan Hidup Nomor 115 Tentang Pedoman Penentuan Status Mutu Air, 2003).

Results and Discussion

Composition and abundance of seaweed species

The findings show a total of 32 species of seaweed discovered in the coastal area of South Aceh, consisting of 11 species of the *Chlorophyceae* class, 11 of the *Phaeophyceae* class, and 10 of the *Rhodophyceae* class (Table 2). This number is much higher than what previous research found in the waters of Teluk Tapaktuan, South Aceh Regency (Pasar Lama Labuhan Haji, Lhok Pawoh Sawang, Pantai Bidari and Batee Tunggay Samadua, Batu Merah and Lhok Rukam Tapaktuan), i.e. 23 species (Fitria et al., 2019), as well as in the waters of Air Berudang Tapaktuan, i.e. 11 species (Ulfah et al., 2017). As the present research was conducted in different locations which had never been studied, different species were newly discovered.

Table 2. Composition and abundance of seaweed species in the coastal area of South Aceh Regency

Seaweed Species	Species Abundance Index (%)					
	STI	ST2	ST3	ST4	ST5	ST6
***Chlorophyceae* (Green Algae)**						
Boergesenia forbesii (Harvey) Feldmann 1938	0.61	6.41	2.87	6.76	11.15	-
Dictyosphaeria cavernosa (Forsskål) Børgesen 1932	1.47	6.54	-	-	-	-
Valoniopsis pachynema (G.Martens) Børgesen 1934	-	1.28	3.49	4.35	-	-
Cladophora catenata Kützing 1843	-	-	17.45	-	1.50	-
Chaetomorpha antennina (Bory) Kutzing 1847	-	-	-	-	2.16	-
Halimeda opuntia (Linnaeus) J.V. Lamouroux 1816	2.08	-	14.78	-	-	49.58
Halimeda macrophysa Askenasy 1888	-	-	7.39	-	-	-
Caulerpa taxifolia (M.Vahl) C.Agardh 1817	-	-	-	-	5.49	-
Caulerpa racemosa var macrophysa (Sonder ex Kützing) W.R.Taylor 1928	-	-	-	-	-	18.22
Tydemania expeditionis Weber Bosse 1901	-	-	-	-	2.50	-
Ulva compressa (Linnaeus) Nees 1820	-	-	-	4.35	-	-
***Phaeophyceae* (Brown Algae)**						
Sargassum oligocystum Montagne 1845	23.38	12.95	-	-	-	-
Sargassum plagiophyllum C.Agardh 1824	2.69	37.95	-	4.83	2.00	-
Sargassum aquifolium (Turner) C.Agardh 1820	12.85	-	-	3.38	1.00	-
Sargassum illicifolium (Turner) C.Agardh 1820	6.00	7.44	-	-	3.66	-
Sargassum echinocarpum J.Agardh 1848	-	-	-	5.31	-	-
Hormophysa cuneiformis (J.F.Gmelin) P.C.Silva 1987	-	0.64	-	-	-	-
Cystoseira indica (Thivy & Doshi) Mairh 1968	0.98	-	-	-	-	-
Turbinaria decurrens Bory C 1828	15.62	-	2.87	10.63	0.33	-
Padina australis Hauck 1887	2.45	17.69	6.16	-	18.97	-
Padina boryana Thivy 1966	1.35	-	-	-	2.00	-
Dictyota bartayresiana JV Lamouroux 1809	-	-	-	-	0.33	-
***Rhodophyceae* (Red Algae)**						
Amphiroa foliacea J.V.Lamouroux 1824	20.69	-	20.74	46.86	-	5.08
Amphiroa fragilissima J.V.Lamouroux 1824	-	4.87	5.95	-	26.46	0.85
Gelidiella acerosa (Forsskal) Feldmann & Hamel 1934	2.45	4.23	16.43	13.53	8.49	10.59

Seaweed Species	Species Abundance Index (%)					
	STI	ST2	ST3	ST4	ST5	ST6
Hypnea pannosa J. Agardh, 1847	7.59	-	-	-	-	10.59
Actinotrichia fragilis (Forsskal) Borgesen 1932	-	-	1.85	-	-	-
*Tricleocarpa fragilis (*Linnaeus) Huisman & R.A.Townsend 1993	-	-	-	-	4.16	-
Champia parvula (C.Agardh) Harvey 1853	-	-	-	-	2.16	-
Gracilaria canaliculata Sonder 1871	-	-	-	-	1.33	0.85
Acanthophora spicifera (M.Vahl) Børgesen 1910	-	-	-	-	-	4.24
Griffithsia japonica Okamura 1930	-	-	-	-	6.32	-

The composition of seaweed species found in this area not only has ecological benefits in its habitat but is also economically beneficial. Some of them include the *Sargassum* genus, which plays a role in producing alginate which is used in the food, medicine and cosmetics industries (Cokrowati et al., 2021); *Padina* and *Turbinaria decurrens* genera producing alginate (Kadi, 2005); *Gelidiella acerosa* producing jelly/gelatin and *Acanthophora spicifera* producing carrageenan (Kadi, 2004) which are widely used as raw materials for food, medicine, and cosmetics. This serves as information for utilizing resources and developing seaweed cultivation in the future.

Moreover, the abundance as shown in Table 3 denotes the species with the highest abundance and those with the lowest one at each station. This indicates that each location has unique features diverse substrate characteristics and different environmental conditions. The structure of the bottom substrate of the water strongly determines the variety of macroalgae species that can be found in the location (Ayhuan et al., 2017). Besides, the physical and chemical conditions of water greatly influence the existence and abundance of a species (Mornaten, 2019). Several seaweed species are found in the highest abundance (>20%) on the coast of South Aceh, namely *Sargassum oligocystum, Amphiroa foliacea, Sargassum plagiophyllum, Amphiroa fragilissima,* and *Halimeda opuntia.* Meanwhile, species with medium abundance are at a percentage of 15%–20%, and those with low abundance are at <15%.

Sargassum oligocystum is the species with the highest abundance at Station I (Keumumu Hilir) with a percentage of 23.38%, as is *Sargassum plagiophyllum* at Station II (Paya Peulemat) with a percentage of 37.95%. This is due to the favorable conditions and suitable substrate with flat coral reef habitats found at Stations I and II. *Sargassum oligocystum* is detected in abundance at Station I, forming large communities on the rocks of the intertidal and subtidal zones along the coastline on flat reefs; as is *Sargassum plagiophyllum* at Station II, which is dominant along areas of dead coral and intertidal to subtidal rocks and tide pools. The *Sargassum* genus has a disc-shaped holdfast that can attach and grip hard substrates in the form of dead coral and intertidal rocks in flat coral reef habitats so that it can survive exposure to high waves. As mentioned by Kadi (2005), *Sargassum* grows dominantly in stretches of coastal waters in the flat reef

exposure zone, starting from the coastline to the tip of the edge, including in intertidal and subtidal waters with basic substrates in the form of coral rocks, dead coral, volcanic rocks, and massive objects that occupy the bottom waters. *Sargassum* thrives in the ocean or along coasts with coral reef bottoms and strong tides in both tropical and subtropical oceans (Rosado-Espinosa et al., 2020).

Amphiroa foliacea is the species with the highest abundance at Station I (Keumumu Hilir) with a percentage of 20.69%, Station III (Ujong Nibong) with a percentage of 20.74%, and Station IV (Ujong Seurudong) at 46.86%. Its abundance at these three stations is due to the supporting characteristics of the habitat and substrate. *Amphiroa foliacea* lives on hard substrates such as live coral, dead coral, and rocky areas, especially on flat reefs. This is in line with Titlyanov et al. (2018), suggesting that *Amphiroa foliacea* grows on rocks, stones, and dead coral colonies, from intertidal to subtidal areas and from protected areas to places with moderate waves. *Amphiroa foliacea* contains lime deposits (calcium carbonate) which are associated with coral reefs, so it is also called coralline algae. As stated by Pondaag et al. (2022), coralline algae are red algae that own extracellular calcium carbonate and are known to be important organisms in coral reef ecosystems. *Amphiroa fragilissima* is considered the species with the highest abundance at Station V (Gunong Cut) with a percentage of 26.46%. This is possible as the species lives on both hard substrates (dead coral or rocks) and soft substrates (a mixture of gravel and sand) in the exposure zone of flat reefs. *Amphiroa fragilissima* has a disc holdfast shape, which is a crust that can adhere to a hard substrate and stick to the sand base with a wide distribution (Romimohtarto & Juwana, 2009).

Halimeda opuntia is found to be the species with the highest abundance at Station VI (Pulo Dua) with a percentage of 49.58 %. This is due to the suitability of the habitat and substrate inhabiting the coral reef areas, including dead coral substrates and dead coral fragments (rubble). Since the characteristics of the habitat and substrate are suitable for the life of *Halimeda opuntia*, especially dead coral fragments or rubble, this species can grow and develop in large numbers in groups in this area. As mentioned by Ain et al. (2014), *Halimeda* is the macroalgae that is most commonly found on coral rubble substrates. Also, *Halimeda opuntia* can grow on various substrates because of its relatively high adaptability (Sandy et al., 2021).

Aquatic environmental parameters

A number of environmental parameters influencing seaweed life were measured and are presented in Table 3. Quality standards for environmental parameters refer to Indonesian Government Regulation No. 22 of 2021 concerning the implementation of environmental protection and management in the category of seawater quality standards. Previous research shows that the water conditions of Air Berudang Tapaktuan cover a temperature range of 25–30^{o}C, a

salinity of 30–35‰, and a pH of 8 (Ulfah et al., 2017), while in the waters of Teluk Tapaktuan of South Aceh Regency, no environmental parameter data is found (Fitria et al., 2019).

Table 3. Average water environmental parameters in South Aceh

Environmental Parameters	Research Station						Quality standards
	ST1	ST2	ST3	ST4	ST5	ST6	
Temperature	32 ± 0.95	32 ± 1.53	32 ± 1.39	32 ± 0.69	29 ± 0.51	31 ± 0.56	28-32°C
Turbidity	0.8 ± 0.50	0.3 ± 0.16	0.4 ± 0.20	0.5 ± 0.25	0.5 ± 0.18	0.3 ± 0.16	5 NTU
Flow Speed	0.2 ± 0.09	0.3 ± 0.12	0.2 ± 0.11	0.3 ± 0.15	0.2 ± 0.09	0.3 ± 0.12	0.2–0.3 m/s
Salinity	30.4 ± 0.59	30.5 ± 0.76	30.8 ± 0.83	30.2 ± 0.37	30.7 ± 0.81	30.8 ± 1.07	28–34‰
pH	9.0 ± 0.77	9.3 ± 0.32	9.5 ± 0.06	9.4 ± 0.10	9.4 ± 0.11	9.5 ± 0.08	7–8.5
DO	5.4 ± 1.00	5.2 ± 0.32	5.3 ± 0.79	5.0 ± 0.25	5.3 ± 0.18	5.5 ± 0.43	.> 5 mg/l
Nitrate	0.6 ± 0.03	0.8 ± 0.34	1.5 ± 0.33	1.5 ± 0.05	0.9 ± 0.22	0.9 ± 0.07	0.06 mgl
Phosphate	0.2 ± 0.10	0.07 ± 0.01	0.06 ± 0.06	0.05 ± 0.03	0.09 ± 0.08	0.06 ± 0.02	0.015 mg/l
BOD	2.0 ± 0.76	3.6 ± 3.58	2.1 ± 1.10	1.6 ± 0.19	2.2 ± 1.12	1.7 ± 1.34	20 mg/l

Average measurements of environmental parameters in South Aceh's coastal areas have been commonly obtained based on seawater quality standards of Indonesian Government Regulation No. 22 of 2021. However, there are slight differences in pH, nitrate and phosphate which exceed the quality standards, thus affecting the water quality index (Table 4). Water is said to be polluted if it cannot be utilized according to its normal use (Hamuna et al., 2018).

Table 4. Sea water quality index via the Pollution Index (IP) method in the South Aceh coastal area

Research Station	Pollution Index (IP)	Quality Status
ST1 (Pantai Keumumu Hilir)	4.9	Lightly Polluted
ST2 (Pantai Paya Peulemat)	4.8	Lightly Polluted
ST3 (Pantai Ujong Nibong)	5.0	Lightly Polluted
ST4 (Pantai Ujong Seurudong)	5.0	Lightly Polluted
ST5 (Pantai Gunong Cut)	4.3	Lightly Polluted
ST6 (Pantai Pulo Dua)	4.3	Lightly Polluted

Determination of the quality status of the Pollution Index (IP) at all research stations shows the lightly polluted category. This means that water quality is maintained with minimal damage, so it still supports seaweed life.

Diversity, uniformity and dominance of seaweed

Diversity, uniformity and dominance represent the balance of a community in waters, especially for seaweed. High or low diversity depends on the number of species and the number of individuals of each species. Uniformity indicates a balance that shows the distribution pattern of seaweed or the individual composition of each species. If the uniformity index value is relatively high, the existence of each seaweed species is considered stable (Fachrul, 2007). Dominance shows the level of dominance of a species in a community. Seaweed

in the South Aceh coastal area exhibits an average level of moderate diversity, high uniformity, and low dominance (Table 5). This is in line with previous studies (Fitria et al., 2019) & (Ulfah et al., 2017) conducted in South Aceh Regency as well.

Table 5. Diversity (H'), uniformity (E), and dominance (D) indices of seaweed in the coastal area of South Aceh Regency

Station	Diversity (H')		Uniformity (E)		Dominance (D)	
Name	**Value**	**Category**	**Value**	**Category**	**Value**	**Category**
Keumumu Hilir	2.138	Medium	0.810	High	0.150	Low
Paya Peulemat	1.856	Medium	0.806	High	0.210	Low
Ujong Nibong	2.137	Medium	0.891	High	0.138	Low
Ujong Seurudong	1.736	Medium	0.790	High	0.264	Low
Gunong Cut	2.327	Medium	0.805	High	0.139	Low
Pulo Dua	1.500	Medium	0.721	High	0.306	Low
Average	**1.949**	**Medium**	**0.804**	**High**	**0.201**	**Low**

The diversity index values of seaweed on the coast of South Aceh range between 1.500 and 2.327, with an average of 1.949, and the community diversity and stability are categorized as medium (1< H'< 3). Community diversity is characterized by the number of species that make up the community. The greater the number of species, the higher the diversity (Maknun, 2017). The seaweed diversity index on the coast of South Aceh is in the medium category, indicating a fairly good condition of the seaweed community. The medium diversity index denotes that seaweed diversity is influenced by numerous aspects, including habitat and substrate, environmental stability, and human activities.

Habitat and substrate are essential factors influencing seaweed diversity. As (Kadi, 2004) suggests, the diversity of seaweed species is determined by the diversity of habitat/substrate. Stability, hardness, surface texture, and porosity of the substrate are vital for seaweed growth and support its abundance. Seaweed on the coast of South Aceh is found in flat coral reef areas with a variety of substrates and different characteristics at each research station. The substrates commonly found include dead coral, live coral, coral fragments, rocks, gravel, sand and epiphytes. Substrates in coral and rocky coastal habitats are more likely to have diverse types and support seaweed life compared to sandy and muddy coastal habitats. However, if a substrate consists of a mixture of coral and sand, a variety of seaweed will be found there. The substrate is composed of a mixture of coral and sand and the high clarity of the waters determines the diversity of seaweed living in that habitat (Srimariana et al., 2020).

The environment of all research locations indicates mild pollution (Table 6). This lightly polluted condition still indicates stable water quality and influences the level of seaweed diversity, considering that several other environmental parameters also affect it, resulting in a medium level of seaweed diversity at all

stations studied in the South Aceh coastal area. It will result differently if the environment is moderately to heavily polluted, which will suppress the number of seaweed species until they are degraded and reduce their diversity. Otherwise, good water conditions (meeting quality standards) will lead to a balance in the seaweed community and a high level of species diversity.

Excessive human activity negatively affects the level of species diversity. Seaweed is vulnerable to ecological changes or pressures (Poncomulyo et al., 2006). Human activities found in South Aceh's coastal areas include fishing and recreation. Recreational activities, however, are spotted at Station IV (Pulo Dua), which is a tourist area, causing damage to the bottom water substrate due to human activities as many coral fragments are seen at this station. This affects the level of seaweed diversity due to substrate damage, causing lower diversity index values compared to those at other stations (Table 4).

The uniformity index values range from 0.721 to 0.891, with an average of 0.804 and a high uniformity category ($E > 0.6$). A community has high diversity if it is composed of numerous species with even or almost even abundance. Conversely, if the community consists of species with uneven abundance, or certain species dominating, the level of species diversity becomes low. (Soegianto, 1994). There is a low difference in uniformity values at each research station, and it is suspected that the distribution of seaweed at each station is almost even. The greater the value (closer to 1), the more evenly distributed the macroalgae population is, and no particular type dominates. Otherwise, the smaller the value (closer to 0), the smaller the uniformity (Ayhuan et al., 2017). The high uniformity indicates no dominance of seaweed species in South Aceh's coastal area. This uniformity is influenced by factors such as the bottom substrate of the waters and favorable environmental conditions.

The dominance index values range between 0.138 and 0.306, with an average of 0.201 and a low dominance category ($0.00 < D \leq 0.50$). The dominance index value is inversely proportional to the diversity index value. As Ariani et al. (2020) suggest, a species' dominance in a community is closely related to its level of diversity. The high dominance index indicates that there is tight competition between members of the seaweed community (Ferawati et al., 2014). Interspecies competition in seaweed communities causes competition in occupying the substrate. If there are organisms with a high level of diversity, then species dominance is low. A low dominance index value indicates no dominant seaweed species in the coastal area of South Aceh. This shows the stable condition of the seaweed community on the coast of South Aceh, supported by an even distribution of substrate and mild environmental pollution with little influence. A low dominance index value indicates no competition between species in the community. Each species can utilize resources and environmental factors (Ardiyanto et al., 2020).

Conclusion

The findings reveal a total of 32 species of seaweed discovered in the coastal area of South Aceh, consisting of 11 species of the *Chlorophyceae* class, 11 of the *Phaeophyceae* class, and 10 of the *Rhodophyceae* class. The seaweed species with the highest abundance (>20%) in the area include *Sargassum oligocystum, Amphiroa foliacea, Sargassum plagiophyllum, Amphiroa fragilissima,* and *Halimeda opuntia*. Environmental conditions in the coastal area of South Aceh are based on the results of water quality index measurements using the pollution index method at all research stations, indicating that the quality status is considered lightly polluted. The diversity index values range from 1.500 to 2.327, with an average of 1.949, and are considered in the moderate category of community diversity and stability. The uniformity index values range between 0.721 and 0.891, with an average of 0.804, considered in the high category of uniformity. The dominance index values range between 0.138 and 0.306, with an average of 0.201, considered in the low category of dominance. All of these conditions represent the good level of stability of the seaweed community on the coast of South Aceh Regency, with substrates and environmental factors that support seaweed life.

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