

Biodiversity and community structure of seaweeds in Minahasa Peninsula, North Sulawesi, Indonesia

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Abstract. This study was conducted to determine the biodiversity and community structure (species composition, richness, diversity, evenness, dominance and clustering) of seaweeds found along the intertidal zone of Minahasa Peninsula, North Sulawesi Indonesia. The line transect method was used to identify and quantify the seaweeds abounding the three established stations divided into three transects each station, and each transect divided into ten quadrates. A total of 35 different species of seaweeds were identified in the study area belonging Rhodophyta (Rhodomelaceae, Lithophyllaceae, Mastoporaceae, Galaxauraceae, Gelidiaceae, Gracilariaceae, Solieriaceae, Cystocloniaceae), Phaeophyta (Dictyotaceae, Scytosiphonaceae, Sargassaceae) and Chlorophyta (Ulvaceae, Caulerpacae, Halimedaceae, Dichotomosiphonaceae, Cladophoraceae, Anadyomenaceae, Siphonocladaceae, Valoniaceae, Dasycladaceae, Polyphysaceae). The most abundant seaweed species across the three stations were: *Amphiroa fragilissima*, *Gracilaria edulis*, and *Bornetella sphaerica*. The seaweed species identified also has different densities ranging from 0.03 to 23.77/m². *A. fragilissima* had the highest density, and *Hydroclathrus clathratus* had the lowest density. Species richness index, diversity index, evenness index and dominance index were calculated to determine diversity of seaweeds along the study area. Station 2 obtained the highest species richness and station 3 obtained the lowest species richness. On the other hand, station 2 recorded the highest diversity and station 1 recorded the lowest diversity. Evenness index was highest at station 2, while the lowest was at station 1. The dominance index was the highest at the station 1, while the lowest at the station 2. The three sampling stations are divided into 2 groups based on an abundance of 35 species of seaweeds. The two groups are Group I (Kampung Ambong, Poopo), Group II (Tumbak). Apparently, the two station groups are related to the type of sediment and coverage of seagrass.

Key Words: species density, richness, diversity, evenness, dominance, clustering.

Introduction. The term "algae" refers to a large diversity of unrelated phylogenetic entities, ranging from picoplanktonic cells to macroalgal kelps (Stengel & Connan 2015). Algae are photosynthetic, nonvascular plants that contain chlorophyll "a" and structures (Trainor 1978). Algae are aquatic or subaerial (Bold & Wynne 1985). Algae most commonly occur in water, be it freshwater, marine, or brackish (Lee 2008). Macroalgae, which are primary found in the Division Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae), are commonly called seaweeds because of their size, multicellular construction, and attachment to firm substrata (Dawes 1998). Macroalgae (seaweeds) are a diverse group of predominantly marine, multicellular, photosynthetic, chlorophyll "a"-containing, eukaryotic organisms, lacking true roots, stems, and leaves with simple reproductive structures and found from the intertidal zone to 300-m deep (Fleurence & Levine 2016). Algae are found in diverse habitats such as water, land, they also grow as an epiphyte, endophyte, and as well as in extreme conditions (Sahoo & Seckbach 2015). Marine macroalgae or seaweeds are the assemblage of the macroscopic, multicellular photosynthetic organisms classified in three groups based on their pigmentation and cell architecture as green, red and brown (Kumar & Ralph 2017). Macroalgae or seaweeds belong to lower plants, those supposed to have roots, stems, and leaves, but macroalgae do not possess such differentiation. Macroalgae usually have

leaf like thallus that floats in water unlike microalgal suspensions. Naturally, they grow on seabeds, rocky shores, etc., and are found as multilayered, perennial vegetations growing photosynthetically (Singh et al 2015). Algae are biochemically and physiologically very similar to the rest of plants: they essentially have the same metabolic pathways, possess chlorophyll, and produce similar proteins and carbohydrates (Pereira & Neto 2015). Se-Kwon (2012) described algae as living in the sea, rivers and lakes, on soil and walls, in animals and plants.

Seaweeds have been used all over the world for thousands of years for various food and nonfood applications (Tiwari & Troy 2015). Algae are used for food, pharmaceuticals, health-related products, nutraceuticals, cosmetics, fine chemicals, feed components, feed additives, aquaculture products, and agriculture products (Chojnacka et al 2018). Marine macroalgae or seaweeds have been used as food, especially in China and Japan, and crude drugs for treatment of many diseases such as iodine deficiency (Pereira 2018). Bioactive seaweed substances are a group of chemical components extracted from seaweed biomass, which can influence the biological processes of living organisms through chemical, physical, biological, and other mechanisms (Qin 2018).

Dring (1982) has listed 900 Chlorophyceae, 997 Phaeophyceae, and 2,540 Rhodophyceae marine species worldwide. Schooley (1997) has mentioned there are more than 20,000 species of green algae. Rhodophyceae is a very large class, encompassing approximately 4,000 species. Norton et al (1996) has described 4,000 species of red algae, 14,720 species of green algae, and 1,500 species of brown algae.

In Indonesian waters, there were a total of 782 marine algae, consisting of 196 species of green algae, 452 species of red algae, and 134 species of brown algae according to the results of the Siboga Expedition 1899-1900 (Weber-van Bosse 1913, 1921, 1923, 1928). There were 23 species as food (Heyne 1922), 56 species as food and medicinal plants (Zaneveld 1955). There were 61 species consisting of 38 red algae, 15 green algae, 8 brown algae consumed, including 21 species consumed as medicinal plants based on the results of ethnobotany and ethnopharmacology studies (1988-1991) (Anggadiredja 1992). There were 199 species from the results of Buginesia-III Project research in the Spermonde Islands, South Sulawesi in 1988-1990 (Verheij & Prud'homme van Reine 1991). Anggadiredja (1998) has listed 79 species consisting of 37 green algae, 22 red algae, 20 brown algae, including 54 species consumed and 38 species as medicinal plants according to the results of ethnobotany and ethnopharmacology studies in Warambadi, Sumba Island in 1998. Kepel & Dangeubun (2012) have listed 7 species consisting of 6 green algae, and 1 red algae species consumed according to the results of ethnobotany in Southeast Maluku and Aru Islands. Kepel & Baulu (2012) have listed 10 species consisting of 9 green algae, and 1 red algae species consumed according to the results of ethnobotany in Larat Island and 6 species consisting of 5 green algae, and 1 red algae species consumed according to the results of ethnobotany in Yamdena Island.

The present study was conducted to determine the species composition, abundance and diversity of seaweeds found along the intertidal zone of Minahasa Peninsula, North Sulawesi, Indonesia.

Material and Method

Study area. This research was conducted from January to April 2019 (rainy season). The research locations were in the coastal waters of Kampung Ambong, East Likupang Sub-District, North Minahasa Regency (Station 1), coastal waters of Poopoh, Tombariri Sub-District, Minahasa Regency (Station 2), and coastal waters of Tumbak, Pusomaen Sub-District, Southeast Minahasa Regency (Station 3), North Sulawesi Province, Indonesia (Figure 1). Data collection of seaweeds was carried out in 3 points, namely Station 1, Station 2, and Station 3. In the station 1 there was less dense seagrass at near the coast while toward the sea there was rocky substrate. In the station 2 was mostly rocky substrate. In the station 3 was mostly muddy substrate and largely covered with seagrass at near the coast while toward the sea there was fringing reef.

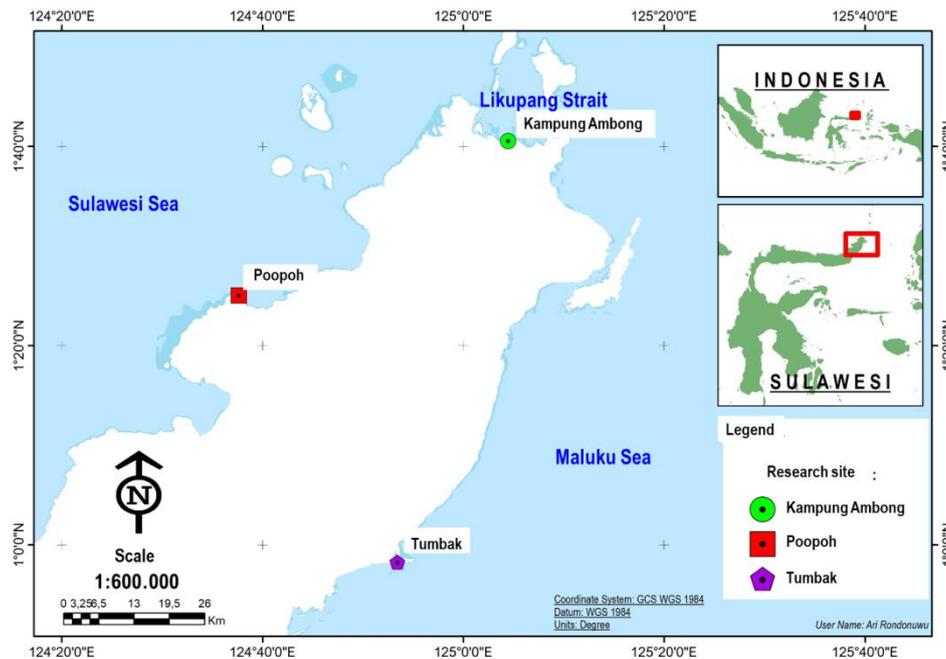


Figure 1. Map of research locations in Minahasa Peninsula, Sulawesi, Indonesia.

Sampling techniques. This research was performed using the Line Transect method with quadratic sampling technique (Krebs 1999). The placement of transects in each location for seaweeds data collection was 3 lines of 100 m long transects drawn perpendicular to the coastline with the assumption that the distribution of the community is evenly distributed. The distance between transects was 5 m and the distance between squares was 10 m. The sample is calculated and taken at the lowest ebb with the square size used to retrieve data that was $1 \times 1 \text{ m}^2$.

The first square was placed near the land where the first seaweeds were found and the last square in the last part of the seaweeds. Likewise, the other nine points were determined systematically between the first square to the last predetermined square, which is random by first specifying the transect length then divided by the sum of squares, the results are randomized based on the square size that can enter the results of the calculation. Inventory is carried out by roaming survey method at the specified research location. Determination of the individual seaweed contained in the square was done by calculating the stand.

Sample identification. Identification of samples was performed using the following references: Trono & Ganzon-Fortes (1988), Calumpang Meñez (1997), Trono (1997), and Atmadja et al (1996).

Species density. Species density was calculated using the formula of Krebs (1999):

$$\text{Species Density} = \text{Number of individuals per species} / \text{sample area}$$

Richness index. The richness Index (R) was calculated using the formula of Ludwig & Reynolds (1988):

$$R = (S - 1) / \ln(n)$$

Where: S is the total number species in a community.

Diversity index. The Shannon's Index (H') was calculated using the formula of Ludwig & Reynolds (1988):

$$H' = - \sum \left(\frac{n_i}{N} \right) \ln \sum \left(\frac{n_i}{N} \right)$$

Where: n_i is the number of individuals of i th species and N is total number for all S species in the population.

Evenness index. The evenness Index (E) was calculated using the formula of Ludwig & Reynolds (1988):

$$E = \frac{H'}{H'_{\max}}$$

Where H' is the diversity index and H'_{\max} is the maximum value.

Dominance index. Dominance Index was calculated using the formula (Odum 1971):

$$D = \sum \left(\frac{n_i}{N} \right)^2 = \sum p_i^2$$

Where: D is n_i is the number of individuals of i th species and N is the total number for all species.

Correspondence analysis. Correspondence analysis (CA) is to provide a geometric presentation in which the studied variable is mapped into points in the cross axis. This CA is suitable for analyzing variables and observations that have been presented in the form of contingency tables or matrices (Lebart et al 1982). The CA application in this study aims to provide the best presentation simultaneously between species groups (i rows) and station groups (j columns), to get the correct correspondence or relationship between the two variables studied (species and stations). The notation used is:

$k = \sum \sum k_{ij}$ = effective total individuals (total amount)

$f_{ij} = k_{ij}/k$ = relative frequency

$f_{i.} = \sum f_{ij}$ = relative marginal frequency

$f_{.j} = \sum f_{ij}$ = relative marginal frequency

In this case, the distance between 2 species i and i' is given by the formula (distance χ^2):

$$d^2(i, i') = \sum_{j=1}^p \frac{1}{f_{.j}} (f_{ij}/f_{i.} - f_{i'j}/f_{i'.})^2$$

In the same way the distance between 2 stations j and j' is given by the formula:

$$d^2(j, j') = \sum_{i=1}^n \frac{1}{f_{i.}} (f_{ij}/f_{.j} - f_{ij'}/f_{.j'})^2$$

According to Lebart et al (1982), this weighted distance has the advantage of meeting the principle of "equivalence distribution". Another advantage of using distance χ^2 in CA is that variable and observation roles are symmetrical and are not affected by the presence of double absences on distance stability.

Two series of coefficients for each element of the two corresponding groups are calculated to interpret certain axes in the CA. This data displayed in the two-way contingency table through CA was done using the STATGRAPHICS Centurion packaging program through the Correspondence Analysis menu selection.

Results and Discussion

Species composition. There were 35 species of seaweeds identified from 21 families belonging to Rhodophyta, Phaeophyta, and Chlorophyta (Table 1).

Table 1

Summary of identified seaweeds species

No.	Class	Order	Family	Species	
1		Ceramiales	Rhodomelaceae	<i>Laurencia papillosa</i>	
2			Lithophyllaceae	<i>Amphiroa fragilissima</i>	
3		Corallinales		<i>Amphiroa rigida</i>	
4			Mastoporaceae	<i>Mastophora rosea</i>	
5	Rhodophyceae	Nemaliales	Galaxauraceae	<i>Galaxaura rugosa</i>	
6		Gelidiales	Gelidiaceae	<i>Gelidiella acerosa</i>	
7				<i>Glacilaria edulis</i>	
8		Gracilariales	Gracilariaceae	<i>Glacilaria salicornia</i>	
9				<i>Kappaphycus alvarezii</i>	
10		Gigartinales	Cystocloniaceae	<i>Hypnea boergesenii</i>	
11				<i>Dictyota dichotoma</i>	
12			Dictyotales	Dictyotaceae	<i>Padina australis</i>
13					<i>Padina minor</i>
14	Phaeophyceae	Ectocarpales	Scytosiphonaceae	<i>Hydroclathrus clathratus</i>	
15				<i>Turbinaria ornata</i>	
16		Fucales	Sargassaceae	<i>Turbinaria decurrens</i>	
17			Ulvales	Ulvaceae	<i>Ulva prolifera</i>
18					<i>Caulerpa racemosa</i>
19					<i>Caulerpa serrulata</i>
20				Caulerpaceae	<i>Caulerpa sertularioides</i>
21					<i>Caulerpa taxifolia</i>
22			Bryopsidales		<i>Caulerpa urvilliana</i>
23					<i>Halimeda incrassata</i>
24			Halimedaceae	<i>Halimeda macroloba</i>	
25				<i>Halimeda opuntia</i>	
26	Ulvophyceae		Dichotomosiphonaceae	<i>Avrainvillea erecta</i>	
27				<i>Chaetomorpha crassa</i>	
28		Cladophorales	Cladophoraceae	<i>Anadyomene wrightii</i>	
29				<i>Boergesenia forbesii</i>	
30			Siphonocladaceae	<i>Boodlea composita</i>	
31		Siphonocladales	Valoniaceae	<i>Dictyosphaeria cavernosa</i>	
32					<i>Bornetella oligospora</i>
33			Dasycladaceae	<i>Bornetella sphaerica</i>	
34		Dasycladales		<i>Neomeris annulata</i>	
35			Polyphysaceae	<i>Acetabularia dentata</i>	

Density parameter. The density of seaweeds found along the intertidal zone of Station 1 is shown in Figure 2. In Station 1, there were 25 species having a density of 0.03-23.77 ind./m² with an average density of 3.92 ind./m² where the highest density was in *Amphiroa fragilissima* 23.77 ind./m², while the lowest density was in *Hydroclathrus clathratus* 0.03 ind./m².

In Station 2, there were 26 species having a density of 0.07-19.90 ind./m² with an average density of 3.05 ind./m² where the *Gracilaria edulis* had the highest density of 19.90 ind./m². The lowest density was recorded in *Kappaphycus alvarezii* 0.07 ind./m² (Figure 3).

There were 20 species in Station 3 with a density of 0.07-11.37 ind./m² with an average density of 2.9 ind./m² where the *Bornetella sphaerica* had the highest density of 11.37 ind./m². The lowest density was recorded in *Amphiroa rigida* 0.07 ind./m² (Figure 4).

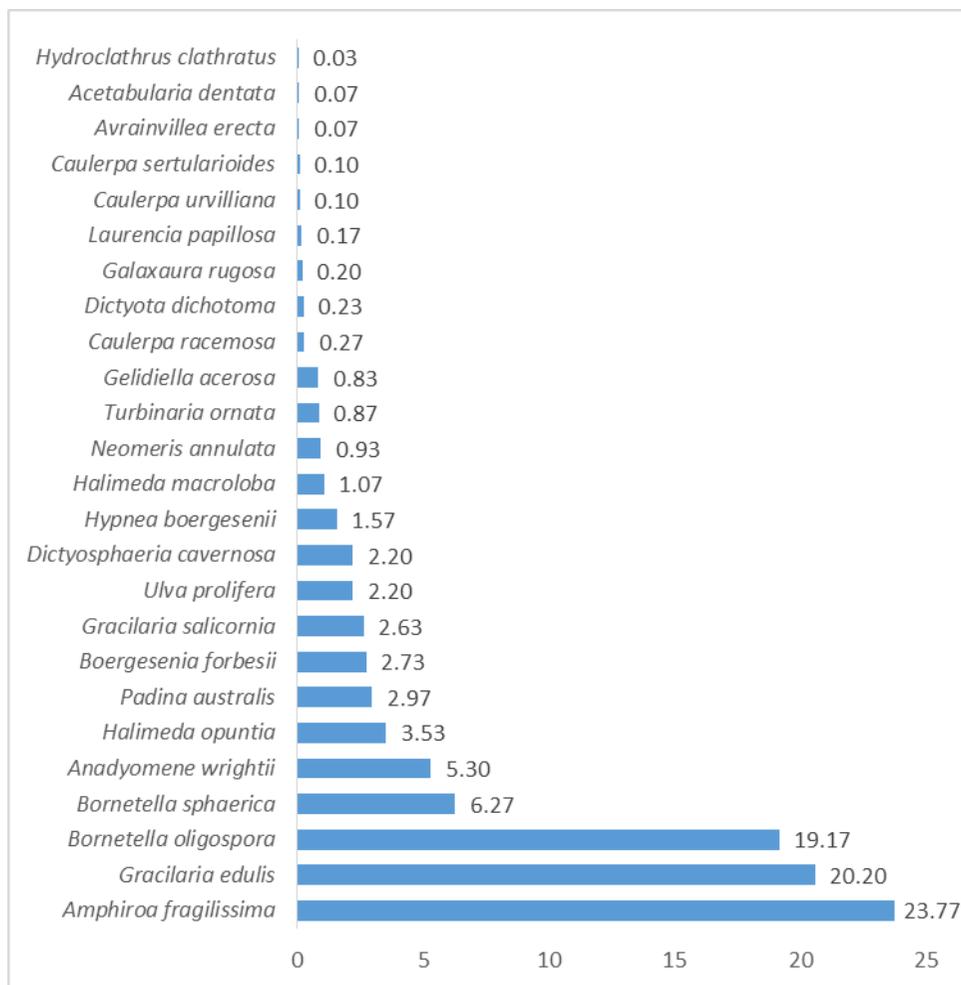


Figure 2. Density of seaweeds in station 1.

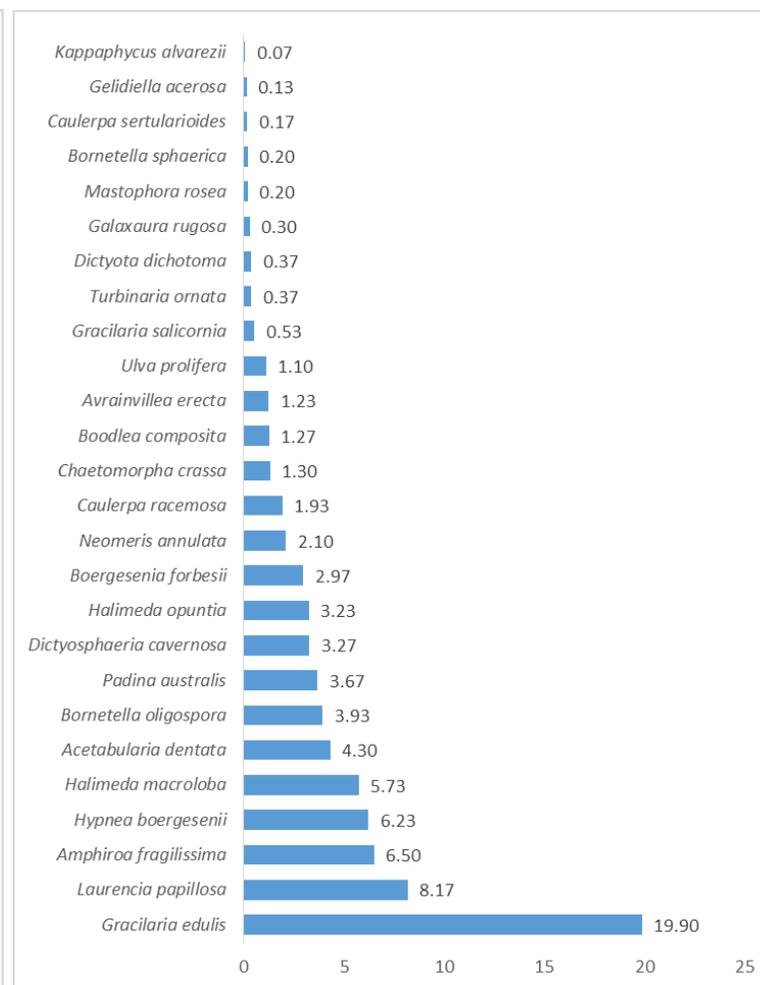


Figure 3. Density of seaweeds in station 2.

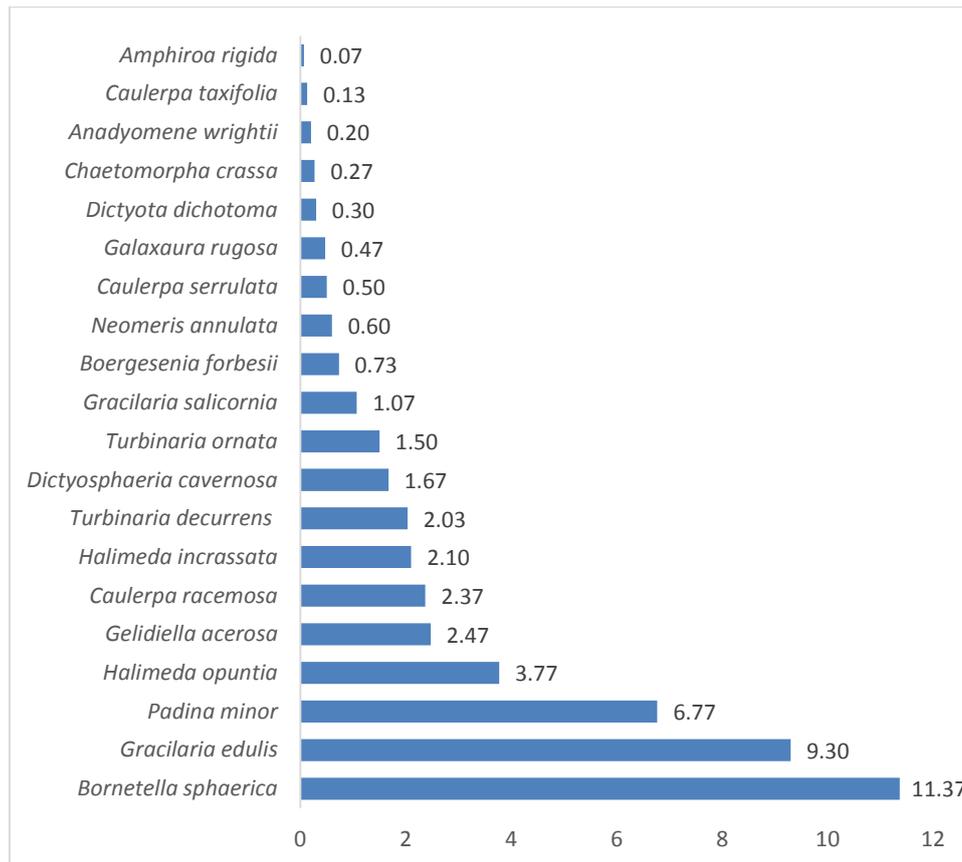


Figure 4. Density of seaweeds in station 3.

Richness index, diversity index, evenness index, dominance index. Based on the calculation of several ecological indices of seaweeds at each station, the values of the Richness Index (R), Diversity Index (H'), Evenness Index (E), and Dominance Index (D), are shown in Table 2.

Table 2

Value of seaweeds community indices

Station	D	H'	E	R
1	0.154	2.242	0.696	3.006
2	0.107	2.621	0.805	3.216
3	0.134	2.346	0.783	2.615

Based on the results of Table 2, it appears that the highest species richness index value was in station 2 with 3.216 and then the station 1 with 3.006 and the lowest in station 3 with 2.615. The diversity index value in these three locations shows that at station 2 the highest diversity value was 2.621. Then followed by station 3 with 2.346, while the lowest was at station 1 with 2.242. Evenness index value was highest at station 2 with 0.805, followed by station 3 with 0.783, while the lowest was at station 1 with 0.696. The dominance index value indicated the highest value at the station 1 with 0.154, then station 3 with 0.134, while the lowest in station 2 with 0.107.

The richness index value showed that the highest species richness was 3.216 (station 2) with 26 species found. The lowest value was recorded at station 3 as 2.651 with 20 species found. This shows that the higher the number of a species found in one area, higher is the value of species richness.

Overall seaweed species richness (biodiversity) found in the three stations in the high category (35 species), when compared to 11 species of Bentenan waters, Minahasa (Kepel et al 2002), 22 species of marine protected area in Tumbak, Minahasa (Beelt &

Kepel 2003), 23 species of Poopoh waters, Minahasa (Kepel & Rumondor 2003), 23 species of Gangga Island, 15 species of Tindila Island and 3 species of Lehaga Island (Kepel et al 2006), 14 species in Kahuku waters and 14 species in Lihunu waters of Bangka Island, North Minahasa (Kepel et al 2010a), 16 species in Libas waters and 8 species in Pahepa waters of Bangka Island, North Minahasa (Kepel et al 2010b), 7 species new record of Mantehage Island and Siladen Island (Wattimury et al 2010a), 7 species of Mokupa (Wowor et al 2015), 15 species of Tongkaina waters, Manado (Kepel et al 2018a), 14 species of Blongko waters, South Minahasa (Kepel et al 2018b), 8 species of Bahoi, North Minahasa (Baino et al 2019), and 10 species of Kora-Kora waters, Minahasa (Kepel & Mantiri 2019), but is in the lower category, when is compared to 44 species of Mantehage Island (Wattimury et al 2010b), and 45 species of Mantehage Island (Kepel et al 2019). In addition, studies were conducted on the existence of *Ulva* sp. (Kepel et al 2018c) and *Halimeda opuntia* (Mantiri et al 2018) and *Padina australis* (Mantiri et al 2019) related to polluted environmental conditions in the waters of Totok Bay and the waters of Blongko, North Sulawesi.

The difference between the high and low levels of seaweed biodiversity obtained compared to other research results is due to differences in the number of sampling locations, as well as differences in environmental parameters both in coastal topography, substrate, transparency of waters, anthropogenic impacts and seasonal influences. Our three research stations showed that the area has sloping beach topography; the substrate is generally sand, muddy sand, sandy coral fractures, and dead and live coral. In the research location there was also no river flow, however, in some points there are human activities. In Station 1, as Marine Station of Faculty of Fisheries and Marine Science, Sam Ratulangi University, there are sometimes student activities. In Station 2, are fishermen activities. In Station 3, are coastal community activities.

The diversity index value in the three stations was 2.242 (station 1), 2.621 (station 2), 2.346 (station 3) categorized as moderate. According to Odum (1971), the higher the value of H' and E means that the community is increasingly diverse. Furthermore, it is said that the value of $H < 2$ means that it shows low species diversity, whereas if $H = 4$ means high species diversity.

Evenness index values at stations 1, 2, and 3 ranged from 0.696 to 0.805. This shows that the seaweeds community in these three stations is stable. This is consistent with the statement of Odum (1971) that a community is said to be stable if the value of the evenness index of a species ranges between 0.6-0.8.

The dominance index value in the three locations was 0.154 (station 1), 0.107 (station 2), 0.134 (station 3) which is categorized as low. This shows that in the three stations is no dominance of species in the seaweed community. This is supported by the statement of Kepel et al (2012) that if the dominance index value is close to zero, it means that in the community there is no dominant organism or vice versa if the value approaches one means that in the community has a dominant organism.

Correspondence analysis. Correspondence Analysis (CA) was carried out based on abundance data in two-way contingency tables, namely 35 rows of species and 3 station columns. Station 1 with less dense seagrass at near the coast while toward the sea there is rocky substrate, station 2 with mostly have rocky substrate, and station 3 with largely covered with seagrass at near the coast while toward the sea there are patch reef.

In this analysis, the total inertia obtained for the 2 axis was 0.4518 (61.4%), 0.2839 (38.6%) with a total of 100 % (Table 3).

Table 3

Inertia and chi-square decomposition

Dimension	Singular value	Inertia	Chi-Square	%	Cumulative percentage
1	0.6721	0.4518	3045.3767	61.4116	61.4116
2	0.5328	0.2839	1913.5831	38.5884	100.0000
Total		0.7356	4958.959		

Figure 5 is a dendrogram that classifies seaweed species and Figure 6 is a dendrogram that classifies the three sampling stations into 2 groups based on an abundance of 35 species. The two groups are Group I (Kampung Ambong, Poopoh), and Group II (Tumbak). Apparently, the two station groups are related to the type of sediment and coverage of seagrass.

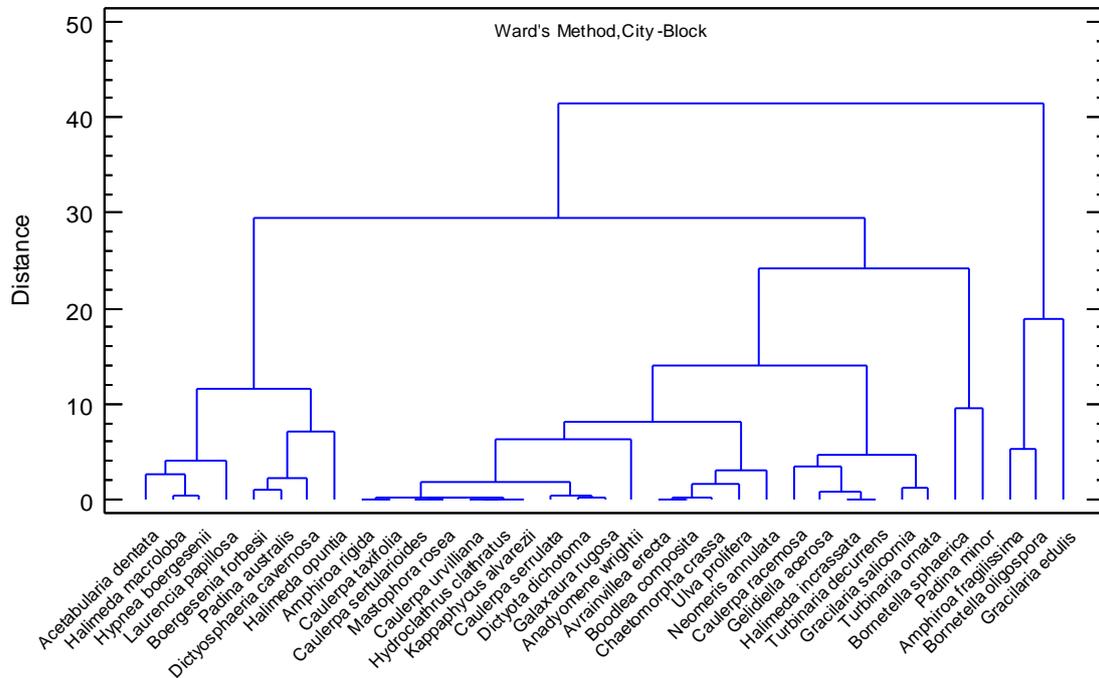


Figure 5. Cluster analysis dendrogram (seaweeds).

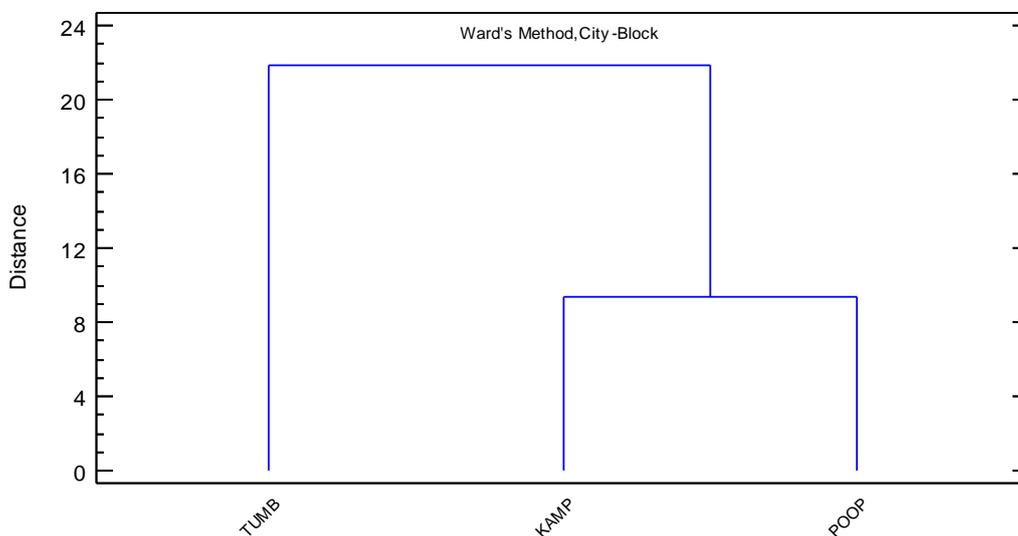


Figure 6. Cluster analysis dendrogram (stations).

Overall, seaweeds are grouped into 3 station groups namely group I consisting of station 1 and station 2 (Kampung Ambong, Poopoh) with rocky substrate, and group II consisting of station 3 (Tumbak) with mostly muddy substrate (Figure 7).

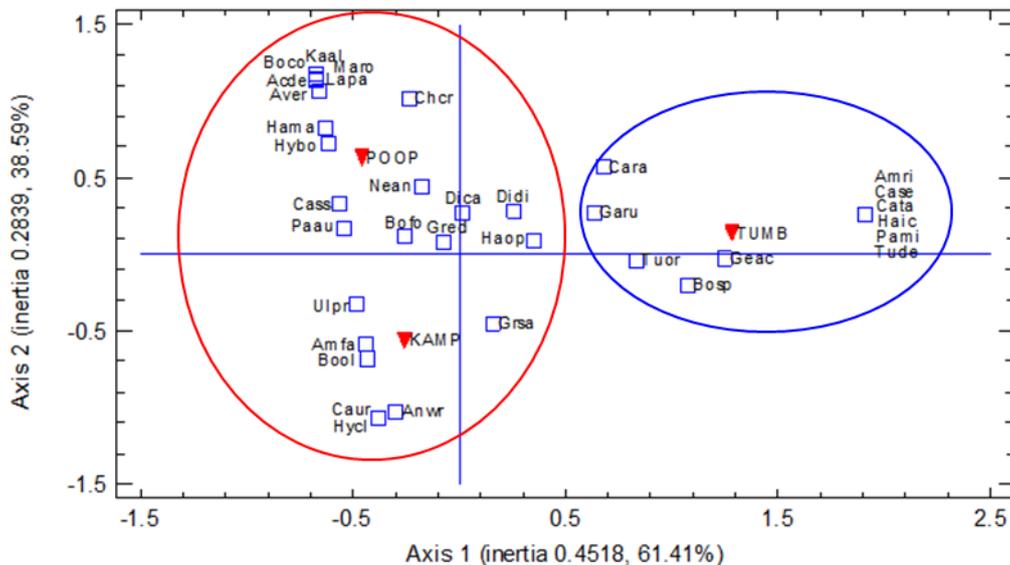


Figure 7. Correspondent map. Note: Acde (*Acetabularia dentata*), Amri (*Amphiroa rigida*), Amfa (*Amphiroa fragilissima*), Anwr (*Anadyomene wrightii*), Aver (*Avrainvillea erecta*), Bofo (*Boergesenia forbesii*), Boco (*Boodlea composita*), Bool (*Bornetella oligospora*), Bosp (*Bornetella sphaerica*), Cara (*Caulerpa racemosa*), Case (*Caulerpa serrulata*), Cass (*Caulerpa sertularioides*), Cata (*Caulerpa taxifolia*), Caur (*Caulerpa urvilliana*), Chcr (*Chaetomorpha crassa*), Dica (*Dictyosphaeria cavernosa*), Didi (*Dictyota dichotoma*), Garu (*Galaxaura rugosa*), Geac (*Gelidiella acerosa*), Gred (*Gracilaria edulis*), Grsa (*Gracilaria salicornia*), Haic (*Halimeda incrassata*), Hama (*Halimeda macroloba*), Haop (*Halimeda opuntia*), Hycl (*Hydroclathrus clathratus*), Hybo (*Hypnea boergesenii*), Kaal (*Kappaphycus alvarezii*), Lapa (*Laurencia papillosa*), Maro (*Mastophora rosea*), Naen (*Neomeris annulata*), Paau (*Padina australis*), Pami (*Padina minor*), Tude (*Turbinaria decurrens*), Tuor (*Turbinaria ornata*), Ulpr (*Ulva prolifera*).

Group I is the seaweeds inhabitants of station 1 and station 2 with characteristics of rocky substrate consisting of 23 species: *Acetabularia dentata*, *Amphiroa fragilissima*, *Anadyomene wrightii*, *Avrainvillea erecta*, *Boergesenia forbesii*, *Boodlea composita*, *Bornetella oligospora*, *Caulerpa sertularioides*, *Caulerpa urvilliana*, *Chaetomorpha crassa*, *Dictyosphaeria cavernosa*, *Dictyota dichotoma*, *Gracilaria edulis*, *Gracilaria salicornia*, *Halimeda macroloba*, *Halimeda opuntia*, *Hydroclathrus clathratus*, *Hypnea boergesenii*, *Kappaphycus alvarezii*, *Laurencia papillosa*, *Mastophora rosea*, *Neomeris annulata*, *Padina australis*, *Ulva prolifera*.

Group II is the seaweeds inhabitants of station 3 with the characteristics of muddy sand substrate consisting of 12 species: *Halimeda opuntia*, *Galaxaura rugosa*, *Caulerpa racemosa*, *Turbinaria ornata*, *Bornetella sphaerica*, *Gelidiella acerosa*, *Amphiroa rigida*, *Caulerpa serrulata*, *Caulerpa taxifolia*, *Halimeda incrassata*, *Padina minor*, *Turbinaria decurrens*.

Conclusions. The results of the seaweeds inventory in the coastal waters of Minahasa Peninsula totaled 35 species. The seaweeds community structure showed that it is still stable with high values of diversity, evenness and species richness, while the value of domination is low. The highest density of the seaweeds was found in 3 stations, namely (station 1, 2 and 3) *Amphiroa fragilissima*, while the lowest density in 3 stations upon *Hydroclathrus clathratus*. In general, seaweeds species richness (biodiversity) was found in the high category. Overall, seaweeds were grouped into 2 station groups, group I consisting of station 1 and 2 with rocky substrate, and group II consisting of station 3 with mostly muddy substrate.

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