Community structure of seaweeds along the intertidal zone of Mantehage Island, North Sulawesi, Indonesia

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Abstract. This study was conducted to determine the community structure (species composition, richness, diversity, evenness, dominance and clustering) of seaweeds found along the intertidal zone of Mantehage Island, North Sulawesi Indonesia. The line transect method was used to identify and quantify the seaweeds abounding the four established stations divided into three transects in each station, and each transect was divided into ten quadrates. A total of 45 different species of seaweeds were identified in the study area belonging to Rhodophyta (Ceramiaceae, Rhodomelaceae, Lithophyllaceae, Mastophoraceae, Galaxauraceae, Gracilariaceae, Solieriaceae, Cystocloniaceae), Phaeophyta (Dictyotaceae, Scytosiphonaceae, Sargassaceae), and Chlorophyta (Caulerpaceae, Halimedaceae, Udoteaceae, Dichotomosiphonaceae, Codiaceae, Cladophoraceae, Anadyomenaceae, Siphonocladaceae, Valoniaceae, Dasycladaceae). The most abundant seaweed species across the four stations are: *Halimeda opuntia, Caulerpa racemosa, Gracilaria edulis,* and *Chaetomorpha crassa.* The seaweed species identified also have different densities ranging from 0.01 to 2.96 ind m^{-2}. *G. edulis* had the highest density, and *Sargassum cristaefolium, Galaxaura apiculata* and *Eucheuma denticulatum* 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 3 obtained the highest species richness and station 1 obtained the lowest species richness. On the other hand, station 3 recorded the highest diversity and station 4 recorded the lowest diversity. Evenness index was highest at station 1, while the lowest was at station 4. The dominance index was the highest at the station 4, while the lowest at the station 1. The four sampling stations are divided into 3 groups based on the abundance of 45 species of seaweeds. The three groups are Group I (Tinongko, Buhias), Group II (Bango), Group III (Tangkasi). Apparently, the three station groups are related to the type of sediment.
Key Words: density, richness, diversity, eveness, dominance.

Introduction. According to the results of the Siboga Expedition 1899-1900 in Indonesian waters a total of 782 marine algae were obtained, consisted of 196 species of green algae, 452 species of red algae, and 134 species of brown algae (Weber-van Bosse 1913, 1921, 1923, 1928). There were 23 species as food (Heyne 1922), 56 species as food and medicinal plants (Zaneveld 1955). Based on the results of ethnobotany and ethnopharmacology studies (1988-1991), there were 61 species consisting of 38 red algae, 15 green algae, 8 brown algae consumed, including 21 species consumed as medicinal plants (Anggadiredja 1992). From the results of Buginesia-III Project research in the Spermonde Islands, South Sulawesi in 1988-1990 there were 199 species (Verheij & Prud'homme van Reine 1993). According to the results of ethnobotany and ethnopharmacology studies in Warambadi, Sumba Island in 1998, there were 79 species consisting of 37 green algae, 22 red algae, 20 brown algae, including 54 species consumed and 38 species as medicinal plants (Anggadiredja 1998).

Algae are very simple, chlorophyll-containing organisms (Bold & Wynne 1985). Morphologically the body structure of the algae cannot be distinguished between holdfast, stipe, and blades so that it is grouped into plants Thallophyta which is a plant that has a leafless structure, stipe and holdfast, but all consisting of thallus. Algae are plants that mostly live in the sea which are unicellular and muilticellular. Based on its life cycle, there are those living as phytoplankton (planktonic algae) that float and some live as phytobenthos (benthic algae) that are attached to the bottom of the waters. There are those that are shaped like tubes, round flat, flat, bags, hairs, etc. (Trainor 1978). There are two basic types of cells in the algae, prokaryotic and eukaryotic. Prokaryotic cells lack membrane-bounded organelles (plastids, mitochondria, nuclei, golgi bodies, and flagella) and occur in the cyanobacteria (Lee 2008). Algae are simple organisms. Many are unicellulars, while others are multicellulars and more complex, but they all have rudimentary conducting tissues (Pereira & Neto 2015). Kim (2012) described the characteristic feature of marine macroalgal substances, source species, types, production and applications (biological, biotechnological, industrial). Stengel & Connan (2015) described the current progress in algal biotechnology is driven by an increased demand for new sources of biomass due to several global challenges, new discoveries and technologies available as well as an increased global awareness of the many applications of algae.

This study was conducted to determine the species composition, abundance and diversity of seaweeds found along the intertidal zone of Mantehage Island, North Sulawesi, Indonesia.

Material and Method

Study area. This research was conducted in November 2016 to March 2017. The research location was in the coastal waters of Mantehage Island, Wori District, North Minahasa Regency, North Sulawesi Province (Figure 1). The geographical location of Mantehage Island is 1041'24.35"-1046’20.45" North Latitude, 124043’31.43"-1240 47’3.83" East Longitude. Data collection of seaweeds was carried out in 4 points, namely Station 1 (Bango), Station 2 (Tinongko), Station 3 (Buhias), and Station 4 (Tangkasi). Station 1 has muddy sand substrate with dense seagrass. Station 2 has rocky substrate with dense seaweed. Station 3 has rocky substrate with dense seagrass. Station 4 has sandy substrate with dense seagrass.

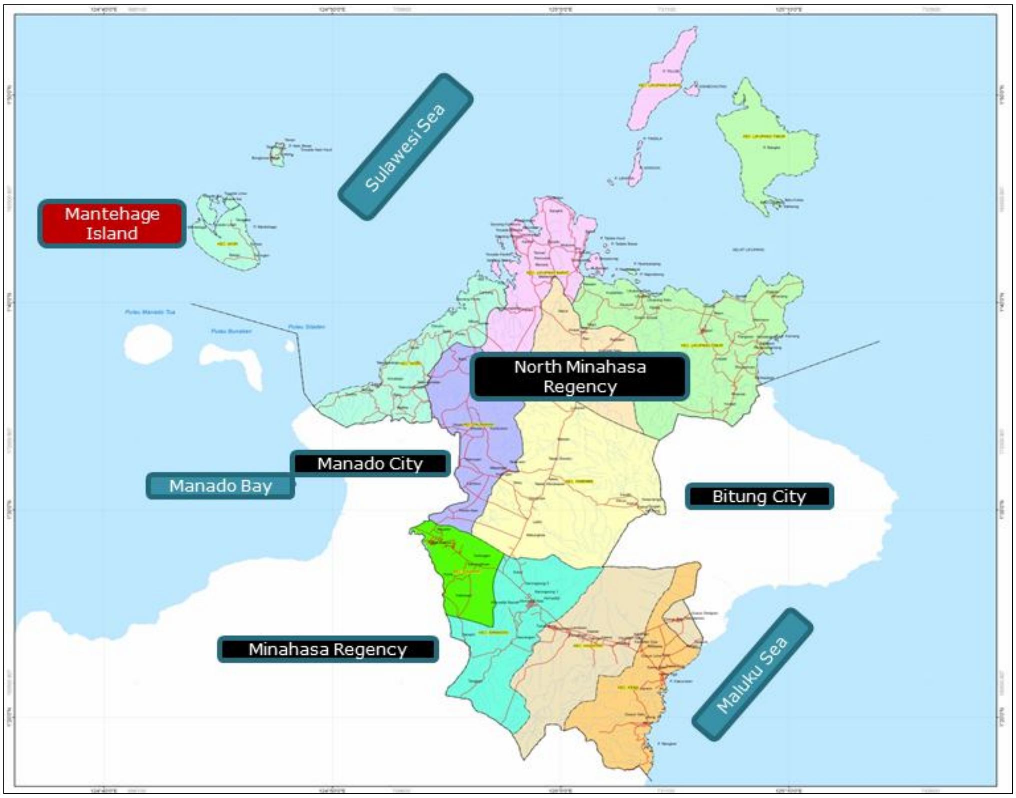

Figure 1. Map of research location in Mantehage Island (source: Study Program of Aquatic Management Resources, Faculty of Fisheries and Marine Science, Sam Ratulangi University).

Sampling techniques. This research was done 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 50 m and the distance between squares is 10 m. The sample was calculated and taken at the lowest ebb with the square size used to retrieve data that is 1 x 1 m^2 (Figure 2).

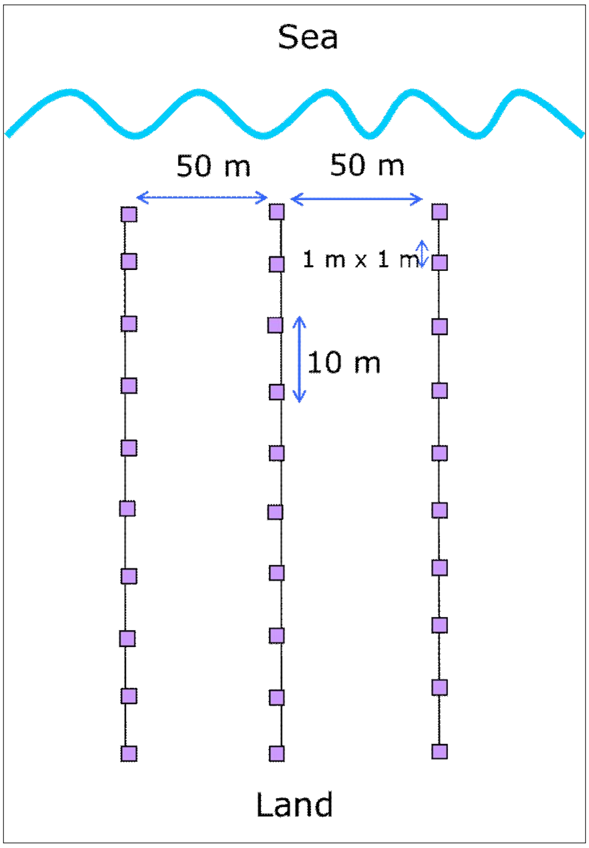

Figure 2. The placement of transects.

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

Sample identification. Identification of samples has been done using the books of Trono & Ganzon-Fortes (1988), Atmadja et al (1996), Calumpong & Meñez (1997), and Trono (1997).

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

Species density = number of individuals per species / the area of the sample

Richness index. The richness index (R) is calculated using the formula (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') is calculated using the formula (Ludwig and Reynolds 1988):

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

where: n*i* is the number of individuals of *i*th species, and N is total number for all species in the population.

Evenness index. The evenness index (E) is calculated using a formula (Ludwig & Reynolds 1988):

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

where: H' is evenness index, and H' is maximum value.

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

$$D = \sum\left(\frac{ni}{N}\right)^2 = \sum Pi^2$$

where: D is n*i* is the number of individuals of *i*th species, and N is total number for all species.

Correspondence analysis. Correspondence analysis (CA) is to provide a geometric demonstration 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 demonstration simultaneously between observation groups (*j* lanes) and variable groups (*i* rows), 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;
or in the form of a matrix as follows (in this case, the distance between 2 species i and i 'is given by the formula (distance χ^2)):

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

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

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

According to Lebart et al (1982), this weighted distance has the advantage of meeting the principle of "equivalence distribution". Another advantage of using distance $\chi 2$ 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 an CA. This data display in the two-way contingency table through CA is done using the NTSYS-PC packaging program through the Correspondence Analysis menu selection.

Results and Discussion

Species composition. There were 45 species of seaweeds identified from 19 families belonging to Rhodophyta, Phaeophyta, and Chlorophyta (Table 1).

Table 1

Summary of identified seaweeds species

No.	*Class*	*Order*	*Family*	*Species*
1	Rhodophyceae	Ceramiales	Ceramiaceae	*Spyridia filamentosa*
2			Rhodomelaceae	*Amansia glomerata*
3				*Laurencia papillosa*
4		Corallinales	Lithophyllaceae	*Amphiroa rigida*
5			Mastoporaceae	*Mastophora rosea*
6		Nemaliales	Galaxauraceae	*Galaxaura apiculata*
7				*Galaxaura fastigiata*
8				*Galaxaura filamentosa*
9				*Actinotrichia fragilis*
10		Gracilariales	Gracilariaceae	*Gracilaria edulis*
11				*Gracilaria gracilis*
12				*Gracilaria salicornia*
13				*Gracilaria textorii*
14				*Gracilaria verrucosa*
15		Gigartinales	Solieriaceae	*Eucheuma denticulatum*
16			Cystocloniaceae	*Hypnea spinella*
17	Phaeophyceae	Dictyotales	Dictyotaceae	*Dictyota dichotoma*
18				*Padina australis*
19		Ectocarpales	Scytosiphonaceae	*Hydroclathrus clathratus*
20		Fucales	Sargassaceae	*Sargassum cristaefolium*
21	Ulvophyceae	Bryopsidales	Caulerpaceae	*Caulerpa lentillifera*
22				*Caulerpa racemosa*
23				*Caulerpa serrulata*
24				*Caulerpa sertularioides*
25			Halimedaceae	*Halimeda cuneata*
26				*Halimeda cylindracea*
27				*Halimeda discoidea*
28				*Halimeda incrassata*
29				*Halimeda macroloba*
30				*Halimeda opuntia*
31				*Halimeda tuna*
32			Udoteaceae	*Udotea geppiorum*
33			Dichotomosiphonaceae	*Avrainvillea erecta*
34				*Avrainvillea lacerata*
35			Codiaceae	*Codium ovale*
36		Cladophorales	Cladophoraceae	*Chaetomorpha crassa*
37				*Chaetomorpha spiralis*
38			Anadyomenaceae	*Anadyomene wrightii*
39				*Microdictyon marinum*
40			Siphonocladaceae	*Boergesenia forbesii*
41				*Dictyosphaeria cavernosa*
42			Valoniaceae	*Valonia aegagropila*
43				*Valonia fastigiata*
44		Dasycladales	Dasycladaceae	*Bornetella sphaerica*
45				*Neomeris annulata*

Density parameter. The density of seaweeds found along the intertidal zone of station 1 (Bango village) in Mantehage Island, North Sulawesi, Indonesia is shown in Figure 3. In station 1, there were 22 species having a density of 0.03-0.97 ind m^{-2} with an average density of 0.28 ind m^{-2}. The species that has the highest density is *Halimeda opuntia* 0.97 ind m^{-2}, while the species that has the lowest density is *Galaxaura apiculata* 0.03 ind m^{-2}.

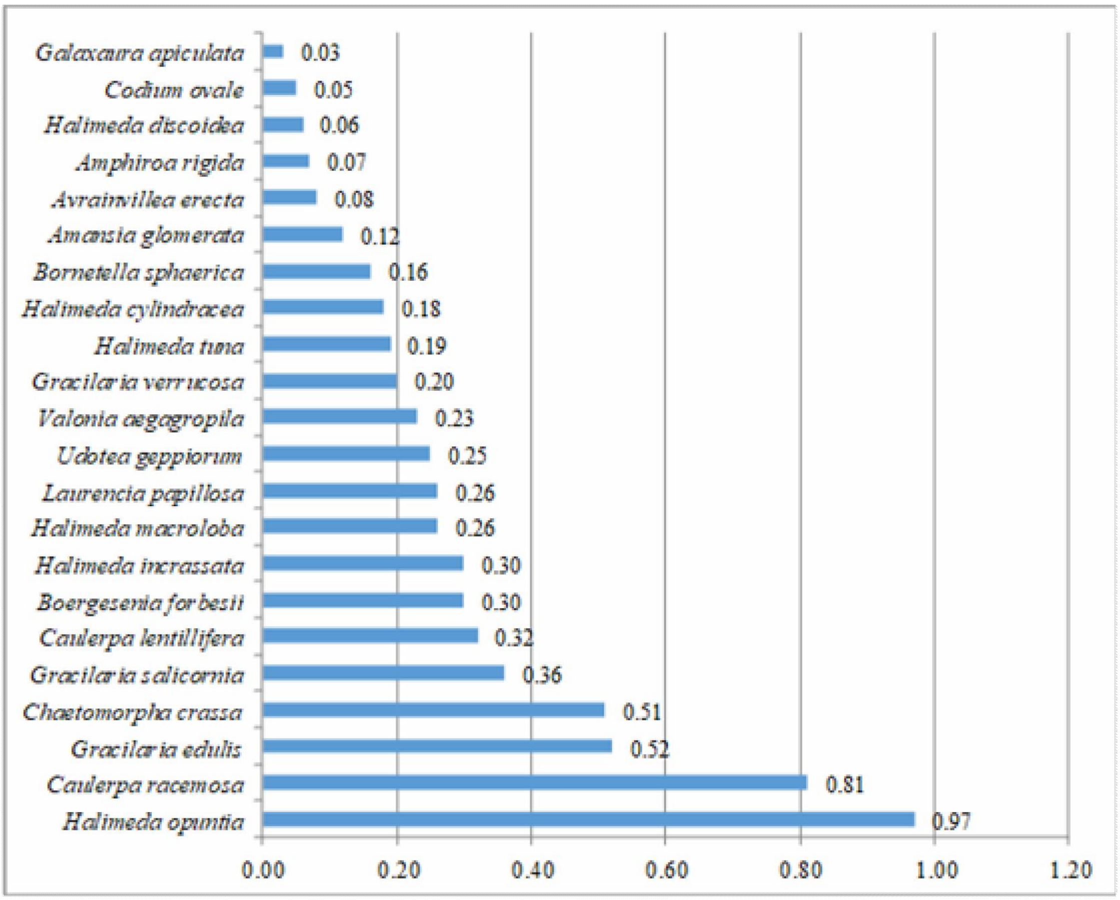

Figure 3. Density of seaweeds in station 1.

In station 2 (Tinongko village), there were 23 species having a density of 0.01-0.97 ind m^{-2} with an average density of 0.21 ind m^{-2}, where the *Halimeda opuntia* has the highest density of 0.97 ind m^{-2}. The lowest density is *Sargassum cristaefolium* 0.01 ind m^{-2} (Figure 4).

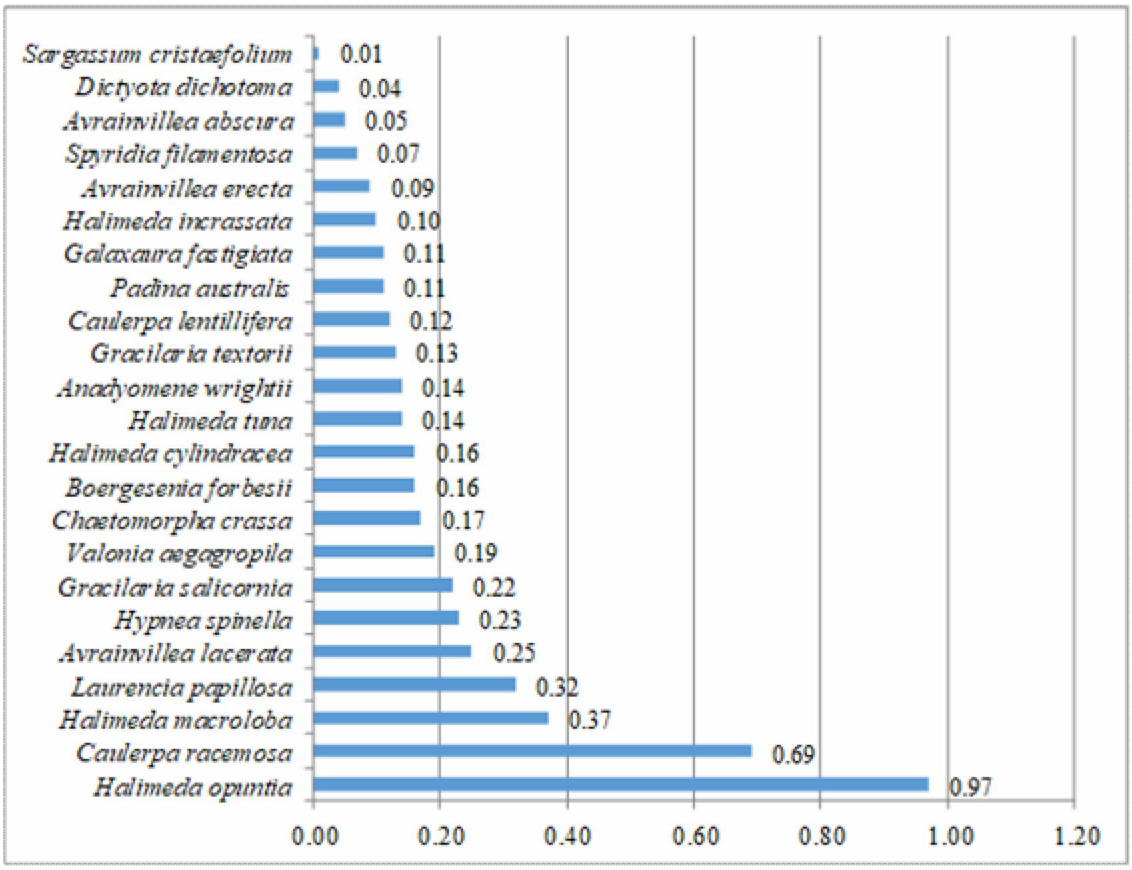

Figure 4. Density of seaweeds in station 2.

There were 34 species in station 3 (Buhias village) with a density of 0.01-2.05 ind m^{-2} and an average density of 0.28 ind.m^{-2} where the *Halimeda opuntia* has the highest density of 2.05 ind m^{-2}. The lowest density is *Galaxaura apiculata* 0.01 ind m^{-2} (Figure 5).

Figure 5. Density of seaweeds in station 3.

There were 30 species in Station 4 (Tangkasi village) with a density of 0.01-2.96 ind m^{-2} and an average density of 0.36 ind m^{-2} where the *Gracilaria edulis* has the highest density of 2.96 ind.m^{-2}. The lowest density is *Eucheuma denticulatum* 0.01 ind m^{-2} (Figure 6).

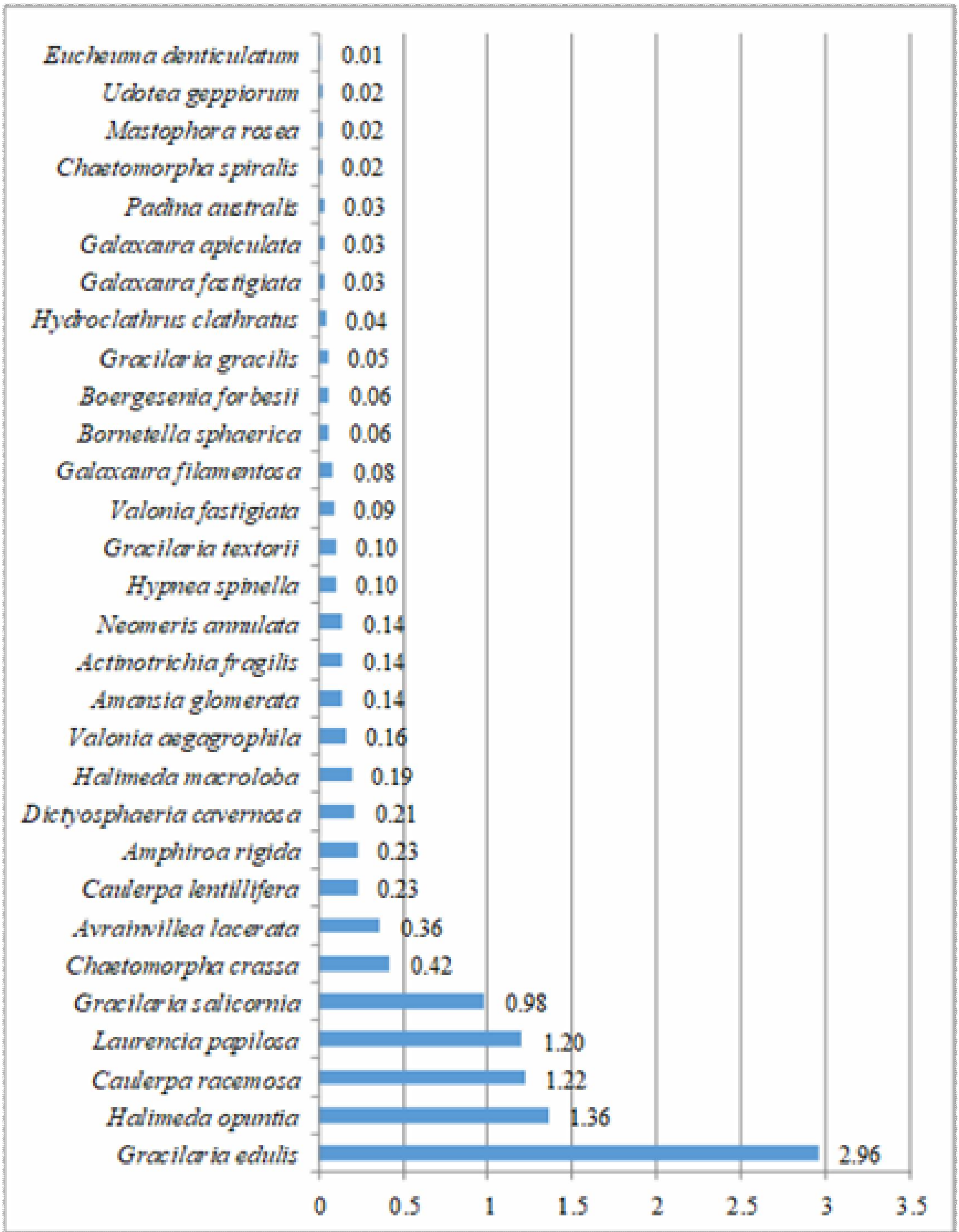

Figure 6. Density of seaweeds in station 4.

Richness index, diversity index, evenness index, dominance index. Based on the calculation of several ecological indices from 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 (Bango)	0.076	2.797	0.904	21.84
2 (Tinongko)	0.091	2.798	0.892	22.40
3 (Buhias)	0.092	2.867	0.813	35.85
4 (Tangkasi)	0.122	2.420	0.080	29.85

Based on the results in Table 2, it appears that the highest species richness index (R) value is in station 3 is 35.85. Then the station 4 is 29.85, and then the station 2 is 22.40 and the lowest is station 1 is 21.84. The diversity index (H') value in these four locations shows that at station 3 the highest diversity value is 2.867. Then followed by station 2 is 2.798, station 1 is 2.797, while the lowest was at station 4 is 2.420. Evenness index value (E) was highest at station 1, which is 0.904, followed by station 2 is 0.892, station 3 is 0.813, while the lowest was at station 4 is 0.080. The dominance index value (C) is the highest species at the station 4 is 0.122, then station 3 is 0.092, station 2 is 0.091, while the lowest station 1 is 0.076.

The richness index (R) value shows that the highest species richness is 35.85 (station 3) with the number of species found 34 species. The lowest value at station 1 is 21.84 with the number of species found in 22 species. This shows that the greater the number of species found in one area, the greater the value of species richness in the area will increase.

Overall seaweed species richness (biodiversity) found in the four stations are in high category, when compared to 11 species of Bentenan waters, Minahasa (Kepel et al 2002), 22 species of marine potected 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), 44 species of Mantehage Island and 27 species of Siladen Island (Wattimury et al 2010b), 7 species of Mokupa, Minahasa (Wowor et al 2015), 15 species of Tongkaina waters, Manado (Kepel et al 2018a), and 14 species of Blongko waters, South Minahasa (Kepel et al 2018b). In addition, studies were conducted on the existence of *Ulva* sp. (Kepel et al 2018c) and *Padina australis* (Mantiri et al 2018) 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 the differences in the number of sampling locations, as well as differences in environmental parameters both in coastal topography, substrate, transparancy of waters and anthropogenic impacts. At the four research stations showed that the area has slopy beach topography, the substrate is generally sand, muddy sand, sandy coral fractures. In the research location there is also no river flow, however, in some points there are human activities.

The diversity index value (H') in the four stations is 2.797 (station 1), 2.798 (station 2), 2.867 (station 3), 2.420 (station 4) categorized as moderate. According to Odum (1971), the greater the value of H' and E means 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 (E) at stations 1, 2, and 3 ranges in value from 0.81 to 0.90. This shows that the seaweeds community in these three stations is stable. The station 4 is 0.08 which shows that the location of the seaweeds community is unstable. 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 (D) in the four locations is 0.076 (station 1), 0.091 (station 2), 0.092 (station 3), 0.122 (station 4) is categorized as low because it tends to close to zero. This shows that in the four stations found to be uneven or there 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 there is a dominant organism.

Correspondent analysis. Correspondent analysis (CA) is carried out based on abundance data after log transformation (x + 1) in two-way contingency tables, namely 45 line types and 3 station columns. Station 1 with muddy sandy sediment, station 2 with rocky sediment, station 3 with rocky sediment, and station 4 with sandy sediment.

In this analysis, the total inertia obtained for the 3 axis was 0.2427 (48.9%), 0.1332 (26.8%), 0.1199 (24.1%) with a total of 99.8 % (Table 3).

Table 3

Inertia and chi-square decomposition

Dimension	*Singular value*	*Inertia*	*Chi-square*	*%*	*Cumulative percentage*
1	0.4926	0.2427	760.2251	48.9482	48.9482
2	0.3649	0.1332	417.2449	26.8649	75.8131
3	0.3463	0.1199	375.6514	24.1869	100.0000
Total		0.4958	1553.121		

Figure 7 is a dendogram that classifies seaweed species and Figure 8 is a dendogram that classifies the four sampling stations into 3 groups based on the abundance of 45 species. The three groups are Group I (Tinongko, Buhias), Group II (Bango), Group III (Tangkasi). Apparently, the three station groups are related to the type of sediment.

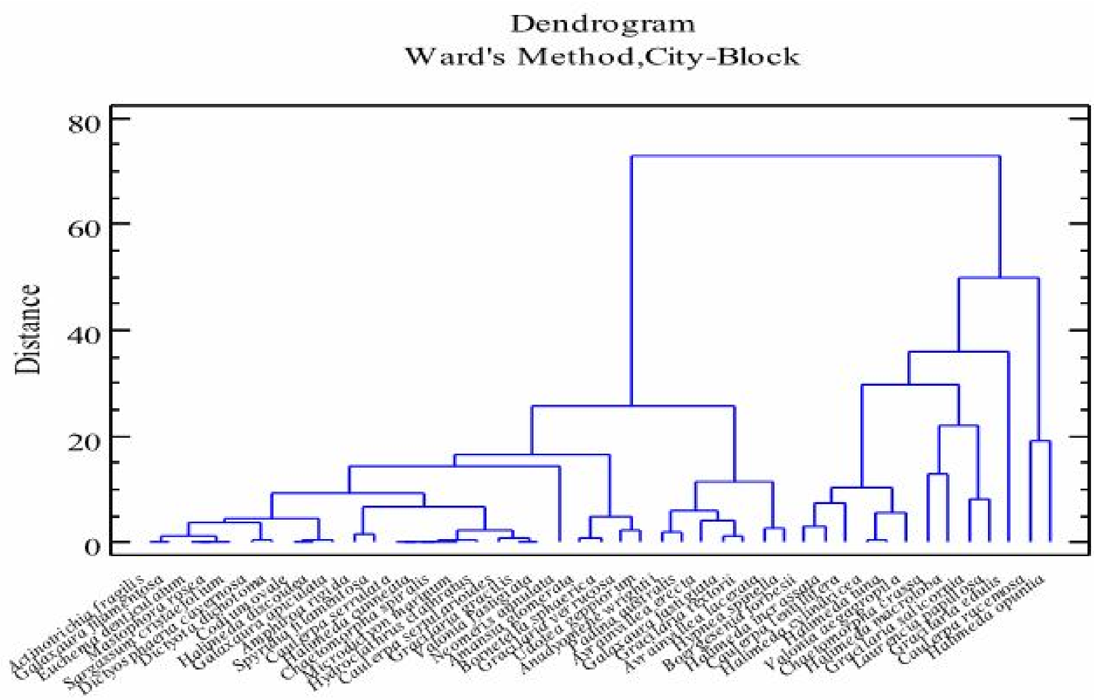

Figure 7. Cluster analysis dendogram (seaweeds).

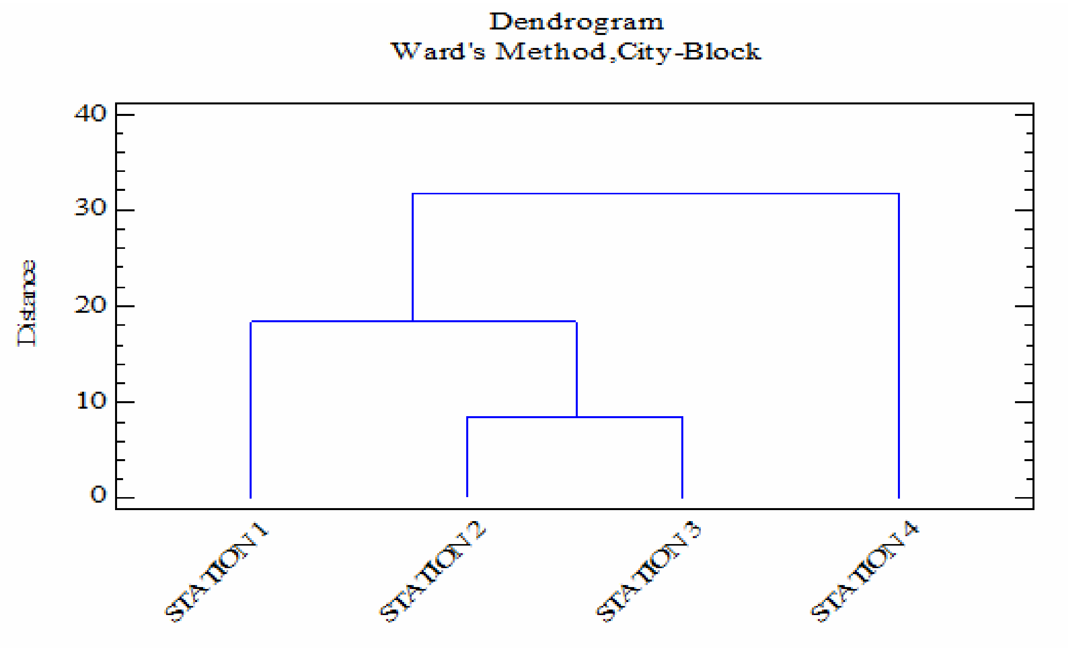

Figure 8. Cluster analysis dendogram (stations).

Overall, seaweed is grouped into 3 station groups namely group I consisting of station 2 (Tinongko) and station 3 (Buhias) with rocky substrate, group II consisting of station 1 (Bango) with muddy sand substrate and group III consisting of stations 4 (Tangkasi) with sandy substrate (Figure 9).

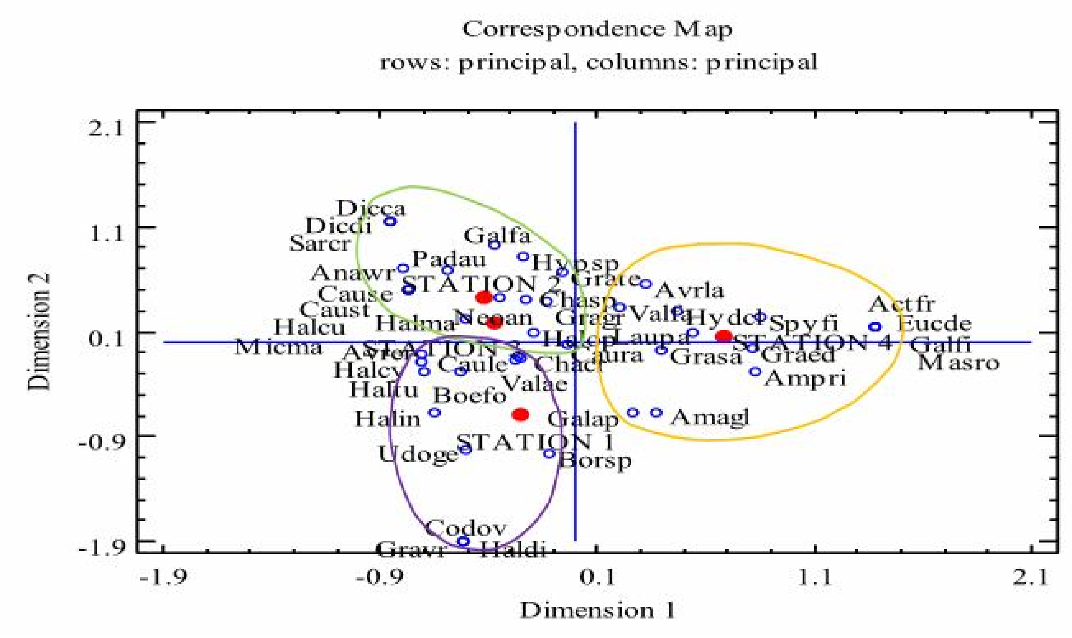

Figure 9. Correspondent map: Actfr (*Actinotrichia fragilis*), Amagl (*Amansia glomerata*), Ampri (*Amphiroa rigida*), Anawr (*Anadyomene wrightii*), Avrer (*Avrainvillea erecta*), Avrla (*Avrainvillea lacerata*), Boefo (*Boergesenia forbesii*), Borsp (*Bornetella sphaerica*), Caule (*Caulerpa lentillifera*), Caura (*Caulerpa racemosa*), Cause (*Caulerpa serrulata*), Causs (*Caulerpa sertularioides*), Chacr (*Chaetomorpha crassa*), Chasp (*Chaetomorpha spiralis*), Codov (*Codium ovale*), Dicdi (*Dictyota dichotoma*), Eucde (*Eucheuma denticulatum*), Galap (*Galaxaura apiculata*), Galfa (*Galaxaura fastigiata*), Galfi (*Galaxaura filamentosa*), Graed (*Gracilaria edulis*), Spyfi (*Spyridia filamentosa*), Gragr (*Gracilaria gracilis*), Grasa (*Gracilaria salicornia*), Grate (*Gracilaria textorii*), Dicca (*Dictyosphaeria cavernosa*), Glavr (*Gracilaria verrucosa*), Halcu (*Halimeda cuneata*), Halcy (*Halimeda cylindracea*), Haldi (*Halimeda discoidea*), Halin (*Halimeda incrassata*), Halma (*Halimeda macroloba*), Halop (*Halimeda opuntia*), Haltu (*Halimeda tuna*), Hydch (*Hydrochlatrus chlatratus*), Hypsp (*Hypnea spinella*), Laupa (*Laurencia papillosa*), Masro (*Mastophora rosea*), Micma (*Microdictyon marinum*), Neoan (*Neomeris annulata*), Padau (*Padina australis*), Sarcr (*Sargassum cristaefolium*), Udoge (*Udotea geppiorum*), Valae (*Valonia aegagropila*), Valfa (*Valonia fastigiata*).

Group I is the seaweeds inhabitants of station 2 and station 3 with characteristics of rocky substrate consisting of 18 species: *Dictyota dichotoma, Dictyosphaeria cavernosa, Sargassum cristaefolium, Anadyomene wrightii, Caulerpa serrulata, Caulerpa sertularioides, Halimeda cuneata, Microdictyon marinum, Padina australis, Galaxaura fastigiata, Hypnea spinella, Gracilaria textorii, Neomeris annulata, Chaetomorpha spiralis, Gracilaria gracilis, Halimeda macroloba, Halimeda opuntia, Caulerpa racemosa*.

Group II is the seaweeds inhabitants of station 1 with the characteristics of muddy sand substrate consisting of 13 species: *Avrainvillea erecta, Halimeda cylindracea, Halimeda tuna, Boergesenia forbesii, Valonia aegagropila, Chaetomorpha crassa, Caulerpa lentillifera, Halimeda incrassata, Udotea geppiorum, Bornetella sphaerica, Codium ovale, Gracilaria verrucosa, Halimeda discoidea*.

Group III is the seaweeds inhabitants of station 4 with the characteristics of sandy substrate consisting of 14 species: *Avrainvillea lacerata, Valonia fastigiata, Hydrochlatrus chlatratus, Laurencia papillosa, Gracilaria salicornia, Amansia glomerata, Galaxaura apiculata, Spyridia filamentosa, Gracilaria edulis, Amphiroa rigida, Actinotrichia fragilis, Eucheuma denticulatum, Galaxaura filamentosa, Mastophora rosea*.

Conclusions. The results of the seaweeds inventory in the coastal waters of Mantehage Island totaled 45 species. The seaweeds community structure shows that it is still stable with high values of diversity, evenness and species richness, while the value of domination is small. The density of the seaweeds species *H. opuntia* has the highest density found in 3 stations, namely stations 1, 2 and 3, while in case of station 4 it is *G. edulis* with the highest density. In general, seaweeds species richness (biodiversity) is found in the high category. Overall, seaweeds are grouped into 3 station groups, group I consisting of station 2 and 3 with rocky substrate, group II consisting of station 1 with muddy sand substrate and group III consisting of station 4 with sandy substrates.

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