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Phytoplankton abundance in Haruku Strait, Central Maluku, Indonesia

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ABSTRACT

The Haruku Strait in the Central Moluccas is a potential marine resource located eastern Indonesia. Small pelagic fishes have been noted in abundance in the waters of this strait. Their abundance is mainly associated with the ample amount of plankton organisms serving as food for the former. To address the abundance of phytoplankton in Haruhu Strait, a study was carried out in September 2022. Sampling was achieved using a sample bottle from a depth of 1 meter. After that, the sample was filtered with a Kitahara net. Nineteen genera of phytoplankton were found in Haruku Strait during the study period. The phytoplankton abundance varied between 4,5 x 102 – 1,65 x 103 cells/l. Phytoplankton consists of Bacillariophyceae (Diatom) with 63% of the total genera, Dinoflagellata with 32 % of the total genera, and Cyanobacteria with 5%, while *Chaetoceros*, *Rhizosolenia*, *Gonyaulax*, *Coscinodiscus*, and *Ceratium* were the predominant phytoplankton genera in this area. The distribution pattern forms 8 groups.

INTRODUCTION

The Maluku Province is considered the highest marine fish resource in Indonesia either demersal, small, or large pelagic fish **(Tuapetel *et al.*, 2018)**. The potency fishery sector of the Central Maluku Regency is quite substantial and consists of marine fishery resources, mariculture potency, and fish processing potency **(Central Maluku Fisheries Board, 2012)**. The marine fisheries potency is related to the long coastal line of this area and its productive ecosystems, viz. the mangroves, seagrass beds, and coral reefs that distribute immensely. The Central Maluku Regency fish production amounted to 83,304 tons **(Kaihatu, 2018)**.

The central Maluku area is dominated by marine waters of 264,311 km2w width and 11,595.57 km^2 terrestrial area, which means that 95.89% of this area is dominated by seawater. With this condition, Central Maluku Province provides approximately 154,590 tons of capture-based fishery per year, consisting of large pelagic fish amounted to 76,608 tons per year and small pelagic fish with 30,299 tons per year, and 12,931 tons of other fishes per year **(BPS Maluku Tengah, 2018)**.

Most local fishers are considered small-scale fisheries, and the dominant fish caught were small pelagic fish, such as the flying fish (*Decapterus* sp.), the mackerel (*Rastrellinger* sp.), the scad fish (*Selaroides* sp.), the mackerel tuna (*Euthynnus affinis*), and the skipjack tuna (*Katsuwonus pelamis*) **(Ruban *et al.*, 2021)**. In the marine food web, the pelagic fish play an important role in the marine food web **(Vander Zaden & Vadeboncoer, 2002; Albouy *et al.*, 2019)**. The production capacity of small pelagic fish resources determines the availability of stocks for fisheries. There are internal and external factors that interact with each other to affect the carrying capacity of fish resources. Internal factors are biological and ecological processes, while external factors are the marine environment and fishing activities. External factors can be identified through changes in fishing efforts and oceanographic conditions posed on fish production **(Nelwan *et al.*, 2015)**.

Plankton has an essential role in the fluctuations happening in the naturalistic survival rates of the fish juveniles and larvae and the consequent effects on the adult fish stock. This means that tiny organisms control the development of the future fish stock. As larvae grow, many become less dependent on plankton, thereby reducing mortality rates with age. There is a correlation between the abundance of fish and the plankton abundance. Fishery wealth is commonly dependent on the wealth of plankton. The abundance of planktivorous fish promotes the growth of smaller zooplankton and phytoplankters, while larger zooplankton flourish with fewer fishes **(Abo-Taleb, 2019)**.

Phytoplankton is a type of microscopic plankton capable of photosynthesis found in oceans, seas, and freshwater, and an essential component of aquatic ecosystems. Phytoplankton can range in size and shape, and since they are photosynthesizing autotrophic organisms, they inhabit waters exposed to sunlight. Although each organism is microscopic in sufficient numbers, phytoplankton can be observed as colored patches at the surface of phytoplankton communities in the water bodies to support the base of the natural food chain depending on the natural fauna including the fish populations which can survive. At the same time, they produce almost 70 % of the world's atmospheric oxygen of water, or where two currents meet due to the presence of chlorophyll **(Pal & Choudhury, 2014; Pachiappan *et al.*, 2019)**. The objective of this research was to analyze phytoplankton composition, abundance, diversity, and distribution pattern in the waters of the Haruku Strait.

MATERIALS AND METHODS

1. Description of the study sites and data sampling

The research addressed the Haruku Strait of the Central Maluku Regency in September 2022. There were 16 stations selected for phytoplankton sampling. Astronomically, the sampling station lies between 3° 32‘6.84” - 3° 36‘52.329" South Latitude and 128° 21‘28.845“- 128° 24‘3.663" East Longitude (Fig. 1). Global Position System (GPS) Model 76CSx was used to coordinate the position of the research station.

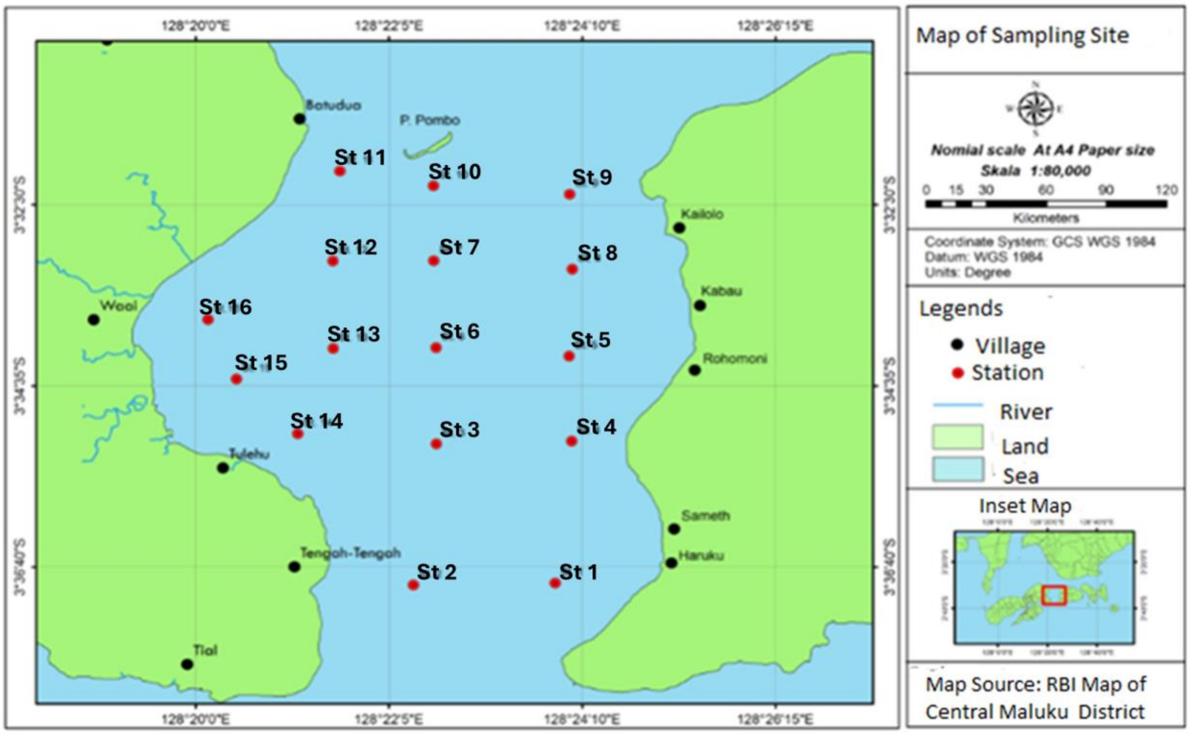

Fig. 1. Map of the study site and the sampling station

The fishing vessel was used as a transportation unit for phytoplankton sampling. The phytoplankton sampling was conducted by way of taking water samples at a depth of 1m using a sampler bottle. The water sample was then filtered using a phytoplankton net (Kitahara type), with a net diameter of 0.30m, 1m in length, and a mesh size of 60µm. The phytoplankton sample collected was then preserved with a 4% formaldehyde concentration and then left in the laboratory for 24 hours.

2. Analysis of phytoplankton abundance

The phytoplankton cell was then identified, and the cell was counted using Olympus electric microscope. The phytoplankton identification was done following the guidelines of **Yamaji (1984)**, **Newell and Newell (1977)**, and **Tomas (1996)**. Identification was done up to the genus level. Phytoplankton abundance was counted following **Huliselan *et al.* (2007)** modified from **Perry (2003)** with the following formula:

$$D = \frac{Nf \times Vp}{V}$$

Where:

D : phytoplakton abundance (cell/l)
Nf : number of cells withing 1 ml (sub-sample)
Vp : dilution volume
V : volume of filtered water (l)

3. Statistical analysis

A Bay-Curtis similarity analysis **(Clarke & Warwick, 1994)** was performed to determine groups of phytoplankton distributed at each sampling station. Data on phytoplankton abundance were first transformed following the log (X+1) formula and then standardized prior to group distribution analysis. For Shannon Wiener's diversity index (H'), species dominance (Simpson index l) and Pielou's evenness index J were calculated using the PRIMER-5 software program.

RESULTS

1. Composition of phytoplankton types

There were 19 genera of phytoplankton recorded during the research consisting of 3 classes, 4 orders, and 12 families. Diatom, dinoflagellate, and cyanobacteria were the phytoplankton class found. The diatom consists of 12 genera (63%), dinoflagellate consists of 6 genera (32%), and cyanobacteria consists of 1 genus only (5%). Table (1) shows phytoplankton genera found in Haruku Strait.

Table 1. Phytoplanktondi found in Haruku Strait

Class	Order	Family	Genera
Bacilariophyceae (Diatom)	Centrales	Biddulphiaceae	*Biddulphia*
		Chaetoceraceae	*Chaetoceros*
		Coscinodiscaceae	*Coscinodiscus*
		Hemiaulaceae	*Hemialus*
		Leptocylindraceae	*Leptocylindrus*
		Melosiraceae	*Melosira*
		Rhizosoleniaceae	*Rhizosolenia*
	Pennales	Naviculaceae	*Thalassiosira*
			Pleurosigma
		Nitzshiaceae	*Nitzshia*
		Fragilariaceae	*Thalassiothrix*
			Thalassionema

Dinoflagellate	Dinoflagellida	Dinophyaceae	*Ceratium*
			Dinophysis
			Protoperidinium
			Gonyaulax
			Alexandrium
		Desmophyaceae	*Prorocentrum*
Cyanophyceae	Oscillatoriales	Oscillatoriaceae	*Trichodesmium*

Based on the distribution of phytoplankton genera number in the waters of Haruku Strait, Station 4 shows the highest genera number, whilst Station 5 shows the lowest (Fig. 2). Four phytoplankton genera distributed at all stations with a 100% presence were *Coscinodiscus*, *Rhizosolenia*, *Ceratium*, and *Gonyaulax*. While, some genera including *Melosira*, *Thalassiothrix*, *Thalassionema*, *Prorocentrum*, and *Alexandrium* were only found at specific stations.

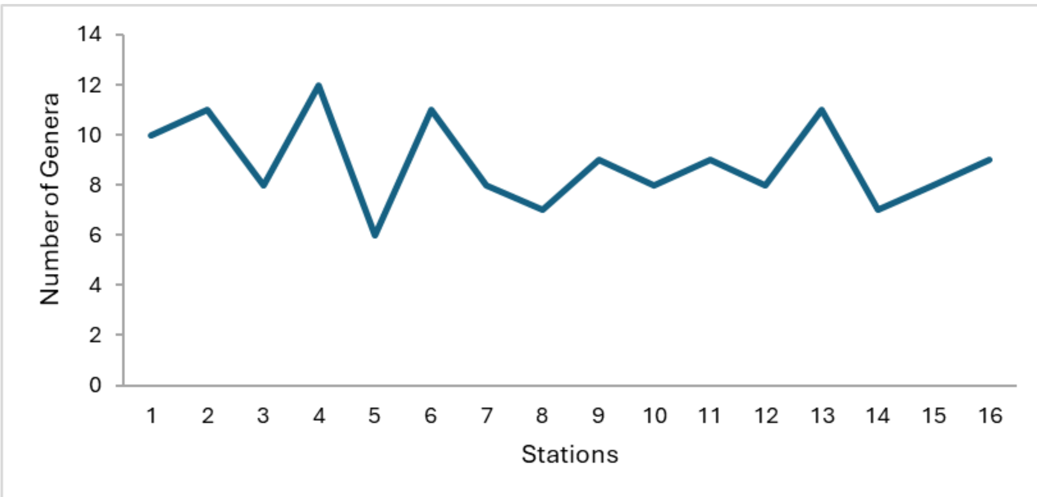

Fig 2. Number of phytoplankton genera found at stations under study

The similarity index of phytoplankton between research stations shows that the phytoplankton varies between 52.21 & 84.84%. This shows that the average similarity of the phytoplankton genera between stations was 50%. The highest similarity index was found at Station 10 and Station 14, indicating that 84.84% of the phytoplankton genera found at Station 10 were also found at Station 14. If the similarity index found in Table (2) was linked to the similarity criteria proposed by **Michael (1984)**, the similarity between the phytoplanktons at the research station (Haruku Strait) would be categorized as similar (S = 50-75%) to very similar (S = 75-100%).

Table 2. Similarity index between stations

	ST 1	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8	ST 9	ST 10	ST 11	ST 12	ST 13	ST 14	ST 15
ST 2	73.53														
ST 3	68.95	59.58													
ST 4	71.11	71.57	61.60												
ST 5	61.08	61.02	72.69	65.01											
ST 6	58.17	52.21	48.62	64.38	53.32										
ST 7	79.78	68.42	64.29	77.48	68.68	65.64									
ST 8	77.15	72.79	66.97	74.59	73.67	58.91	83.97								
ST 9	72.84	62.22	68.01	67.44	63.81	69.81	69.87	76.69							
ST 10	71.89	75.69	60.93	81.39	68.95	62.43	72.68	80.83	79.48						
ST 11	68.04	63.83	68.68	70.74	68.89	71.38	67.06	74.45	84.29	80.13					
ST 12	73.01	62.40	57.45	74.35	62.20	73.53	75.63	73.94	77.01	79.14	81.99				
ST 13	56.24	58.95	58.18	67.99	53.94	62.65	57.05	59.74	64.21	72.25	72.74	74.70			
ST 14	72.61	67.25	62.76	68.56	66.68	62.85	71.69	80.63	83.29	84.84	82.79	79.16	70.24		
ST 15	68.16	69.47	61.58	64.67	70.25	61.15	74.13	82.22	70.51	75.21	69.51	66.70	66.91	78.73	
ST 16	58.44	57.96	66.91	62.55	59.19	73.56	63.9	67.31	75.91	66.48	80.18	77.78	78.34	71.65	73.35

2. Phytoplankton abundance

Phytoplanktn abundance in the Haruku Strait waters (Fig. 3) range from 4.5x102 – 1.65x103 cell/l, with a mean of 8.55x102 cell/l. The highest phytoplankton abundance was found at station 6, and the lowest abundance was found at Station 15. From 19 genera recorded, the dominant genera were *Chaetoceros*, followed consecutively by *Rhizosolenia*, *Gonyaulax, Coscinodiscus* and *Ceratium*.

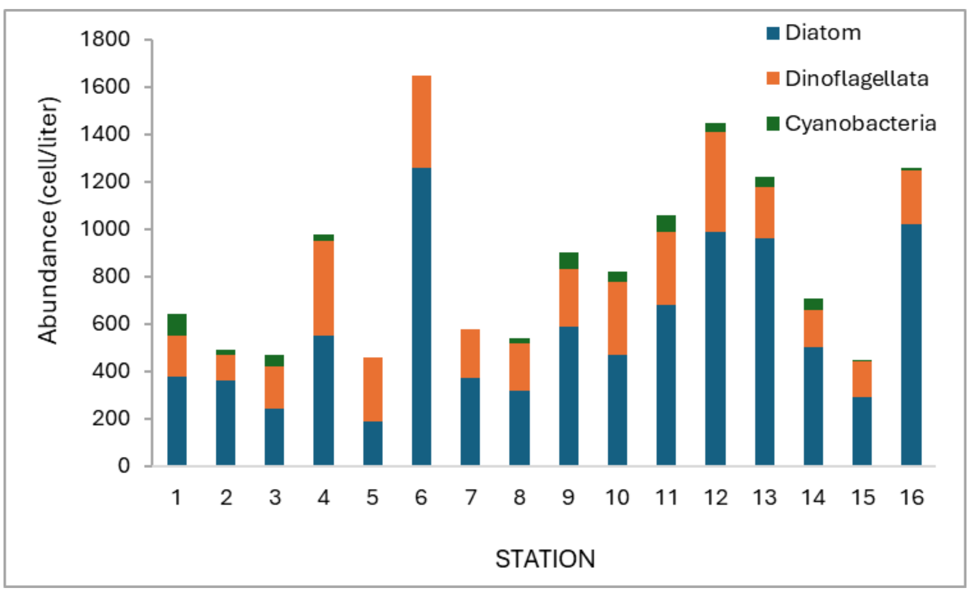

Fig. 3. Phytoplankton abundance between stations in the Haruku Strait waters

Based on the phytoplankton abundance, the Bacilariophyceae (Diatoms) was found to lead at all the station. Fig. (3) displays three groups of phytoplankton: Diatom with an abundance of 9.17 x 103 cell/l, followed by Dinoflagellate with an abundance of 3.97 x 103 cell/l, and Cyanobacteria with an abundance of 5.4 x 102 cell/l. Diatom and dinoflagellate were commonly found to be abundant globally and usually, and the abundant phytoplankton community was found in particular in the coastal area **(Lalli & Parsons, 1997; Romihartarto & Juwana, 2005)**. Diatom is one of the most important primary production organisms in the marine environment **(Perry, 2003)**. Morover, it is the primary food chain undertaking photosynthesis to change the sun's energy to chemical energy. The phytoplankton abundance was found to vary between 1.9 x 102 & 1.26 x 103 cells/l. The highest abundance was found at station 6, followed consecutively by station 12, 16, 13, and 11 (Fig. 3).

The highest phytoplankton genera abundance was denoted by *Rhizosolenia* and was found at stations 1, 3, 8, and 15. *Coscinodiscus* was found at stations 2, 5, and 16. The highest *Gonyaulax* was found at stations 4 and 10, whilst *Chaetoceros* showed the highest abundance at stations 5, 6, 7, 11, 12, 13, 14, and 16 (Table 3). From 19 phytoplankton genera found in the Haruku Strait waters, the *Chaetoceros* was the dominant genera. This condition was also found in Ambon Bay where *Chaetoceros* was the most abundant genera **(Pello *et al.*, 2016)**. **Parson e*t al.* (1984)** affirmed that generally diatom was dominant globally in all aquatic environments and can be assumed that *Chatoceros* cells can form a long chain; therefore, these genera were more abundant compared to other genera.

Table 3. The abundance proportion (%) of dominant phytoplankton genera in Haruku Strait

	Stations	Genera of phytoplankton								
		Rhz	*Cer*	*Cos*	*Tric*	*Cha*	*Nitz*	*Gony*	*Prot*	*Lept*
Proportion (%)	ST 1	25.00	18.75	18.75	14.06	9.38				
	ST 2	18.37	14.29	32.65		12.24	8.16			
	ST 3	29.79	23.40	12.77	10.64			10.64		
	ST 4	28.26	15.22	13.04				30.43	8.70	
	ST 5	10.91	10.30	27.27		23.64		10.91		
	ST 6	10.91	10.30	27.27		23.64		10.91		
	ST 7	18.97	22.41	13.79		24.14		8.62		
	ST 8	22.22	14.81	14.81		22.22			12.96	
	ST 9	20.00	10.00	12.22		22.22		14.44		
	ST 10	15.85	8.54	14.63		18.29		26.83		
	ST 11	11.32		10.38	6.60	38.68		19.81		
	ST 12	14.48	8.97	6.90		45.52		17.93		
	ST 13	16.39	3.28			48.36		13.93		5.74
	ST 14	19.72		16.90	7.04	33.80		18.31		
	ST 15	22.22	11.11	15.56		17.78		20.00		
	ST 16	11.11	8.73	7.14		54.76		8.73		

Notes: *Rhz = Rhizosolenia, Cer = Ceratium, Cos = Coscinodiscus, Tric = Trichodesmium, Cha = Chaetoceros, Nitz = Nitzshia, Gony = Gonyaulax, Prot = Protoperidinium, Lept = Leptocylindrus*

3. Phytoplankton diversity

The phytoplankton diversity index (H’) value found in this study (Fig. 4a) reveals that the diversity of phytoplankton at Haruku Strait was considered low. The diversity index ranges between 1.5194 to 2.1754 with an average of 1.8237. The highest diversity index was found at station 4, and the lowest one was found at station 16. The highest and the lowest values of diversity index (H’) were strongly determined by the number of species and individual abundance of each species **(Odum, 1971)**. According to **Stirn (1981)**, H’< 1 explains that the community is in an unstable condition. While, if H’ ranges from 1 – 3, then the community is in a moderate stability, and H’> 3 means that the community is in a stable condition. The higher the H’, the more diverse the organism in that area or that particular area forming an ideal living area. The conditions in this area easily change with only small environmental changes.

The phytoplankton evenness index (J’) analysis shows a high J’ value (Fig. 4b). The phytoplankton community evenness index (J’) inthe waters of the Haruku Strait ranges between 0.6893 and 0.9464, with an average of 0.8449. If the evenness index of one particular organism varies between 0.6 – 0.8 **(Odum, 1971)**, then this organism is in a steady state. Based on the findings, the phytoplankton community in Haruku Stait was considered to be less stable since the average J’value is slightly higher than the reference J’value. The evenness index value ranges from 0 – 1, and the value close to 0 means that the evenness between species is low; on the other hand, when the J’value is close to 1, then the evenness between species is alike and does not have high differences. **Krebs (1985)** describes the evenness value varying between 0- 1, with evenness criteria as follows: the value between 0.0 &0.4 is considered a low evenness; the value ranging between 0.5 – 0.6 is categorized as moderate, and the value range between 0.7 -1.0 is categorized as a high evenness. Based on this category, the phytoplankton evenness index for the Haruku Strait is considered high.

The low evenness index displays that the highest phytoplankton was found at station 8, and the lowest evenness was found at station 13. Stations with the highest diversity index (H’) and evenness (J’) have the lowest dominance index, indicating that there is a particular phytoplankton genus that dominates the phytoplankton composition. On the other hand, the highest phytoplankton dominant index was found at station 16, whilst the lowest was found at station 4. The domination index is a proportional inverse of the species diversity index **(Odum, 1971)**. One particular community with a high diversity index will have a low dominant index. Whereas, a community with a low diversity index will have a high dominance index.

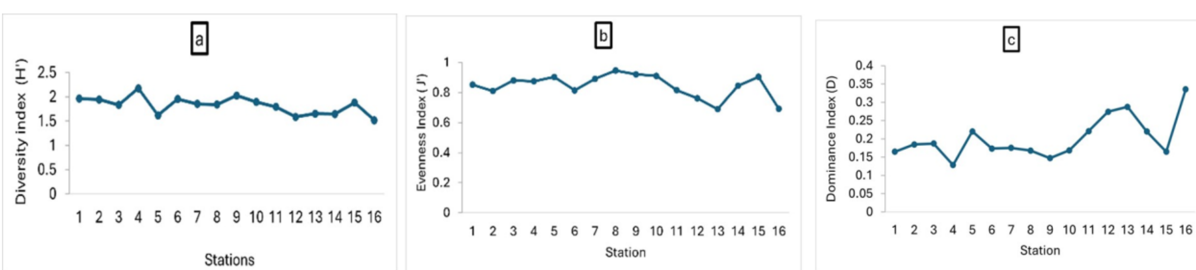

Fig 4. **a.** Diversity (H’), **b.** Evenness (J’) and **c.** Dominance (D) indexes of phytoplankton in Haruku Strait

4. Distribution pattern

The cluster analysis using the Bray-Curtis similarity index was performed through a dendrogram chart, and the result is shown in Fig. (5). Data show the formation of 8 clusters based on the cluster analysis result, and the cluster was as follows:

1. Cluster 1 (Station 3 and 5) is characterized by low phytoplankton abundance. The dominant phytoplanktons in this group are *Rhizosolenia, Ceratium, Coscinodiscus*, and *Chaetoceros*
2. Cluster 2 (Station 2) is characterized by a low dominance of *Rhizosolenia*
3. Cluster 3 (Station 4) characterized by the dominance of *Nitzshia*;
4. Cluster 4 (Stations 9, 10, 11, 12, and 14) is characterized by a high abundance *Chaetoceros, Rhizosolenia*, and *Gonyaulux.*
5. Cluster 5 (Station 15) is characterized by a very low phytoplankton abundance compared to other stations.
6. Cluster 6 (Stations 1, 7, and 8) is characterized by the abundance of *Ceratium;*
7. Cluster 7 (Station 6) is characterized by high phytoplankton abundance and dominated by *Coscinodiscus.*
8. Cluster 8 (Stations 13 and 16) characterized by high *Chaetoceros* abundance.

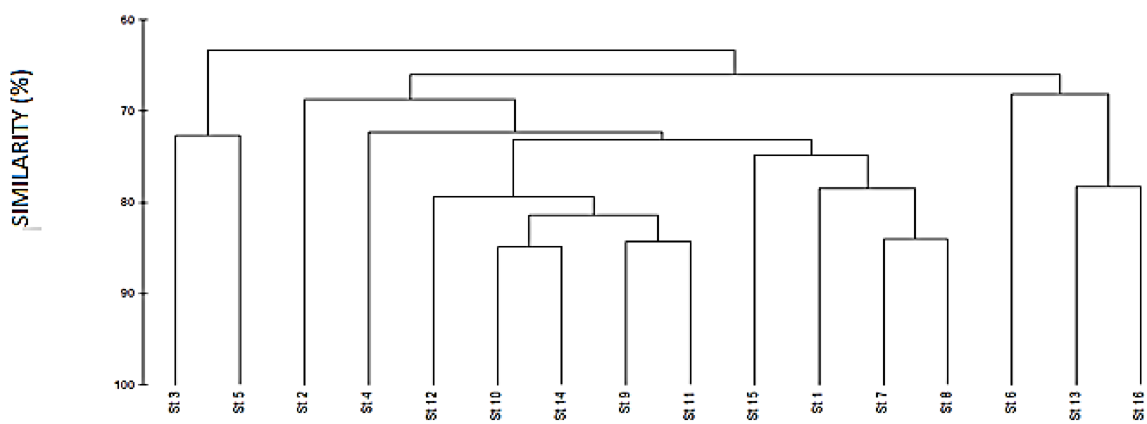

Fig. 5. Dendograms showing distributed groups of types by station

The MDS analysis with stress value of 0.16 also shows 8 groups of phytoplankton found in Haruku Strait (Fig. 6).

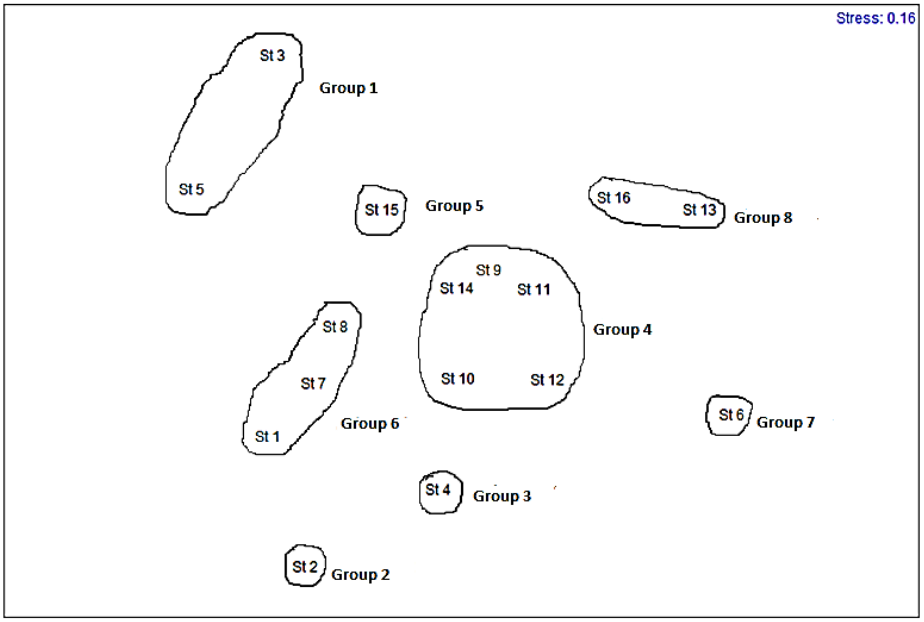

Fig. 6. MDS Grouping of stations based on abundance and number of genera

DISCUSSION

The dominance of Bacillariophyceae (Diatoms) is suspected because phytoplankton belonging to this class has a high adaptability and survival in various aquatic environments including extreme conditions. According to **Odum (1998)**, the large number of classes of Bacillariophyceae (Diatoms) in waters is due to their ability to adapt to the environment, be cosmopolitan, be resistant to extreme conditions and have high reproductive power. **Praseno and Sugestiningsih (2000)** stated that when there is an increase in nutrient concentration, diatoms can reproduce three times more in 24 hours, while dinoflagellates are only able to do it once in 24 hours under the same nutrient conditions.

The phytoplankton that is commonly found abundantly in one area is a diatom followed by a dinoflagellate **(Lalli & Parsons, 1997)**, whilst **Nontji (2008)** stated that diatoms usually dominate one water body since their reproductive potency is bigger than other phytoplankton group. The existence of all the phytoplankton genera at all stations explains that particular genera have a wide distribution in the marine environment and can adapt to the environmental condition. On the other hand, genera that are less frequent and only found to distribute at a particular station have limited distribution. If the similarity index found in Table (2) was linked to similarity criteria proposed by **Michael (1984)**, the similarity between phytoplankton at the research station (Haruku Strait) would be categorized as similar (S = 50-75%) – to very similar (S = 75-100%).

The highest and the lowest diversity index (H') was strongly determined by the number of species and individual abundance of each species **(Odum, 1971)**. According to **Stirn (1981)**, H'< 1 explains that the community was in an unstable condition. When H' ranges from 1 – 3 means that the community is in a moderate stability, and when H'> 3 means the community is in a stable condition. The higher the H', the more diverse the organism in that area, or that this particular area is an ideal living area. The conditions in this area easily change with only small environmental changes.

The evenness index of one particular organism varies between 0.6 – 0.8 **(Odum, 1971)** meaning this organism is in a steady state. Based on the findings, the phytoplankton community in Haruku Strait was considered to be less stable since the average J'value is slightly higher than the reference J'value. The evenness index value ranges from 0 – 1 when the value is close to 0 means that the evenness between species is low; on the other hand, when the J'value is close to 1 means the evenness between species is alike and does not have high differences **(Odum, 1971)**. **Krebs (1985)** describes that the evenness value varies between 0-1, with evenness criteria as follows: the value between 0.0 -0.4 is considered low evenness; when the value range between 0.5 – 0.6, evenness is categorized as moderate, and the value range between 0.7 -1.0 is categorized as high evenness. Based on this category, the phytoplankton evenness index in the waters of Haruku Strait is considered high. The domination index is a proportional inverse of the species diversity index **(Odum, 1971)**. One particular community with a high diversity index will have a low dominant index. While, a community with a low diversity index will have a high dominance index.

CONCLUSION

Based on the analysis of the phytoplankton composition in Haruku Strait, it can be concluded that there were 19 genera of phytoplankton found in Haruku Strait. The phytoplankton abundance ranged from 4.5x102 to 1.65x103 cells/l, and the diversity was considered low, and the distribution pattern formed 8 groups.

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