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Distribution of phytoplankton abundance in thermocline layers of Sangihe Talaud Island, Indonesia

Abstract

The aim of this study was to determine the abundance of phytoplankton in the thermocline layer of Sangihe Talaud Islands. The research was conducted in 33 stations in October 2018 and the samples were taken at the thermocline depth using a rosette sampler as much as 10 L Environmental parameter, namely temperature, salinity, and depth, was measured using the SBE 911-Plus CTD (Conductivity Temperature Depth). The water samples were concentrated into 40mL using plankton net with mesh size 20 µm. The phytoplankton enumeration was conducted using the Sedgwick-Rafter Cell Counter under a 100x magnification microscope and identified to the species level. Mapping of the phytoplankton abundance, temperature, and salinity in form of contours was conducted by Surfer 9 software, and the similarities among stations were analyzed based on the Bray-Curtis index using Biodiversity Pro Ver.2 software. The result showed there were 84 species found during sampling with an abundance of 7059-542,222 cell m-3. The highest abundance was observed to be as a result of warm water temperatures, while low abundance were observed in some stations due to the presence of high salinity level. Based on the Bray-Curtis index, 2 pairs of stations had a similarity >50%. This was associated with the general similarities found in the community.

Keywords: diversity, phytoplankton, thermocline, sangihe talaud waters

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Introduction

The waters of Sangihe Talaud is a potential fishing area for commercial fish commodities like Tuna. The catch for tuna fisheries production always increases yearly, with the projection of reaching 21,678 tons/year by 2019.[1] The thermocline layer is a habitat with an optimum temperature range of 10-16°C favored by a large pelagic fish such as the big eye and yellow fin tuna and to meet their dietary needs, these fishes always migrate vertically.[2,3] Furthermore, habitat conditions and food availability will largely determine the existence of fish in the sea, and the optimal conditions that support to the adequate food availability was found in Sangihe Talaud waters. The phytoplankton groups are the basic foundation of the food chain in the marine ecosystems and about 45% of primary production is donated by them.[4] Their abundance will be directly proportional to the presence of high commercial fish such as tuna, because of its ability to photosynthesize by utilizing sunlight.[5] They can make their own food without depending on other organisms, and serve as food for the trophic level above. However, this ability may become a challenge if there is no sun to photosynthesize.[6]

Thermocline, as a euphotic zone, has the ability to receive sunlight but at a limited amount of 1%. The zone can support the growth of phytoplankton though the rate may not be as high as it would be on the surface layer. The waters can still receive sunlight up to a depth of 200 m. The limited sunlight in the thermocline layer has a close relationship to the temperature, which consequently affects salinity. The temperature is more influential on phytoplankton blooms than sunlight,[7] while salinity has an effect on the movement and osmotic pressure as well as the ability to absorb nutrients.[8] Therefore, the oceanographic conditions will affect to the abundance of phytoplankton in the thermocline layer. Several studies have been conducted on the dynamics of planktons in Indonesian waters. However, the research on phytoplankton in the thermocline layer, especially in Sangihe Talaud waters is very limited. Phytoplankton play very important role in the existence of other biotas in the sea, but they have limited life due to the sunlight for photosynthesis. Nevertheless, they have the ability to survive in the thermocline layer. Therefore, the aim of this study was to determine the abundance of phytoplankton in the thermocline layer of Sangihe Talaud Waters.

Method and material

The research was conducted 33 stations in October 2018 using the Baruna Jaya VIII Research vessel. The area was located on coordinates 2°4'13"-4°44'22"N and 125°9 '28"-125°56'57"E, which is directly adjacent to Republic of Philippines in the north, Northern Sulawesi Province in the south, Pacific Ocean and Maluku Sea in the east, and Sulawesi Sea in the west. The research location is presented in Figure 1. The measurement of physical and chemical parameter, i.e. temperature, salinity, and depth, was conducted using the SBE 911-Plus CTD (Conductivity Temperature Depth) with Carousel Water Sampler Sensor. This tool was equipped with 12 rosettes bottles sampler with capacity of 10 liters each, which was used to collect phytoplankton samples at the thermocline depth. The water was filtered using hand plankton net mesh size 20µm, and collected of the 40ml filtrate was preserved in Lugol solution. The phytoplankton was enumerated through the use of Sedwick-Rafter Counting Cell under a microscope 100x magnification and identified to the species level based on on Yamaji,[9] Shirota,[10] Omura et al.,[11] Algabase[12] and

WoRMS.[13] The plankton density data was analyzed descriptively by charts and graph, while contour mapping of the phytoplankton temperature, salinity, and abundance was analyzed using surfer software.

The abundance of phytoplankton was calculated using a formula as follow Perry formula modified by Huliselan et al.,[14] as stated below:

$$D = \frac{N f_x V_p}{V}$$

Notes:

D=Phytoplankton Abundance (cell m^3)

Nf=Clel total per 1ml

Vp=dilution volume

V=iltered water volume (m^3)

The value of abundance was used as a parameter for cluster analysis in order to show the similarities among stations,[15] as follows:

$$S_{jk} = 100\left(1 - \frac{\sum|Yij\text{-}Yij|}{\sum(Yij+Yik)}\right)$$

Notes:

S_{jk} = index of similarity between samples j and k in percent;

Y_{ij} = number of species i in column j;

Y_{ik} = number of species I in column k.

This similarity was further analyzed by Bray Curtis Cluster Analysis (Group leverage) using Biodiversity Pro Ver.2 software.[16] The clustering were presented in the form of a dendrogram, such that if the value is close to 100% with a shorter distance level, a high level of similarity is achieved. Meanwhile, if the value approaches 0% with a farther distance level, there is either low or no level of similarity.

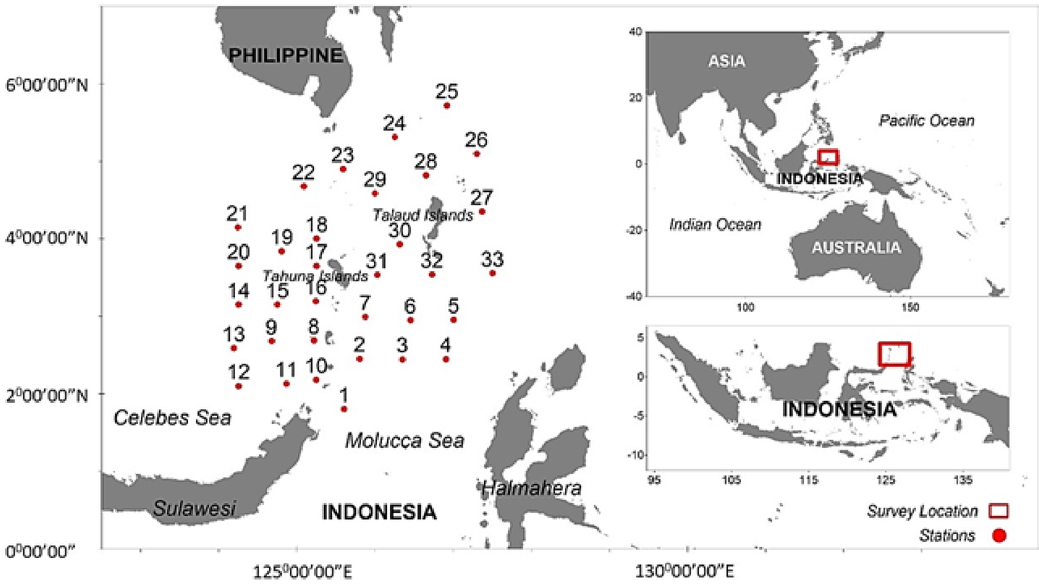

Figure 1 Map showing research location in Sangihe Talaud Waters, the sampling station indicated with no 1 to 33.

Result and discussion

Hydrological parameter

In this study, the temperature and salinity of Sangihe Talaud waters weas taken from CTD data recordings up to a depth of 600m. This was necessary to clearly illustrate the stratification profile of the three layers of the sea i.e. mixed, thermocline, and cold layers under the thermocline.[17] The hydrological parameter values obtained at the 33 stations are presented in Figure 2.

Figure 2A shows that the temperature profile continue to decrease with increasing depth. The thermocline layers was found in the depth between 100m and 200m. The highest temperature was found at the surface depth of 5m to be 30.24°C, and it decreased dramatically to 14.83°C at 167m at the thermocline layers, and to 6.5°C at 600m. This is in contrary to the salinity pattern (Figure 2B), where the decreasing depth results in increasing salinity. The salinity was found the lowest at the surface depth of 5m to be 33.55%. It increased to 35.08% at a depth of 92m known as halocline layer, and remained stable between 34-35% at 600m.

Composition of phytoplankton species

From the 33 observed stations, there were 84 species of phytoplankton consisted of 4 classes, 24 orders, 34 families, and 41 genera. The four classes include Bacillariophyceae (12 orders, 16 families, and 21 genera), Dinophyceae (10 orders, 16 families, and 18 genera), Raphidophyceae and Cyanophyceae (each of which is 1 in order, family and genus). The Bacillariophyceae (Diatom) were found the highest among Phytoplankton species in the thermocline layer of the Sangihe-Talaud Waters as shown in Figure 3. The Bacillariophyceae were found to be some 51 species.

The second largest composition was the Dinophyceae (Dinoflagellata) with 30 species, while the least observed was

Raphydophyceae and Cyanophyceae with 2 and 1 species, respectively. Furthermore, there were 5 species observed to be dominating the phytoplankton composition of the thermocline layers of Sangihe Talaud waters, and they include *Chaetoceros affinis*, *Trichodesmium erythraeum*, *Thalassionema nitzchioides*, *Leptocylindrus danicus*, and *Detonula pumila* as shown in Figure 4.

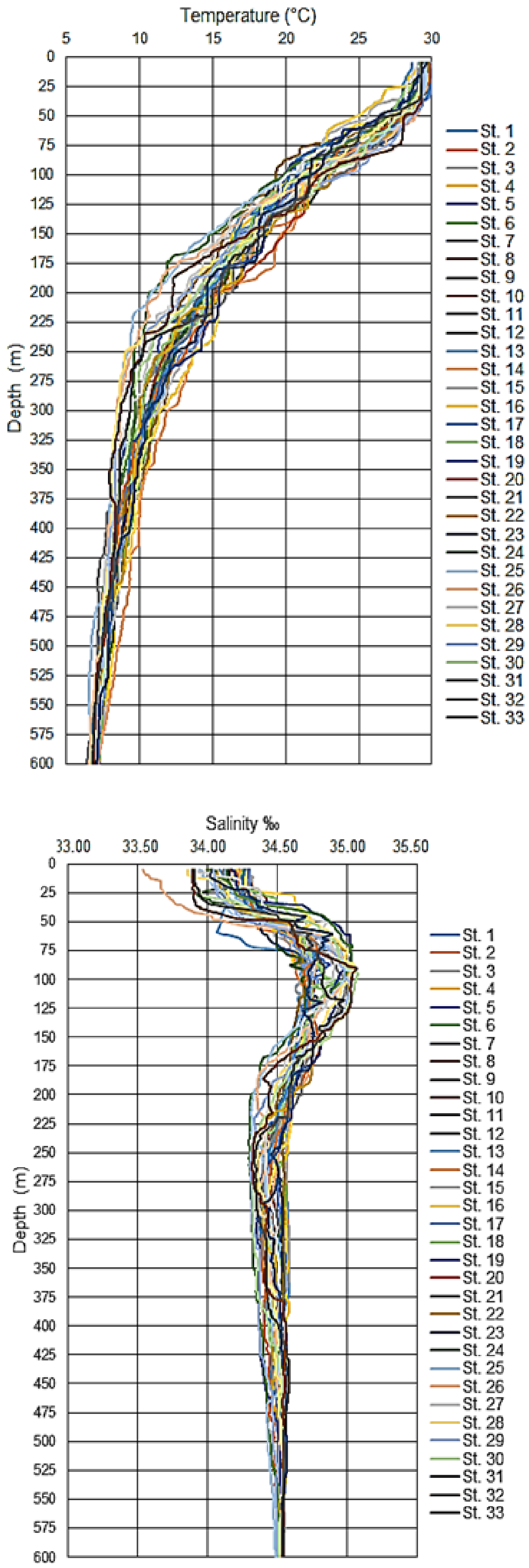

Figure 2 Profile of temperature (A) and salinity (B) in Sangihe Talaut sea waters.

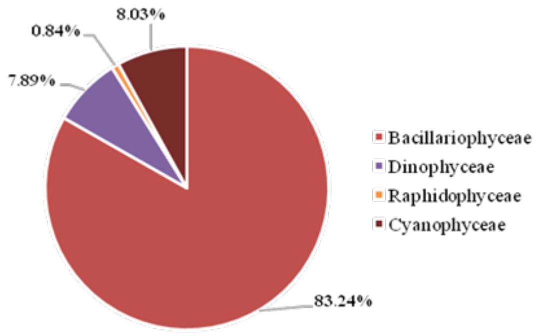

Figure 3 Taxon composition based on phytoplankton classes.

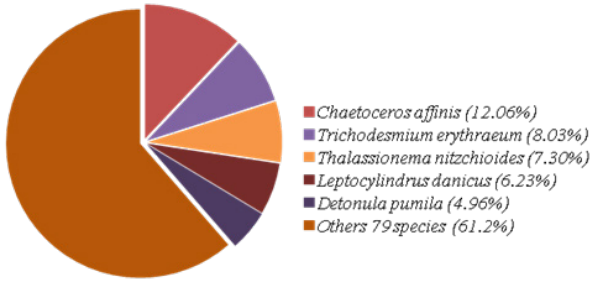

Figure 4 Phytoplankton composition base on the dominated species.

The dominant species have total abundance values in all stations with *Chaetoceros affinis* 364,667 cell m^{-3}, *Trichodesmium erythraeum* 242,667 cell m^{-3}, *Thalassionema nitzchioides* 220,825 cell, *Leptocylindrus danicus* 188,444 cell m^{-3}, and *Detonula pumila* 149,830 cell m^{-3}. The phytoplankton with very less abundance (<2000 cell m^{-3}) were *Dinophysis parvula*, *Nitzchia sigma*, *Oxytoxum elegans*, *Rhizosolenia setigera*, *Rhizosolenia stolterforthii*, *Ditylum brightwelli*, *Bacteriastrum hyalinum*, and *Nematodinium* sp.

Comparison of phytoplankton abundance between stations

There was quite a variation in the comparison of the phytoplankton abundance between stations. Some species have very high abundance, while others were much lower as shown in Figure 5.

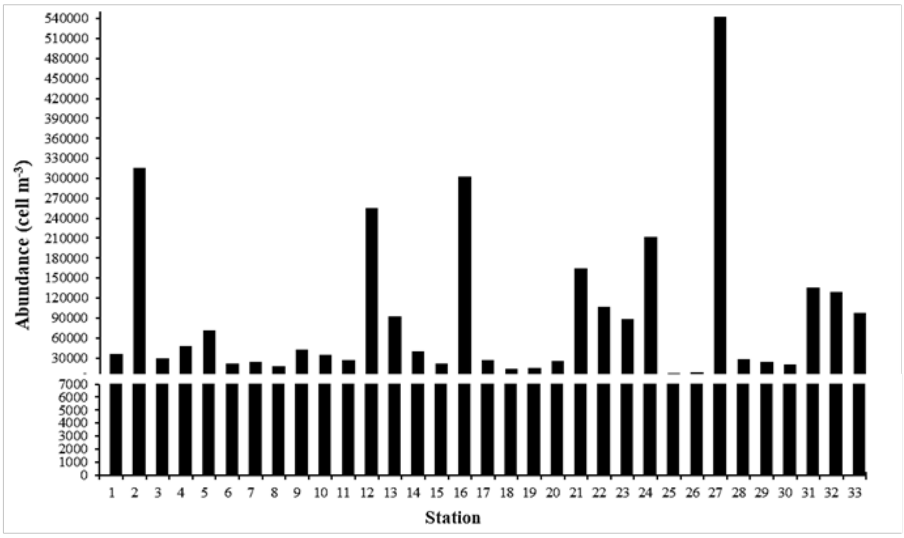

Figure 5 Abundance in 33 stations in thermocline layers.

The total abundance in all stations ranged from 7059 to 542,222 cell m^{-3}. Stations 27, 2, 16, 12, and 24 have the highest abundance, while 25, 26, 18, 19, and 8 were the lowest. The abundance of phytoplankton has a relationship with the physics and chemistry of water as a medium of life. The difference in the abundance between stations was dependent on the temperature and salinity of the thermocline layer, and supported by the distance of the islands, which allows the distribution of nutrients to support phytoplankton cell growth. The areas with warm temperatures were observed to have the tendency of having a high abundance, while those with high salinity were lower. This phenomenon is explained in Figure 6.

Figure 6A shows low temperatures contour in the thermocline layer, which spread across to southeastern area with an average temperature of 18.07^{o}C. This was found to be the reason for the low abundance of phytoplankton when compared to other stations, such as stations 2, 12, 16, 27, and 24 which an average temperature of 21.47^{o}C. However, this was not always directly proportional to the phytoplankton abundance because of the salinity level. For example, stations 22, 23, 24, and 25 have a high temperature but low abundance of phytoplankton. Figure 6B showed contours of salinity level with an average of 35.01%. Figure 6C showed the contour of phytoplankton abundance among the stations. The highest Phytoplanktonn abundance tended to the area of north eastern and south western, that were affected by ocean current condition. Phytoplankton with the same life characteristics will occupy the same niche.[18,19] Even though the habitat was different but if the environmental condition were the same, the same phytoplankton will be present.

The relationship between stations in Sangihe Talaud Waters produced the similarity dendrogram shown in Figure 7.

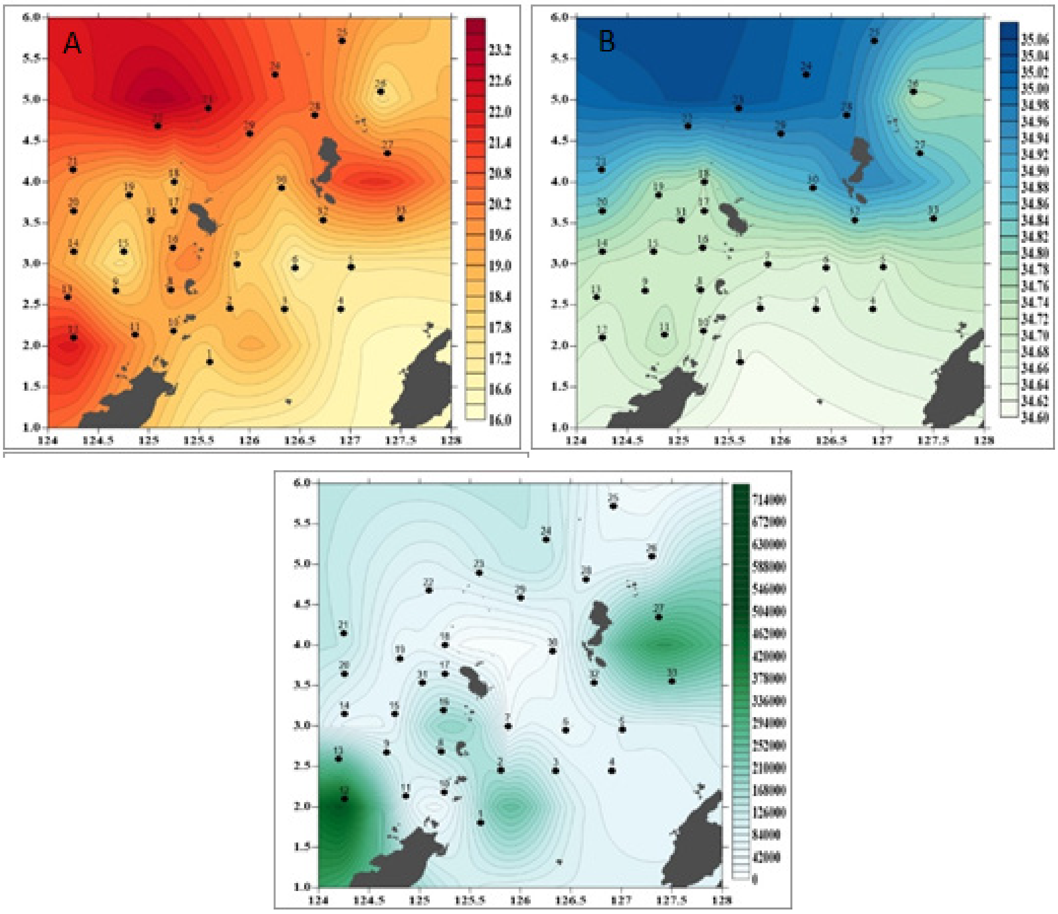

Figure 6 Contour of temperature (A), salinity (B), phytoplankton abundance (C) in Sangihe Talaud thermocline layers.

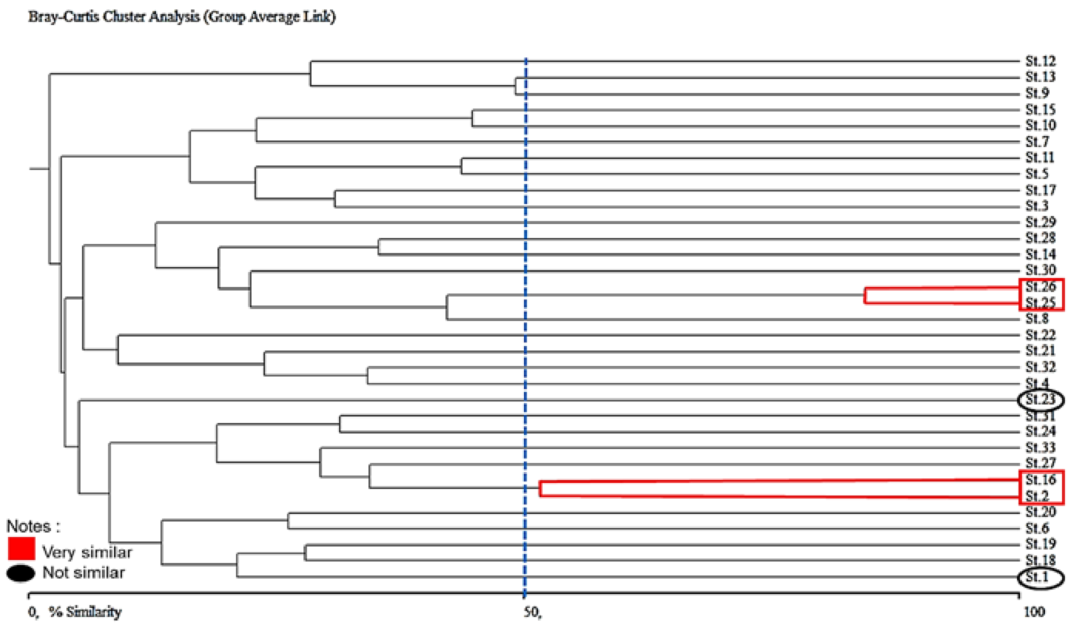

Figure 7 Bray curtis analysis with a similarity level of 50%.

Based on the similarity analysis of Bray Curtis with a similarity rate of 50% (Figure 7), divided 2 group of stations with similarities above 50%, namely station 25 with 26 (84%), and station 2 with 16 (51%), while station 1 and 23 have the lowest percentage of similarity was 12%. The presence of the same type of phytoplankton causes high similarity between stations. The presence of phytoplankton is presented in Table 1.

Table 1 The presence of phytoplankton with similarities above 50% and the low similarity stations

Similarity 84%		
Presence	St.25	St.26
Dinophysis	√	√
Mesoporos	√	√
Podolampas	√	√
Similarity 51%		
Presence	St.2	St.16
Bacteriastrum	√	-
Chaetoceros	√	√
Coscinodiscus	√	√
Dactyliosolen	√	-
Hemialus	√	-
Planktoniela	√	-
Pseudo-nitzschia	√	√
Rhizosolenia	√	-
Thalassionema	√	√
Pyrocystis	√	√
Chattonella	√	√
Similarity 12%		
Presence	St.1	St.23
Chaetoceros	√	-
Coscinodiscus	√	√
Pseudo-nitzschia	√	-
Ceratium	√	-
Hemialus	-	√
Lauderia	-	√
Chattonella	-	√

Station 25 and 26 with 84% similarity present the same phytoplanktons at both station namely from Genus Dinophysis, Mesoporos, and Podolampas, while the similarity of 51% includes several genera that were not present, namely Bacteriastrum, Dactyliosolen, Hemialus, Planktoniela, and Rhizosolenia. The similarity of 12% was only one genus of phytoplankton, which was found to be the same between station 1 and 23.

Discussion

The average thermocline depth at Sangihe Talaud waters was found to be 130m. Figure 2A shows that the temperature of the surface layer has decreased dramatically at this depth due to the decrease in the penetration of sunlight, which transfers heat.[20,21] However, Figure 2B shows that the salinity profile is inversely proportional to temperature, where the salinity increases with the increasing depth. This is related to the density of water and buoyancy, where heavier mass tends to sink to reach equilibrium, while the less dense rises to the surface. The temperature and salinity conditions in the thermocline layer form a specific phytoplankton community structure.

The results of this study found that most phytoplankton came from the class of Bacillariophyceae. This is in accordance with the finding of some researchers, that Bacillariophyceae dominate any type of waters.[22–26] Besides the research Sharma et al.,[27] found that similarities in phytoplankton from Bacillariophyceae dominate 47% of most waters in Dodi Tal from Gahwal Himalaya. This is associated with the characteristic high survival and adaptability of Bacillariophyceae.[22,28] Their fucoxanthin, chlorophyll-a, and chlorophyll-c pigments allow them to be able to live well by utilizing minimal light to photosynthesize in the thermocline layer. Bacillariophyceae tends to like conditions with not too strong light intensity.[29]

There were 4 species observed to have the highest abundance in the thermocline layer throughout the stations, and they were all from the Bacillariophyceae Class, and one of them from the Cyanobacteria. The species that occupied the first position was *Chaetoceros affinis*. The genus *Chaetoceros* has a strategy to survive by forming cysts as resting stages.[30,31] The quite extreme condition of the thermocline layer allows this species to live and develop without obstacles. Next, *Trichodesmium erythareum* was found to be the second most abundant species. This is in line with the study of Thoha et al.,[32] who found that *Trichodesmium* sp. dominated approximately 50-95% (4842-83,043 cell m^{-3}) in almost all the research stations (14 of 17 stations). The third was *Thalassionema nitzchoides* and Boonyapiwat (1998) found a tendency for the high abundance of *Thalassionema* sp. in the thermocline layer than in the surface layer and in the coastal area of the South China Sea. This shows that the thermocline is the optimal place of life for the *Thalassionema* sp. *Leptocylindrus danicus* is the fourth most abundant species in the thermocline layer. The species was commonly found abundantly in almost all seas.[33] *L.danicus* was able to live in waters that contain enough nutrients. Rainfall factors can cause nutrients to be mixed well in the thermocline layer, so that it can support the growth of *L. danicus* biomass properly. During the rainy season *L. danicus* was abundant in the coastal waters of the Andaman and Nicobar Islands, India.[33] The abundant phytoplankton community reached 67,000 cellsl^{-1} and covers 95-99%. This condition also occurred in this study where in October, rainfall in the waters of Sangihe Talaud was high enough. This was in accordance with the weather forecast by BMKG (Meteorology Climatology and Geophysics Council) which states that 77.44% of Indonesia's territory has entered the rainy season from October to January. The rare species was *Detonula pumila*, a species that could grow at a temperature of 12-16^{o}C.[34] In extreme conditions that species can produce spores.[35] The genus *Detonula* was able to live at a temperature of 0-5 ^{o}C.[35] An extreme water conditions in the thermocline layer may affect phytoplankton to form communities with special characteristics.

The stations with the highest abundance of phytoplankton have a relationship with water temperature and proximity to the island. The map contour of phytoplankton abundance showed that highest phytoplankton abundance was located in the area with a temperature

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range of 20-23.47°C. In addition, some stations namely 2, 12, 16, and 27, tend to be closer to the island, and it was possible to receive more nutrient input than other stations. The nutrient input could stimulate the growth of phytoplankton cells. The stations with the lowest abundance of phytoplankton occurred in the area with low temperatures, namely between 16-18°C, and that areas were found remote to the island. However, station 8, which was adjacent to the island, also has a low phytoplankton abundance, and this was attributed to the low temperate of 17°C. This shows that temperature was a limiting factor for the abundance of phytoplankton, such that when temperatures exceed the tolerance threshold, it will result in inhibition of growth through metabolic activity, disruption of respiration, and death of cells. There are several stations with high temperatures not directly proportional to the abundance of phytoplankton, as illustrated in Figure 6A & Figure 6C. For example, stations 22, 23, 29, 28, and 32 have quite high water temperatures at a range of 20.47-23.88°C coupled with high level of salinity of 35% among other stations as shown in Figure 6B. This shows that, in addition to temperature, salinity was also an important abiotic factor, which limits the growth of phytoplankton. Such that, the salinity above cell tolerance limit could result in osmosis stress, inhibition in the absorption of nutrients, and limitation of cell movement. Extreme condition can only be tolerated by certain species.

Based on the analysis of Bray-Curtis similarity, there were two pairs of stations interrelated with similarity levels above 50% and they include stations 25-26 and 2-16. The stations 25 and 26 have almost the same phytoplankton abundance of 8000 and 7059 cellm^{-3}, respectively. Meanwhile stations 2 and 16 have phytoplankton abundance of 316,190 and 302,222 cellm^{-3}, respectively. The relatively similar conditions of temperature and salinity which ranges between 19-20°C and stable salinity 34,74%, may cause the station to be the same. There were similarities in genera that appear in community niches, which could be as a result of the influence of nutrient input, or physical and chemical waters. Stations 1 and 23 have the lowest percentage of similarity, because there were differences in environmental conditions, i.e. station 1 has a temperature of 16°C, while the station 23 has a warm temperature of 24°C. Other than that, differences in the presence of phytoplankton was affected by station location. Stations that were close to island such as station 1 will be different from station 23 which was in the open ocean. Antropogenic activities and input of various materials from islands are known to increase nutrients.[36] The nutrients may lead to increased phytoplankton growth rates.[37,38] But the open ocean, input nutrients was very small, therefore there would be a different pattern to adaptation of phytoplankton.

Conclusion

The average depth of the thermocline layer on the Sangihe Talaud waters was found to be 150 m. There were 84 species of phytoplankton, which consisted of 4 classes, Bacillariophyceae, Dinophyceae, Raphidophyceae, and Cyanophyceae. The abundance of phytoplankton in all stations ranged from 7059 to 542,222 cellm^{-3}. The Bacillariophyceae was the most abundant in all stations, followed by *Chaetoceros affinis*, *Trichodesmium erythraeum*, *Thalassionema nitzchioides*, *Leptocylindrus danicus*, and *Detonula pumila*. The stations with the highest abundance of phytoplankton was found in the area with high temperature and close to the island. However, other stations with high temperatures and salinity got less phytoplankton, due to high salinity could affect cells in motion and absorption of nutrients. Furthermore, based on the Bray-Curtis index, the similarities above 50% occurred because the similarities of genera in the phytoplankton community. The differences in environmental condition provided different adaptation patterns, so that it will form phytoplankton community structures with different life characteristics.

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Conflicts of interest

There is no conflicts of interest to declare regarding the publication of this paper.

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