BONOROWO WETLANDS
Volume 9, Number 2, December 2019
Pages: 51-58

P-ISSN: 2088-110X
E-ISSN: 2088-2475
DOI: 10.13057/bonorowo/w090201

Community structure of phytoplankton in the surface and thermocline layers of Sangihe and Talaud waters, Indonesia

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Manuscript received: 9 July 2019. Revision accepted: 15 August 2019.

Abstract. *Sriwijayanti LA, Djumanto, Setiawan RY, Firdaus MR, Fitriya N, Sugeha HY. 2019. Community structure of phytoplankton in the surface and thermocline layers of Sangihe and Talaud waters, Indonesia. Bonorowo Wetlands 9: 51-58.* The aim of this study was to determine the species dominance and distribution, and community structure of phytoplankton in the surface and thermocline layers of Sangihe and Talaud waters Indonesia. Phytoplankton samples were collected at the Sangihe-Talaud waters in October 2018 at 14 research stations. Water samples were collected at 5 m (surface) and thermoclines layers using rosette sampler equipped with Conductivity, Temperature, and Depth (CTD) recorder. Samples were concentrated to 40 ml using hand plankton net (mesh size 20 µm), then preserved with 4% formaldehyde. Phytoplankton species were identified using a guidebook based on morphological character traits. The cell count of each species of plankton was calculated using a Sedgwick rafter counting cell chamber. The result showed that there were 4 classes of phytoplankton (Bacillariophyceae, Dinophyceae, Cyanophyceae, and Raphydophyceae) which consisted of 59 species in the surface and 56 species in the thermocline, respectively. The abundance of phytoplankton at surface ranged from 77,333-4,024,000 cell m^{-3}, meanwhile in the thermocline layer 8,000-542,222 cell m^{-3}. The average of phytoplankton diversity of the surface was 0.82 and the thermocline was 1.71. The surface layer was dominated by *Leptocylindrus danicus* (8.92 x 106 cell m^{-3}), *Trichodesmium erythareum* (5.83 x 106 cell m^{-3}), and *Detonula converfacea* (0.62 x 106 cell m^{-3}). The thermocline layer was dominated by *Chaetoceros affinis* (2.74 x 105 cell m^{-3}), *Thalassionema nitzchioides* (2.21 x 105 cell m^{-3}), and *Chaertoceros dichaeta* (1.38 x 105 cell m^{-3}). The low phytoplankton abundance was found at the stations 12 and 13 caused by higher salinity concentration. The highest phytoplankton abundance was found in the stations with warmer temperatures, both in the surface and in the thermocline. The shallow depth thermocline layer (75-100 m) has a higher abundance than the deeper thermocline layer (110-150 m). Temperature was the environmental parameter that has the greatest influence on the abundance and species of phytoplankton, the phytoplankton in the surface layer reached 10 times more abundant than the thermocline layer.

Keywords: Phytoplankton, surface, thermocline, tropical

INTRODUCTION

Plankton is groups of microscopic organisms found in almost all types of waters, moving passively following the flow, their biomass in marine waters reach 98% of all micro-sized organisms (Sardet 2015). Phytoplankton is a group of plankton that can photosynthesize and contribute to almost half of the total global net primary productivity (Falkowski et al. 1998). As a primary produces, phytoplankton is a food source for all populations in the sea (Lagus et al. 2004; Sardet 2015; Rowe et al. 2017). The first consumer of phytoplankton is zooplankton, which is as food source of many marine biotas such as fish, shrimp, lobsters, crabs and various types of small fish. Many studies show that phytoplankton has a positive correlation between high commercial fish catches such as mackerel (Tangke 2012), sardinella (Putra et al. 2012), and tuna (Tangke et al. 2015; Tangke et al. 2016). In addition, the four types of high commercial fish mostly live in the thermocline layer. However, the existents of phytoplankton tend to follow the movement towards water currents. It also very affected by physical and chemical changes in the waters. Depth, temperature, and salinity are some crucial parameters that will determine the phytoplankton community structure both horizontally and vertically (Sardet 2015).

The water column vertically has a different density gradient depending on the temperature and depth. Temperature will decrease to seawater depth, otherwise water pressure increase. At a certain depth, the temperature will drop dramatically and it called the thermocline layer. In addition to temperature, salinity also has a similar pattern, which will increase dramatically at a certain depth, and it is referred to as a halocline layer. The thermocline and halocline layers create unique conditions that make phytoplankton adaptable to survive. Phytoplankton communities make different adaptations so that there are variations in community structure between water columns based on their abilities and characteristics of life.

Sangihe Talaud waters which are directly adjacent to the Mindanao Islands (southern Philippines), have water masses that are affected by North Pacific waters (Gordon 2005). This water mass will flow through the thermocline layer (Koch-Larrouy et al. 2007) so that it will provide different water conditions with the surface layer. Indirectly it will form the structure of the phytoplankton community that lives in it. Various studies on the dynamics of plankton have been carried out in Indonesian waters. However, research on the phytoplankton community structure in the surface and thermocline layers in Indonesia, especially the Sangihe Talaud waters is still very rarely reported. Phytoplankton as the basis of the food chain so that research on the abundance and species of phytoplankton in the surface layer and thermocline layer is very important, especially in waters that become fishing ground for fishes with high economic value. Therefore, this study aims to determine the phytoplankton community structure in the surface layer and thermocline in the Sangihe Talaud Sea Waters.

MATERIALS AND METHODS

Study area

The research was conducted at Sangihe Talaud Waters on October 2018. Sampling was carried out at 14 research stations located on the northeastern side of Sulawesi Island (2 ° 4 '13 "- 4 ° 44 '22" N) and (125 ° 9 '28 " - 125 ° 56 '57 "E) (Figure 1). Sampling was done by using the Baruna Jaya VIII Research Vessel belongs to the Indonesian Institute of Sciences (P2O LIPI).

Procedures

Measurements of temperature, salinity and depth parameters were carried out using the SBE 911-Plus CTD (Conductivity Temperature Depth) with Carousell Water Sampler Sensor. This tool was equipped with 12 rosette sampler bottles with a capacity of 10 liters, and it was used to take water samples as phytoplankton samples at surface depth (5 m) and thermoclines layers. The phytoplankton samples were filtered using hand plankton net mesh size 20 µm. The collected filtrate was transferred to a 40 ml sample bottle and preserved using 1% Lugol. Phytoplankton enumeration was done using Sedwick-Rafter Counting Cell under a microscope with 100x magnification. Phytoplankton identification was carried out morphologically by referring to the book Yamaji (1976), Shirota (1996), and Omura et al. (2012).

Data analysis

The results of enumeration and identification of phytoplankton were then used to analyze phytoplankton communities based on their abundance. Phytoplankton abundance was calculated using a formula according to Perry (2003) which was modified by Huliselan et al. (2006):

$$D = (Nf*Vp)/v$$

D = plankton abundance (ind / m^3)
Nf = number of cells per 1 ml
Vp = dilution volume (ml)
V = volume of filtered water (m^3)

The diversity of phytoplankton is determined by following equation (Spellerberg and Fedor 2003):

$$H' = - \sum P_i \ln P_i$$

H' = diversity index
Pi = Proportion of species = Pi = ni / N
Ni = Number of individuals of a species
N = Total number of individuals of all species

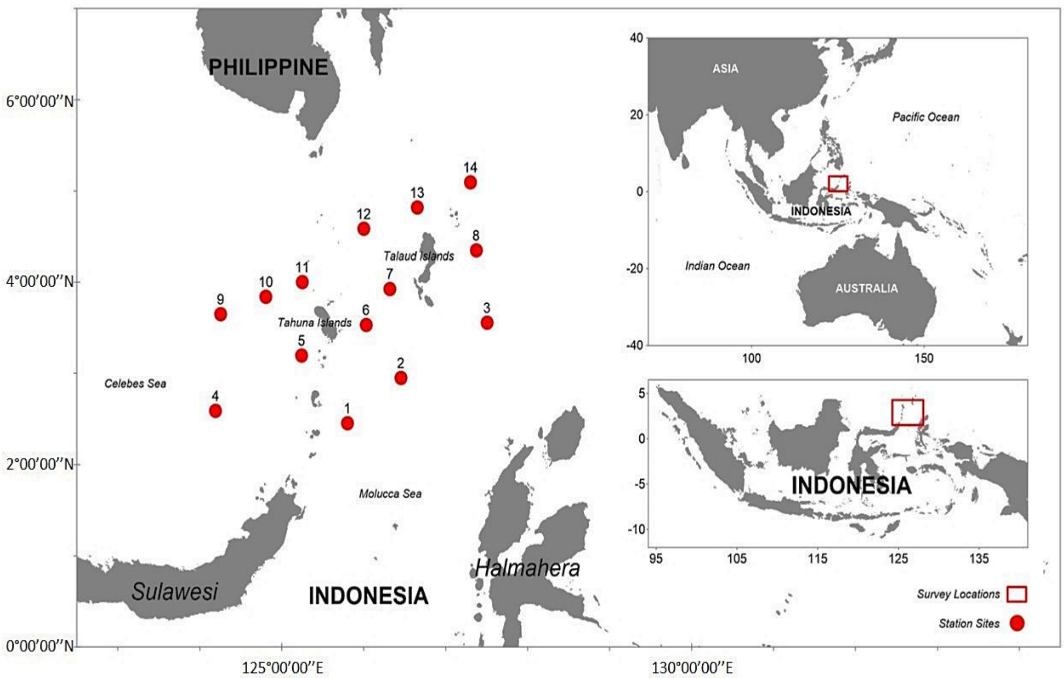

Figure 1. The map showing research station (indicated number 1 to 14) in the Sangihe-Talaud Warters, North Sulawesi, Indonesia

The diversity index was categorized based on Krebs (1989): (i) H'<1.0: small diversity (high ecological pressure), (ii) 1.0 <H'<3.322: medium diversity (productivity is quite good, the ecosystem is quite balanced, pressure is ecologically balanced), (iii) H'> 3.322: high diversity (very high productivity).

The relationship of water quality with the abundance of phytoplankton at each station was mapped in the form of contours using Surfer 9.1.352.

RESULTS AND DISCUSSION

Physical and chemical parameters

The values of physical and chemical parameters of waters such as temperature and salinity in Sangihe Talaud waters were taken up to a depth of 600 m in order to clearly describe the stratification profile in the thermocline layer and the layer below the thermocline (Steele and Thorpe 2009). Vertical profiles of temperature and salinity in 14 stations are shown in Figure 2.

Figure 2 shows that in the water layer increased deeper causing salinity to increase, but the temperature decreased. The temperature and salinity of the surface were 29.23-30.24°C and 33.55 - 34.31 ‰, while on the thermocline layers were 14.83-27.04°C and 34.5-35.08 ‰, respectively. The average temperature and salinity in the surface was 29.64 ± 0.29°C and 34.07 ± 0.22 ‰, while in the thermocline layers were 19.95 ± 02.23°C and 34.80 ± 0.12 ‰, respectively. The temperature in the surface 30.24 °C dropped drastically until the thermocline layer reaches 14°C, while the salinity didn't show a significant increase. The average depth in the thermocline layer of the Sangihe-Talaud waters were 130 m.

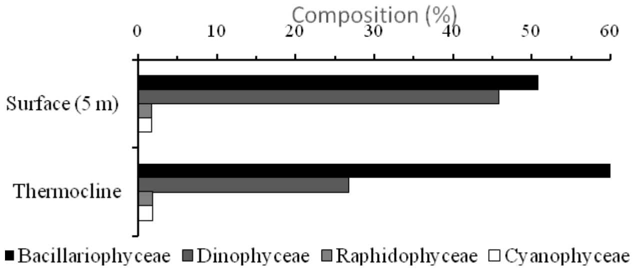

Figure 3. Composition of the number of phytoplankton species based on class composition of surface and thermoclines layers.

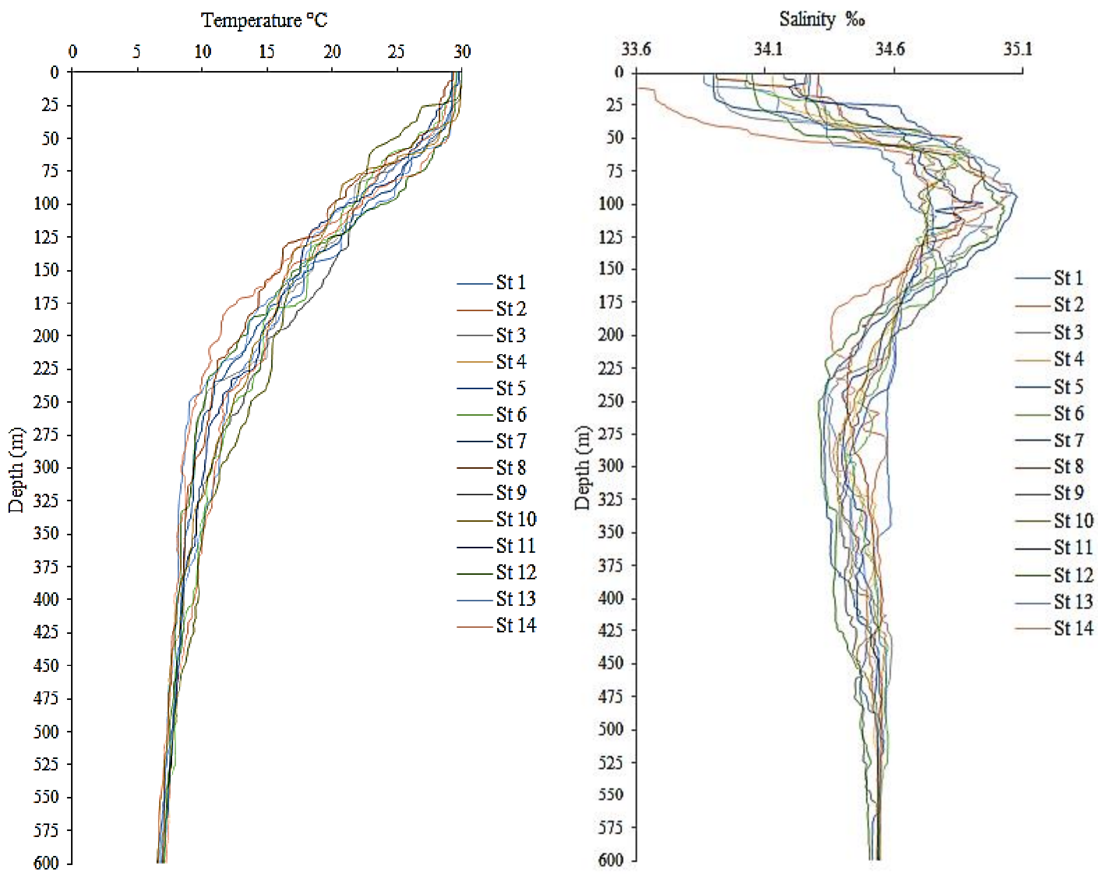

Figure 2. Vertical profile of temperature and salinity in the Sangihe Talaud waters, Indonesia

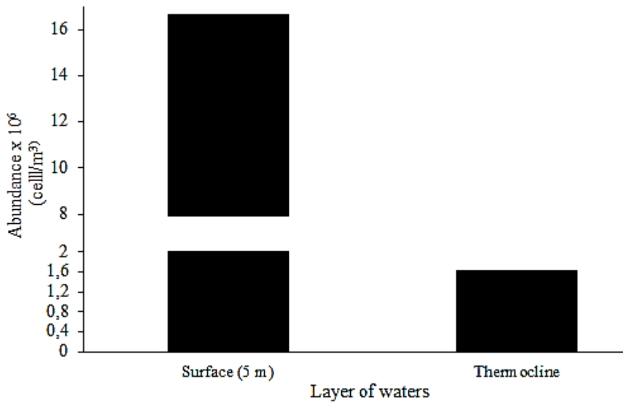

Figure 4. Abundance of phytoplankton on the surface and thermocline layers in the Sangihe-Talaud waters

Abundance and diversity of phytoplankton

Identification of phytoplankton consisted of 4 classes namely Bacillariophyceae, Dinophyceae, Cyanophyceae and Raphydophyceae with a total of 59 species in the surface, and 56 species in the thermocline layers. The number of species based on the phytoplankton class is shown in Figure 3.

The surface was dominated by Bacillariophyceae 50.85%, and Dinophyceae 45.76%, and the remaining was from Cyanophyceae and Raphidophyceaen each 1.69%. The dominance numbers of the Bacillariophyceae in the thermocline layer was found greater than the surface at sum 69.64%, the remaining from the Dinophyceae 26.79%, and from the Cyanophyceae and Raphidophyceae each 1.79%. The total abundance of phytoplankton in the surface layer and the thermocline shows a significantly different value, namely the surface layer 10 times greater than the thermocline. This condition is presented in Figure 4.

The abundance of phytoplankton in the surface layer ranged 77,333 - 4,024,000 cell m^{-3}, meanwhile in the thermocline layer ranged from 8,000 to 542,222 cell m^{-3}. Phytoplankton species that were dominant and abundant in surface waters were very different from the thermocline layer. The surface was dominated by *Leptocylindrus danicus*, *Trichodesmium erythareum*, and *Detonula converfacea*, while the thermocline layer was dominated by *Chaetoceros affinis*, *Thalassionema nitzchioides*, and *Chaertoceros dichaeta* (Figure 5).

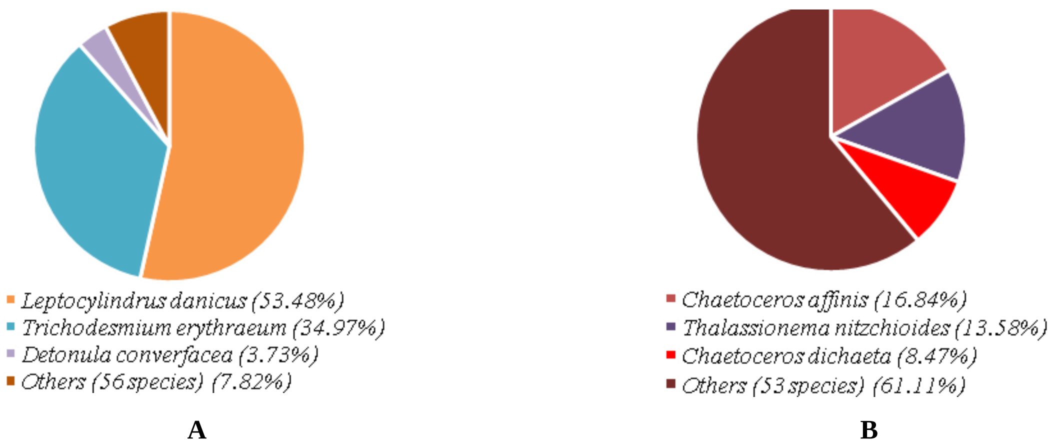

Figure 5. The composition of predominant phytoplankton species on the surface (A), and the thermocline layer (B)

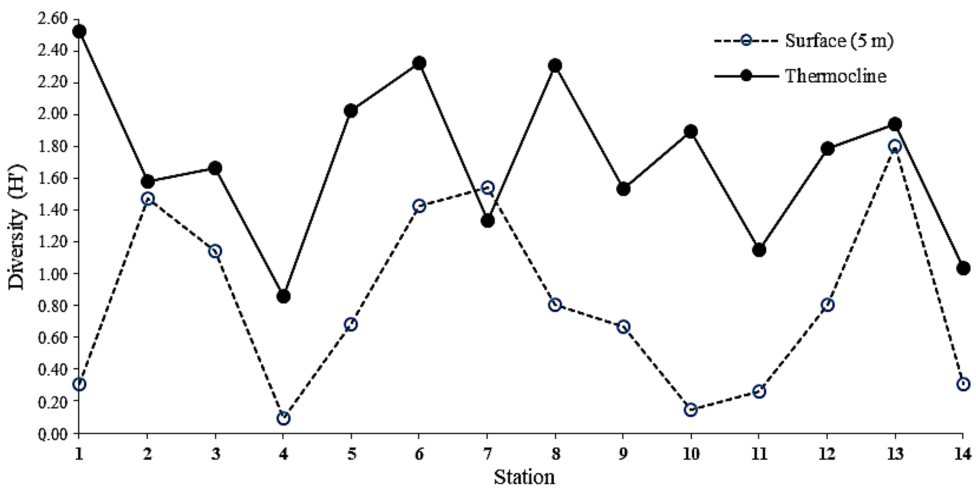

Figure 6. Diversity value (H ') at 14 stations of Sangihe-Talaud waters *(surface and thermocline)*

Among the research stations, especially in the surface, *L. danicus* has an abundance value of 8.92 x 10^6 cell m^{-3}, T. *erythareum* 5.83 x 10^6 cell m^{-3}, and *D. converfacea* 0.62 x 10^6 cell m^{-3}. The smaller value of the total abundance at thermocline layer was *C. affinis* 2.74 x 10^5 cell m^{-3}, *T. nitzchioides* 2.21 x 10^5 cell m^{-3}, and *C .dichaeta* 1.38 x 10^5 cell m^{-3}. Although the abundance of phytoplankton was concentrated in the surface layer, it was not followed by high phytoplankton diversity values (H'). Figure 6 shows that H 'phytoplankton in the surface was lower than the thermocline layer.

The diversity of Phytoplankton (H') in the surface ranged from 0.089 to 1.807 with an average of 0.81, whereas in the thermocline layer ranged from 0.86 - 2.52 with an average of 1.71. Based on the category of diversity value, the diversity of phytoplankton in the surface layer was small, meanwhile in the thermocline layer was a medium.

Effect of environmental parameters on phytoplankton abundance between stations

The abundance of phytoplankton among stations showed varies because there were several stations that have very high abundance, while others were much lower. This is illustrated in Figure 7.

At surface waters, high phytoplankton abundance was found at stations 5, 4, 11, and 1, while low abundance was found at stations 6, 7, 13, and 2. In the thermocline layer, the highest phytoplankton abundance was found at stations 8, 1, 5, and 6, while low abundance was found at stations 14, 11, 10, and 7. Physical and chemical properties of water such as temperature and salinity were always closely related to the life of phytoplankton which indirectly affects its distribution. This phenomenon is described as a contour pattern in Figure 8.

Layers with warm temperatures and relatively uniform salinity were found at stations 10, 4, 5, and 11 (29.64°C and 34.07 ‰). This was the reason for the high abundance of phytoplankton in the area of study. Thermoclines with an average warm temperature were found at stations 8, 1, 5 and 6. The areas with warm temperatures and low thermocline depths (75-100 m) were followed by the highest abundance values. However, stations 12 and 13 with relatively warm temperatures (21°C), high salinity, and relatively shallow depths (100 m) has not high abundance of phytoplankton.

Discussions

Oceanographic parameters observed in the Sangihe Talaud waters influenced each other. Temperature affects salinity by increasing seawater density as depth increases (Thurman 1993; Hadikusumah 2008). In addition, salinity was also related to gravity and buoyancy, ie when the depth increases, heavier water masses tend to sink to reach equilibrium and less dense water will rise to the surface. The temperature profile decreases along with increasing depth due to the penetration of sunlight decreases to transfer heat to the deeper water column (Nontji 2002).

Phytoplankton composition found in the surface or thermocline layer was dominated by the Bacillariophyceae class. Extensive distribution for the Bacillariophyceae family in the waters because of their high ability to survive, so they can adapt to various environmental characteristics (Arinardi et al. 1996). The discovery of Bacillariophyceae which predominates in the thermocline layer was supported by the ownership of pigments such as fucoxanthin, chlorophyll-a, and chlorophyll-c so that it can utilize minimal light for photosynthesis (Rissik 2009).

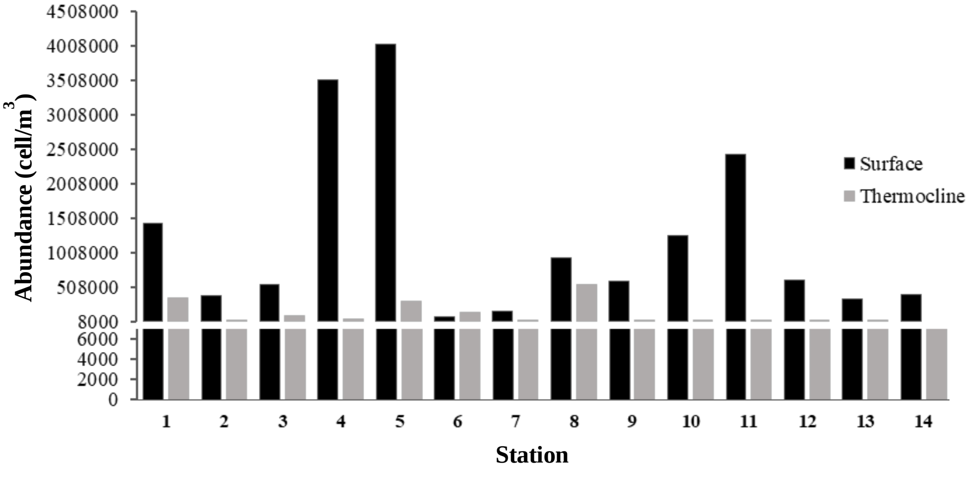

Figure 7. Abundance of total phytoplankton species at each sampling station in the surface and thermocline layer

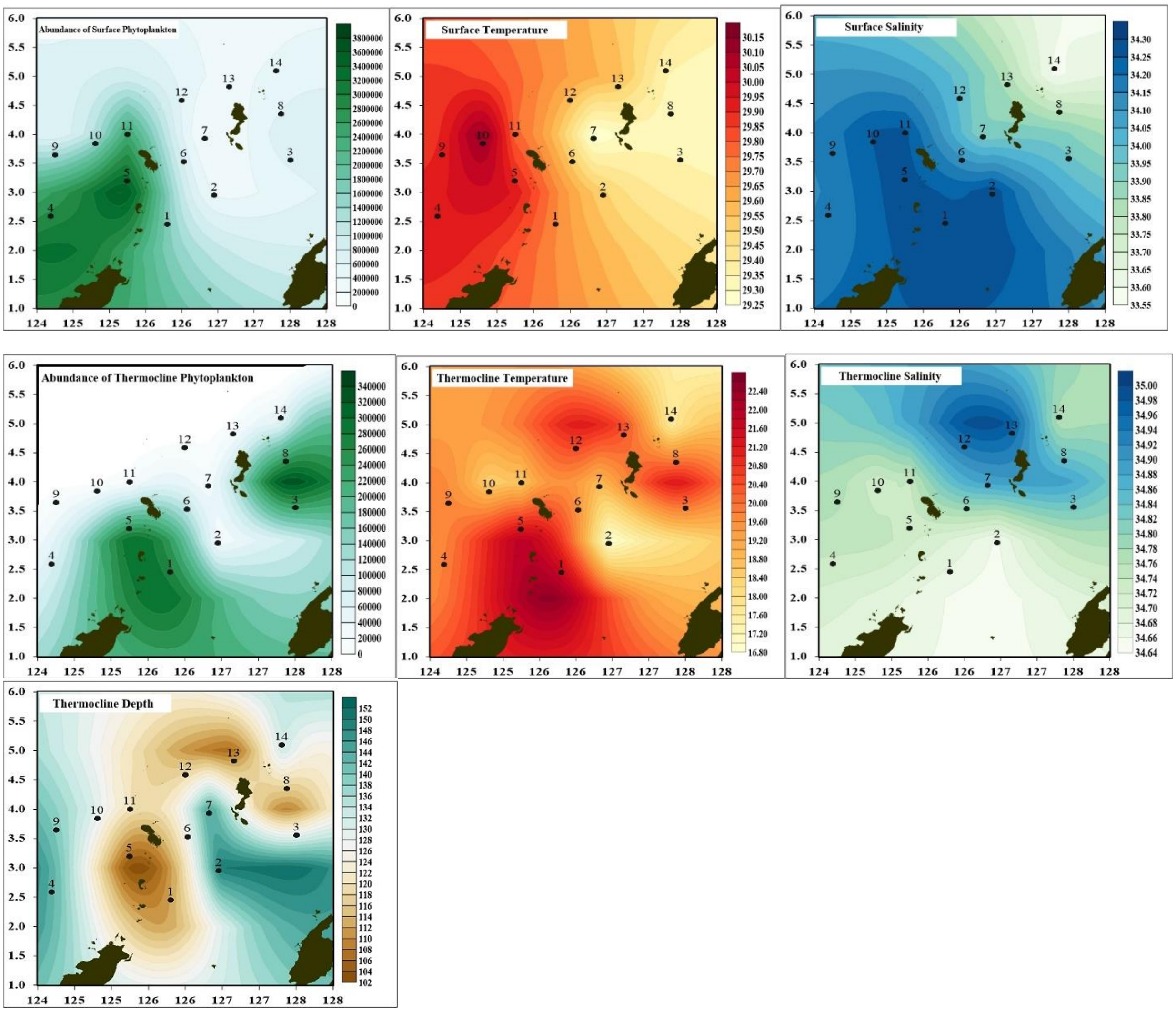

Figure 8. The contours of relationship of phytoplankton abundance, temperature, salinity and thermocline depth An explanation of the legend of each picture is presented on each panel

The abundance of phytoplankton in the surface layer and thermocline has a contrast difference, where abundance in the surface layer can reach 4 million cell m^{-3}, while in the thermocline no more than 1 million cell m^{-3}. Differences in aquatic conditions also show variations in the types of phytoplankton that live in it and affect to abundance. The types of phytoplankton which have high abundance in the surface layer was *L.danicus* as much as 53.48%. This phenomenon is common in marine environments throughout the world (Karthik 2017). It is known that the species L.*danicus* dominates 95-99% (67,000 cells) of the total abundance of phytoplankton in Coastal Waters of Andalaman and Nicobar India (Karthik 2017). The ability to tolerate strong light and warm temperatures caused *L. danicus* to live well on the surface layer. This phenomenon was supported by the results of the study of Penelope et al. (2016) who found that *L. danicus* grew more slowly at 18°C, while at warmer temperatures (25°C) showed good productivity.

The second dominant species in the surface layer was *T. erythraeum* (37.97%), this species was found abundantly in the Sangihe-Talaud waters. Thoha and Fitriya (2010) found *Trichodesmium* sp. dominate 50-95% (4842 - 83,043 cell m^{-3}) in almost all research stations. Community structure of the surface was different from the thermocline layer. The thermocline layer was dominated by the genus *Chaetoceros*, especially *C. affinis* as much as 16.84%. The second species abundant in the thermocline layer was *T. nitzchoides* 13.58%. Genus *Chaetoceros* has live strategy to survive by forming cysts during resting stages (Trottet et al. 2018). *Thalassionema* sp. in the South China Sea tended to high abundance in thermocline layer rather than surface (Boonyapiwat 2000). Thermocline layer that was low in light cause differences in environmental conditions from the surface, causing some types of phytoplankton in thermoclines to have special characteristics to be able to live and develop.

Phytoplankton abundance that varies between stations and layers of water was influenced by temperature and salinity. In general, the temperature will be directly proportional to the abundance of phytoplankton. The optimum temperature supports phytoplankton metabolic activities for cell development. As founding of this study that stations in the surface with the highest temperature have the highest abundance. Similar conditions also occur to thermocline layers that have an average warm temperature. Thermocline as an euphotic zone has a limit of a depth of 150 m (Raymont et al. 1980). Thermocline layer can be penetrated by sunlight to support the growth of phytoplankton (Barnes and Mann 1991) but the intensity was limited. A deeper thermocline layer has lower light availability than a shallow thermocline layer. Therefore, phytoplankton at shallow thermocline depths can do photosynthesis better than in deeper thermocline layers. This condition was evidenced by the higher abundance of phytoplankton in stations with a depth of 75-100 m compared to 120-150 m. However, there were two stations that were affected by the highest salinity namely station 12 and 13, indicating that the abundance of phytoplankton was not directly proportional to salinity. This result was supported by Soedarsono et al. (2013) who found phytoplankton abundance at salinity 40 ‰ of 22.25 cell m^{-3} dropped dramatically to 2.8 cell m-3 at salinity 27.5 ‰. Salinity above the tolerance threshold of phytoplankton causes osmosis stress, which has the effect of inhibiting growth with ion loss, inhibiting absorption of nutrients, and inhibiting cell movement. Phytoplankton that cannot tolerate high salinity will avoid this area for life. Phytoplankton that can survive when in extreme conditions are only a few species by forming cysts or spores (Sachlan 1972). In appropriate salinity, it will increase phytoplankton metabolic activity, so that its survival will be high which is supported by increased RNA synthesis and DNA replication (Skarlato et al. 2017).

The composition of phytoplankton species at each observation station affected the diversity of phytoplankton. The diversity values were as an indicator of the stability level of the phytoplankton community against environmental disturbances. The diversity of phytoplankton in the surface was classified in small categories (Krebs 1989), because most of the H' values were <1.00. The small value of diversity as an indicator occurrence of high ecological pressure. On the other hand, the value of H 'in the majority thermocline layer was> 1.00, which was included in the category of moderate diversity, as an indicator of fairly balanced ecosystem conditions. The higher phytoplankton diversity of the thermocline layer was due to the phytoplankton community dominated by species from Class Bacillariophyceae and Cyanophyceae, which favor low sunlight intensity (Sellers and Markland 1987). Chlorophyll synthesis in species from Class Bacillariophyceae and Cyanophyceae did not require strong light, even very strong light will damage phyto-oxidative phytoplankton enzymes and cause phytoplankton to die (Wetzel 1975; Barnes and Mann 1991; Riyono 2007). High phytoplankton diversity values in the surface and thermocline layer tended to be found at stations closed to the island (Station 13 - Talaud Island, Station 1 - Sangihe Island), meanwhile, the lowest diversity values in the surface and thermocline layer were found at stations far enough from the island (Station 4). High phytoplankton diversity values at stations closed to the island were caused by nutrients input from the mainland. Nutrients were needed by many species of phytoplankton to increase growth, meanwhile, stations far from the mainland have fewer nutrient inputs so that the diversity was low.

To conclude, the total abundance of phytoplankton in the surface was 10 times greater than the thermocline layer. The phytoplankton abundance range from 77,333 to 4,024,000 cell m^{-3} in the surface, and from 8,000 to 542,222 cell m^{-3} in the thermocline layer. The differences in water conditions affect the variations in the species of phytoplankton. The surface layer was dominated by *Leptocylindrus danicus, Trichodesmium erythareum,* and *Detonula converfacea,* meanwhile the thermocline was dominated by *Chaetoceros affinis, Thalassionema nitzchioides,* and *Chertoceros dichaeta.* Environmental parameters of temperature, salinity, and depth were factors that influence the abundance of phytoplankton. Temperature shows a stronger influence on phytoplankton in the surface layer. Similar conditions were found in the shallower thermocline depths (75-100 m) that areas with relatively high temperatures (21°C) have relatively high abundance. But the abundance of phytoplankton in the thermocline layer will be inversely proportional to salinity.

ACKNOWLEDGEMENTS

This research is part of the 2018 Widya Nusantara Expedition Cruise (EWIN 2018 Cruise) held by the Research Center for Oceanography, Indonesian Institute of Sciences. The expedition was carried out at Sangihe Waters on 6-22 October 2018. We thank all the crew of the Baruna Jaya VIII and Dr. Rozi Irwan Damli for his assistance and cooperation in the field.

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