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

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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: 57-64.* This study aimed 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 a rosette sampler equipped with a 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 plankton species was calculated using a Sedgwick rafter counting cell chamber. The result showed 4 classes of phytoplankton (Bacillariophyceae, Dinophyceae, Cyanophyceae, and Raphydophyceae), consisting of 59 species in the surface 56 species in the thermocline, respectively. The abundance of phytoplankton at the 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 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 found at stations 12 and 13 was caused by higher salinity concentrations. The highest phytoplankton abundance was found in the stations with warmer temperatures, both on the surface and in the thermocline. The shallow depth thermocline layer (75-100 m) is more abundant than the deeper thermocline layer (110-150 m). The temperature was the environmental parameter that had 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 a group of microscopic organisms found in almost all types of waters, moving passively following the flow; their biomass in marine waters reaches 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 producer, 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, a food source of 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 is also significantly affected by physical and chemical changes in the waters. Depth, temperature, and salinity are crucial parameters determining the phytoplankton community structure horizontally and vertically (Sardet 2015).

The water column vertically has a different density gradient depending on the temperature and depth. The temperature will decrease to seawater depth. Otherwise, water pressure will increase. The temperature will drop dramatically at a certain depth, 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 directly adjacent to the Mindanao Islands (southern Philippines) have water masses affected by North Pacific waters (Gordon 2005). This water mass will flow through the thermocline layer (Koch-Larrouy et al. 2007) to 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 plankton dynamics have been carried out in Indonesian waters. However, research on the phytoplankton community structure in Indonesia's surface and thermocline layers is rarely reported, especially in the Sangihe Talaud waters. Phytoplankton is the basis of the food chain. Research on the abundance and species of phytoplankton in the surface and thermocline layers 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 in 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 using the Baruna Jaya VIII Research Vessel belonging to the Indonesian Institute of Sciences (P2O LIPI).

Procedures

The temperature, salinity, and depth parameters were measured 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 the 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

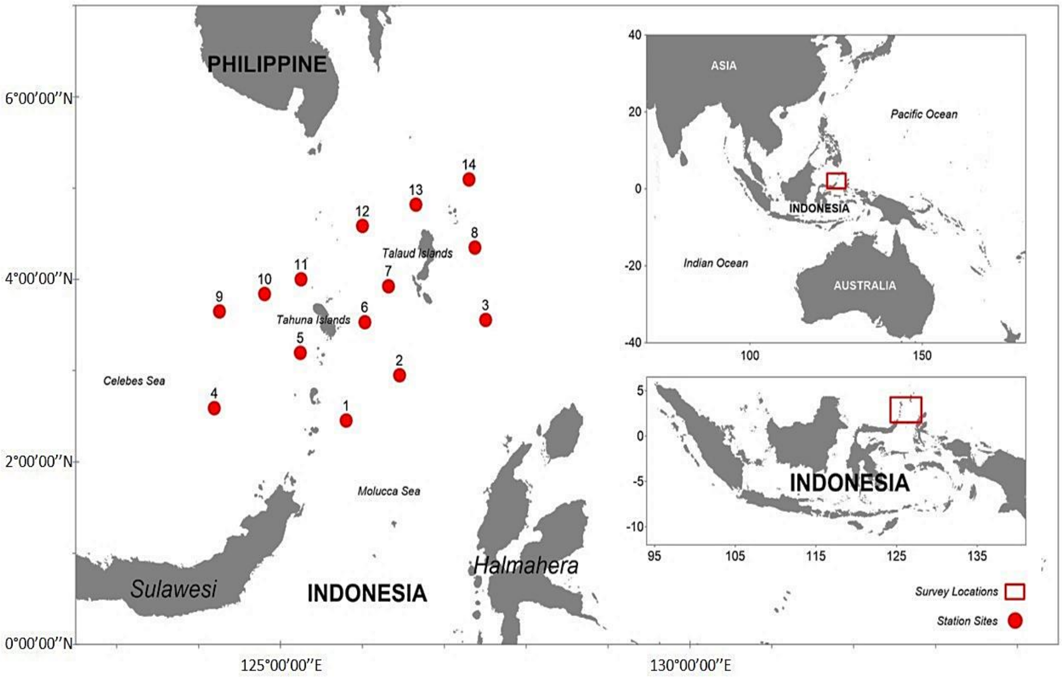

Figure 1. The map showing research station (indicated number 1 to 14) in the Sangihe-Talaud Warters, North Sulawesi, Indonesia

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 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 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 on the surface, 30.24 °C, dropped drastically until the thermocline layer reached 14°C, while the salinity didn’t show a significant increase. The average depth in the thermocline layer of the Sangihe-Talaud waters was 130 m.

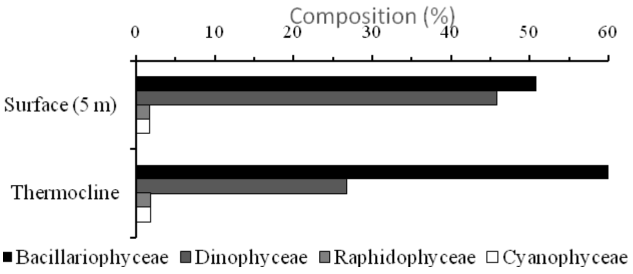

Figure 3. Composition of the number of phytoplankton species based on the class composition of surface and thermoclines layers.

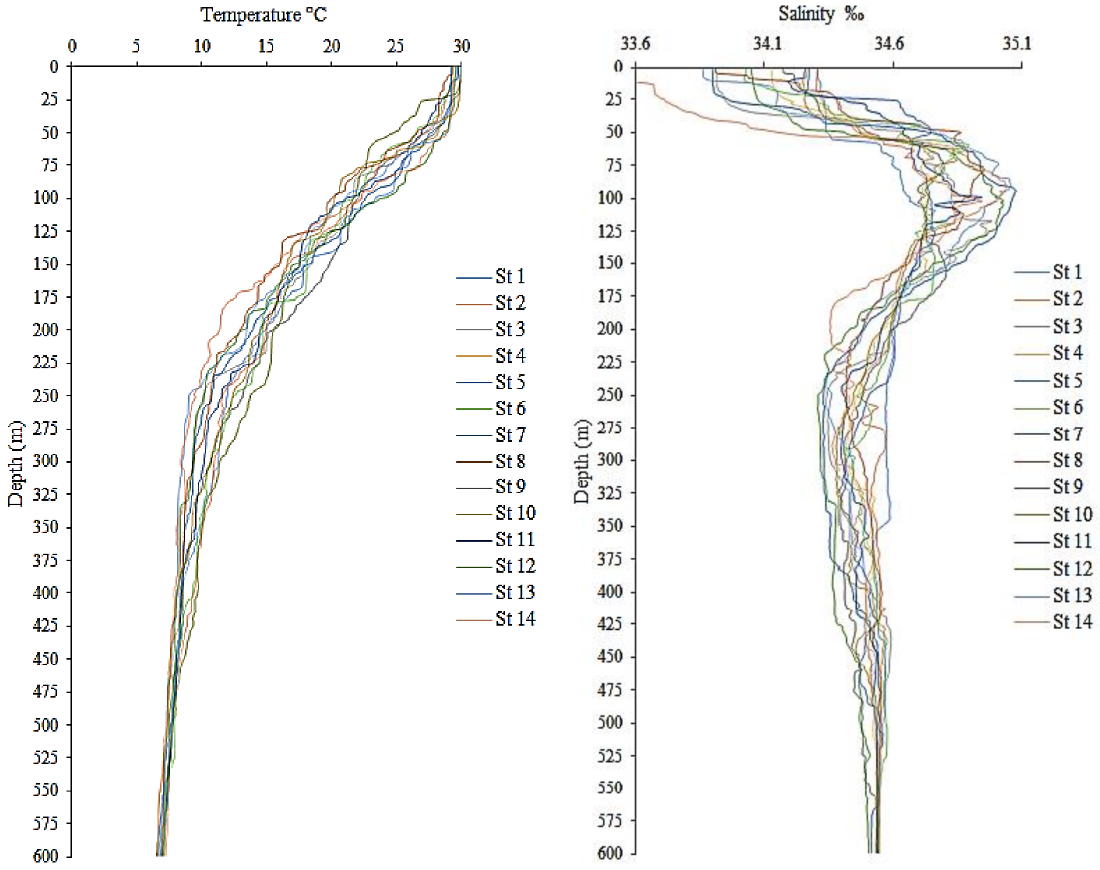

Figure 2. Vertical profile of temperature and salinity in the Sangihe Talaud waters, Indonesia

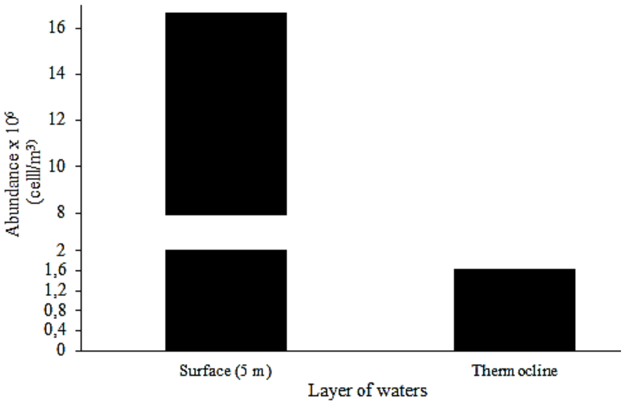

Figure 4. The abundance of phytoplankton on the surface and thermocline layers in the Sangihe-Talaud waters

Abundance and diversity of phytoplankton

Phytoplankton identification consisted of 4 classes, namely Bacillariophyceae, Dinophyceae, Cyanophyceae, and Raphydophyceae, with a total of 59 species on the surface 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 were found more significant 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 phytoplankton abundance in the surface layer ranged 77,333 - 4,024,000 cell m-3; meanwhile, the thermocline layer ranged from 8,000 to 542,222 cell m^{-3}. Phytoplankton dominant and abundant species in surface waters differed 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).

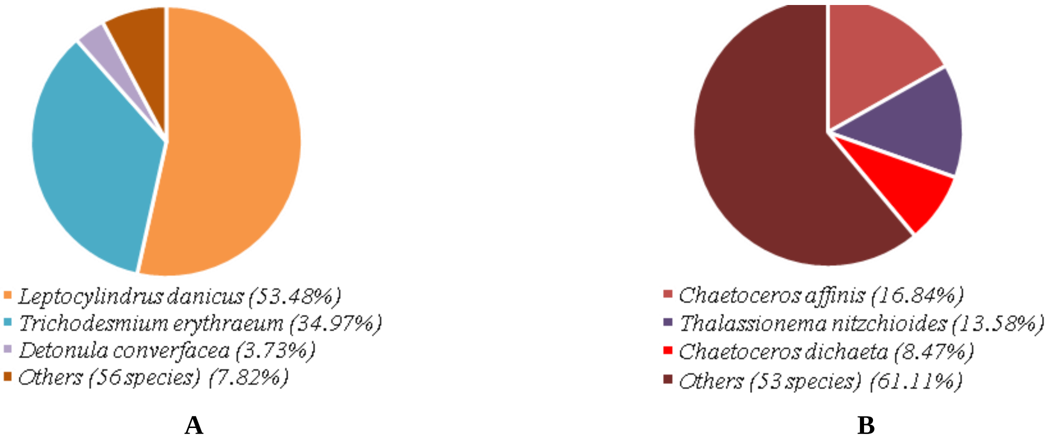

Figure 5. The composition of predominant phytoplankton species on the surface (A) and the thermocline layer (B)

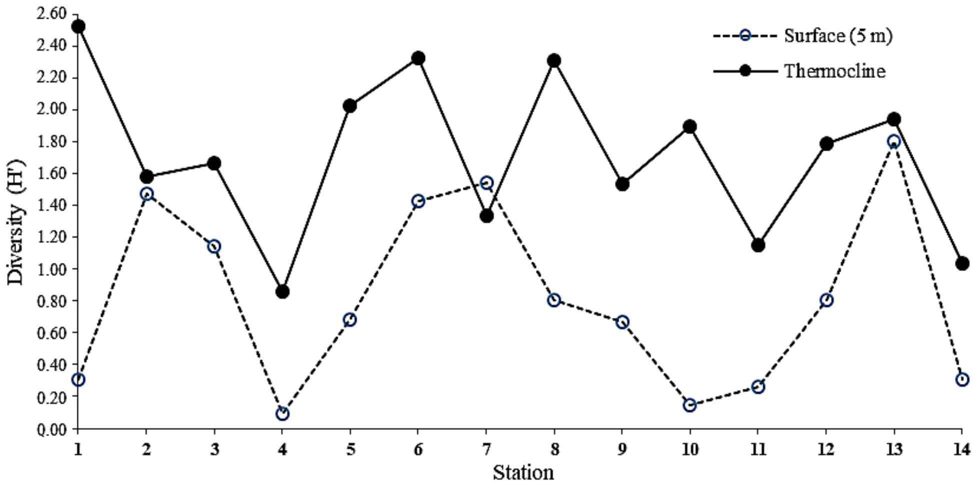

Figure 6. Diversity value (H ') at 14 stations of Sangihe-Talaud waters *(surface and thermocline)*

Among the research stations, especially on 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 the 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, the thermocline layer was a medium.

Effect of environmental parameters on phytoplankton abundance between stations

The abundance of phytoplankton among stations varied because several stations had a 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. Water's physical and chemical properties, such as temperature and salinity, were closely related to phytoplankton's life, indirectly affecting 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 study area. Thermoclines with an average warm temperature were found at stations 8, 1, 5, and 6. The highest abundance values followed warm temperatures and low thermocline depths (75-100 m). However, stations 12 and 13 with relatively warm temperatures (21°C), high salinity, and relatively shallow depths (100 m) do not have high phytoplankton abundance.

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. 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).

The Bacillariophyceae class dominated phytoplankton composition found in the surface or thermocline layer. Extensive distribution for the Bacillariophyceae family in the waters because of their high ability to survive to 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 to utilize them minimal light for photosynthesis (Rissik 2009).

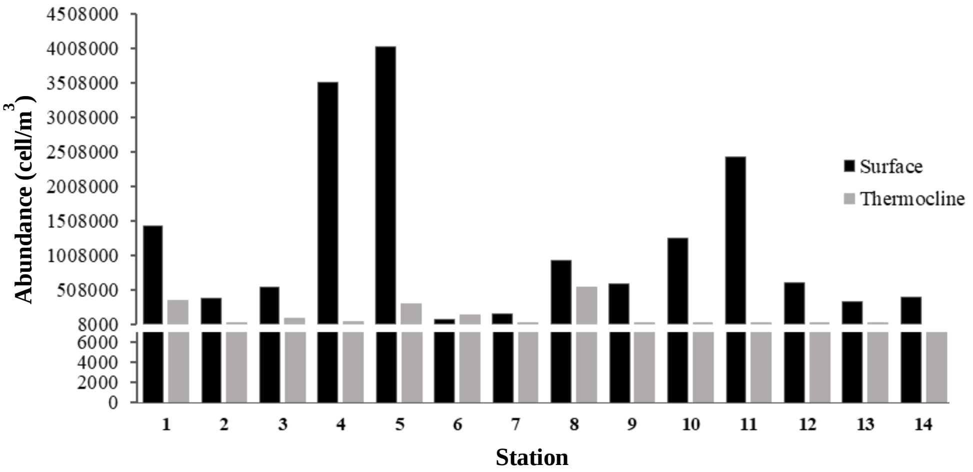

Figure 7. The abundance of total phytoplankton species at each sampling station in the surface and thermocline layer

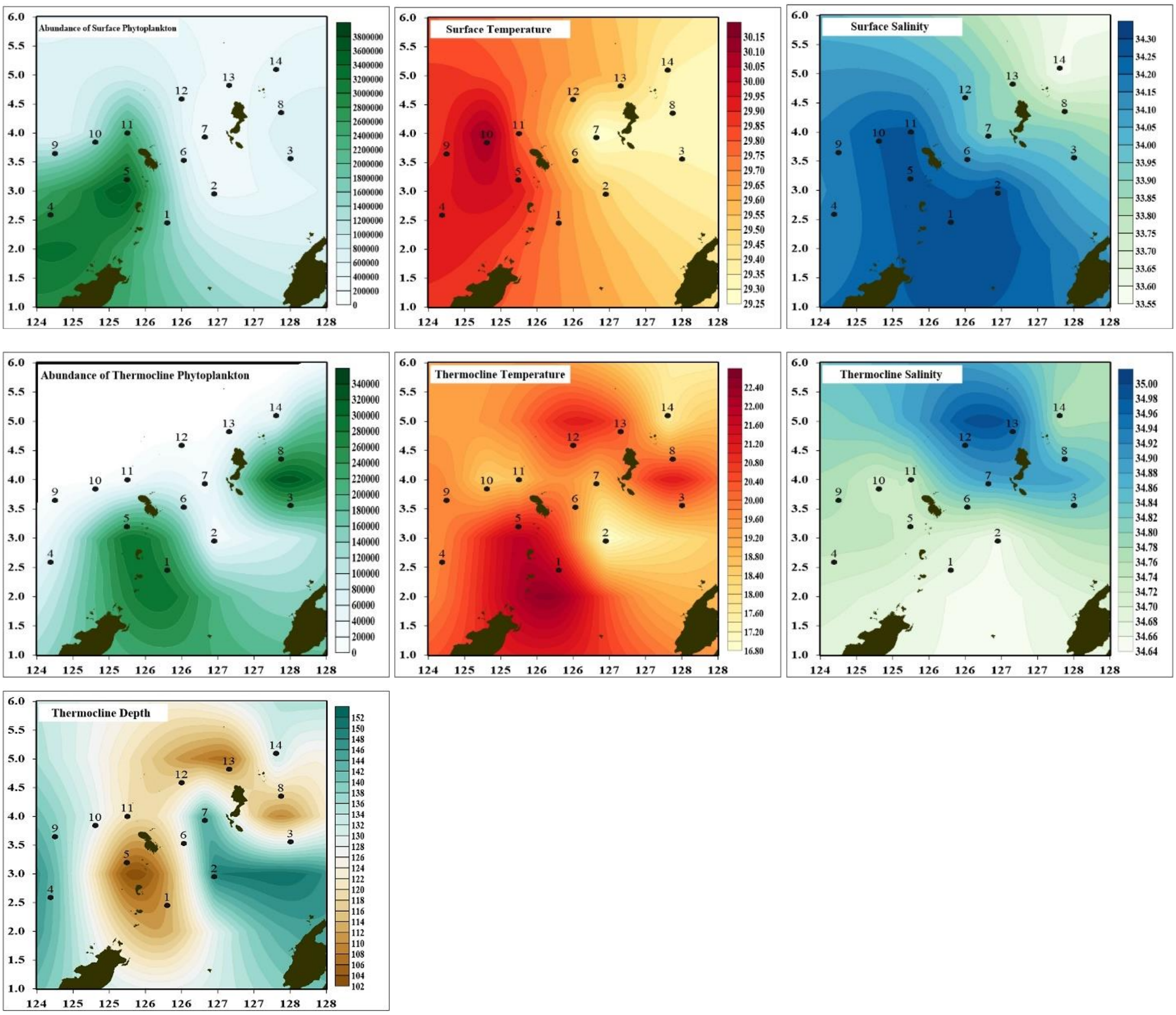

Figure 8. The contours of the relationship of phytoplankton abundance, temperature, salinity, and thermocline depth An explanation of the legend of each picture is presented on each panel

The abundance of phytoplankton in the surface layer and thermocline has a contrast difference, where abundance in the surface layer can reach 4 million cells m^{-3}. At the same time, there are no more than 1 million cells in the thermocline m^{-3}. Differences in aquatic conditions also show variations in the types of phytoplankton that live and affect abundance. The types of phytoplankton with high abundance in the surface layer were *L.danicus*, as much as 53.48%. This phenomenon is common in marine environments worldwide (Karthik 2017). It is known that the species L.*danicus* dominates 95-99% (67,000 cells) of the total abundance of phytoplankton in the Coastal Waters of Andaman and Nicobar, India (Karthik 2017). The ability to tolerate intense light and warm temperatures caused *L. danicus* to live well on the surface layer. This phenomenon was supported by the results of Penelope et al.'s (2016) study, 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. The 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 a 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 the thermocline layer rather than the surface (Boonyapiwat 2000). The low thermocline layer in light caused differences in environmental conditions from the surface, causing some types of phytoplankton in thermoclines to have unique characteristics 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 the founder of this study, stations on the surface with the highest temperature have the highest abundance. Similar conditions also occur to thermocline layers that have an average warm temperature. The thermocline is a euphotic zone that has a limit of a depth of 150 m (Raymont et al., 1980). The 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 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, two stations were affected by the highest salinity, namely stations 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 inhibits growth with ion loss, inhibiting the absorption of nutrients, and inhibiting cell movement. Phytoplankton that cannot tolerate high salinity will avoid this area for life. Phytoplankton can survive when only a few species are in extreme conditions by forming cysts or spores (Sachlan 1972). Inappropriate salinity 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 an indicator of the stability level of the phytoplankton community against environmental disturbances. The phytoplankton diversity in the surface was classified into small categories (Krebs 1989) because most of the H' values were <1.00. The small m of diversity is 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 being 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 intense light; even powerful 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 close to the island (Station 13 - Talaud Island, Station 1 - Sangihe Island). Meanwhile, the lowest diversity values in the surface and thermocline layers were found at stations far from the island (Station 4). High phytoplankton diversity values at stations close to the island were caused by nutrient input from the mainland. Many species of phytoplankton need nutrients to increase growth. Meanwhile, stations far from the mainland have fewer nutrient inputs, so the diversity was low.

To conclude, the total abundance of phytoplankton on the surface was 10 times greater than the thermocline layer. The phytoplankton abundance ranges from 77,333 to 4,024,000 cell m-3 on the surface and 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 influenced 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), and 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.

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