Distribution of phytoplankton in Pangkep Waters, South Sulawesi, Indonesia

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Abstract. The coastal water of Pangkajene Kepulauan, or Pangkep, in South Sulawesi has been influenced by high anthropogenic activities, where the inflow of nutrient from the land has caused several cases of harmful algal blooms and mass fish mortality. Thus, it was important to understand the community structure and distribution of phytoplankton, with particular interest on the bloom-forming and harmful genus, to better mitigate the effects of harmful algal blooms in the future. Sample collection for this study was conducted on May 2017 at 22 stations from three zones, the northern, middle, and southern coastal area of Pangkep. From this study, the phytoplankton density in Pangkep was found varied between $2.179 \times 10^6$ cells/m$^3$ to $2.192 \times 10^8$ cells/m$^3$, with the highest density of phytoplankton was observed in the northern and southern area of Pangkep. On the other hand, the middle area has lower phytoplankton density but has the highest diversity and evenness. Two stations, station 15 and 21, have a distinct phytoplankton community structure which might have caused by a combined effect of temperature and nutrient input from the land. Twenty-nine genera of phytoplankton were observed, with the diatoms Skeletonema as the most dominant genus which contributes to over 95% of total phytoplankton density. The occurrence of Ceratium, which once was found as a dominant genus in Pangkep coastal and estuaries, has caused a concern whether it might blooms and replacing the dominance of diatoms in these areas.

1. Introduction
Phytoplankton is a photosynthetic organism that plays an important role as a primary producer that produce organic matter and oxygen in the water which then serves as a foundation in the marine food web [1]. However, an excessive number of cells from certain phytoplankton species could reduce the water's quality in the ocean [2]. The explosion of phytoplankton populations followed by the presence of toxic phytoplankton species will lead to the Harmful Algae Blooms (HABs) event. The very dense population of toxic phytoplankton in waters can cause various negative consequences for aquatic ecosystems, such as reduced oxygen in the water (hypoxia), which can cause the mass mortality of various aquatic creatures, including fish [3]. One factor that can trigger rapid growth of phytoplankton population is eutrophication, which could be caused by the upwelling process that lifts water masses rich in nutrients or caused by the heavy rain which inputs large amounts of water from the land into the sea [4].

Harmful Algal Blooms (HABs) phenomenon has occurred in several coastal areas of Indonesia, both in the eastern and in western regions of Indonesia. For example, it was known that phytoplankton of Noctiluca sp. species experienced several rapid growth or blooms in Jakarta Bay, while other
phytoplankton species such as *Pyrodinium bahamense* were recorded to have caused HABs in Kao Bay, Ambon Bay, Seram Island and Papua Waters [5]. Another region in Indonesia that have experienced blooms of HABs is on the coast of Pangkajene and Islands (Pangkep), South Sulawesi. Mass fish mortality and dinoflagellate blooms were reported at the estuarine and coastal area of Pangkajene (Pangkep) Nasir (2014) in [6]. The coastal area of Pangkep has similar characteristics with the waters of Jakarta Bay which are mostly polluted by the substances from the land, which enters the ocean through the land run-off, river flow, combined with stirring (turbulence) and local ocean currents that further enriched the waters [6]. That condition was favourable for some noxious phytoplankton species and could increase the frequency and duration of the Harmful Algal Blooms (HABs) events.

In general, this study aimed to better understand the phytoplankton communities in the coastal waters of Pangkep, which includes the community structure, distribution, and diversity, with particular interest on the bloom-forming or harmful phytoplankton genus. This research was also a part of an efforts to mitigate the HABs in Indonesian water by collecting data on the phytoplankton community and the presence of harmful or toxic phytoplankton species in Pangkep waters, South Sulawesi. The data and information generated from this study were aimed to help the local government to devise a management strategy to mitigate any negative impacts from the HABs event that might occur in their waters in the future.

2. Materials and Methods

Phytoplankton samples were collected from 22 sampling sites in Pangkep, South Sulawesi, Indonesia, on 15-16 May 2017. Sampling sites were divided into three zones that included (1) North Zone (PK 1-7) located between Bombang-Talaka, Kanaungan, and Bonto Manai, (2) Middle Zone (PK 8-14) located in front of Baccini Baji harbour, and (3) South Zone (PK 15-22) located next to the Semen Tonasa harbour Figure 1. In this study, the selection of sites was based on the previous records of HABs case, topography, water depth, anthropogenic activities, riverine inputs, and types of bottom sediment.

2.1 Environmental Parameters and Location Description

In this study, sampling locations (coordinates) were recorded using a Garmin GPS. Environmental parameters such as depth, pH, temperature, and DO were taken using YSI portable water quality checker. The surface water salinity was measured using a hand refractometer. Additionally, data on the condition of the water, the weather, the state of anthropogenic activities, and the history of the occurrence of algal blooms were also collected from each study zones.

2.2 Plankton Samples in the Water Column

Plankton samples were taken using the vertical towing method using the Kitahara plankton net (mesh size 20 µm) for phytoplankton, and the NORPAC net (mesh size 300 µm) Figure 2 (a) (b). The depth of plankton sampling was varied between 4-10m according to the bottom depth of the study area. A sampling of phytoplankton was also conducted by using a modified Nansen Bottle with a volume of 1 Litre from the surface layer (±1m). Samples taken with plankton nets were preserved using 4% formaldehyde, while samples taken with Nansen Bottle were preserved with Lugol's Iodine [8].

2.3 Identification and Calculation of Plankton Cells

The phytoplankton cell analysis process was carried out by the fraction method using a stamp pipette (0.1 ml) or syringe (2 ml) and Sedgewick Rafter Counting Chamber (SRCC) Figure 2 (c). Samples that have been inserted into SRCC are then observed with a light microscope at magnifications between 100-400X Figure 2 (c). Plankton identification were done based on Yamaji [9], Shirotta [10], Wickstead [11], Davis [12], Praseno and Sugestiningsih [13], Tomas [14], and Omura [15].
Figure 1. Locations of 22 sampling stations divided into three zones (North Zone, Middle Zone and South Zone) in Pangkep Waters, South Sulawesi

Figure 2. (a) and (b) Phytoplankton collections using plankton Kitahara net having a mesh size of 80 μm^1; (c) Phytoplankton observation with Sedgwick Rafter Cell
2.4 Data Analysis

All raw enumeration data from fraction method were then converted into cells/m³ using a modified formula from Sournia [16] and LeGresley and McDermott [17]. In this study, Shannon-Wiener diversity index (Shannon H') and Shannon Equitability/Evenness index (Shannon J) was used to determine the level of diversity and to detect the presence of dominance in the phytoplankton community. Those indexes were calculated using the formula as described in Magurran [18]. Clustering analysis using Unweighted Pair Group Method with Arithmetic mean (UPGMA) [19] was used to find the occurrence of a distinct grouping of sampling stations based on the phytoplankton community structure. All statistical analysis was done in R Studio program.

3. Results

3.1 General Conditions of Sampling Location

The study location was located among a small cluster of Pangkajene Islands and Southern Sulawesi Islands. In addition to the existence of small islands, the location of the study was also influenced by the input of at least 8 rivers that flows to the coastal waters of the Pangkajene Islands. The presence of port activities at 2 piers namely the Semen Tonasa pier (South Zone) and the Baccini Baji passenger pier (Middle Zone), adding more anthropogenic stressors to the coastal ecosystem of Pangkep.

The surface salinity in the study stations varied between 29 ppt to 32 ppt Table 1. PK 1 and PK 2 stations, which located between Sulawesi and Sabangko islands, were the stations with the highest salinity values. On the contrary, the lowest salinity values were recorded at 6 stations, namely PK 6, 8, 9, 10, 14 and 15.

The results of surface temperature measurements show variations between 29.6 °C to 31.9 °C with the highest temperature recorded at PK 21 station and the lowest temperature recorded at PK 15 station Table 1. Dissolved oxygen measurement shows variations between 4.29 mg/L to 6.29 mg/L with the highest value recorded at PK 5 station and the lowest value recorded at PK 9 station.

Table 1. Environmental parameters that were taken from 22 sampling stations of Pangkep Waters. NA = data not available due to problem in the measuring equipment

| Zone                        | Stations       | pH  | Temperature (°C) | Salinity (ppt) | Oxygen (mg/L) |
|-----------------------------|----------------|-----|-----------------|----------------|---------------|
| North Zone                  | PK 1           | 8.75| 30.9            | 32             | 69.8          |
| (among Mattiro Bombang Island and Talaka Island, Kanaungan, Bonto Manai) | PK 2           | 8.7 | 31.2            | 32             | 65.2          |
|                             | PK 3           | 8.85| 30.7            | 31             | 62            | 5.74          |
|                             | PK 4           | 8.95| 31.1            | 30             | 76.3          | 6.29          |
|                             | PK 5           | 8.81| 30.8            | 30             | 67            | 5.76          |
|                             | PK 6           | 8.77| 30.5            | 29             | 60.5          | 5.42          |
|                             | PK 7           | 8.80| 30.6            | 29             | 71.2          | 5.42          |
|                             | PK 8           | 8.70| 30.6            | 29             | 73.1          | 5.66          |
|                             | PK 9           | 8.70| 29.9            | 29             | 71.4          | 5.16          |
| Middle Zone                 | PK 10          | 8.60| 31.5            | 29             | 71.2          | 5.42          |
| (Baccini Baji passenger pier) | PK 11          | 8.60| 30.4            | 30             | 73.1          | 5.66          |
|                             | PK 12          | 8.70| 29.9            | 29.5           | 71.4          | 5.16          |
|                             | PK 13          | 8.71| 30.5            | 30             | 67.3          | 5.28          |
|                             | PK 14          | 8.70| 29.9            | 29             | 67.3          | 5.28          |
| South Zone                  | PK 15          | 8.8 | 29.6            | 29             | 67.3          | 5.28          |
| (Semen Tonasa pier)         | PK 16          | 8.70| 31.1            | 30             | 80.5          | 6.13          |
|                             | PK 17          | 8.71| 30.5            | 30             | 73.4          | 5.4           |
3.2 Composition and Abundance of Phytoplankton

In this study, the total abundance of phytoplankton in Pangkep coastal water was ranged from $2.179 \times 10^6$ cells/m$^3$ to $2.192 \times 10^8$ cells/m$^3$ in Figure 3(a). In average, the highest abundance was recorded in station PK 21 ($2.192 \times 10^8$ cells/m$^3$) and the lowest in station PK 15 ($2.179 \times 10^6$ cells/m$^3$). Diatom accounted for more than 80% of total abundance in all locations. The highest proportion of diatom was recorded in station PK 21 (99.98%) and the lowest observed in PK 15 (85.09%) in Figure 6. Diatoms density was high at the stations located in the northern and southern area but was low at the stations in the middle area of Pangkep Figure 3(c). Unlike diatoms, the density of dinoflagellates shows an increasing southward trend, with the highest density of dinoflagellate that was found at station PK 19 in Figure 3(d).

Noted that the density of phytoplankton was higher at the northern and southern area of Pangkep in Figure 3 & Figure 4, while stations at the middle of the study area have much lower phytoplankton density in Figure 3 & Figure 4. Despite its lower cell density, the middle area, in general, has much higher diversity and evenness compared to the northern and southern area of Pangkep in Figure 4. In this study, the phytoplankton diversity was varied between 0.09 – 1.61, while the evenness index was between 0.03 to 0.54. The highest diversity was found at PK 15, while the lowest was at PK 21 in Figure 4.

| PK  | Total Abundance | Diversity Index | Diatom Density | Dinoflagellate Density |
|-----|----------------|-----------------|----------------|-----------------------|
| 18  | 8.61           | 30.8            | NA             | 5.63                  |
| 19  | 8.71           | 30.7            | 31             | 69.9                  |
| 20  | 8.71           | 30.7            | NA             | 4.62                  |
| 21  | 8.7            | 31.9            | NA             | 77.2                  |
| 22  | 8.7            | 30.5            | 31             | 5.26                  |

**Figure 3.** (a) Total abundance (cell density) of phytoplankton; (b) Diversity index (Shannon H'); (c) Diatoms density; (d) Dinoflagellate density
Figure 4. Boxplot of density and ecological indexes; (a) Cells density; (b) Number of species; (c) Diversity index (Shannon H); (d) Evenness index (Shannon J).

Figure 5. Genus composition in Pangkep waters, South Sulawesi, Indonesia. (a) Diatom group, which dominated by *Skeletonema*; (b) Dinoflagellate group, which co-dominated by *Ceratium* and *Dinophysis*. *Amphizolenia* has very low density was not visible in the diagram; (c) Total phytoplankton composition.
Twenty-nine genera were found in Pangkep waters, which consists of 23 genera of diatoms and 6 genera of dinoflagellates. Two genera of diatoms, *Skeletonema* and *Nitzschia* and 5 genera of dinoflagellates, *Ceratium*, *Dinophysis*, *Protoperidinium*, *Alexandrium* and *Pyrophacus*, were found frequently amongst total 22 stations. In general, the phytoplankton community in Pangkep was dominated by diatoms, which contributes to over 95% of the total phytoplankton cell density in Figure 5 (c). The diatoms *Skeletonema* was found dominating the phytoplankton community in Pangkep waters in Figure 5 & Figure 6 (a). On the other hand, the dominant genera in dinoflagellates groups were *Ceratium* in Figure 5, which could be found in almost all stations. However, *Ceratium* density was very low and only accounted for 2% of total cell density Figure 5 (b).

**Figure 6.** Composition and relative density of phytoplankton at 22 stations in Pangkep waters, Indonesia. There was a dominance of *Skeletonema* in all stations, which contributes to 59-98% of total phytoplankton density.

**Figure 7.** Bray–Curtis dissimilarity cluster of phytoplankton among 22 stations, dash line indicates the threshold for grouping (dissimilarity index: 0.3). The map on the right shows the spatial distribution of the group in the study area.
Based on the Bray-Curtis dissimilarity index, there was no distinct spatial grouping among three zones Figure 7. Stations located at each zone (north, middle, south) did not clump together and have fairly different phytoplankton communities Figure 7. Similarly, there were no distinct grouping of stations based on its distance from the shoreline Figure 7. However, station PK 15 and PK 21 were found to have a very different community structure compared to other stations Figure 7. In station PK 15, the density of *Thalassiosira, Ceratium* and *Dinophysis* have more contributions in the phytoplankton community of the said area. While in station PK 21, there was an over domination of *Skeletonema* which contributes to more than 98% of total abundance of phytoplankton, and with a cell density of more than 2 x 10^5 cells/m^3 Figure 6. As a note, station PK15 was the station with the lowest phytoplankton density but with the highest diversity Figure 3(a) & Figure 4(b), while station PK21 was found with the highest phytoplankton cell density but with the lowest diversity Figure 3(a) & Figure 4(b).

4. Discussions

The high abundance of phytoplankton was found at stations located in the south area (PK 16-22), which located at the outflow of two river mouths and with the presence of a large harbour. The average of the total phytoplankton abundance in the southern area was 6.06×10^7 cell/m^3. On the other hand, the northern area, which has three rivers (Lepangeng, Limbangan and Lerang Lerang river) that outflow to the coastal area, the average phytoplankton density was 6.01×10^7 cell/m^3. The stations located in the middle area have the lowest average of total phytoplankton abundance, with cell density only 1.86×10^7 cell/m^3. As a note, it was known that Pangkep coastal waters were enriched by the river and surface run off that carried nutrient, such as nitrate, phosphate, and silica, which originate particularly from the agriculture activities upstream [6]. Based on that information, it could be assumed that the high density of phytoplankton at the northern and southern area was influenced by the river inputs in those areas. However, due to the lack of nutrient data in this study, that assumption cannot be proven until a further study is carried out in Pangkep coastal waters.

It was interesting that a high density of phytoplankton in the coastal water of Pangkep was not followed by a high diversity or evenness. The northern and southern zone of Pangkep, which have a very high density of phytoplankton, have low diversity and evenness. In contrast, the middle zone of Pangkep, which generally have a low density of phytoplankton, was found to have the highest diversity and evenness. It means, the middle zone of Pangkep in this study has a better water quality, which could sustain more number of genera in the phytoplankton community. As a note, the level of phytoplankton diversity in this study, which ranged from 0.09 to 1.61, was generally lower than what was found in a previous study by Rahsdy et al [20].

Another interesting trend in this study was the fact that no distinct grouping was found between all stations in three zones in Pangkep. Furthermore, no grouping also found in stations based on its distance from the shoreline. This trend indicates that phytoplankton spatial heterogeneity was high and no zones have a very distinct phytoplankton community that differs from the other zones. However, two stations, which were station PK 15 and PK 21, did have a unique phytoplankton community. The reason for such unique phytoplankton community was not clear due to lack of sufficient environmental data in this study.

But in this study, station PK 15 was found with the lowest surface water temperature (29.6 °C) and located furthest from the coastline, while station PK 21 has the highest surface water temperature (31.9 °C) and located very close to the coastline. Unfortunately, it was not possible to confirm whether the temperature was the main forces that drive the uniqueness in the phytoplankton assemblages in those stations. Even so, water temperature, combined with nutrient concentration, were regarded as important factors that directly, and indirectly, affecting the phytoplankton community structure by controlling the nutrient availability as well as the metabolic activities, such as cellular growth, nutrient uptake, enzyme activities, protein synthesis, and permeability of membranes [21]. Based on that information, it was then assumed that the distance to the coastline, which affects the nutrient concentration in the water column, along with water temperature, were two important factors that support the unique phytoplankton assemblages in station PK15 and PK 21.
At Rahsdy et al study identifies 29 genera of phytoplankton, which is higher than the number found in a previous study, in which 15 genera of phytoplankton were identified at that time [20]. However, instead of *Ceratium*, which was the most abundant phytoplankton [20], the dominant phytoplankton in Pangkep waters of this study was *Skeletonema*. Another study by Nasir et al [6] also revealed different dominant genera, in which the dominant phytoplankton in Pangkep coastal waters and its estuaries were *Chaetoceros*, *Rhizosolenia*, and *Nitzschia*. The dominance of diatoms in this study, which contributed to up to 99% of the total abundance of plankton, was also found in the previous study by Nasir et al [6].

The *Skeletonema* domination in all stations could be related to the nutrient-enriched conditions in Pangkep coastal waters, which related to the high nutrient input from the rivers. *Skeletonema* is one commonly dominant diatoms in some highly enriched or eutrophic coastal waters of Indonesia, such as Jakarta Bay [22],[23]. The dominance of *Skeletonema* in marine ecosystems was due to its ability to effectively absorbing nutrient from the water column, thus increasing its productivity and growth rate [13]. On the other hand, the presence of *Ceratium*, which co-dominate the dinoflagellate group in this study, was known to have blooms in either mesotrophic or eutrophic habitats [24],[25]. As stated earlier, *Ceratium* was also dominant in the Pangkep water during a study that was conducted by Rahsdy et al [20]. High densities of *Ceratium* also were recorded globally in tropical eutrophic water bodies such as Argentina [26], Australia [27], South Africa [28], and Japan [29]. In Indonesia, *Ceratium* also commonly found in highly eutrophic waters, such as Jakarta Bay and was known to have a peak in its density after diatoms blooms in that bay [30]. Considering that mass fish mortality and dinoflagellates bloom has been recorded in Pangkep coastal waters and estuaries [6], and *Ceratium* once was found dominant in Pangkep [20], there is a chance that bloom of *Ceratium* could occur in the future.

### 5. Conclusions

From this study, it can be concluded that diatoms dominate up to 99% of total cell density of phytoplankton in all area in Pangkep coastal waters, with *Skeletonema* as the most dominant genus in the phytoplankton communities in all sampling stations. High cell density and low diversity of phytoplankton at northern and southern zones of Pangkep might be related to the riverine input to the coastal area, which carried nutrient and pollutant from anthropogenic activities on the coastline. On the other hand, higher diversity and lower cell density in the middle zone might also be related to the lack of riverine input, despite the location was next to a harbour (Baccini Haji). In general, there were no big differences in the phytoplankton community structures in Pangkep coastal waters. However, station 15 dan 21 were found with a unique community structure which might be related to the combined effect of temperature and nutrient input from the land. The occurrence of *Ceratium*, which once was found as a dominant genus in Pangkep coastal water, leads to a question whether the bloom of *Ceratium* could happen in the future or not. But considering the role of high temperature due to global change, and increasing anthropogenic nutrient inputs to the ecosystem, the dominance of *Skeletonema* in this study could shift to *Ceratium*. However, a further study with regular monthly sampling is required to further test that assumption and to better understand the seasonal succession in the phytoplankton communities of Pangkep.

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