Phytoplankton species potentially Harmful Algal Blooms (HABs) in Jakarta Bay

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Abstract. The occurrence of algal bloom causes problems in many parts of the world, including in tropical Indonesian coastal waters. Harmful algal bloom events in Jakarta Bay have been increased since several years ago and causing massive fish kills which lead to economic losses in local fisheries, a decrease of water quality, and threat to people consuming fish from the bay. Research was conducted in Jakarta Bay in 2008, 2009, 2010, 2011, 2013 and 2015, to study the variability of phytoplankton species that potentially as bloom maker. The samples were taken by 20 μm mesh size plankton net which deployed vertically to a depth of 7 - 10 meter at each station. The results showed that the abundance of phytoplankton ranged from $10^6$ to $10^8$ cells.m$^{-3}$. The population composed of 27 taxa, mostly belong to diatoms and dinoflagellates. We observed there are nine genera of phytoplankton which potentially as harmful algal bloom species, occurring in Jakarta Bay. Three of them are known as the predominant species of algal bloom in this bay, namely: Skeletonema, Chaetoceros, and Thalassiosira. Besides that, there are some species also playing a role in the tragedy of fish-killing due to oxygen depletion during blooms events in Jakarta Bay.

Keywords: algal blooms; potentially; predominant; variability

1. Introduction
Phytoplankton bloom often occurs, especially in the coastal waters, and causes discoloration in the surface water, traditionally known as "red tide" [1-3]. Most of the algal bloom may cause detrimental impact, so this event now referred to as harmful algal bloom (HABs). Harmful algal bloom (HABs) may now be defined as a significant increase in abundance, biomass or the population size of micro-algae and in its turn, may harm human health, fisheries, aquaculture, and tourism. HABs may cause harm to the environment and other organisms in several ways, even though not all phytoplankton blooms are harmful [4].

The causative species of red tide, usually comprised of one or two, even more, phytoplankton species which are identified as the predominant species. Most of the phytoplankton responsible for the bloom events in the coastal belong to six algal groups; diatoms, dinoflagellates, haptophytes, raphidophytes, cyanophytes, and pelagophytes [5-7]. The growth and distribution of algal blooms, traditionally controlled by the complex environmental process involving multiple factors such as; solar radiation, temperature, current patterns, and other associated factors and the nutritional requirements of the organisms [8]. There is growing recognition that HAB's are affected by human activities, but their exact
causes are still under debate. Eutrophication is one of the major causes of many blooms, although not all blooms are the result of anthropogenic changes in nutrient loadings [8-13].

Recently, Jakarta Bay has been experiencing algal blooms events since 1991 [14]. The frequency and distribution of algal bloom phenomena have been increasing and had caused massive fish kills which led to economic losses in local fisheries, decrease of water quality, and also affected the areas of local tourism in the surrounding bay [15-17]. Most of the algal bloom occurs due to phytoplankton population explosion, especially diatom, dinoflagellates, and cyanobacteria groups [18-20].

The purpose of the research was to study the abundance of phytoplankton population and to identify the species that potentially HABs species and as bloom-forming species in Jakarta Bay. The survey was carried out to provide baseline information on harmful algal bloom ecology for management purposes of the bay shortly.

2. Methods

2.1. Study sites

The survey took place in Jakarta Bay. Jakarta Bay is a tropical estuary part of the Java Sea located north of the DKI Jakarta province, Indonesia. In this bay, 13 rivers flow into the bay. Jakarta Bay, which covers an area of about 514 km², is a shallow water area with an average depth of up to 15 meters. The sediment for the study was collected at 13 sampling stations. Map of Jakarta Bay and the sampling station is showed in figure 1.

![Map of Jakarta Bay and the sampling stations.](image-url)
2.2. Research period
The research was carried out in the east-monsoon season or dry seasons in 2008, 2009, 2010, 2011, 2013 until 2015. The study was conducted in the dry season, considering the algal bloom events usually reoccurred in this bay during the east-monsoon season. Commonly, the season in this region is classified into west-monsoon or rainy season. Between the two seasons, there are two transitional seasons. The rainy season occurs from October to March and the dry season from April to September. In the rainy season, usually anthropogenic material enters the waters through sewage discharge, freshwater run-off, rivers flowing into the bay. After the rainy season, the concentration of nutrients (mainly N and P) usually increased and fertilizing the waters to a certain level.

2.3. Sample collection and analysis
Phytoplankton sampling was carried out using a 125 cm length and 25 cm opening mouth cone-shaped 20 µm mesh-size phytoplankton net which at the end was installed with a pinch to collect concentrates of phytoplankton samples. At the end of the net, a ballast was installed so that it can be lowered vertically. The sampling was carried out by lowering the phytoplankton net vertically up to a depth of 7-10 m and then being drawn slowly with a constant from a desired depth to the surface. Phytoplankton samples were collected in the bucket and then put into a sample bottle and given preservatives. Samples were preserved immediately using acidic 5% Lugol's solution [21]. The preserved phytoplankton samples were brought to the laboratory for further quantitative and qualitative analysis under an Olympus inverted microscope (Model IX50-S8F2). Phytoplankton removal was done by Sedgwick-Rafter Counting Cell [22, 23]. Quantitatively, the abundance of phytoplankton cells from each phytoplankton genus was calculated. Phytoplankton was identified to the genus level using identification keys of several taxonomic references [24-26]. The cell counts were used to compute the cell abundance using formula according to the procedure described in a manual book [21]. The total number of cells of individual species collected at each depth of each station was quantified and the phytoplankton abundance was expressed as the number of cells per cubic volume.

2.4. Measurement of nutrients and oceanographic parameters
The nutrients measured were dissolved inorganic nitrogen (DIN), including ammonium nitrogen (NH4-N), nitrate-nitrogen (NO3-N), and nitrite-nitrogen (NO2-N), and dissolved inorganic phosphorus (DIP), including phosphate-phosphorus (PO4-P). The method for analysis of nutrients used in this study was based on the transformation, through a chemical reaction of the substance to be analyzed, to another compound that can be measured colorimetrically within the wavelength range of the visible spectrum according to the method of by Strickland et al [27]. The water sample was filtered through Millipore filter paper pore size 0.45 µm (GF/C). The spectrophotometer employed in this study was a Philips PYE Unicam (Model PU8600). As a general rule, all samples were analyzed as soon as possible after collection and especially when the concentration was expected to below. Other Oceanographic parameters such as water depth, water temperature, dissolved oxygen, and salinity were measured in situ. The readings of water temperature and dissolved oxygen were taken directly from a YSI Dissolved Oxygen Meter (Model 59) and salinity (in parts per thousand) was measured using an ATAGO Hand Refractometer. The degree of acidity (pH) of seawater is measured by the pH meter of the TOA model of HM-IK model by dipping the electrode into it.

3. Results and discussions

3.1. Oceanographic parameters
The water temperature during the study period ranged from 29.72 °C –30.48 °C with 29.97 °C average. The lowest temperature value was 29.37 °C in May 2008 and the highest was 30.48 °C observed in March 2013. Salinity values of the bay ranged from 27.72–30.88 psu and, average 28.98 psu. The lowest salinity during the study was 26.41 PSU, which occurred in March 2009 and the highest salinity was 30.88 occurred in May 2010. The salinity range was relatively stable with the exception in May 2008.
and March 2009 and June 2009. The dissolved oxygen (DO) ranged from 2.96 – 4.12 ppm. The lowest oxygen was 2.96 ppm recorded in March 2009. The pH ranging from 7.68–8.30. The lowest pH occurred in July 2015 and the highest in May 2015. There are no extreme values of the oceanographic parameters during the study periods, except dissolved oxygen was depleted in March 2009. And also, there is no distinct stratification occurred due to shallow water depth (6–15 meters) of the bay, as well as the flushing by tides motion and currents.

3.2. Surface water discoloration due to algal bloom

The results of observations of colour changes due to algal blooms in the waters of Jakarta Bay are shown in table 1. The presence of algal blooms is seen from March to July and September to November. The algal bloom phenomenon occurs not only during the eastern season (dry season) but also at the beginning of the western season (wet season). This shows that the occurrence of the algal bloom phenomenon is still difficult to predict with certainty and does not only occur in the eastern monsoon. In the waters of Jakarta Bay, the HABs phenomenon is more intense in the eastern season or after the rainy season. If the water conditions are favourable, in general, the phenomenon of algal bloom will occur during that season. In several countries such as Hong Kong, Japan, and the Philippines, and China, there has been a shift in both the frequency and season of the occurrence of the algal bloom phenomenon in coastal waters [13, 28]. The occurrence of the algal bloom phenomenon almost every month can be seen on the surface of the waters with different locations, colours, and coverage areas. The frequency of algae blooms in Jakarta Bay tended to increase during the study from 2008 to 2015. The colours seen ranged from mixed colours to single, more striking colours. The area where the colour change occurs also varies from 25 percent to 50 percent of the area of Jakarta Bay [19]. The phenomenon of algal bloom is more often seen in these waters at the beginning of the eastern season (dry season) or the end of the western season (rainy season) until the end of the eastern season, and the exact time and time of its occurrence cannot be predicted.

| Months      | Surface water Discoloration due to algal bloom | Frequency |
|------------|-----------------------------------------------|-----------|
|            | 2008 | 2009 | 2010 | 2011 | 2013 | 2015 |           |
| January    | -    | -    | -    | -    | -    | -    | 0         |
| February   | -    | -    | -    | -    | -    | -    | 0         |
| March      | x    | x    | x    | x    | x    | x    | 5         |
| April      | x    | x    | x    | x    | x    | x    | 6         |
| May        | x    | x    | x    | x    | x    | x    | 5         |
| June       | x    | x    | x    | x    | x    | x    | 6         |
| July       | -    | -    | -    | x    | x    | x    | 3         |
| August     | -    | -    | -    | -    | -    | -    | 0         |
| September  | x    | x    | x    | x    | x    | x    | 6         |
| October    | x    | x    | x    | x    | x    | x    | 6         |
| November   | x    | x    | x    | x    | x    | x    | 6         |
| December   | -    | -    | -    | -    | -    | -    | 0         |

3.3. The abundance of phytoplankton

The abundance of phytoplankton during this study ranging from 21.71x10^6 cells.m^-3 up to 20.61x10^8 cells.m^-3. The highest abundance of phytoplankton population observed in 2010, ranging from 46.6x10^7 cell.m^-3 up to 28.49x10^8 cell.m^-3. The graph of phytoplankton abundance is shown in figure 2. The abundance of phytoplankton in 2010 was enormously multiplied in cells number. There is connectivity of this condition, high abundance with El-Nino. The abundance was very distinctive comparing to the condition before and after 2010. The highest peaks of the population reached an abundance of more than 10^6 cells.m^-3. During that time, water discoloration appeared in the surface water, due to algal bloom
[29-31]. Normally, surface water discoloration in this bay reappearing, if the abundance of the cell reached a number more than $10^5$ cells.m$^{-3}$ [32].

In Jakarta Bay, most of the algal bloom events reoccur in the dry season, precisely beginning a few weeks after the rainy season is over [20]. In this study, the highest frequency of bloom incidence was observed from March to June and during the rainy season from September to November. Algal bloom events appeared during the dry season which is started from March to June and then reappeared mostly from September to November. The dry season is usually characterized by less precipitation, high nitrate and phosphate concentration, higher air temperature, and available sunlight intensity. This condition will trigger the growth of phytoplankton to grow faster and reach a high density of cells during that season.

So far, the incidence of algal blooms in Jakarta Bay has been increasing both in frequency and distribution [33]. Discoloration due to algal blooms phenomena in Jakarta Bay, reoccurring mainly in March until June and occasionally in September to November. During the rainy season from December to February, there was no appear discoloration of surface waters due to algal bloom. It is apparent, that the algal bloom episode in Jakarta Bay is associated with the dry season (precisely after rainy season) when the N/P ratio increased in the waters from March and April [33, 34].

It is quite interesting to note the graph abundance of phytoplankton during the year of 2010. The results showing that the phytoplankton population in March 2010 dominated by Skeletonema (relative abundance: 86.03%), in May 2010 dominated by Chaetoceros (relative abundance: 62.9%) and Skeletonema (relative abundance: 32.34%). In June 2010, it was observed three predominant species namely Skeletonema (relative abundance: 59.79%), Chaetoceros, (relative abundance: 29.3%) and Thalassiosira (relative abundance: 17.45%). In conclusion, the main predominant species during 2010 were Skeletonema, Chaetoceros, and Thalassiosira. Bloom phenomena in the waters can be recognized visually through the discoloration of surface water due to the occurrence of phytoplankton species in a high abundance [17, 18]. Usually, in Jakarta Bay, the discoloration can be seen in the surface water when the population of phytoplankton reached abundance between $10^5$-$10^6$ cells.m$^{-3}$ [19, 20]. The primary factor that can trigger the growth of phytoplankton, such as the availability of nutrients mainly phosphate (P) and nitrogen (N).

Figure 2. The abundance of phytoplankton throughout the study.
3.4. Nutrient ratio
The average concentration of nitrate during the study period ranged from 0.01-15.89 ppm, and the concentration of phosphate ranged from 0.01-2.5 ppm. The highest concentration of phosphate was observed in 2009, while the highest nitrate was observed in 2015. The concentration of phosphate tends to decrease, on the contrary, the nitrate concentration tends to increase throughout the study. The results revealed that nitrate concentration increasing and phosphate concentration decreasing in the waters from 2008 until 2015. A previous study, showing an increasing inorganic matter observed in Jakarta Bay, resulting in an increased incidence of algal blooms since the 1970s [15]. Starting in the ’70s to the 80’s algal blooms were rarely seen, but in the ’90s the algal bloom seemed to increase in connection with the increasing amount of anthropogenic nutrients in the bay. The relationship between the increase of eutrophication with the expansion of algal bloom in the bay is still not proven although in general eutrophication may result in the explosion of phytoplankton population [28].

The average of N/P ratio during this study is ranged from 0.2 – 45.5. It was recorded that a higher N/P ratio was observed from 2010 until 2013. In 2010, the highest concentration of nitrate was recorded in May with a value of 10.61 μg/L and phosphate 0.58 μ/L. During the study, the N/P ratio reaches the value to 18, which means that N plays a role as a triggering factor and P as a limiting factor for the growth of phytoplankton. It is evident, that ratio or proportions of nutrients, especially nitrogen (N) and phosphorus (P), as the primary cause of changing blooms in the bay. The nitrogen and phosphor were acting as the key factors which stimulate phytoplankton growth. The nutrient N/P ratio during the study ranged from 0.2 up to 45.5. Nitrogen was playing as a triggering factor, while phosphate was a limiting factor to the growth of phytoplankton.

It is apparent, that there is a strong linkage between nitrate concentration and the abundance of phytoplankton. There was a connection between high ratios of N/P with the algal bloom abundance. The nutrients ratio of N/P showing that N plays as the primary factor that can stimulate the growth of phytoplankton. The concentration of P is the limiting factor, meaning that at least, there should be a certain amount of P in the waters. Both of these nutrients N and P is seemed to be complementary to each other and together may controlling the growth of phytoplankton.

3.5. The composition of phytoplankton population
The results of the study showing that Skeletonema, Chaetoceros, and Thalassiosira were the predominant species that cause algal bloom in Jakarta Bay (figure 3). The predominant species in this case meaning that the species which can reach an abundance of more than 10%. These predominant species are classified quite important in this bay because, they play an important role in the ecosystem dynamics, and as well as an indicator of the ecological condition. The relative abundance of Skeletonema ranged from 12.25%-86.0% of the total population, while the abundance of Chaetoceros ranged from 1.41%-63.96% of the total population and Thalassiosira abundance ranged from 0.2%-26.26% of total abundance.

![Figure 3. The relative abundance of predominant species throughout the study.](image-url)
Table 2. The phytoplankton has the potential for HAB’s in Jakarta Bay.

| Phytoplankton     | Relative Abundance (%) |       |       |
|-------------------|------------------------|-------|-------|
|                   | Minimum | Maximum | Averages |
| Skeletonema       | 12.25   | 86.03   | 48.55   |
| Chaetoceros       | 1.41    | 63.96   | 29.33   |
| Thalassiosira     | 0.18    | 26.26   | 6.91    |
| Navicula          | 0.24    | 25.99   | 2.20    |
| Thalassiotrix     | 0.01    | 16.17   | 3.10    |
| Leptocylindrus    | 0.01    | 13.74   | 1.60    |
| Asterionella      | 0.01    | 10.18   | 1.67    |
| Ceratium          | 0.04    | 6.63    | 0.89    |
| Nitzschia         | 0.54    | 6.13    | 2.63    |
| Bacteriastrum     | 0.07    | 2.61    | 1.27    |
| Others            | 0.001   | 1.25    | 0.001   |

Most of the predominant species in this bay belong to diatom (table 3). They can be classified as the potential species of algal bloom-forming namely; Skeletonema, Chaetoceros, Thalassiosira, Navicula, Thalassiotrix, Leptocylindrus, and Asterionella. There are two other species such as Ceratium and Nitzschia can be classified as species that potentially bloom-forming species in these waters. The species Skeletonema and Chaetoceros are often found dominant in the coastal waters.

4. Conclusion
Most of the causative species of phytoplankton blooms belong to the group of diatoms, which is responsible for the incidents of fish kills during bloom events in Jakarta Bay. The diatoms that are classified as common species and bloom-forming species in this bay namely; Skeletonema, Chaetoceros, and Thalassiosira, Bacteriastrum, Coscinodiscus, Leptocylindrus, Nitzschia, and Thalassiotrix. Three of them such as Skeletonema, Chaetoceros, and Thalassiosira were classified as the primary species which potentially as HABs in Jakarta Bay. The predominant species usually reach an abundance of more than 10% of the total population. Therefore, those species are quite important in the ecosystem because it plays important role in the dynamics of marine life and as well as a biological indicator for the condition of the waters.

The abundance of phytoplankton is closely related to the increasing N/P ratio in the waters. Eutrophication or excess nutrients in the waters may result in changing of nutrients (N/P) ratio. Consequently, changes in total biomass and species composition leading to succession between populations. The range of the N/P ratio in the waters of the Bay of Jakarta in the eastern monsoon is around 0.2-45.5.

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