Spatial distribution of nutrients in Maumere Bay, East Nusa Tenggara

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Abstract. The availability of nutrients in the marine environment is very important for primary production and as indicator of the health condition in waters. East Nusa Tenggara Province is one of the province that has a potential fishery, especially in Maumere Bay of Sikka Regency. Therefore, it is necessary to monitor the water quality and spatial distribution of nutrients in that area. This study aims to determine water quality, assess water trophic status, and determine limiting factors in Maumere Bay. Sampling was conducted in August 2017 at 14 research stations and 1 daily station. The results showed that the relationship between DIN, DIP, and DSi at the daily station was a weak correlation. DIN reaches maximum concentration after 8 hours, whereas DIP and DSi reach maximum concentration after 12 hours. The average DIN, DIP, and DSi were 1.082 μmol L⁻¹, 0.123 μmol L⁻¹, and 4.544 μmol L⁻¹, respectively. The average DIN/DIP ratio was 11.554. It can be concluded that Maumere Bay is an oligotrophic area and phosphate as a limiting nutrient for phytoplankton growth.

1. Introduction

The availability of nutrients in the sea is very important, especially for the growth of phytoplankton. In addition, nutrients are often used as a parameter in assessing the water quality and its productivity level. Thus, nutrients are an important factor that support potency of fisheries sector indirectly.

The main nutrients in the sea are nitrogen, phosphorus, and silicon. These nutrients are involved in the life processes of organisms. The main source of nutrients in the sea comes from rock weathering, organic material decomposition, and waste from human activity which brought by rivers to the sea [1]. The distribution of nutrients is influenced by seasonal factors (biotic factors, temperature, and wet deposition), physical factors (upwelling and water mixing), biology factors (primary producers consumption and bacteria regeneration), and anthropogenic load [2].

The coastal area of Sikka district is potential area because it has coral reefs that widespread in the southern and northern waters (Maumere Bay) [3]. In addition, the abundance of fish is found in mangrove and seagrass ecosystems [4], [5]. Maumere Bay in Sikka Regency, East Nusa Tenggara Province, is one of the waters area that have good fisheries commodity due to the coral reef and seagrass ecosystems existence. However, the anthropogenic influence that can change the quality and the productivity of waters is expected to increase along with the development of the city.

This study aims to determine water quality, assess water trophic status, and determine limiting factors in Maumere Bay.
2. Materials and methods

2.1. Nutrient analysis
Seawater samples for measurement of nutrient concentrations were taken from 14 spatial distribution stations and one daily observation station (SH) around Maumere Bay, Sikka Regency, East Nusa Tenggara Province in August 2017 (Figure 1). Sampling for daily observations is carried out every 4 hours. Samples were taken from the surface layer (<1m) of 1 liter and placed in a polyethylene bottle and stored in a cool box. Then, the sample was filtered with a cellulose acetate membrane with a pore size of 0.45 µm and a diameter of 47 mm. The concentrations of inorganic nutrients were measured using a Shimadzu UV-1800 spectrophotometer based on Strickland and Parsons (1972) [6]. We define DIN as the sum of NO$_3^-$, NO$_2^-$, and NH$_4^+$, PO$_4^{3-}$ is reported as dissolved inorganic phosphorus (DIP), while Si(OH)$_4$ is reported as dissolved silicate (DSi).

2.2. Data processing
Spatial distribution for all parameters were generated with Ocean Data View. The relationship between all variables was investigated through Spearman's correlation analysis using SPSS 19.0 software.

![Figure 1](image)

Figure 1. Location of seawater sampling for nutrient measurement around Maumere Bay, NTT, August 2017.

2.3. Eutrophication status
DIN and DIP were used as the potential eutrophication evaluation model for knowing status eutrophication in the study area (Table 1) [7].
Table 1. The evaluation standards for potential eutrophication.

| Grade | Nutrient level                          | DIN (μmol L\(^{-1}\)) | DIP (μmol L\(^{-1}\)) | DIN/DIP |
|-------|----------------------------------------|-------------------------|------------------------|---------|
| I     | Oligotrophic level                     | < 14.28                 | < 0.97                 | 8-30    |
| II    | Moderate-level nutrient                 | 14.28-21.41             | 0.97-1.45              | 8-30    |
| III   | Eutrophication                         | > 21.41                 | > 1.45                 | 8-30    |
| IV\(_p\) | Phosphate-limiting moderate-level nutrient | 14.28-21.41         | -                      | > 30    |
| V\(_p\) | Phosphate moderate limiting potential | > 21.41                 | -                      | 30-60   |
| IV\(_N\) | Nitrogen-limiting moderate-level nutrient | -                       | 0.97-1.45             | < 8     |
| V\(_N\) | Nitrogen moderate limiting potential    | -                       | > 1.45                 | 4-8     |
| VI\(_N\) | Nitrogen-limiting potential eutrophication | -                       | > 1.45                 | < 4     |

3. Results and discussion

The following illustrates the spatial distribution and nutrient dynamics observed around Maumere Bay in August 2017.

3.1. Dissolved oxygen (DO) and pH

The DO is an important measure of water quality. It is considered of the limiting factors for aquatic physiological metabolism. DO value is an indicator of aquatic growth conditions and pollution status. DO concentration is depend on oxygen from atmosphere, algal photosynthesis and organism respiration [8]. The regeneration of nutrients by organisms respiration is also a process that contribute critical importance to the maintenance of marine life. Nutrients will release to the environment when algal cells die and decomposed. This process with other biogeochemical processes will impact to the dynamic and total biomass of phytoplankton [9].

The dissolved oxygen in Maumere Bay ranged from 5.9 to 6.8 ppm with an average of 6.4 ppm. This indicates that the Bay was oxygenated [10]. The highest DO is found at station 11 and the lowest DO is found at station 1. The pattern of DO showed that DO increases from east to west. In the present study, no significant correlations were found between DO and nutrients, which could be explained by the following two reasons. First, nutrients did not show in the solution because nutrients were adsorbed on suspended particulate solids. Second, the complex biomineralization process produced many organic nutrients instead of inorganic nutrients [9]. Jung et al reported that inconsistent correlation between dissolved oxygen and nutrients. They suggested that higher nutrients in water may not necessarily indicate oxygen deficiency, although it is known that excessive nutrients lead to the depletion of dissolved oxygen through algal bloom and eutrophication [11].

The pH is a key on chemical water indicator. The pH in the Maumere Bay ranged from 8.07-8.11, with a mean value of 8.09. This pH value is higher than pH in Laizhou Bay, China. In 2012 at Laizhou Bay, the mean pH value was 7.81 and decreased every year. It is indicating that in the Bay occurred acidification [12]. The water conditions is very acid or very base, endanger the survival of the organism because it will cause disturbance metabolism and respiration. In eutrophic waters, pH value can increase up to 9 or 10. A high pH may inhibit the photosynthesis of algae [8].

3.2. Dissolved inorganic phosphorus (DIP)

Phosphate is mostly adsorbed by soil particles and reported as a limiting nutrient in marine environment. The capacity of soil particles to adsorbed P is related to the level of organic matter in sediment [13].
Dissolved Inorganic Phosphorus (DIP) concentration in Maumere Bay ranged from 0.047 to 0.186 μmol L\(^{-1}\) with an average of 0.123 μmol L\(^{-1}\). This value is similar with the DIP concentration in Hurun Bay, Lampung [14]. However, this concentration was less than Jiaozhou Bay with 0.27 μmol L\(^{-1}\) [15], Mullica River-Great Bay estuarine system with 0.15 μmol L\(^{-1}\) [16], Jakarta Bay with 0.21 μmol L\(^{-1}\) [17], and Pagametan Bay with 0.65 μmol L\(^{-1}\) [18].

**Figure 2.** Spatial distribution nutrient in Maumere Bay, August 2017.
The phosphate distribution around Maumere Bay is quite interesting. Usually, the phosphate tends to be high near land and decreases towards the sea as it is located near Maumere and Nangahale City. But the results showed the opposite pattern. The lowest value was observed at stations 5, 7, and 8 while the highest value was observed at stations 4, 9, 12, and 13. The phosphate concentration near Nangahale and Maumere are relatively low. Phosphate tends to increase towards the sea. This is happen because the high phosphate around Nangahale is diffused to the northwest while the phosphate in Maumere is diffused to the northeast. That is why the water area between the two cities is not or less affected by phosphate diffusion from the land.

In general, Bay has low concentrations of DIP. This may be related from less concentration of DIP from soil, adsorption on suspended particulate matter, and scavenged by iron oxides [13]. Phosphate concentrations of this magnitude are common in marine waters, especially outside the littoral zone due to low land effects.

3.3. Dissolved inorganic nitrogen (DIN)

DIN was the second most abundant nutrients in the Bay. The DIN concentration in Maumere Bay ranged from 0.839 to 1.590 μmol L⁻¹ with an average of 1.082 μmol L⁻¹. The range of average DIN was less compared with other bays. In Hurun Bay, Lampung, the DIN value was 1.26 μmol L⁻¹ [14], Pagametan Bay was 7.85 μmol L⁻¹ [18], Jiaozhou Bay was 16 μmol L⁻¹ [15], Mullica River-Great Bay estuarine system was 32 μmol L⁻¹ [16], and Jakarta Bay was 41.46 μmol L⁻¹ [17]. The pattern of DIN showed that the concentration tends to increase towards the sea. The lowest value being observed at station 11, while the highest value is found at station 3.

DIN was dominated by NO₃⁻ which is 33-64% with mean 51%, followed by NH₄⁺ between 21.2-49.9% with mean 30.7% and the lowest is NO₂⁻ with percentage 12.5-26.4% with mean 18.2%. The range concentration of nitrate is relatively low with 0.358-0.811 μmol L⁻¹. Usually, a low concentration of nitrate had found in the open sea due to less land impact. In general, the pattern of nitrate is different from the DIN pattern. The nitrate concentration tends to decrease towards the sea except for the north area of Maumere City. The lowest nitrate concentration is found in the North of Maumere City. This is different from DIP which the highest concentration is found near Maumere City and Nangahale City. The highest nitrate concentration is found in the southeast of Besar Island and in the middle area between Maumere City and Nangahale City. Nitrates seem to have the same diffusion pattern as phosphates. Nitrate with a high concentration in the east of Maumere City diffuses to the northeast, while nitrate in the southeast of Besar Island diffuses to the northwest. The range concentration of ammonium is 0.270-0.722 μmol L⁻¹. The ammonium concentration is not really different between the station except stations 3 and 13. The range concentration of nitrite is 0.130-0.242 μmol L⁻¹. The concentration of nitrite is not really different between the station.

3.4. Dissolved silicate

The Dissolved Silicate (DSi) concentration in Maumere Bay ranged from 1.988 - 26.026 μmol L⁻¹ with an average of 4.544 μmol L⁻¹. Silicate concentrations were distributed almost evenly in Maumere Bay. The lowest concentration being observed at station 5, while the highest concentration being found at station 1 or east of Besar Island. DSi was the most abundant dissolved nutrients in Maumere Bay. This is similar to the condition with high DSi, such as Jiaozhou Bay with 5.48 μmol L⁻¹ [15] and Jakarta Bay with 7.82 μmol L⁻¹ [17]. The high DSi concentration is caused by chemical weathering, dissolution of plant litter, and soil erosion. The differences of the DSi concentration is related to the differences in the process [13].

DSi concentration will affect to phytoplankton community. If the availability of silicates is more than 0.07 μg/L, diatoms will dominate the phytoplankton community with a proportion of more than 70% [19]. Compared to other species, diatoms has high rate of nutrient consumption and growth. They play an important role in CO₂ absorption, oxygen production, and increasing the primary productivity of waters.
3.5. Nutrient ratios

The nutrient ratio, commonly known as Redfield ratio (N:P:Si=16:1:1), is a requirement for the reproduction and growth of phytoplankton. In addition, nutrient ratios can be used to determine nutrient limitations and alteration in the phytoplankton community [13]. Each phytoplankton species has different nutrient requirements. For instance, when silicate concentration is low, non-diatom plankton will dominate the waters. On the other hand, when the silicate concentration is high, the diatom species will dominate. When the concentration P is low and the N is sufficient, the dominant species of the phytoplankton community will change from diatoms to dinoflagellates. The research about nutrient uptake kinetics has reported that the threshold values for phytoplankton growth are DIN=1 μmol L⁻¹, DIP=0.1 μmol L⁻¹, DSi=2 μmol L⁻¹ [9,20].

The DIN:DIP ratio values varied from 4.993 to 22.474, with an average of 11.554. The high of DIN:DIP ratio means that the increased concentration of DIN. The DIN:DIP ratio in Maumere Bay is less compared with other bays. In Jiaozhou Bay, the DIN:DIP ratio is 76 [15], DIN:DIP in Mullica River-Great Bay estuarine system is 213 [16], the DIN:DIP in Jakarta Bay is 197 [17], and in Pagametan Bay is 12.08 [18]. However, the DIN:DIP ratio is greater than the inner Ambon bay with 3.47. The low N/P ratio in Ambon Bay is due to differences in conditions and processes that occur in the aquatic environment. When the nitrogen consumption rate by phytoplankton takes place quickly and not proportional to the phosphate use rate, the N/P ratio will decrease. Beside that, the rate of regeneration phosphate from the suspended material or sediment progresses is more quickly and not accompanied by sufficient nitrogen supply [21].

The DSi:DIP ratio values are in the range 11.655-186.486 with an average of 43.812. The large range of DSi:DIP ratio because of low concentration of DIP relative to DIN. In the study area, molar ratios of DSi:DIP were averagely higher compared with Jiaozhou Bay and Jakarta Bay with ratio 20.30 and 37.24, respectively [15,17].

Referring to the eutrophication status (Table 1), with an average value of DIN = 1.082, DIP = 0.123, and DIN: DIP = 11.554, the waters in Maumere Bay are included in the oligotrophic level. To find out which nutrient is the limiting factor, Justic et al. proposed about the nutrient ratios. If N:P ratio <10 and Si:N ratio >1 indicate N would be the limiting nutrient, while Si:N ratio <1 and Si:P ratio <3 indicate Si would be the limiting nutrient; and N:P ratio >20–30 and Si:P ratio >20–30 indicate P would be the limiting nutrient [20]. Based on the value obtained, it can be conclude that phosphate is the limiting factor in Maumere Bay.

3.6. Daily nutrient dynamics

Daily nutrient dynamics measurements were carried out at one station (SH) for 24 hours near a seagrass ecosystem with a small area cover. Figure 3 showed that the concentration of DIN, DIP, and DSi has fluctuated. The results showed at the same time but on different days, different concentrations of nutrients were obtained. However, it seems to be a pattern formed in the one-day cycle. In one day cycle, nutrient concentrations have fluctuated. The pattern of fluctuations in DIP is the opposite of that of DIN and DSi. Meanwhile, the DIN and DSi fluctuations patterns are similar, but there is a time shift for 4 hours. This means that the DSi concentration will reach its maximum or minimum value 4 hours after the DIN reaches its maximum or minimum concentration. DIP reaches its maximum concentration every 12 hours, namely at 20:00 and 24:00, while the lowest concentration is reached in the afternoon. DSI concentration is reached the maximum at 20:00, but the lowest concentration is reached at midnight. Unlike the case with DIP and DSi, the maximum concentration of DIN occurred after 8 hours, namely in the afternoon, and the lowest concentration occurs during the day and night. The fluctuation of nutrients is due to differences in the input or output of these nutrients. For example, the maximum concentration is obtained because the phytoplankton is not using nutrients at that time. Otherwise, the minimum concentration means that at that time is the optimal time for nutrient utilization. DIP and DSi are not used by phytoplankton at night, while DIN is not used by phytoplankton in the afternoon. The spatial distribution of dissolved inorganic nutrients were varied because of many factors, such as terrestrial inputs, phytoplankton reproduction, and organic
matter decomposition [9].

Figure 3. Graphic of daily nutrient.

3.7. Correlation analysis

The correlation analysis is used to know the influencing factor between the parameter. Table 2 shows that DIP negatively correlated with DIN/DIP and DSi/DIP. When the concentration DIP is high, then the DIN/DIP and DSi/DIP ratio are low. Besides that, NO$_3^-$ positively correlated with DIN. If the concentration NO$_3^-$ is high, then DIN concentration also high. NO$_3^-$ was the major form of DIN in Maumere Bay. However, at the daily station, the correlation between DIP, DIN, and DSi shows a weak correlation (Table 3).

Table 2. Spearman’s correlations at 14 stations.

|         | DIP   | NO$_3^-$ | NO$_2^-$ | NH$_4^+$ | DIN   | DIN/DIP | DSi    | DSi/DIP | pH    | DO   |
|---------|-------|----------|----------|----------|-------|---------|--------|---------|-------|------|
| Correlation Coefficient | 1.000 | -0.137   | 0.384    | -0.011   | 0.125 | -0.921** | 0.207  | -0.770** | -0.251 | 0.018 |
| DIP Sig. (2-tailed) | -     | 0.641    | 0.176    | 0.969    | 0.671 | 0.000   | 0.477  | 0.001   | 0.386  | 0.951 |
| N       | 14    | 14       | 14       | 14       | 14    | 14      | 14     | 14      | 14     | 14   |
| Correlation Coefficient | -0.137 | 1.000    | -0.058   | -0.271   | 0.731** | 0.400   | 0.494  | 0.466   | -0.218 | -0.501 |
| NO$_3^-$ Sig. (2-tailed) | 0.641 | 0.844    | 0.348    | 0.003    | 0.157 | 0.073   | 0.093  | 0.455   | 0.068  |      |
| N       | 14    | 14       | 14       | 14       | 14    | 14      | 14     | 14      | 14     | 14   |

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Spearman’s correlations at one daily station.

|         | DIP   | NO$_3^-$ | NO$_2^-$ | NH$_4^+$ | DIN   | DSi    | pH    | DO   |
|---------|-------|----------|----------|----------|-------|--------|-------|------|
| Correlation Coefficient | 1.000 | -0.291   | -0.312   | -0.140   | -0.691 | 0.147  | -0.403 | -0.127 |
| DIP Sig. (2-tailed) | -     | 0.527    | 0.496    | 0.764    | 0.086 | 0.753  | 0.371  | 0.786 |
| N       | 7     | 7        | 7        | 7        | 7    | 7      | 7     | 7    |
| Correlation Coefficient | -0.691 | 0.536    | 0.559    | 0.055    | 1.000 | 0.234  | 0.000  | 0.036 |
| DIN Sig. (2-tailed) | 0.086 | 0.215    | 0.192    | 0.907    | 1.000 | 0.613  | 1.000  | 0.939 |
| N       | 7     | 7        | 7        | 7        | 7    | 7      | 7     | 7    |
| Correlation Coefficient | 0.147 | 0.450    | -0.173   | 0.167    | 0.234 | 1.000  | 0.000  | -0.144 |
| DSi Sig. (2-tailed) | 0.753 | 0.310    | 0.711    | 0.721    | 0.613 | 1.000  | 1.000  | 0.758 |
| N       | 7     | 7        | 7        | 7        | 7    | 7      | 7     | 7    |

*. Correlation is significant at the 0.05 level (2-tailed).
4. Conclusion
In general, the concentration of nutrients in Maumere Bay was decreased towards the sea. High concentrations of DIP were found near Maumere and Nangahale City, while high DIN and DSi concentrations were found in north of Nangahale City or east of Besar Island. The range of nutrient concentrations measured in Maumere Bay was relatively low. Maumere Bay is an oligotrophic area and phosphate as a limiting nutrient for phytoplankton growth.

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