Distributions of dissolved inorganic nitrogen to estimate trophic state in Jakarta Bay

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Abstract. Jakarta Bay is a coastal area that receives a lot of organic material input from rivers in Jakarta. The organic material is decomposed into nutrients and has implications for increasing the trophic state of Jakarta Bay. The aims of this study are to analyze the spatial distribution of dissolved inorganic nitrogen (DIN) and to estimate the trophic state of Jakarta Bay. The study was conducted from July to October 2017. Spatio-temporal distribution analysis of nitrogen was carried out with ArcGIS 10.4.2. Estimation of trophic state used TRIX Index. Ammonia and DIN distribution tends to be higher in the river mouth and in the middle of the bay, nitrite was higher in the eastern part of the bay and river mouth, while nitrates tend to be higher in the eastern part of the bay to the middle waters. Trophic state of Jakarta Bay can be divided into three trophic status, hypertrophic in coastal area, eutrophic in the middle of the bay, and mesotrophic in the high seas.

1. Introduction
The Jakarta Bay Region has an important role, both in ecological and economic terms. Human activities on land will contribute organic matter to the waters which will eventually flow to the Jakarta Bay. The rivers in Jakarta and surrounding areas are now widely misused to be the location of household and industrial waste disposal. A large number of inputs, both in the form of domestic waste and industrial waste into river waters, has a negative impact that can affect the physical and chemical conditions of the bay water environment.

According to Damar [1], there are at least 25000 tons of nitrogen input and 6700 tons of phosphate entering the Jakarta Bay through the river systems in Jakarta and its surroundings for one year period (December 2000 to December 2001). The input of nutrients that had been high during this period was due to lack of proper management, such as inadequate wastewater treatment in Jakarta, so that a lot of organic and inorganic wastewater entered to river systems and finally lead into the Jakarta Bay without good processing.

The increase number population in Jakarta to 15 328 people/km2 and the growth rate of 1.07% [2], has contributed Dissolved Inorganic Nitrogen (DIN) to Jakarta Bay in 2016 approximately 1 900 tons/month. This will cause nutrient enrichment in the bay. Hydro-oceanographic factors such as ocean currents have a direct effect on the pattern of nitrogen distribution in the waters, this is because the circulation of ocean currents can distribute DIN from one place to another. When the tide occurs, ocean
currents will transform the mass of sea water from the high seas to the coast. As for the low tide, the current will transform the mass of sea water from the coast to the high seas. Therefore, wastes from the land will spread in all directions when it reaches the river mouth.

Eutrophication occurs due to the enrichment of nutrients both naturally and artificially into the waters. The rate of eutrophication will be faster with human activity. According to Koropitan et al. [3], Jakarta Bay area is a waters that have very high trophic levels in Indonesia. This research was conducted with the aim to analyze the spatial distribution of dissolved inorganic nitrogen and estimate the trophic status of Jakarta Bay.

2. Material and Methods
The study was conducted from July to October 2017 in the waters of Jakarta Bay. There were 15 points stations, where the station is considered to represent the estuary, western, central, and eastern part of the bay (Fig. 1). Nutrient analysis was carried out in the Aquatic Productivity and Environment Laboratory, Department of Aquatic Resources Management, Bogor Agricultural University.

![Figure 1. Location of sampling stations in Jakarta Bay](image)

The data collected in this study are primary and secondary data. Primary data were obtained through laboratory analysis, in the form of nitrogen concentration values (nitrate, nitrite, and ammonium). Sample analysis was carried out with reference to APHA [4]. Data of water quality (in situ), chlorophyll-a, and orthophosphate were obtained from Damar et al. (in prep) [5] (analyzis based on APHA 2012). In situ parameter consists of depth, temperature, transparency, pH, salinity, and DO.

Water sampling was conducted by using 2 liter Van Dorn water sampler. The water sample that has been taken was then stored into a 250 ml sample bottle then given H2SO4 preservation. Sample bottles were then transported in a coolbox (cooled at 4 °C) to the main laboratory.

Data analysis used in this study includes analysis of various water quality characteristics, analysis of similarity of water conditions between stations, analysis of nitrogen spatial distribution, and analysis of trophic status. Variance analysis was conducted to find out whether there is a difference in the distribution of parameters measured between stations and between times. Furthermore, further testing was carried out with the Tukey HSD test.

Similarities between stations were analyzed through the Canberra Index approach [6]. The Canberra index is used to see the similarities between observation stations based on the inequality of the physical-chemical parameters, then carried out through clustering analysis [7]. Based on this index value, groups are formed from each location by the dendrogram. This dendrogram divides all groups thoroughly through a chart form.
Spatial distribution of nitrogen includes the distribution of ammonium, nitrate, nitrite, and DIN. Spatial analysis is performed using ArcGIS 10.4.2. ArcGIS is a GIS software created by ESRI (Environmental System Research Institute). The method used in this analysis were IDW and contour.

Determination of the trophic status of the Jakarta Bay waters was carried out through the TRIX Index. This index was basically developed by Vollenweider et al. [8] aimed to characterize the trophic state of coastal marine waters, involving the eutrophication-related parameters, chlorophyll-a, oxygen saturation (%O2), dissolved inorganic nitrogen (DIN), and orthophosphate. The trophic status scale using TRIX is indicated by values 0 to 10, which describe conditions from oligotrophic to hypertrophic. Table 1 presents the TRIX value limit. The calculation of TRIX is as follows.

$$\text{TRIX} = \left( \frac{k}{n} \right) \times \sum_{i=n}^{k} \left[ \frac{(\log U- \log L)}{(\log M- \log L)} \right]$$

Information:

- $k = 10$ (scaling factor)
- $n =$ number of parameters (4)
- $U =$ upper limit
- $L =$ lower limit
- $M =$ parameter value

| TRIX range value | Trophic status |
|------------------|----------------|
| 0 < TRIX < 4     | Oligotrophic   |
| 4 < TRIX < 5     | Mesotrophic    |
| 5 < TRIX < 6     | Eutrophic      |
| 6 < TRIX < 10    | Hypertrophic   |

3. Results and Discussion

The results obtained during observation and sampling are concentration of dissolved inorganic nitrogen in the form of ammonium, nitrite, and nitrate. There is also an in situ parameter that is used as support for research obtained from the study of Damar et al. (in prep) [5].

Based on Fig. 2, the results obtained show that the transparency value is higher in the high seas and tends to decrease towards the estuary with the highest values at station 4 (4.87 m), and the lowest transparency is at station 14 (0.23 m). The temperature ranges between 29 - 32 oC, where the temperature in the estuary area is higher than on the high seas. pH values tend to be the same at each station with average values from 7.43 to 8.27.

Salinity values tend to be the same in high seas, but different with estuary areas whose values are lower. The range of salinity values is between 19 - 32 o/oo. The lowest salinity is in the estuary area, which is station 14. Furthermore, DO values tend to be different for each station with a range of values between 1 – 6.90 mg/L. The lowest DO was found in the estuary area, station 15. The low DO value in estuary areas is suspected due to the high use of DO in the decomposition of organic matter. Based on variance analysis, it was found that there were no significant differences between stations and between time for in situ parameters of Jakarta Bay (sig <0.05).

The average ammonium, nitrate, nitrite, and DIN concentrations at each observation station are presented in Table 2. Based on Table 2, the highest ammonium concentration is at station 14 with an average value of 1,721 mg/L. This is suspected because station 14 is one of the estuaries, where there are many activities that produce domestic waste. According to Santoso [9], the height of ammonia compounds in water is suspected as a result of aquaculture activities in these waters as well as river water runoff from aquaculture and agricultural activities. Based on variance analysis, ammonium concentration values were no significant differences between stations (sig <0.05), but between times there were significant differences (sig> 0.05).
Figure 2. The average measurement of in situ parameters at 15 research stations

Source: Damar et al. (in prep) [5].

The highest nitrate concentration was at station 14 with an average value of 0.237 mg/L. Station 14 is in the estuary area. This is directly proportional to the high ammonium at station 14 too. It is suspected that the decomposition process in this station was high. Based on variance analysis, the value of nitrate concentration was significantly different between stations (sig > 0.05), but there were no significant differences between times (sig < 0.05).

Nitrite concentration at each station showed a value that tends to be low in the high seas and high at estuary. The highest average nitrite concentration was at station 12 with an average value of 0.024 mg/L. An increase in nitrite concentration always applies in areas affected by rivers such as estuaries [1]. Based on the results of the variance analysis showed that there were significant differences in nitrite concentration between stations (sig > 0.05), but not significantly different between times (sig < 0.05).
Table 2. The average concentration of ammonium, nitrate, nitrite, and DIN at 15 research stations.

| Station | Ammonium mg/L | Nitrate mg/L | Nitrite mg/L | DIN mg/L |
|---------|---------------|--------------|--------------|----------|
| 1       | 0.051 ± 0.018 | 0.109 ± 0.011 | 0.008 ± 0.003 | 0.169 ± 0.011 |
| 2       | 0.040 ± 0.026 | 0.112 ± 0.011 | 0.007 ± 0.002 | 0.159 ± 0.023 |
| 3       | 0.072 ± 0.049 | 0.115 ± 0.016 | 0.008 ± 0.002 | 0.196 ± 0.047 |
| 4       | 0.073 ± 0.032 | 0.137 ± 0.029 | 0.008 ± 0.002 | 0.219 ± 0.047 |
| 5       | 0.091 ± 0.024 | 0.209 ± 0.076 | 0.008 ± 0.003 | 0.309 ± 0.074 |
| 6       | 0.044 ± 0.011 | 0.144 ± 0.051 | 0.011 ± 0.006 | 0.200 ± 0.047 |
| 7       | 0.052 ± 0.019 | 0.151 ± 0.074 | 0.009 ± 0.004 | 0.213 ± 0.079 |
| 8       | 0.050 ± 0.030 | 0.166 ± 0.084 | 0.014 ± 0.007 | 0.230 ± 0.076 |
| 9       | 0.048 ± 0.013 | 0.124 ± 0.042 | 0.015 ± 0.009 | 0.187 ± 0.039 |
| 10      | 0.133 ± 0.030 | 0.154 ± 0.071 | 0.012 ± 0.004 | 0.299 ± 0.090 |
| 11      | 0.131 ± 0.060 | 0.119 ± 0.026 | 0.005 ± 0.002 | 0.255 ± 0.075 |
| 12      | 0.154 ± 0.032 | 0.130 ± 0.027 | 0.024 ± 0.009 | 0.309 ± 0.056 |
| 13      | 0.411 ± 0.177 | 0.199 ± 0.032 | 0.006 ± 0.001 | 0.617 ± 0.168 |
| 14      | 1.721 ± 0.351 | 0.237 ± 0.016 | 0.017 ± 0.001 | 1.975 ± 0.339 |
| 15      | 1.527 ± 0.253 | 0.207 ± 0.013 | 0.007 ± 0.001 | 1.742 ± 0.243 |

DIN (Dissolved Inorganic Nitrogen) contain the composition of ammonium, nitrite, and nitrate. As with ammonium, the highest average DIN concentration was at station 14 with an average value of 1.975 mg/L. This is related to the composition of DIN which is dominated by ammonium in the estuary area. Whereas in marine waters, the composition of DIN tends to be dominated by nitrates. DIN composition graph is presented in Fig. 3. Based on Fig. 3, it is known that in the estuary area (stations 13, 14, 15), ammonium dominates the composition of DIN with an average percentage of 80.48%, followed by nitrate 18.75%, and nitrite 0, 76%. Whereas in marine waters (stations 1-12), nitrate dominates the composition of DIN with an average percentage of 62.10%, followed by ammonium 33.02%, and nitrite 4.87%.

![Figure 3. DIN composition at each research station.](image)

Analysis of similarities between stations was conducted by first testing the pre-analysis temporally using rainfall amount data. Temporally, it was found that the study time was grouped into one season, the dry season, where the rainfall at the time of this study (July, August, September, and October) was on a basement of less than 50 mm.
After knowing the number of season groups, spatial analysis of similarities between stations was carried out. Based on the similarity analysis between stations (Fig. 4), it can be seen that the observation station is divided into 5 groups (based on the color difference formed), where 2 groups are in the high seas and 3 groups are in the estuary. This shows that stations in the waters of Jakarta Bay have characteristics of physical and chemical parameters that are different from each group formed, which later can be used in management recommendations based on the physical-chemical characteristics of the waters in each group formed.

Ammonia distribution patterns (Fig. 5) in Jakarta Bay high in estuary areas and tends to decrease towards the high seas at any time of observation. Temporally, the highest ammonia concentrations were in July and September, while the lowest distribution was in August. According to Damar [1], this is related to the amount of rainfall that carries the ammonia load from the river. It is known that July is the beginning of the dry season which is still getting influence from the flow of the rainy season in June.

Nitrite distribution in the waters of Jakarta Bay also showed different patterns each month (Fig. 6). In July, the spread of nitrite tends to be high in the east to the middle of the bay. This is due to the presence of waste from shrimp culture waste on the east coast of the Jakarta Bay [1]. Then in August, the distribution of nitrite tends to be high in the western estuary and central of the bay, then decreases towards the high seas. Whereas in September, the spread was not too high compared to August, but the pattern of spread was the same as it declined towards the high seas. According to Muchtar [10], the estuary is a source of nutrients in marine waters. In general, the concentration of nutrients in the estuary will be higher and will be lower when heading towards the high seas. Nitrite distribution in October showed even results in each bay area.

Distribution of nitrate concentrations in Jakarta Bay waters varies for each study month (Fig. 7). In July and August, nitrate concentrations tend to spread high in the western part of the bay. This is related to ocean currents at the time of the observation. Based on the current pattern of the Jakarta Bay [11], in July and August, the current direction tends to move from the east of the bay to the west of the bay due to the influence of the direction of the wind in the east season. Whereas in September and October showed that the nitrate distribution was getting higher towards the middle of the bay and the eastern part of the bay. It is known that the current direction moved from west to east of the bay due to the influence of the wind in the west season. According to Damar [1], on the east coast of the bay, there is an intensive shrimp aquaculture pond that periodically removes wastewater and contains high amounts of nitrate.

The spatial distribution of DIN showed a pattern that is almost same as ammonia, where the high distribution is in the estuary area (Fig. 8) and tends to decreased towards the high seas. The temporal distribution of DIN was high in September, where the DIN concentration was high to reach the central bay and the lowest distribution occurred in August.
Legenda:

- Daratan
- Amonia (mg/L)
  - 0.011 - 0.417
  - 0.418 - 0.824
  - 0.825 - 1.231
  - 1.232 - 1.638
  - 1.639 - 2.045
  - 2.046 - 2.452
  - 2.453 - 2.859

Figure 5. Distributions of ammonia in Jakarta Bay.
Figure 6. Distributions of nitrite in Jakarta Bay.
Figure 7. Distributions of nitrate in Jakarta Bay.
| Legenda: | Stasiun pengamatan | % | Daratan | DIN (mg/L) |
|---------|--------------------|---|---------|------------|
|         | Sissun pengamatan   |   |         | 0.085 - 0.463 |
|         |                     |   |         | 0.464 - 0.841 |
|         |                     |   |         | 0.842 - 1.22 |
|         |                     |   |         | 1.221 - 1.599 |
|         |                     |   |         | 1.600 - 1.978 |
|         |                     |   |         | 1.979 - 2.356 |
|         |                     |   |         | 2.357 - 2.735 |

Figure 8. Distributions of dissolved inorganic nitrogen in Jakarta Bay.
Figure 9. Trophic status in Jakarta Bay for each station.

The results of TRIX index are presented in Fig. 9, where in the graph it can be seen that the Jakarta Bay are divided into three trophic status, namely mesotrophic, eutrophic, and hypertrophic. According to Damar [1], Jakarta Bay waters are already at eutrophic - hypertrophic levels. Tammi et al. [12] state that determining spatial trophic status can be used to determine the purification schedule for water quality in certain groups.

Figure 10. Distribution of trophic level in Jakarta Bay based on TRIX value.

Fig. 10 showed that the highest level (hypertrophic) occurred in the coastal area, continued to the eutrophic level towards the middle of the bay, and mesotrophic in the high seas. The level of eutrophication that is already very high in the waters of Jakarta Bay from the coast to the middle of the bay, so this is not possible for cultivation activities, because it will increase nutrient input which makes the waters increasingly eutrophic and produce negative impacts.
The high level of trophic status that occurred in these waters is suspected due to the input of organic material from the river mouth with high concentration, so that the available nutrients also increase. Increased concentration on nutrients, causing photosynthesis to occur very optimally supported with sufficient light intensity.

Appropriate management is needed to improve the water quality of Jakarta Bay. The high level of trophic status that occurred needs to be of particular concern so that the positive impacts that were previously generated from eutrophication does not turn into negative impacts and harmed various aspects. Regulation of nutrient input from rivers in Jakarta and its surroundings can be done by controlling input sources, such as by the presence of waste treatment in advance from various housing and industry, so that the concentration of organic material entering the waters has met the established quality standards.

4. Conclusion
Spatial distribution of ammonia, nitrite, nitrate, and DIN showed different patterns. Ammonia and DIN tend to be higher in estuary areas while nitrates and nitrites tend to be higher in the eastern part of the bay. The trophic status of Jakarta Bay divided into three level, hypertrophic in estuary area, eutrophic in the middle of the bay, and mesotrophic in the high seas.

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References
[1] Damar A. 2003. Effects of Enrichment on Nutrient Dynamics, Phytoplankton Dynamics and Productivity in Indonesia Tropical Waters: A Comparison between Jakarta Bay, Lampung Bay, and Semangka Bay. [Disertasi]. Kiel (DE): Christian Albrechts.
[2] [BPS]. 2015. Kepadatan penduduk menurut provinsi, 2000-2015.
[3] Koropitan AF, Ikeda M, Damar A, Yamanaka Y. 2009. Influences of physical processes on the ecosystem of Jakarta Bay: A coupled physical-ecosystem model experiment. ICES Journal of Marine Science: Journal du Conseil 66(2) 336-348.
[4] [APHA]. 2012. Standard Methods for The Examination of Water and Waste Water 22nd Edition. Ohio (US): AWWA; WEA.
[5] Damar A, Vitner Y, Prismayanti AD, Rahayu SM, Wirahadi F, Nugraha H. 2018. Eutrophication status of Jakarta Bay, Indonesia. In prep.
[6] Krebs CJ. 1999. Ecological Methodology. Menlo Park, California (US): Benjamin/Cummings.
[7] Sachoemar SI. 2008. Evaluasi kondisi lingkungan perairan kawasan Pulau Abang, Galang Baru, Batam berdasarkan analisa indeks storet dan similaritas canberra. JA/4(1) 81-87.
[8] Vollenweider RA, Giovanardi F, Montanari G, Rinaldi A. 1998. Characterization of the trophic conditions of marine coastal waters with special reference to the NW Adriatic sea: Proposal for a trophic scale, turbidity, and generalized water quality index. Environmetrics 9 329-357.
[9] Santoso AD. 2006. Kualitas nutrien perairan Teluk Hurun, Lampung. Jurnal Teknik Lingkungan 7(2) 140-144.
[10] Muchtar. 2001. Distribusi beberapa parameter kimia di perairan muara Sungai Digul dan Arafura, Irian Jaya. Oseanologi-LIPI 13-14.
[11] Adhyatma D. 2015. Studi pemodelan numerik 3D sirkulasi arus di Teluk Jakarta: Sebelum dan sesudah reklamasi. Bogor (ID): Institut Pertanian Bogor.
[12] Tammi, Pratiwi, Hariyadi, Radiarta (2015). Aplikasi analisis kластер dan indeks TRIX untuk mengkaji variabilitas status trofik di Teluk Pegamatan, Singaraja, Bali. Jurnal Riset Akuakultur 10(2) 271-281.