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Characteristics and Distribution of Chemical-Biological Parameters in The Seawaters of Eastern Java Sea

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ABSTRACT

The Java Sea is influenced by the west and east monsoons, which have an impact on hydrodynamic processes and chemical-biological water quality. Chemical-biological parameters play an important role in the food chain cycle that occurs in these waters. The quality of the eastern Java Sea waters is still limited by chemical-biological parameters, so the characteristics and distribution of these waters can be comprehensively known. chemical-biological. This study aimed to analyze the characteristics and distribution of nitrate, phosphate, oxygen, chlorophyll-A, and NPP parameters in the eastern Java Sea waters. This study used secondary data with daily temporal resolution from January to December 2020. Spatial analysis uses the climatological averaging method for 6 months as a statistical representative of the west monsoon and east monsoon. For each parameter, a vertical analysis was conducted to compare parameter values between the coastal waters of Tuban, Java Sea, and Banjarmasin Waters. Correlation analysis between parameters was conducted using the Pearson correlation method. Nitrate, phosphate, oxygen, chlorophyll-A, and NPP concentrations have temporal and spatial variability. Monsoon factors in Indonesia have a strong influence on the variability of nitrate, phosphate, oxygen, chlorophyll- A, and NPP concentrations. During the east monsoon, the concentration of chemical-biological parameters decreases, while in the west monsoon, the concentration increases and reaches its highest value. Generally, high concentrations occur in the northern and southern parts of the study site, around the coastal areas of Java and Kalimantan.

Keywords: Chemical-Biological Parameters, Java Sea, Tuban Waters, Banjarmasin Waters.

ABSTRAK

Laut Jawa dipengaruhi oleh angin muson barat dan timur, yang berdampak pada proses hidrodinamika dan kualitas air secara kimiawi-biologis. Parameter kimia-biologi berperan penting dalam siklus rantai makanan yang terjadi di perairan ini. Kualitas perairan Laut Jawa bagian timur masih terbatas terkait parameter kimia-biologi sehingga karakteristik dan sebaran di perairan tersebut dapat diketahui secara komprehensif. Penelitian ini bertujuan untuk menganalisis karakteristik dan sebaran parameter nitrat, fosfat, oksigen, klorofil-a, dan NPP di perairan Laut Jawa bagian timur. Penelitian ini menggunakan data sekunder dengan resolusi temporal harian dari bulan Januari hingga Desember 2020. Analisis spasial menggunakan metode rata-rata klimatologis selama 6 bulan sebagai perwakilan statistik dari monsun barat dan monsun timur. Untuk setiap parameter, analisis vertikal dilakukan untuk membandingkan nilai parameter antara Perairan Pesisir Tuban, Laut Jawa, dan Perairan Banjarmasin. Analisis korelasi antar parameter dilakukan dengan menggunakan metode korelasi Pearson. Konsentrasi nitrat, fosfat, oksigen, klorofil-A dan NPP memiliki variabilitas temporal dan spasial. Faktor musim di Indonesia memiliki pengaruh yang kuat terhadap variabilitas konsentrasi nitrat, fosfat, oksigen, klorofil-A dan NPP. Selama musim timur, konsentrasi parameter kimia-biologi menurun sementara pada musim barat, konsentrasi meningkat dan mencapai nilai tertinggi. Secara umum, konsentrasi yang tinggi terjadi di bagian utara dan selatan lokasi penelitian di sekitar wilayah pesisir Jawa dan Kalimantan.

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Kata kunci: Parameter kimia-biologi, Laut Jawa, perairan Tuban, perairan Banjarmasin.

1. Introduction

Understanding the spatial and temporal distribution of chemical and biological parameters in the Java Sea is needed. This is related to several key nutrient parameters because they are considered important to be able to describe the food chain cycle in the ocean. The fertility condition of a water body can be described through nutrient concentrations. In general, nutrients focused on phosphate (Paytan and McLaughlin., 2007) and nitrate (Sanusi., 1994) in these waters can affect aquatic primary production (Conkright et al., 2000). The amount of nutrients affects the balance of fertility ~~of~~ in a water body, if the amount is excessive and supported by certain oceanographic conditions, it needs to be watched out because it can trigger the occurrence of algae blooms, which is referred to as the eutrophication phenomenon (Davidson et al., 2014). One of the factors that cause high nutrient concentrations in waters is water mass circulation. Poor water mass circulation is often found in closed water areas and has the potential to increase nutrient concentrations (Grundle et al., 2009) which affect the nitrate, phosphate and oxygen content of waters. In addition, the presence of biotic and abiotic processes and anthropogenic activities on land also affect the amount of nutrient discharge ~~to~~ into the waters (Pasqueron de Fommervault et al., 2015).

The Java Sea is Indonesia's interior waters that have a strategic role, one of which is related to fishery commodities. These waters are fishing grounds that contribute greatly to the economy of coastal communities with the main catch of pelagic fish (Merta et al., 2004) amounting to 1.5 - 2.5 tons/day (Pasaribu et al., 2004). The great potential of fishery commodities in the Java Sea is supported by chemical-biological conditions. The Java Sea is dominantly influenced by the monsoon system (Koropitan et al., 2009). In the west monsoon, water masses from the South China Sea ~~with~~ have low salinity characteristics (Susilo et al., 2015), while the east monsoon gets input from the east with higher salinity characteristics (Najid et al., 2012) into the waters of the Java Sea. In addition, the monsoon system also influences the source of nutrients that are carried into the sea through river flow (Chen, 2011). Nutrients play an important role in marine biogeochemical cycles related to phytoplankton growth and water productivity (Wei et al., 2016). The main constituents of these nutrients are nitrate and phosphate as well as silicate, which play a role in phytoplankton growth and determine the geo-chemical characteristics of a water area (Li et al., 2015).

Another indicator that can be used to determine the level of fertility in a water body is the Net Primary Productivity (NPP) parameter expressed in $mgC/m^{-2}/day^{-1}$ (Lee et al., 2014; Aryanti et al., 2019). NPP is described as the formation of organic matter per unit time in the process of photosynthesis by phytoplankton. The abundance of phytoplankton that plays a role in photosynthesis in a water body is characterized by chlorophyll-A (Garini et al., 2021). Generally, the concentration of chlorophyll-A in coastal areas is higher than in the open sea due to the supply of nutrients sourced from land (Nuzapril, 2017). In some waters, chlorophyll-A concentration is influenced by monsoons and even global climate phenomena (Marpaung et al., 2020). In addition, NPP and chlorophyll-A play an important role in the fertility of marine ecosystems (Sihombing et al., 2013; Gunawan et al., 2019). Concentrations of NPP and Chlorophyll-A are likely to be affected by spatial and temporal variability (Lazzari et al., 2012). Research related to the analysis of NPP and Chlorophyll in the waters of the eastern Java Sea is very limited on a spatial and temporal scale considering time and cost. Therefore, this work was conducted to analyze the characteristics and distribution of nitrate, phosphate, oxygen, chlorophyll-A, and NPP parameters in the eastern Java Sea waters, so that the Java Sea can provide comprehensive information related to the condition of water quality and sustainable management of marine resources.

2. Material and Methods

The research was conducted in the waters of the eastern Java Sea with a geographical area of 110° - 115° East and 6.75° - 3.75° N-S at three observation points, namely Tuban Waters, Java Sea, and Banjarmasin Waters (Figure 1). These three observation points represent the significant influence of each major island (Java and Kalimantan) that has a river flowing into the waters of the Java Sea. The use of hindcast data comes from the Global Ocean Biogeochemistry Hindcast (https://data.marine.copernicus.eu/products) with Product ID GLOBAL_MULTIYEAR_BGC_001_029.

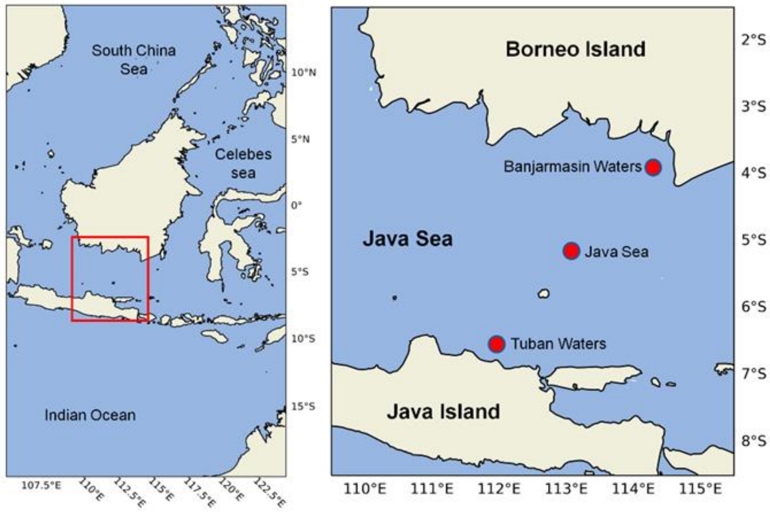

Figure 1. The research location is in the eastern Java Sea in three observation locations, namely Tuban Waters, Java Sea, and Banjarmasin Waters.

The data used includes Mass concentration of chlorophyll a in sea water (CHL), Mole concentration of dissolved molecular oxygen in sea water (O_2), Mole concentration of nitrate in sea water (NO_3), Mole concentration of phosphate in sea water (PO_4) and Net primary production of biomass expressed as carbon per unit volume in sea water (NPP). All data are of daily temporal resolution during January-December 2020, representing the rainy monsoon (west monsoon) and dry monsoon (east monsoon) in Indonesia. The data used has a spatial resolution of 0.25° × 0.25° with 75 elevations (depths) that have been processed to Level 4 (ready to use).

The spatial analysis used a 6-month climatological average method to statistically represent the west monsoon and east monsoon. All datasets were combined based on calculations by Wirasatriya et al. (2017). The averaged data were then combined into a single temporal dataset and visualized at the surface layer, 25m and 50m, respectively, to see the spatial distribution at each depth. At each depth, calculations were made to find the minimum, maximum, average and standard deviation values. In addition, at each depth a vertical analysis was also conducted comparing parameter values between Tuban Waters, the Java Sea (northern area) and Banjarmasin Waters.

Correlation analysis between parameters was conducted using the Pearson correlation method to see how strong the relationship is between the independent and dependent variables. The relationship coefficient (r) has an interval from -1 to 1 ($-1 \leq r \leq 1$). Variables are said to have a strong relationship if they have a value greater than 0.5 or smaller than -0.5. A positive correlation is an increase or decrease in the value of the independent variable followed by an increase or decrease in the value of the dependent variable, while a negative correlation means an increase in the value of the independent variable followed by a decrease in the value of the dependent variable and a decrease in the value of the independent variable followed by an increase in the dependent variable. An example of a formula to determine the correlation (r) between the independent variable x (NO_3) and the dependent variable y (PO_4) with n as the amount of data as used by Budiwati et al. (2010)

3. Result and Discussion

The spatial distribution of chemical-biological parameters in the eastern Java Sea in the west monsoon can be seen in Figure 2 and in the east monsoon in Figure 3. In the west monsoon, the highest concentration of nitrate in the surface layer (Figure 2A) was found in the coastal waters of Banjarmasin and Java Island, Tuban waters. Spatially, the nitrate concentration will decrease the farther away the coast because the farther away from the land is filled with anthropogenic activities. At a depth of 25m (Figure 2B), nutrient concentration conditions tend to be homogeneous as in the surface layer, while at a depth of 50m (Figure 2C), nutrient concentrations are high and distributed around

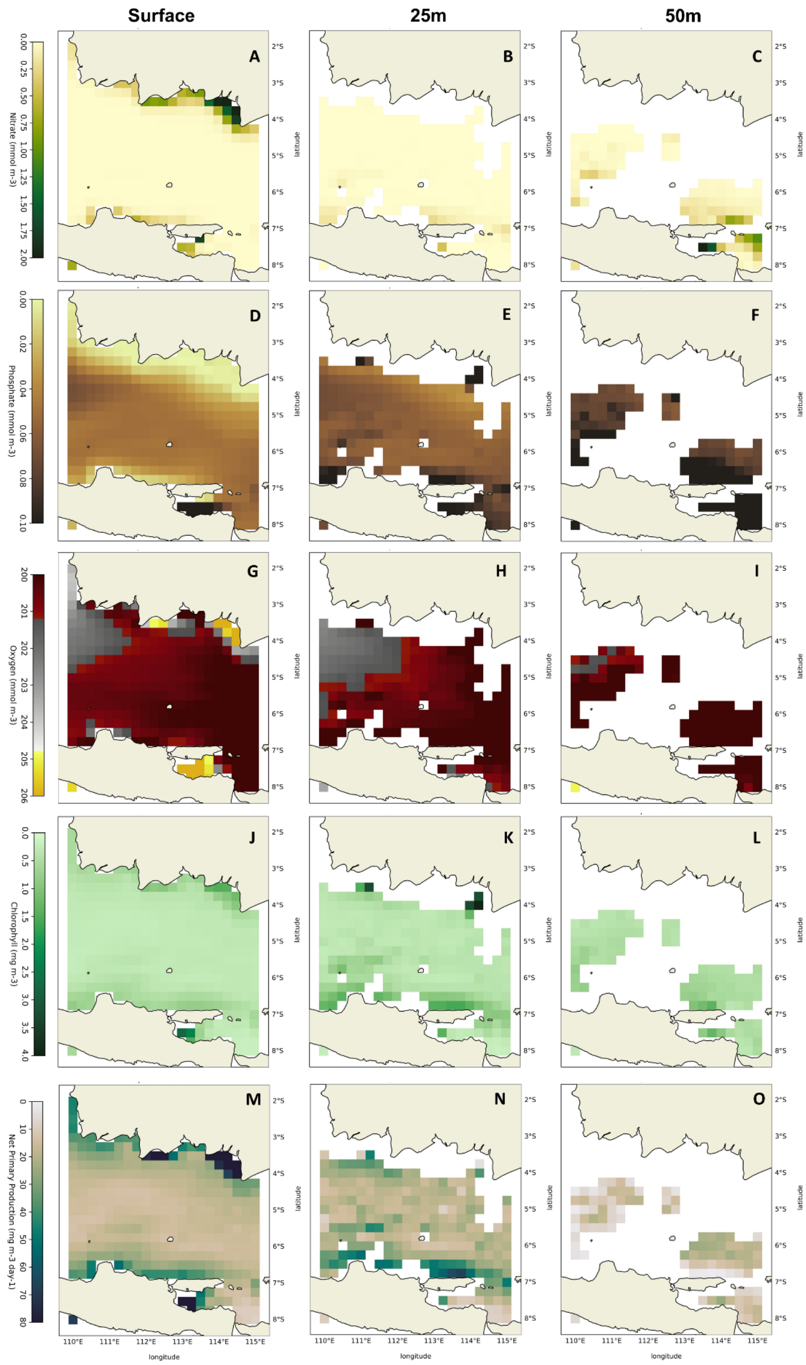

Figure 2. Spatial distribution in the surface layer, 25m depth and 50m depth in the west monsoon for nitrate (A, B and C), phosphate (D, E and F), oxygen (G, H and I), chlorophyll-A (J, K and L), and NPP (M, N and O) parameters.

the coast and appear to accumulate at the bottom of the waters such as in the Madura Strait between Java Island and Madura Island. During the east monsoon (Figures 3A, 3B, and 3C), nitrate concentrations had a similar pattern to that during the west monsoon, but with lower concentrations. In general, nitrate concentrations in the surface layer and at certain depths in shallow seas (<200m) tend to be highly distributed in the area around the coast due to the dominant influence of the presence of coastal ecosystems and anthropogenic activities around land and coast (Hutagalung and Rozak, 1997).

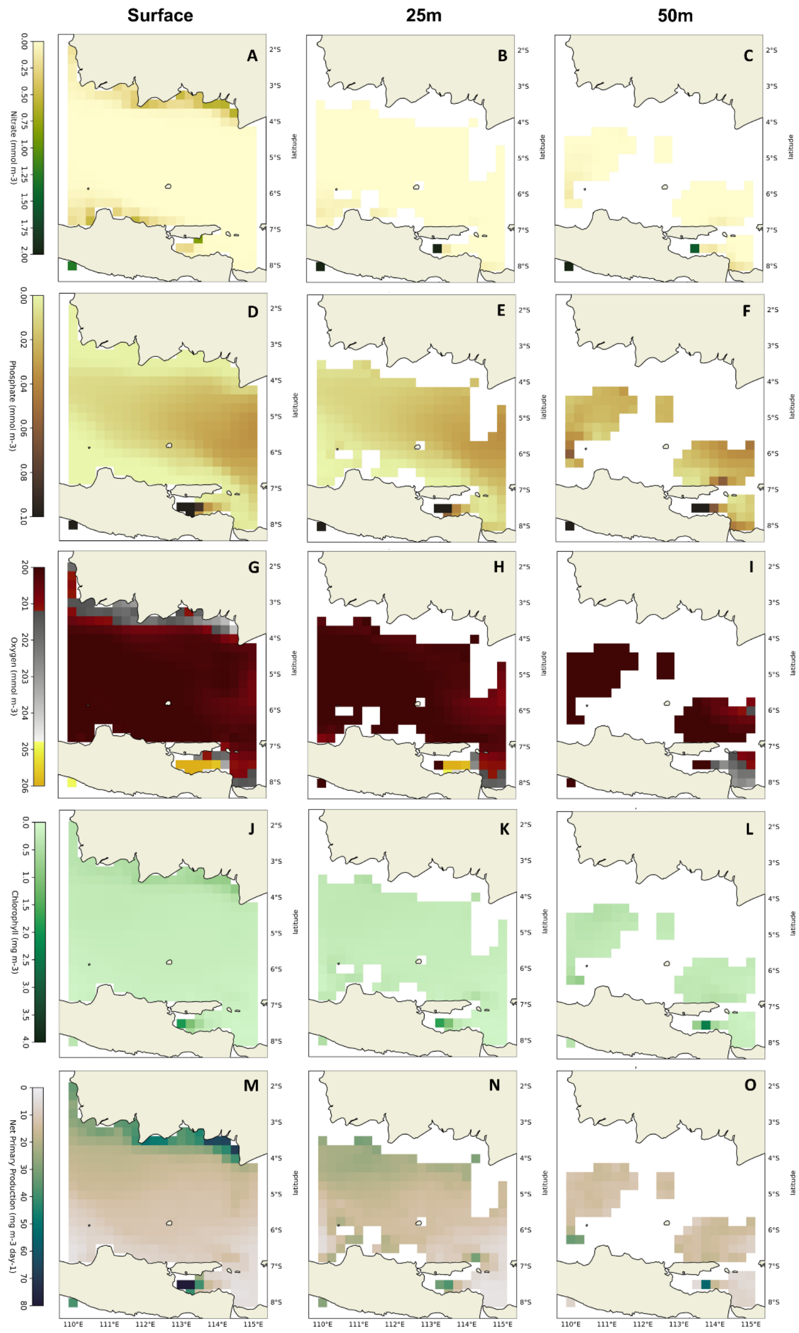

Figure 3. Spatial distribution in the surface layer, 25m depth and 50m depth in the west monsoon for nitrate (A, B and C), phosphate (D, E and F), oxygen (G, H and I), chlorophyll-A (J, K and L), and NPP (M, N and O) parameters.

Nitrate and phosphate elements play an important role in the growth of phytoplankton or algae which can be an indicator of water quality and fertility (Gurning et al., 2020), affecting the life of marine biota (Harun et al., 2008) and coastal ecosystems (Faizal et al., 2020). Its formation is through the process of decomposition, weathering or decomposition of the remains of organisms and plants that die in these waters. The amount of phosphate and nitrate content can be influenced by inputs from land through rivers that flow into marine waters such as anthropogenic waste discharges, animal feed residues and agricultural waste. Meanwhile, the dissolved oxygen content in the waters is used by organisms for the respiration process and the process of decomposition of organic substances (organic decomposition) (Patty et al., 2015), which is followed by the process of breaking down the material with the help of microbes and then breaking down into nutrients (Wattayakorn, 1988).

In the west monsoon (Figure 2F) at the 50m depth layer, in general, high concentrations are evenly distributed at the bottom of the water while in the east monsoon (Figure 3F) there is an accumulation at several points.Phosphate concentration in the surface layer and the bottom layer area has a significant difference. This difference can be seen where the average phosphate concentration near the bottom layer has a higher concentration when compared to the surface layer as a result of accumulation (phosphate deposit). Phosphate in the bottom layer of waters comes from the decomposition of organic compounds by microorganisms and accumulates (Edward and Tarigan, 2003). This condition is in line with the study in the Cisadane Estuary conducted by Muchtar and Simanjuntak (2008), which states that naturally phosphate is evenly distributed from the surface layer to the bottom layer of the water. In addition, vertically the phosphate concentration will be distributed higher towards the bottom layer of the water as a result of the bottom layer of marine waters that are rich in nutrients, while the low concentration of phosphate in the surface layer is likely due to massive phytoplankton activity so that the concentration is reduced. Phosphate in waters that have too high a concentration can be considered as a potential trigger for eutrophication (Anhwange et al., 2012).

During the west monsoon, oxygen content in the surface layer in the Java Sea tends to be evenly distributed in the open sea and more variable in coastal or nearshore areas (Figure 2G). During the east monsoon (Figure 3G), the oxygen content in the surface layer tends to have the same pattern but with lower concentrations at some points. At 25m depth (Figure 2H) and 50m depth (Figure 2I) or bottom waters are relatively more homogeneous with a range that is not too wide. According to Nybakken (1988), it is horizontally known that dissolved oxygen levels decrease the closer to the sea. High and low oxygen levels in this area are closely related to the turbidity of seawater and the activities of micro-organisms to break down organic substances into inorganic substances that require dissolved oxygen (bioprocessing).

In general, oxygen levels in these waters are relatively lower when compared to oxygen levels in marine waters in general. In Sutamihardja's (1987) research, it was mentioned that oxygen levels in normal marine waters ranged from 5.7-8.5 ppm, while oxygen levels in the Java Sea waters were lower. The low oxygen content in these waters is thought to be due to the high organic matter input from the river into the waters. The amount of organic matter requires a lot of oxygen to be able to decompose it by micro-organisms, so that the less dissolved oxygen content in the waters. Dissolved oxygen levels in a body of water will decrease due to the process of decomposition of organic matter, respiration, and reaeration being inhibited (Andriani, 1999). In addition to the influence of the influx of organic materials, the input of high phosphate concentrations in the waters can result in algae blooming, thus reducing dissolved oxygen levels (Yolanda et al., 2016).

The spatial distribution of each depth layer of the chlorophyll-A parameter during the west monsoon (Figures 2J, 2K, and 2L) and east monsoon (Figures 3J, 3K, and 3L) has a distribution that tends to be the same as that of the NPP parameter during the west monsoon (2M, 2N, 2O) and east monsoon (Figures 3M, 3N, and 3O) because these three parameters are closely related (further explained in the correlation between parameters). The highest values of chlorophyll-A, and NPP parameters are seen in Banjarmasin Waters both in the surface layer and at a depth of 25m, while the bottom waters tend to be homogeneous with low values for each parameter. Chlorophyll-A and NPP have an important role in relation to the level of fertility of a marine ecosystem. In addition, chlorophyll and NPP are closely related to the capture fisheries sector. The fisheries sector related to chlorophyll and NPP is the estimation of potential zones as fishing grounds. In relation, chlorophyll is one of the parameters that greatly influences the distribution and variation of net primary productivity or NPP in marine waters (Sihombing et al., 2013; Gunawan et al., 2019).

The presence of phytoplankton (vertical distribution) is one of the determinants of primary productivity (NPP) and biological indicators in determining the quality of a water body. This is related to its sensitivity to changes in aquatic environmental conditions (Reygondeau and Beaugrand 2011). In addition, the presence of phytoplankton is also related to energy transfer from the lowest trophic level to higher trophic levels (Mellard et al. 2011). Phytoplankton in marine waters are found in the surface layer of water to depths where sunlight can penetrate. Phytoplankton live floating in the water and are primary producers in the food chain in marine waters (Reynolds, 2006). Phytoplankton can convert inorganic compounds (nutrients) into organic compounds through the process of photosynthesis and have an important role in the ecosystem to support the life of marine organisms (Davies et al. 2016). The composition and abundance of phytoplankton greatly affect the presence of other marine biological resources in the waters (Haumahu, 2005).

The values of nitrate, phosphate, oxygen, chlorophyll-A and NPP parameters at the study site horizontally at each depth layer for each parameter can be seen in Table 1. The nitrate parameter has the largest average value in the bottom layer of the water, which is 0.085 with the maximum value in the surface layer. The phosphate parameter with the largest average value in the bottom layer of waters is 0.481 with the maximum value also in the bottom layer of waters. The oxygen parameter has the largest average in the surface layer of 204.899 as well as the maximum value in the same layer. The chlorophyll parameter has the largest average value in the deep layer of 0.545 with the maximum value being in the surface layer. Furthermore, for the NPP parameter with the largest average in the surface depth of 38.290 with a maximum in the same layer.

Vertically, the concentration of each chemical-biological parameter in Tuban, Java Sea and Banjarmasin Waters has different values with depth during the west monsoon and east monsoon (Figure 4). In the nitrate parameter, Tuban and Java Sea waters have similar values during the east monsoon with relatively low values, but different for Banjarmasin waters during the west monsoon with large values (Figure 4A). The phosphate parameter tends to have different values both at the monsoon scale and different locations. The highest values of phosphate are found in the Tuban and Java Sea during the west monsoon, while the Banjarmasin waters have values that tend to be lower (Figure 4B). In the oxygen parameter, Banjarmasin waters have a greater value when compared to Tuban and Java Sea waters during the west monsoon (Figure 4C). During the east monsoon, oxygen levels at all three locations tend to be relatively low.

Chlorophyll-A and NPP parameters have the same pattern, which can be seen from the concentration values of both getting bigger as the depth increases (Figure 4D and 4E). The highest chlorophyll-A value was found in Banjarmasin Waters during the west monsoon of > 1.75 while in the east monsoon it was relatively low like other waters both during the west monsoon and east monsoon. Furthermore, for the NPP parameter, the largest value is in Banjarmasin Waters during the west monsoon and tends to be lower in the east monsoon. Banjarmasin waters have maximum values for several parameters that are strongly suspected due to the input of river flows that empty into these waters, such as the Barito River, Martapuran River, and Alalak River.

Table 1. Chemical-biological parameter concentrations in Eastern Java Sea Waters

Depth	Value	Parameter									
		NO3 (mmol m^3)		PO4 (mmol m^3)		O2 (mmol m^3)		CHL (mg m^3)		NPP (mg m^3 $days^1$)	
		west	east	west	east	west	east	west	east	west	east
Surface	min	0.003	0.053	0.000	0.000	196.188	198.027	0.148	0.140	5.657	9.351
	ave	0.060	1.285	0.041	0.175	200.619	204.899	0.357	0.350	20.715	38.290
	max	3.488	3.607	0.093	0.394	213.752	209.164	4.234	0.625	243.488	68.786
	std.dev	0.241	1.074	0.019	0.125	1.208	3.221	0.242	0.102	14.624	14.484
25 m	min	0.000	0.000	0.023	0.004	86.860	156.843	0.118	0.105	2.173	3.187
	ave	0.015	2.111	0.065	0.266	199.601	195.590	0.538	0.496	23.257	28.296
	max	0.613	7.082	0.878	0.658	203.519	208.739	7.608	1.051	196.755	57.016
	std.dev	0.046	1.765	0.053	0.169	7.382	11.577	0.579	0.239	16.277	14.330
50 m	min	0.000	0.000	0.048	0.010	163.991	123.963	0.184	0.192	0.071	2.127
	ave	0.085	4.456	0.093	0.481	197.065	171.838	0.545	0.350	12.306	5.896
	max	1.391	10.145	0.380	0.910	202.699	206.080	2.938	0.583	69.028	17.617
	std.dev	0.156	2.966	0.040	0.247	5.144	23.497	0.266	0.081	10.041	4.365

Description: min= minimum, max= maximum, ave= average, std.dev= standard deviation, west= west season, east= east season

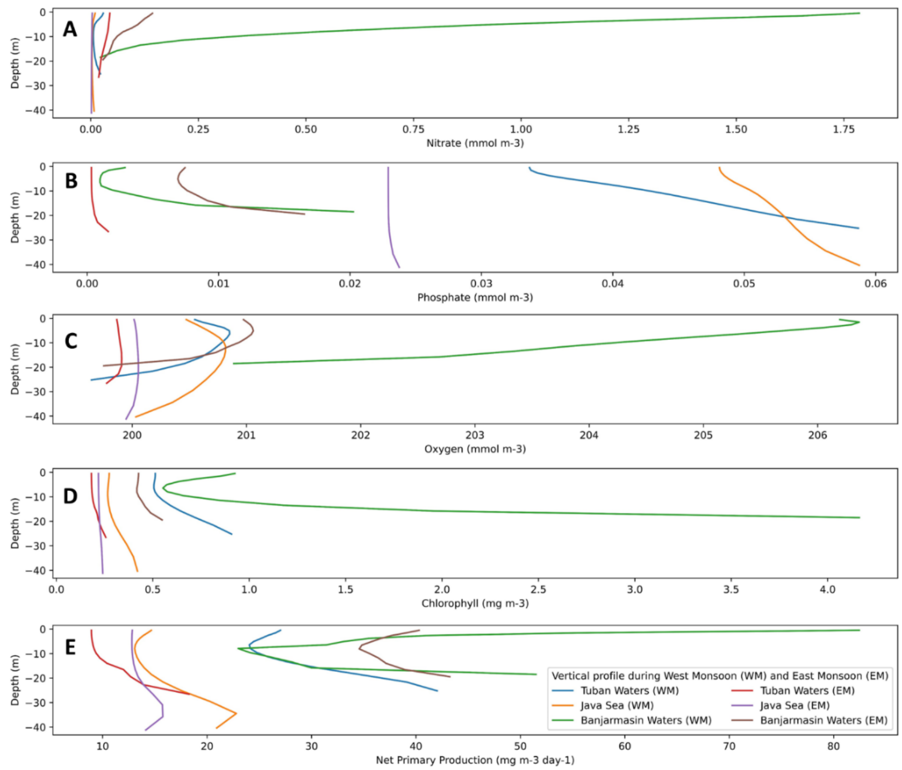

Figure 4. Vertical profiles of parameters (A) nitrate, (B) phosphate, (C) oxygen, (D) chlorophyll-A, and (E) NPP in Tuban Waters, Java Sea and Banjarmasin Waters during the west monsoon and east monsoon.

The correlation analysis results show significant values. In Tuban waters, during the east monsoon (Figure 5A) there is a positive correlation between chlorophyll-A and phosphate (r = 0.92) and NPP and chlorophyll (r = 0.99), while for negative correlations, between chlorophyll-A and oxygen (r = -0.99) and NPP and oxygen (r = -0.94). During the west monsoon (Figure 5D), there were positive correlations between phosphate and chlorophyll (r = 0.9), NPP and phosphate (r = 0.85) and chlorophyll-A and NPP (r = 0.98), while for negative correlations, between chlorophyll and oxygen (r = -0.78) and NPP and oxygen (r = -0.74). In the Java Sea, during the east monsoon (Figure 5B) there is a positive correlation between chlorophyll-A and phosphate (r = 0.92) and NPP and chlorophyll-A (r = 0.99), while for the negative correlation between chlorophyll-A and oxygen (r = -0.99) and NPP and oxygen (r = -0.94). During the west monsoon (Figure 5E) there is a positive correlation between NPP and chlorophyll-A (r = 0.99), NPP and phosphate (r = 0.96), and chlorophyll-A and phosphate (r = 0.92), while for the negative correlation between chlorophyll and nitrate (r = -0.95) and NPP and nitrate (r = -0.92). In Banjarmasin waters, during the east monsoon (Figure 5C) shows a positive correlation between chlorophyll and phosphate (r = 1), oxygen and NPP (r = 0.88), while for negative correlation between oxygen and phosphate (r = -0.86), chlorophyll-A and oxygen (r = 0.82). The west monsoon (Figure 5F) shows a positive correlation between chlorophyll and phosphate (r = 0.99), while a negative correlation between chlorophyll-A and oxygen (r = -0.99), oxygen and phosphate (r = -1).

The Java Sea is a water area with high turbidity as an indication of the influence of dissolved suspension from rivers that carry freshwater masses. The mass of water entering through the river as a source of input, can be seen from several parameters that are concentrated near the land, especially the estuary area as an area directly adjacent to the sea. Based on the correlation results that have been calculated, there is a strong relationship between NPP and chlorophyll. The results obtained are almost the same as the results of research from Merina & Zakaria (2016), that the higher the concentration

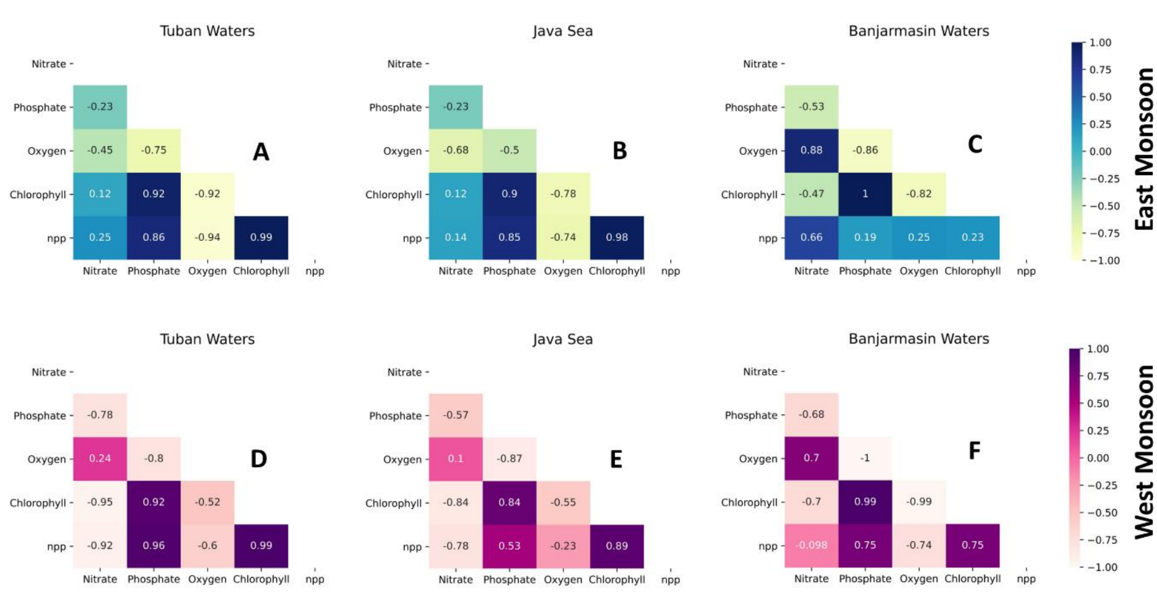

Figure 5 Correlation between chemical-biological parameters during the east monsoon in (A) Tuban waters, (B) Java Sea and (C) Banjarmasin waters and during the west monsoon in (D) Tuban waters, (E) Java Sea and (F) Banjarmasin waters.

of chlorophyll-A, the concentration of NPP will increase and vice versa. Nitrate is utilized by phytoplankton for photosynthesis (primary productivity) in euphotic areas (Millero and Sohn 1992). Similarly, the correlation that occurs between nitrate and oxygen, nitrogen compounds (nitrate, nitrite, and ammonium) require dissolved oxygen for the nitrification process so that when the nitrate concentration is high, the DO value decreases.

4. Conclusions

The monsoon system in Indonesia has a strong influence on the spatial and temporal variability of nitrate, phosphate, oxygen, chlorophyll and NPP concentrations. In the east monsoon, the concentrations of the chemical-biological parameters decrease while in the west monsoon, the concentrations increase and reach ~~the~~ their highest values. Generally, high concentrations occur in the southern Java Sea and northern Banjarmasin Waters as a result of the large input of river flow into these waters. Chlorophyll-A and NPP have a strong linear relationship and are positively correlated. Increases and decreases in NPP and Chlorophyll-A concentrations correspond temporally. Nitrate is the limiting factor for primary production in the Java Sea. Chemical-biological parameters in these waters are indicated to influence each other.

The monsoon system significantly impacts the spatial and temporal variations of nitrate, phosphate, oxygen, chlorophyll, and NPP concentrations in Indonesia. During the east monsoon, there is a decrease in the levels of these chemical and biological parameters, while in the west monsoon, concentrations rise, reaching their peak values. Typically, elevated concentrations are observed in the southern Java Sea and northern Banjarmasin Waters due to substantial river flow input. There exists a strong linear relationship and positive correlation between Chlorophyll-A and NPP, with changes in their concentrations aligning temporally. Nitrate serves as the limiting factor for primary production in the Java Sea, and there is mutual influence among the various chemical-biological parameters in these waters.

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References

Andriani, E.D. 1999. Kondisi Fisika-Kimiawi Air Perairan Pantai Sekitar Tambak Balai Budidaya Air Payau (BBAP) Jepara, Kabupaten Jepara, Jawa Tengah. Skripsi.

Fakultas Perikanan an Ilmu Kelautan, Institut Pertanian Bogor.

Anhwange, B. A., Agbaji, E. B., & Gimba, E. C. (2012). Impact assessment of human activities and seasonal variation on River Benue, within Makurdi Metropolis. International Journal of Science and Technology, 2(5), 248–254.

Aryanti, N.L.N., I.G. Hendrawan, & Y. Suteja. 2019. Studi variabilitas produktivitas primer bersih serta hubungannya dengan El-Niño Southern Oscillation (ENSO) dan Indian Ocean Dipole (IOD) di Laut Banda berdasarkan data satelit Aqua MODIS. J. of Marine and Aquatic Sciences, 5(1): 64-76. https://doi.org/10.24843/jmas.2019.v05.i01.p08

Budiwati, T., A. Budiyono, W. Setyawati, & A. Indrawati. 2010. Analisis korelasi Pearson untuk unsur-unsur kimia air hujan di Bandung. J. Sains Dirgantara, 7(2): 100-112. http://jurnal.lapan.go.id/index.php/jurnal_sains/article/view/1118/1006

Chen, C.-T. & A. 2011. Nutrient Cycling in the Oceans. Encyclopedia of Life Support System (EOLSS) 1:13 pp.

Conkright, M. E., W. W. Gregg, and S. Levitus. 2000. “Seasonal Cycle of Phosphate in the Open Ocean.” DeepSea Research Part I: Oceanographic Research Papers 47 (2): 159–75. doi: 10.1016/S0967-0637(99)00042-4

Davidson, Keith, Richard J. Gowen, Paul J. Harrison, Lora E. Fleming, Porter Hoagland, and Grigorios Moschonas. 2014. “Anthropogenic Nutrients and Harmful Algae in Coastal Waters.” Journal of Environmental Management 146. Elsevier Ltd: 206–16. doi:10.1016/j.jenvman.2014.07.002

Davies, C. H. et al. 2016. Australian Ocean Data Network. Scientific Data. http://dx.doi.org/10.4225/69/56454b2ba2f79

Edward, Tarigan, M.S. 2003, Pengaruh MusimMuson Terhadap Fluktuasi Kandungan Fosfat dan Nitrat di Laut Banda. Makara Sains, Vol. 7(2): 82- 89

Faizal, I., Kristiadhi, F., Nurrahman, Y. A., Purba, N. P., & Prasetiya, F. S. (2020). Coral Reef Distribution around Bakauheni Sea-port, South Lampung, Indonesia. Akuatek, 1(2), 94–103.

Garini, B.N., J. Suprijanto, & I. Pratikto. 2021. Kandungan chl-a dan kelimpahan di perairan Kendal, Jawa Tengah. J. of Marine Research, 10(1): 02-108. https://doi.org/10.14710/jmr.v10i1.28655

Grundle, Damian S., David A. Timothy, and Diana E. Varela. 2009. “Variations of Phytoplankton Productivity and Biomass over an Annual Cycle in Saanich Inlet, a British Columbia Fjord.” Continental Shelf Research 29 (19). Elsevier: 2257–69. doi:10.1016/j.csr.2009.08.013

Gunawan, E.A., A. Agussalim, & H. Surbakti. 2019. Pemetaan sebaran klorofil-a menggunakan citra satelit Landsat multi temporal di Teluk Lampung Provinsi Lampung. J.Maspari, 11(2): 49-58. https://doi.org/10.36706/maspari.v11i2.9467

Gurning, L. F. P., Nuraini, R. A. T., & Suryono, S. (2020). Kelimpahan Fitoplankton Penyebab Harmful Algal Bloom di Perairan Desa Bedono, Demak. Journal of Marine Research, 9(3), 251–260. https://doi.org/10.14710/jmr.v9i3.27483

Harun, N. H., Tuah, P. M., Markom, N. Z., & Yusof, M. Y. (2008). Distribution of heavy metals in Monochoria hastata and Eichornia crassipes in natural habitats. Proceedings International Conference on Environmental Research and Technology

Haumahu S. 2005. Distribusi Spasial Fitoplankton di Perairan Teluk Haria Saparua, Maluku Tengah. Ilmu Kelautan 10 (3): 126-34

Hutagalung, H.P., Rozak, A.. 1997. Metode Analisis Air Laut, Sedimen dan Biota. Buku 2. Pusat Penelitian dan Pengembangan Oseanologi LIPI, Jakarta

Lazzari, P., Solidoro, C., Ibello, V., Salon, S., Teruzzi, A., Beranger, K., Colella, S., and Crise, A. 2012. Seasonal and inter-annual variability of plankton chlorophyll and primary production in the Mediterranean Sea: a modelling approach. Biogeosciences, 9(1): 217-233. https://doi.org/10.5194/bg-9-217-2012, 2012.

Lee, Z., J. Marra, M.J. Perry, & M. Kahru. 2014. Estimating oceanic primary productivity from ocean color remote sensing: A strategic assesment. J. of Marine Systems, 149: 50-59. ttps://doi.org/10.1016/j.jmarsys.2014.11.01

5

Li, H. M., C. S. Zhang, X. R. Han, and X. Y. Shi. 2015. Changes in concentrations of oxygen, dissolved nitrogen, phosphate, and silicate in the southern Yellow Sea, 1980-2012: Sources and seaward gradients. Estuarine, Coastal and Shelf Science 163:44–55

Marpaung, S., R. Faristyawan, A.D. Purwanto, W. Asriningrum, A.G. Suhadha, T. Prayogo, & J. Sitorus. 2020. Analysis of water productivity in the Banda Sea based on remote sensing satellite data. International J. of Remote Sensing and Earth Sciences, 17(1): 25-34. https://doi.org/10.30536/j.ijreses.2020.v17.a3280

Mellard JP, Yoshiyama K, Litchman E, Klausmeier CA. 2011. The vertical distribution of phytoplankton in stratified water columns. J Theor Biol. 269 (1):16-30

Merina, G. & I.J. Zakaria. 2016. Produktivitas primer fitoplankton dan analisis fisika kimia di perairan laut pesisir barat Sumatera Barat. Metamorfosa J. of Biological Sciences, 3(2): 112-119. https://doi.org/10.24843/metamorfosa.2016.v03.i02.p08

Merta, I. G. S., B. Iskandar, and S. Bahar. 2004. MusimMuson Penangkapan Ikan di Indonesia, 2nd edition. Balai Riset Perikanan laut, BRKP DKP, Jakarta.

Millero, F. J., and M. L. Sohn. 1992. Chemical oceanography. p. CRC Press Inc. Boca Ruton. Ann Arbor. USA

Muchtar, M., Simanjuntak. 2008, Karakteristik dan Fluktuasi Zat Hara Fosfat, Nitrat dan Derajat Keasaman (pH) di estuary Cisadane pada MusimMuson yang Berbeda. Dalam: Ruyitno, A., Syahailatua, M., Muchtar, Pramudji, Sulistijo, Susana, T. (Editor). Ekosistem Estuari Cisadane: LIPI: 139-148.

Najid, A., J. I. Pariwono, D. G. Bengen, S. Nurhakim, and A. S. Atmadipoera. 2012. Pola MusimMusonan dan Antar Tahunan Salinitas Permukaan Laut di Perairan Utara JawaMadura. Maspari Journal 4(2):168–177

Nuzapril, M., S.B. Susilo, & J.P. Panjaitan. 2017. Relationship between chlorophyll-A concentration with primary productivity rate using Landsat 8 imagery. J. Teknologi Perikanan dan Kelautan, 8(1): 105-114. https://doi.org/10.24319/jtpk.8.105-114

Nybakken, J.W. 1998. Biologi Laut Suatu Pendekatan Ekologi. Penerjemah: Eidman, M., Koesoebiono, Bengen, D.G., Hutomo, M., Sukarjo,S.. PT. Gramedia. Jakarta. 459 hal

Pasaribu, B. P., D. Manurung, and D. Nugroho. 2004. Fish Stock Assessment using Marine Acoustics Detection and Oceanographical Characteristic in Java Sea. Gayana 68(2):1–5

Pasqueron de Fommervault, O., C. Migon, F. D'Ortenzio, M. Ribera d'Alcalà, and L. Coppola. 2015. Temporal variability of nutrient concentrations in the northwestern Mediterranean sea (DYFAMED time-series station). Deep-Sea Research I 100:1–12.

Patty, S.I., Arfah, H., & Abdul, M. S. 2015. Zat Hara (Fosfat, Nitrat), Oksigen Terlarut dan pH Kaitannya Dengan Kesuburan di Perairan Jikumerasa, Pulau Buru. Jurnal Pesisir Dan Laut Tropis, 3(1), 43–50. https://doi.org/10.35800/jplt.3.1.2015.9578

Paytan, Adina, and Karen McLaughlin. 2007. "The Oceanic Phosphorus Cycle." Chemical Reviews 107 (2): 563–76. doi:10.1021/cr0503613

Reygondeau, Gabriel & Beaugrand, Gregory. 2011. Future climate-driven in distribution of Calanus finmarchicus. Global Ch Biol. 17. 756-766.

Reynols, C. 2006. The Ecology of Phytooplankton. Cambridge University Press, New York.

Sanusi, Harpasis S. 1994. "Chemical Characteristic and Fertility of Pelabuhan Ratu Bay Waters at East and West Monsoon." Jurnal Ilmu-Ilmu Perairan dan Perikanan Indonesia 11 (2): 93–100

Setyorini, H. B., & Maria, E. (2019). Kandungan Nitrat dan Fosfat di Pantai Jungwok, Kabupaten Gunungkidul, Yogyakarta. Akuatik: Jurnal Sumberdaya Perairan, 13(1), 87–93.

Sihombing, R.F, R. Aryawati, & Hartoni. 2013. Kandungan klorofil-a fitoplanton di sekitar perairan Desa Sungsang Kabupaten Banyuasin Sumatera Selatan. J. Maspari, 5(1): 33–39. https://doi.org/10.36706/maspari.v5i1.1295

Susilo, E., F. Islamy, A. J. Saputra, J. J. Hidayat,

A. R. Zaky, and K. I. Suniada. 2015. Pengaruh Dinamika Oseanografi Terhadap Hasil Tangkapan Ikan Pelagis PPN Kejawanan dari Data Satelit Oseanografi. Seminar Nasional Perikanan dan Kelautan V. Universitas Brawijaya

Sutamiharja, R.T.M., 1987. Kualitas dan Pencemaran Lingkungan. Fakultas Pascasarjana, Institut Pertanian Bogor: 92 hal.

Wattayakorn, G. 1988, Nutrient Cycling in Estuarine. Paper presented in the Project on Research and its Application to Management of the Mangrove of Asia and Pasific, Ranong, Thailand.

Wei, Q. S., Z. G. Yu, B. D. Wang, M. Z. Fu, C. S. Xia, L. Liu, R. F. Ge, H. W. Wang, and R. Zhan. 2016. Coupling of the spatial-temporal distributions of nutrients and physical conditions in the southern Yellow Sea. Journal of Marine Systems 156:30–45.

Wirasatriya, A., Setiawan, R.Y. & Subardjo, P. 2017.The effect of ENSO on the variability of chloro-phyll-a and sea surface temperature in the Maluku Sea. IEEE J. Sel. Top. Appl. Earth Obs. Re-mote Sens., 10(12):5513-5518. doi: 10.1109/JSTARS.2017.2745207.

Yolanda, D., Yolanda, D. S., Muhsoni, F. F., & Siswanto, A. D. (2016). Distribusi Nitrat, Oksigen Terlarut, Dan Suhu Di Perairan Socah-Kamal Kabupaten Bangkalan. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, 9(2), 93–98. https://doi.org/10.21107/jk.v9i2.1052