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Freshwater Trophic State of Sindang Heula Dam in Terms of Chlorophyl Content

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ABSTRACT

This study aims to determine the trophic status of the waters of Sindang Heula Dam in terms of chlorophyll-a content and its relationship with other water parameters. The study was conducted in April 2021. The sampling location was determined by purposive sampling method with 5 stations. Sampling of chlorophyll-a was carried out using a composite sampling technique, which was then tested by spectrophotometric methods. Physical and chemical parameters of the waters measured included temperature, brightness, TSS, pH, DO, BOD, nitrate, nitrite, and phosphate. The results showed that the content of chlorophyll-a ranged from 12,733–63,457 g/L. Based on the results of the study, the waters of the Sindang Heula Dam have a eutrophic status to hypereutrophic, this indicates that the waters have been heavily polluted due to high levels of nutrients.

Status Trofik Perairan Bendungan Sindang Heula Ditinjau dari Kandungan Klorofil-a

ABSTRAK: *Penelitian ini bertujuan untuk mengetahui status trofik perairan Bendungan Sindang Heula ditinjau dari kandungan klorofil-a serta hubungannya dengan parameter perairan lainnya. Penelitian dilakukan pada bulan April 2021. Lokasi pengambilan sampel ditentukan dengan metode purposive sampling sebanyak 5 stasiun. Pengambilan sampel klorofil-a dilakukan dengan teknik composite sampling, yang selanjutnya diuji dengan metode spektrofotometri. Parameter fisika dan kimia perairan yang diukur meliputi suhu, kecerahan, TSS, pH, DO, BOD, nitrat, nitrit, dan fosfat. Hasil penelitian menunjukkan bahwa kandungan klorofil-a berkisar 12,733–63,457 µg/L. Berdasarkan hasil penelitian maka perairan Bendungan Sindang Heula memiliki status eutrofik menuju hipereutrofik, hal ini menunjukkan perairan sudah tercemar berat akibat tingginya unsur hara.*

INTRODUCTION

Living things cannot be separated from the need for water. The lack of water available for living things must be managed and used properly and wisely (Tanika et al., 2016). The presence of water is inseparable from pollutants that can affect water quality. Therefore, water management efforts to maintain water availability are very important, one of which is the construction of dams. Dams include slender waters and receive water input from the surrounding rivers so they cannot be separated from

pollutants (Nugroho et al., 2017). One of the dams that are in the spotlight to continue to be monitored for quality is the Sindang Heula Dam.

Sindang Heula Dam is located in Sindang Heula Village, Pabuaran District, Serang Regency, Banten. The construction of this dam is an effort in water management to improve the sustainability of water use from the Cibanten and Cimake rivers. In addition, the construction is motivated by the growing water demand (Kemen PUPR, 2016). Currently, the concern and operational constraint of the dam is the reduction in water area by water hyacinth, which impacts water pollution and can affect water quality physically, chemically, and biologically. Abundant growth of water hyacinth can indicate a high level of fertility in waters (Aisyah & Nomosatryo, 2016).

The fertility of waters is generally related to the nutrient content of the waters. This fertility can be known using biological indicators. According to Zulfia & Aisyah (2013), the bioindicator related to water nutrients is chlorophyll-a. The presence of chlorophyll-a in water can be found in phytoplankton or microalgae. Chlorophyll-a predominates among the others. In addition, chlorophyll-a is an important pigment in photosynthetic reactions and plays an important role in the water food chain (Ward et al., 1998).

The presence of chlorophyll-a in waters has a very important role, especially in monitoring the condition of waters. Chlorophyll-a has the advantage that it can describe the trophic status of waters quantitatively and is more representative than other parameters (Sastrawijaya, 2000). The presence of chlorophyll-a can also affect the physical and chemical conditions of the waters. Therefore, it is important to conduct this research to determine the trophic status of the waters of Sindang Heula Dam in terms of chlorophyll-a content. In addition, to determine the relationship of chlorophyll-a content with other physical and chemical parameters. Research related to the trophic status of waters in terms of chlorophyll-a content has never been carried out in Sindang Heula Dam. Therefore, this research is important to be carried out as renewal research.

METHOD

This research is a quantitative study using dam water as a sample. This research procedure includes determining research stations, sampling and measurement of parameters, sample testing, and data analysis. The study was conducted in April 2021. The sampling location was Sindang Heula Dam, Pabuaran District, Serang Regency, Banten.

Determination of Research Stations

Research stations were determined by purposive sampling method based on water conditions. There are five stations, as shown in Figure 1.

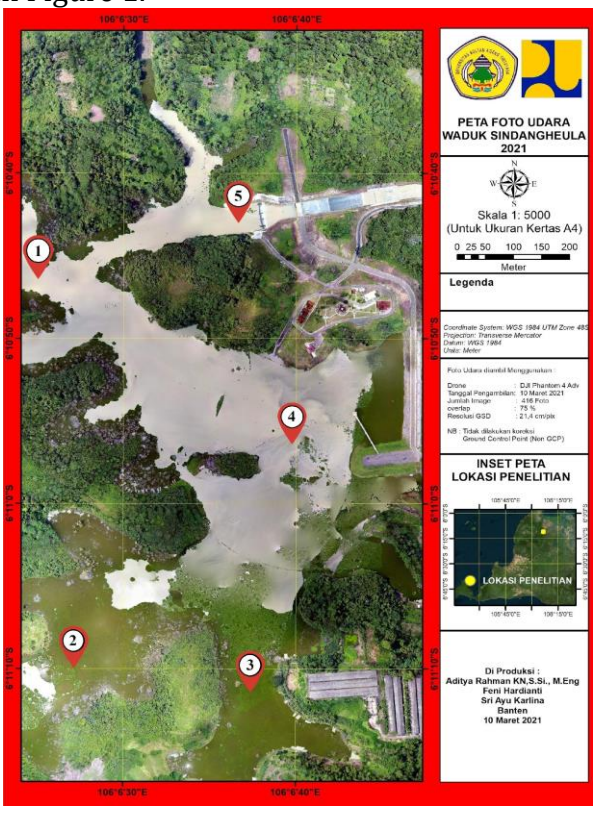

Figure 1. Map of Research Stations

Sampling and Measurement of Water Parameters

Sampling and parameter measurements were conducted from 08.00 to 10.00 West Indonesia Time. Water

parameters measured included physical parameters (temperature, brightness, and TSS) and chemical parameters (pH, DO, BOD, nitrate, nitrite, and phosphate). Chlorophyll-a samples were taken in one take using the composite technique sampling.

Sample Testing

The chlorophyll-a test used the spectrophotometric method. A water sample with a size of 200 mL was taken from an HDPE bottle and filtered through a filter holder. mL of MgCO3 solution10 was then placed in a valve tube. Next, a 90% acetone solution is poured and soaked for 24 hours. After that, the sample was mashed, and acetone solution was added to the cuvette until the total volume was 10 mL. The centrifuge process was carried out for 30-60 minutes with a rotation of 1000 rpm until two layers were produced: clear liquid and precipitate. The clear liquid was put into a spectrophotometric cuvette to be fired at a wavelength of 630, 647, 664 and 750 nm (Sutrisyani & Rohani, 2006).

Data Analysis

Chlorophyll-a content analysis was obtained from the calculation results with the following formula:

$$Chlorophyll - a\ \left(\frac{mg}{m^3}\right) = \frac{\{(11.85 \times E664) - (1.54 \times E647) - (0.08 \times E630)\} \times Ve}{Vs \times d}$$

Note:
E 664 = Abs 664 nm – Abs 750 nm
E 647 = Abs 647 nm – Abs 750 nm
E 630 = Abs 630 nm – Abs 750 nm
Vc = Volume of Acetone extract (mL)
Vs = volume of filtered water sample (L)
d = Width of cuvette diameter (1 cm, 10 cm, 15 cm)

(Sutrisyani & Rohani, 2006)

The average yield of chlorophyll-a was adjusted based on the following table of trophic status criteria.

Table 1. Criteria for Trophic Status of Waters Based on Average Level of Chlorophyll-a

Trophic Status	Average Level of Chlorophyll-a (µg/l)
Oligotrophic	< 2.6
Mesotrophic	2.6-7.3
Eutrophic	7.3-56
Hypereutrophic	>56

(Carlson & Simpson, 1996)

The relationship between chlorophyll-a content and water parameters was analyzed by multiple linear regression analysis with the help of IBM SPSS Statistic 23 software. The strength of the relationship obtained was analyzed based on the correlation coefficient interpretation table according to Sugiyono (2010).

Table 2. Interpretation of Correlation Coefficient

No	Value of r	Interpretation
1	0.00 – 1.199	Poor
2	0.20 – 0.399	Low
3	0.40 – 0.599	Moderate
4	0.60 – 0.799	High
5	0.80 – 1,000	Excellent

RESULTS AND DISCUSSION

Chlorophyll-a Content in the waters of the Sindang Heula Dam

Based on the study's results, the overall chlorophyll-a content values obtained ranged from 18.683 to 63,457 g/L (see Figure 2). The highest value of chlorophyll-a content was at station 4 (centre), which was 63,457 g/L. Meanwhile, the lowest value of chlorophyll-a content was at station 2 (inlet Cibanten) at 12,733 g/L.

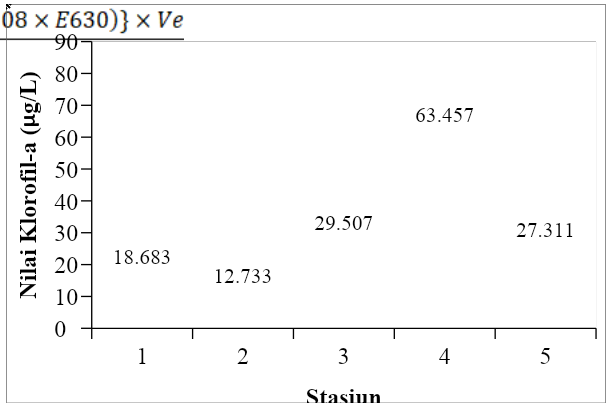

Figure 2. Graph of Chlorophyll-a Content

The high chlorophyll-a content at station 4 is influenced by the input of organic matter from the overflow of agricultural waste and domestic waste from the Cibanten and Cimake rivers. According to Marlian et al. (2015), the presence of

nutrients in waters can come from domestic, agricultural, and industrial waste input. Structurally, the centre of the dam body has a high depth that allows solutes, such as nutrients, to accumulate. According to Mann & Lazier (2013), the distribution of a material in water can be influenced by the movement of water masses. In addition, nutrients can come from the weathering of water hyacinths. Weathering of water hyacinths will produce organic matter, some of which are nitrate and phosphate (Noegraha et al., 2014). These nutrients can affect the formation of chlorophyll-a because nitrogen nutrients are part of the chlorophyll-a molecule so that it can affect the formation of chlorophyll-a (Riyono, 2007).

Chlorophyll-a in waters can also be influenced by phytoplankton or microalgae. According to Kennish (1990), autotrophic organisms such as phytoplankton or microalgae in waters require nutrients, especially nitrogen (N), phosphate (P), and silicate (Si). High levels of nutrients can support the growth of aquatic biota, especially phytoplankton, microalgae, and aquatic plants. When nutrients are available in optimal amounts, the cell population increases, this makes the high content of chlorophyll-a at station 4 at the hypereutrophic level.

Station 2 has the lowest value of chlorophyll-a content among all research stations. The location of station 2 is part of the inlet, where water enters from the Cibanten river. The low value of chlorophyll-a content at this station is influenced by several factors, one of which is the lack of activity around it. Siregar (2009) states that the lack of activity allows minimal input from outside in the decomposition of organic matter and can affect the presence of phytoplankton or microalgae. As a result, the availability of nutrients becomes less than optimal.

Another factor that is thought to affect the low value of chlorophyll-a content at station 2 is the sampling time, which was carried out in conditions of minimal sunlight. According to Yuliana & Mutmainnah (2019), low sunlight can affect the presence of phytoplankton or microalgae; even though the nutrient levels in these water bodies are quite high, their activities cannot occur optimally. Low sunlight will affect the physiological activity of chlorophyll-a in phytoplankton, especially the photosynthesis process. The low chlorophyll-a activity allows a decrease in concentration because it is not able to work optimally and will affect productivity. These two things also affect the chlorophyll-a content at station 2, which is at a low value.

The results of chlorophyll-a at each station have different concentration values. According to Marlian et al. (2015), the waters at each station have different fertility levels because they can be influenced by the hydrodynamics of physics, chemistry, and biology in each of these waters. In addition, high or low concentrations of chlorophyll-a depend on several chlorophyll-forming factors, such as genetic factors, light, temperature, pH, salinity, nitrogen, phosphorus, magnesium and other elements such as Mn, Fe, Cu, and Zn (Zainuddin et al., 2017). Arifin (2009) states that various phytoplankton species have different chlorophyll-a concentrations.

The chlorophyll-a content in the waters of Sindang Heula Dam ranged from 18.683 to 63.457 g/L and was in the criteria of *eutrophic* to *hypereutrophic.* Based on this, the fertility level of the waters of the Sindang Heula dam has reached a high level of fertility. It has even entered a very high fertility level, indicating that excess nutrients have heavily polluted the water's condition. The presence of abundant nutrients will accelerate the growth of aquatic biotas such as phytoplankton and aquatic plants such as water hyacinths, increasing water's primary productivity. Primary water productivity is the result of organic matter from autotrophic organisms through photosynthesis (Pasrons et al., 1984)

The high organic matter produced can trigger an explosive growth of aquatic plants and phytoplankton. Water that undergoes eutrophication and even reaches hypereutrophic will be dangerous for the organisms living there. This will cause an imbalance in the aquatic ecosystem. According to Garno (2016), the high organic matter produced through photosynthesis in waters will negatively impact the dominance of phytoplankton that cannot be eaten, digested, or toxic. In addition, phytoplankton blooms can result in dissolved oxygen depletion. A drastic decrease in dissolved oxygen will cause fish and other fauna to not live properly and will die.

Physical and Chemical Parameters of Sindang Heula Dam Waters

The physical and chemical factors have an important role as an illustration of the condition of the water. The measurement results are depicted in Table 3.

Table 3. Results of Physical-Chemical Parameters of Sindang Heula Dam Waters

Parameters	Station					Average
	1	2	3	4	5	
Physics						
Temperature (^{0}C)	27.4	27.5	28.0	27.8	28.5	27,8
TSS (mg/L)	20	35	25	35	30	29
Brightness (cm)	22.5	32.5	27.5	20.0	25.0	25.5
Chemical						
pH	6.74	6.92	6.91	7.33	7.04	6.99
DO (mg/L)	7.6	8.1	6.6	7.8	6.3	7.3
BOD (mg/L)	1.15	1.10	2.18	1.90	1, 05	1.48
Nitrate (mg/L)	0.905	0.768	0.915	0.931	0.868	Nitrite
	0.822					
(mg/L)	0.116	Phosphate	0.113	(	ttd	0.118 td 0.104
mg/L)	0.182	0.100	0.114	0.155	0.140	0.138

Remarks:
= not detected (< from value LoD (0.0040))

Temperature

The temperature of each station shows a stable change. The highest temperature is at station 5, which is 28.5^0 C, and the lowest is at station 1, which is 27.4^0 C. Judging from the water quality standard, which refers to PP No. 82 Tahun 2001, the water temperature of the Sindang Heula Dam was in the range of 3 deviations, namely 22-28^0 C. In addition, the water temperature is still considered optimal for the growth of aquatic organisms. It is stated by Effendi (2003) that the optimal temperature for aquatic organisms is in the range of 20-30^0 C. According to Boyd (2015), factors affecting high and low temperatures are sunlight, weather, air temperature, and climate.

TSS (*Total Solid Suspended*)

The measurement results show that the highest TSS value is 35 mg/L at stations 2 and 4, while the lowest is at station 1 at 20 mg/L. The overall TSS measurement results have an average value of 29 mg/L. Based on the water quality standard (Peraturan Pemerintah No. 82, 2001) the TSS value in Sindang Heula Dam is classified as good because it is still < 50 mg/L. According to Rinawati et al. (2016), the high value of TSS in waters can inhibit the entry of sunlight into water bodies, affecting the photosynthetic reaction in chlorophyll-a.

Brightness

The results obtained on the brightness measurement at each station show the highest result at station 2, worth 32.5 cm, and the lowest at station 4, worth 20 cm. The brightness level in the waters of the Sindang Heula Dam is, on average, 25.5 cm or 2.6 m^{-1}. Based on PP No. 82 Tahun 2001, the limit of the optimal level of brightness for water is 2-6.9 m^{-1}. Therefore, it can be said that the brightness of the Sindang Heula Dam is still considered optimal. According to Yulius et al. (2018), turbidity, suspended

solids, weather conditions, measurement time, and watercolour can affect brightness values.

Degree of Acidity (pH)

The results of the obtained pH measurements show that the highest pH is at station 4, which is 7.33, and the lowest is 6.74, which is at station 1. The overall pH value is in the range of 6.74 to 7.33. Judging from the water quality standard, which refers to PP No. 82 Tahun 2001, the pH of the waters is in the range of 6-9, namely in class I. In addition, the optimal limit of the pH of the waters for the survival of biota in waters is in the range of 6.5 - 8.0 (Odum, 1971). Biological activity can influence the high and low pH in waters (Hasim et al., 2015).

DO (*Disolved Oxygen*)

Dissolved oxygen (DO) measurement results show stable results at each station. The highest results were at station 2, with a value of 8.1 mg/L, and the lowest was at station 5, with a value of 6.3 mg/L. The overall dissolved oxygen value is 7.3 mg/L. Judging from the water quality standards listed in PP No. 82 Tahun 2001, the DO value in the waters of the Sindang Heula Dam is above the minimum limit of more than 6 mg/L and is still in the class I category. The high and low DO of the activities of different living things can influence values in the oxidation of organic and inorganic materials (Ramadhani et al., 2016).

BOD (*Biochemical Oxygen Demand*)

The results of the BOD measurement from each station show that the high oxygen demand is at station 3 with a value of 2.18 mg/L and a low value at station 5 with a value of 1.05 mg/L. The level of dissolved oxygen required is based on the average result from each station, which is 1.48 mg/L. Judging from PP No. 82 Tahun 2001, related to water quality standards, the BOD value in the waters of the Sindang Heula Dam is below the maximum limit of < 2 mg/L, so the waters are still classified as class I. According to (Kristanto, 2002), one of the factors is the high and low oxygen demand. In water, that is the input of waste into the waters.

Nitrate

The measurement results show that the highest nitrate level is at station 5 at 0.931 mg/L, and the lowest is at station 3 at 0.768 mg/L. The average nitrate content is 0.868 mg/L. According to Nugroho (2006), the nitrate value between 0.227 – 1.129 mg/L has a moderate level of water fertility. Factors that affect the high nitrate content are sources of nitrate, such as waste disposal from the mainland (Effendi, 2003). In addition, according to Patty et al. (2015), the low nitrate content may be influenced by the absorption of phytoplankton or aquatic plants.

Nitrite

The nitrite content obtained based on the measurement results has the highest value at station 2 of 0.172 mg/L, and the lowest is at station 5, which is declared undetectable, where the nitrite content is less than LoD of 0.0040 mg/L. The overall nitrite content is 0.104 mg/L. Judging from the water quality standards listed in PP No. 82 Tahun 2001. Setiyawan & Hari (2010) claim that the high nitrite concentrations will trigger aquatic plants' growth to eutrophication and gradually cause the death of aquatic biota. Risamasu & Prayitno (2012) assure that the rate of conversion of nitrite to nitrate can be a factor in the high and low value of nitrite in waters.

if the correlation coefficient is between 0.800-1,000, it proves that there is a strong relationship between the two variables.

Table 4. Results of Regression Analysis of Chlorophyll-a Content with Physical and Chemical Parameters of Sindang Heula Dam

No	Parameter	Value Correlation Coefficient	Significance
1	Temperature	0.221	0.360

2	TSS	0.386	0.261
3	Brightness	- 0.714	0.088
4	pH	0.888	0.022
5	DO	0.042	0.473
6	BOD	0.608	0.138
7	Nitrate	0.331	0.293
8	Nitrite	- 0.114	0.428
9	Phosphate	0.286	0.321

Description:
(+): indicates the value with the correlation in the same direction
(-): shows the value with the opposite correlation

The high pH can affect the presence of phytoplankton, so it is related to the presence of chlorophyll-a in the waters. In addition, according to Zainuddin et al. (2017), water pH is also a factor that can affect the formation or synthesis of chlorophyll-a. Based on the results obtained, the optimum pH value for the formation of chlorophyll-a in waters is pH 7.33. In addition, pH is a factor that can affect the growth of chlorophyll-a. Optimal pH in waters can accelerate the work of enzymes on the chlorophyll-a present in phytoplankton and microalgae in the photosynthesis process (Odum, 1971).

Photosynthesis is one of the biological activities that can affect high and low pH (Hasim et al., 2015). In the process of photosynthesis, the temperature in the waters will increase so that the solubility of CO_2 will decrease and the partial pressure (PCO_2)will increase. This causes CO_2 to be easily released to the surface of the waters, resulting in a decrease in the concentration of CO_2 in the waters. The low level of CO_2 which then also causes a decrease in H^+ and increases the pH of the waters (Nasprianto et al., 2016).

The value of the low chlorophyll-a content at stations 1 and 2 was followed by a pH value below seven or towards acid but was still in a good range. According to Adani et al. (2013), a decrease in pH in waters can cause an increase in the displacement of various heavy metal compounds that have toxic properties. These toxic compounds can affect the presence of organisms in waters, one of which is phytoplankton, especially those sensitive to heavy metals. In addition, a decrease in pH can also affect the work of enzymes that decrease phytoplankton in the synthesis of chlorophyll-a and the photosynthesis process.

Sindang Heula Dam waters with sufficient nutrients and has an optimal pH to support the growth or synthesis of chlorophyll-a. The high concentration of chlorophyll-a with an optimal pH supports the rate of photosynthesis to increase. The process of photosynthesis will produce organic material in the form of oxygen and carbohydrates, which are expressed as the value of the primary productivity of waters. High photosynthetic activity can affect the high pH of the waters. Based on this, the high chlorophyll-a content with a high but optimal water pH can cause the waters to become eutrophic. Waters with high trophic levels will cause *phytoplankton* blooms which can result in dissolved oxygen depletion, which can cause fish and other fauna not to live properly and die (Garno, 2016).

The analysis showed that apart from pH, other physicochemical parameters that had been measured showed no significant relationship with the chlorophyll-a content. It is suspected that the presence of physicochemical factors does not directly influence the presence of chlorophyll-a in waters Dewanto et al. (2015), The parameters that are limiting factors for the presence of chlorophyll-a, according to Soedibjo (2007) stated that the high number of primary consumers and the competition that occurs in an ecosystem could affect the distribution of phytoplankton, especially chlorophyll-a in water.

The concentration of chlorophyll-a in water generally describes the relationship to the presence of nutrients, where high levels of nutrients can support good phytoplankton growth so that the value of chlorophyll-a concentrations in waters becomes high. However, from the results of this study, it was found that there was no relationship between chlorophyll-a and nutrients in the form of nitrate, nitrite and

phosphate. Based on the research results of Sun et al. (2017) stated that no significant relationship was observed between nutrients and chlorophyll-a. This was because the role of nutrients in these waters to regulate phytoplankton growth was relatively weak. According to Krismono et al. (2009), the absence of a relationship between nutrients to chlorophyll-a in water cannot conclude that nutrients have no effect. This can be suspected due to the presence of water hyacinth plants with a high nutrient absorption level.

CONCLUSIONS AND SUGGESTIONS

The chlorophyll-a content in the waters of the Sindang Heula Dam from one sampling was obtained in the range of 12,733–63,457 g/L. Based on this, the trophic status of the Sindang Heula Dam waters is *eutrophic* and *hypereutrophic*. This indicates that the waters have been heavily polluted due to the high levels of nutrients. The results of the analysis of the relationship between chlorophyll-a and water physicochemical parameters showed that there was a relationship between chlorophyll-a and a pH of 0.888. Based on the values obtained, chlorophyll-a with pH has a significant and strong relationship with a unidirectional relationship. The other physicochemical parameters did not significantly relate to the chlorophyll-a content. So it is suggested that further research is needed on the impact of *hyper eutrophication* on species' survival in the Sindang Heula Dam and its effect on water discharge.

REFERENCES

Adani, N. G., Hendrarto, B., & Muskanonfola, M. R. (2013). Kesuburan Perairan Ditinjau dari Kandungan Klorofil-a Fitoplankton: Studi Kasus di Sungai Wedung, Demak. *Management of Aquatic Resources Journal (MAQUARES)*, 2(4), 38–45.

Aisyah, S., & Nomosatryo, S. (2016). Distribusi Spasial dan Temporal Nutrien di Danau Tempe, Sulawesi Selatan. *Oseanologi dan Limnologi di Indonesia*, 1(2), 31–45.

Arifin, R. (2009). Distribusi Spasial dan Temporal Biomassa Fitoplankton (Klorofil-a) dan Keterkaitannya dengan Kesuburan Perairan Estuari Sungai Brantas, Jawa Timur. *Skripsi*. Program Studi MSP FPIK IPB.

Boyd, C. E. (2015). *Water Quality*. Swizerland: Springer.

Carlson, R. E., & Simpson, J. (1996). *A Coordinator's Guide to Volunteer Lake Monitoring Methods.* North American: North American Lake Management Society.

Dewanto, W., Ismanto, A., & Widianingsih. (2015). Analisis Sebaran Horizontal Klorofil-a di Perairan Tugu Semarang. *Jurnal Oseanografi*, 4(2), 366–378.

Effendi, H. (2003). *Telaah Kualitas Air bagi Pengelolaan Sumberdaya dan Lingkungan Perairan*. Yogyakarta: Kanisius.

Garno, Y. S. (2016). Dampak Eutrofikasi Terhadap Struktur Komunitas dan Evaluasi Metode Penentuan Kelimpahan Fitoplankton. *Jurnal Teknologi Lingkungan*, 13(1), 67–74.

Hasim, Koniyo, Y., & Kasim, F. (2015). Parameter Fisik-kimia Perairan Danau Limboto sebagai Dasar Pengembangan Perikanan Budidaya Air Tawar. *Jurnal Ilmiah Perikanan dan Kelautan*, 3(4), 130–136.

Kementrian Pekerjaan Umum dan Perumahan Rakyat. (2016). *Pembangunan Bendungan Sindang Heula Kabupaten Serang Provinsi Banten*. http://sda.pu.go.id.pdf.

Kennish, M. J. (1990). *Ecology of Estuaries: Antrophogenic Effecis*. Boca Raton: CRC Press.

Krismono, Astuti, L. P., & Sugianti, Y. (2009). Karakteristik Kualitas air Danau Limboto, Provinsi Gorontalo. *Jurnal Penelitian Perikanan Indonesia*, 15(1),

59–68.

Kristanto, P. (2002). *Ekologi Industri*. Yogyakarta: ANDI.

Mann, K. H., & Lazier, J. R. N. (2013). *Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans* (3rd). Canada: Bedford Institute of Oceanography.

Marlian, N., Damar, A., & Effendi, H. (2015). Distribusi Horizontal Klorofil-a Fitoplankton Sebagai Indikator Tingkat Kesuburan Perairan di Teluk Meulaboh Aceh Barat. *Jurnal Ilmu Pertanian Indonesia*, 20(3), 272–279.

Nasprianto, N., Mantiri, D. M. H., Kepel, T. L., Ati, R. N. A., & Hutahaean, A. (2016). Distribusi Karbon di Beberapa Perairan Sulawesi Utara. *Jurnal Manusia dan Lingkungan*, 23(1), 34–41.

Noegraha, L. P., Nitisurparjo, M., & Soedarsono, P. (2014). Penggunaan Probiotik dalam Proses Pelapukan Eceng Gondok (Eichhornia sp.) pada Terbentuknya Bahan Organik, Nitrat dan Fosfat (Skala Laboratorium). *Diponegoro Journal Of Maquares*, 3(4), 125–131.

Nugroho, A. (2006). *Bioindikator Kualitas Air*. Jakarta: Universitas Trisakti.

Nugroho, L. A. B., Ni'am, F., & Soedarsono. (2017). Analisa Kelayakan Ekonomi Bendungan Randu Gunting. *Prosiding Seminar Nasional Inovasi Dalam Pengembangan Smart City*, 1(1), 221–229.

Odum, E. P. (1971). *Fundamental of Ecology*. Philadephia: W.B Sounders Company Ltd.

Pasrons, T. R., M. Takeshi, & B. Hagrave. (1984). *Biological Oceanographic Photosynthesis*. New York: W. H. Freeman & Company.

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.

Peraturan Pemerintah No. 82, T. 2001. (2001). *Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air*. http://web.ipb.ac.id/.

Ramadhani, F., Purnawan, S., & Khairuman. (2016). Analisis Kesesuaian Parameter Perairan Terhadap Komoditas Tambak Menggunakan Sistem Informasi Geografis (Sig) Di Kabupaten Pidie Jaya. *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah*, 1(1), 160–168.

Rinawati, Hidayat, D., Suprianto, R., & Dewi, P. (2016). Penentuan Kandungan Zat Padat (Total Dissolve Solid dan Total Suspended Solid) Di Perairan Teluk Lampung. *Analytical and Environmental Chemistry*, 1(1), 36–46.

Risamasu, F. J. L., & Prayitno, H. B. (2012). Kajian Zat Hara Fosfat, Nitrit, Nitrat dan Silikat di Perairan Kepulauan Matasiri, Kalimantan Selatan. *Ilmu Kelautan: Indonesian Journal of Marine Sciences*, 16(3), 135–142.

Riyono, S. H. (2007). Beberapa Sifat Umum Dari Klorofil Fitoplankton. *Oseana*, 32(1), 23–31.

Sastrawijaya, A. T. (2000). *Pencemaran Lingkungan*. Jakarta: Rineka Cipta.

Setiyawan, A., & Hari, B. (2010). Karakteristik Proses Klarifikasi dalam Sistem Nitrifikasi-Denitrifikasi untuk Pengolahan Limbah Cair dengan Kandungan N-NH_3 Tinggi. *Jurnal Teknik Sipil*, 12(2), 1–13.

Siregar, M. H. (2009). Studi Keanekaragaman Plankton di Hulu Sungai Asahan Porsea. *Skripsi*. USU.

Soedibjo, B. S. (2007). Pengaruh Faktor Lingkungan Terhadap Distribusi Spesial Komunitas Zooplankton di Teluk Klabat, Perairan Belangka Belitung. *Oseanologi dan Limnologi di Indonesia*, 33(1), 47–63.

Sugiyono. (2010). *Statistik untuk Penelitian*.

Bandung: Alfabeta.

Sun, Y., Wang, X. F., Chen, G., Zhan, C. H., Kitao, O., Tamiaki, H., & Sasaki, S. ichi. (2017). Near-infrared Absorption Carboxylated Chlorophyll-a Derivatives for Biocompatible Dye-sensitized Hydrogen Evolution. *International Journal of Hydrogen Energy*, 42(24), 1–8.

Sutrisyani, & Rohani, S. (2006). *Panduan Praktis Analisis Kualitas Air Payau*. Jakarta Selatan: Pusat Riset Perikanan Budidaya.

Tanika, L., Rahayu, S., Khasanah, N., & Dewi, S. (2016). *Fungsi Hidrologi pada Daerah Aliran Sungai (DAS): Pemahaman, Pemantauan, dan Evaluasi*. Bogor: World Agroforestry Centre (ICRAF).

Ward, T., Butler, E., & Hill, B. (1998). *Environmental Indicators for National State of The Environmental Reporting – Estuaries and The Sea*. Canberra: Department of The Environment.

Yuliana, & Mutmainnah. (2019). Kandungan Klorofil-a Dalam Kaitannya Dengan Parameter Fisika Kimia Perairan di Teluk Jakarta. *Prosiding Seminar Nasional KSP2K II*, 1(2), 206–213.

Yulius, Y., Aisyah, A., Prihantono, J., & Gunawan, D. (2018). Kajian Kualitas Perairan untuk Budidaya Laut di Teluk Saleh, Kabupaten Dompu. *Jurnal Segara*, 14(1), 57–68.

Zainuddin, M., Hamid, N., Mudiarti, L., Kursistyanto, N., & Aryono, B. (2017). Pengaruh Media Hiposalin dan Hipersalin Terhadap Respon Pertumbuhan dan Biopigmen Dunaliella salina. *Jurnal Enggano*, 2(1), 46–57.

Zulfia, N., & Aisyah. (2013). Status Trofik Perairan Rawa Pening Ditinjau dari Kandungan Unsur Hara (NO3 dan PO4) Serta Klorofil-a. *Bawal*, 5(3), 189–199.