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The Saprobic Index for Water Quality Based on Fish Aquaculture: A Case Study of White Snapper (*Lates calcarifer*) in Floating Net Cages at Sendang Biru Water, Indonesia

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ABSTRACT

The impact of water organic pollution from leftover fish feed and metabolic waste in floating net cages (FNC) aquaculture can lead to detrimental effects on coastal marine biota. This underscores the necessity for continuous monitoring of water quality in areas surrounding FNCs to mitigate the environmental impacts of aquaculture. One method of evaluating water quality is through the Saprobic Index, which quantitatively analyzes pollution status based on the presence and composition of various organisms, including plankton. This study aims to evaluate the organic pollution potential derived from fish feed in the vicinity of the FNCs at Sendang Biru waters by employing the Saprobic Index. The research identified five classes of phytoplankton in the FNC area: Bacillariophyceae, Dinophyceae, Chrysophyceae, Cyanophyceae, and Globothalamea. Analysis of the phytoplankton composition indicated that the waters surrounding Sendang Biru FNC can be classified as ranging from Oligosaprobic to β-Meso/Oligosaprobic. These findings suggest that the aquaculture practices utilizing the FNC system contribute to a light level of organic pollution in the water. This emphasizes the importance of effective management and monitoring strategies to minimize the environmental impact and ensure the sustainability of aquaculture in coastal marine ecosystems.

INTRODUCTION

Sendang Biru water, located in Malang Regency and part of the Indian Ocean, boasts a high diversity of pelagic fish including Tuna Fish (Jaya et al. 2017). Alongside the wild catch from fishing activities, aquaculture in Sendang Biru, using floating net cages (FNC), has also developed to support ecotourism. FNC is a popular aquaculture cultivation technique among fish cultivation circles. It is space-efficient and does not require any water management, as it utilizes rafts connected to cages around coastal waters (Sadhu et al. 2015). Moreover, the manufacturing cost is low and the harvesting process is simple. However, there are a few problems while applying this method, including air quality, disease transmission, changes in food webs, and requirements for comprehensive feed (Dias 2012).

There are three types of food for fish aquaculture, natural feeds, supplementary feeds, and complete feeds. Natural food, including plankton, worms, shrimp, and small fish, can be easily found in culture areas. Meanwhile, supplementary feeds are made from agriculture byproducts and fish waste bodies and are regularly given to the culture fish. Whereas the complete feeds are made from various ingredients containing complete nutrients for fish growth and the shape should facilitate easy consumption (FAO 2023). Since fish culture in Sendang Biru FNC is semi-intensive, natural food is available. However, the fish are still fed with supplemental feeds.

Hlavac et al. (2014), Madireddy & Brayboy (2022) and Pfeffer (1990) reported that fish-feeding activity is the major contributor to water pollution, particularly nitrates and phosphates from the leftover, feces, which are excreted via gills and kidneys. Since this organic waste creates a considerable threat to the environment. Some organisms, like plankton, are sensitive to this pollutant. Thus, plankton especially phytoplankton, is commonly used as a bioindicator (Pourafrasyabi & Ramenzapour 2014, Awaludin et al. 2015). Bioindicators will quickly provide information regarding water quality (Yeanny 2018).

To evaluate water quality, a saprobic system is employed, involving taxonomic and quantitative analysis of all relevant biocoenosis components, including lower algae and protozoans. The saprobic index is defined as the ratio between the sum of abundance products (the value of saprobic) and the indication weight of individual species (Zahradkova & Soldan 2013). The saprobic index is used to determine the level and status of organic pollution in waters (Canning & Death 2019) by measuring the content of nutrients and pollutants. The approach involves understanding the relationship between the level of organic pollution and the abundance of organisms as a parameter (Indrayani et al. 2014, Szczerbinka & Malgorzata 2015). The saprobic index is commonly employed to assess water quality, thereby enhancing the success rate of fishing businesses in public waters (Sagala 2011). Therefore, it is necessary to conduct research on water quality analysis based on the saprobic plankton index. This research aims to determine the level of pollution, especially organic pollution, in the waters around floating net cages.

MATERIALS AND METHODS

Study Area

Water samples were collected from three sampling sites in Sendang Biru FNC-aquaculture area with coordinates of 8°26’14” S; 112°40’49” E (Fig. 1), including one site at FNC (S1) and two sites at FNC’s surrounding area (S2 and S3).

Procedures

Measurement of Physico-Chemical Parameters of Water

Physico-chemical parameter measurements were carried out to measure the water quality in FNC-aquaculture and its surrounding area. The in-situ parameters, including dissolved oxygen (DO), temperature, pH, and salinity were measured using portable DO meter AMT08, digital thermometer, portable pH Meter pH, and Atago handheld refractometer, respectively. The water flow speed was measured on-site with the floating method according to FAO (2023). The concentration of nitrate (NO_3) and phosphate (PO_4) were analyzed in the laboratory using the spectrophotometric method following The Indonesian National Standard Procedure (SNI 2011, SNI 2005).

Analysis of Proximate Content of Fish Feeds

The fish in the Sendang Biru FNC-aquaculture system were

Fig. 1: Three sampling sites around Sendang Biru FNC-aquaculture area. FNC= Floating Net Cage.; S1=Sampling sire 1; S2= Sampling site 2; S3=Sampling site 3. (Google Earth (Jul 2 2020). Sendang Biru Malang. Retrieved from https://www.google.com/earth)Sendang Biru Malang. Retrieved from https://www.google.com/earth

fed with supplementary feed, like fish waste body pieces and pellets. The proximate values of fish waste body pieces, including protein, fat, ash, and crude fiber content, were analyzed according to The Indonesian National Standard Procedure (SNI 1996). For the proximate test of @Megami GR-5 pellets as artificial feed, utilize the proximate data provided on the packaging.

Plankton Sampling

Plankton sampling was carried out in the morning (08.00-11.00 a.m.) using the horizontal tows method from a boat. The plankton net was towed horizontally at a speed of approximately 1 knot for 1 minute according to the National Standard for plankton sampling (SNI 1998) using a Kitahara-type plankton net with a diameter of 0.3 m and a mesh size of 80 µm. The filtered sample was collected in the 60 mL sample container and then preserved in a 10% formalin solution. (USEPA 2021).

Data Analysis

Plankton Sample Analysis

1 ml of filtered sample was taken using a pipette, then dropped onto a Sedgwick Rafter glass and covered with a glass object. The samples were observed using a compound microscope and identified using identification books (Nontji 2008, Yamaji 1979). The plankton samples found were calculated to determine the individual abundance of each species using the Sedgwick Rafter Counting method according to Fachrul et al. (2007). The results of the plankton abundance calculation are then converted into ind./L with the formula below:

$$N = n \times \frac{Vr}{Vo} \times \frac{1}{Vs} \quad \ldots(1)$$

Where,

N: Number of individual plankton per liter (ind./L)

n : Number of plankton counted in the subsample

Vt: Filtered sample volume (mL)

Vo: Sub sample volume that counted in Sedgwick rafter

Vs: Amount of filtered water (liter)

The calculation of ecological indexes includes the Shannon diversity index (Spellerberg & Fedor 2003). The index of evenness and dominance refers to (Odum 1971) with the formulas as follows.

$$H' = -\sum \mathrm{pi}\,[\ln(\mathrm{pi})] \quad \ldots(2)$$

Where,

H’ = Shannon Diversity Index

pi = Relative abundance of species “i”

pi = ni/N, where ni = number of individuals of species “i” and N = total number of individuals of all species

$$E = \frac{H'}{H'maks} \quad \ldots(3)$$

Where,

E: Evenness index

H’: Diversity index value

H’ max: ln S

S: Number of Types

$$D = \left(\frac{ni}{N}\right) \wedge 2 \quad \ldots(4)$$

Where,

D: Dominance index

ni: Number of individuals per genus

N: Total individuals of the entire species

Moreover, the saprobic index was calculated using the formula referred to (Dresscher & Mark 1976, Samudra et al. 2022).

$$X = \left(\frac{C + 3D - B - 3A}{A + B + C + D}\right) \quad \ldots(5)$$

Where,

X: Saprobic index

A: Cyanophyceae group

B: Dinophyceae group

C: Chlorophyceae group

D: Bacillariophyceae group

RESULTS AND DISCUSSION

Analysis of Proximate of Fish Foods

The proximate analysis of fish food (trash of small tuna fish *(Euthynnus affinis*) and @Megami GR-5 pellets) that was distributed to fish culture in Sendang Biru FNC is given in Table 1.

As shown in Table 1, both types of fish foods contain a high nutrient, particularly protein which is essential

Table 1: Proximate test results of fish feed.

Fish feed	Proximate Test Results			
	Ash (%)	Protein (%)	Fat (%)	Crude Fiber (%)
Trash of small tuna fish	1.64	21.57	3.15	1.09
Pelet @Megami GR-5	10	48	10	2

for fish growth. Protein plays an important role in fish growth, as it contains essential and non-essential amino acids. The protein content in the trash of small Tuna Fish and @Megami GR-5 was 21.57% and 48%, respectively. This protein level falls within the range of 25-50%, which is sufficient for supporting fish growth Iskandar & Fitriadi (2017). However, high protein concentration in fish food results in nitrate and phosphate pollution in the water (Hlavac et al. 2014, Madireddy & Brayboy 2022, Pfeffer 1990). Thus, the evaluation of water quality in the FNC aquaculture system in the Sendang Biru area is important.

Measurement of Physico-Chemical Parameters of Water

In this research, the physico-chemical parameters of FNC water and the surrounding area, including temperature, pH, DO, flow speed, salinity, nitrate, and phosphate levels, were measured. The results are given in Table 2.

The result of the water quality analysis (Table 2) displayed that the temperature in FNC water and its surrounding area was in the range of 21.7-22.5ºC, which indicated that there was no abrupt change (Joseph et al. 2010). Temperature is involved in regulating aquatic ecosystem life, such as metabolic activity and the distribution of aerial organisms (Nontji 2005). Moreover, the temperature, ranging from 20-30 ºC, is suitable for plankton growth as well (Kusumaningtyas et al. 2014). pH values in FNC water and its surrounding area are in the range of 7.35-7.61, which is suitable for marine biota (Joseph et al. 2010), including plankton (Berge 2010). Besides, pH is involved in maintaining water stability. As for the salinity in FNC water and its surrounding area, it ranged from 34 to 37 ppt, which closely aligns with the salinity of the open ocean (33-37 ppt), an optimum range for marine life (Patty 2013). DO levels in FNC water and its surrounding area were in the range of 7.3-8.1 mg/L, which aligns with the optimum level for organisms (3-7 mg/L).

The flow speed in FNC water and its surroundings was in the range of 0.01-0.58 m/s with the current moving from east to west. The water current pattern in South Malang waters follows the South Java current pattern which has the same pattern throughout the year (Sartimbul et al. 2017). The water flow measured in FNC was at the level of 0.01 m/s, which is suitable for feeding activities in the FNC site. Pilditch & Grant (1999) revealed that waters with flow speeds of 0.15-0.1 m/s may inhibit feeding. While the water flow in the FNC water surrounding area was 0.43-0.48 m/s, which is useful to maintain the water flow and DO in FNC.

Nitrate levels in FNC water and its surrounding area were 0.001 mg/L in September, while after one month of fish culture activities (October), it increased around 0.08-0.32 mg/L. This nitrate level in October was higher than standard (Table 2). This incline is possibly related to the feeding activity. Fish culture activity from September to October resulted in the accumulation of leftover, feces and urine, due to an increase in nitrate concentration (Madireddy & Brayboy 2022). Phosphate concentration in all sampling sites is also higher than standard. However, the value fluctuated and there was no indication of increasing concentration from September to October. It is assumed that the source of phosphate concentration in FNC waters may come from inshore anthropogenic activities or natural resources such as weathering and dead organism artifacts (Ruttenberg 2004, Paytan & McLaughlin 2007). The fluctuating value of phosphate is possibly caused by the natural process of phosphate in the soil layer, which is not stable due to its reaction with the aforementioned water flow (Golterman 2004).

Overall, the quality of temperature, DO, pH, and salinity fall within the standards suitable for marine life. Meanwhile, the nitrate and phosphate did not fit the standard according to the previous report by Joseph et al. (2010), Nordin et al. (2009) and KLH (2004). Phosphate is essential for the

Table 2: Results of measurement of water physico-chemical parameters.

Parameter	Water Criteria for Marine Life and Aquaculture *)	Sampling Period/Location Parameters					
		September			October		
		S1	S2	S3	S1	S2	S3
Temperature (ºC)	No abrupt change	22	22.5	22.1	22	21.9	21.7
pH	7.8-8.4	7.35	7.51	7.45	7.32	7.61	7.60
Salinity (ppt)	25- 40	36	36	37	35	34	34
DO (mg/L)	>4 mg/L	7.4	7.7	7.5	7.3	8.1	7.9
Flow speed (m/s)	-	0.01	0.50	0.43	0.01	0.58	0.45
NO_3 (mg/L)	0.008 mg/ L	0.001	0.001	0.001	0.08	0.12	0.32
PO_4 (mg/L)	0.015 mg/ L	0.15	0.11	0.56	0.12	0.50	0.23

* References of water criteria: Joseph et al. 2010, Nordin et al. 2009, KLH 2004.

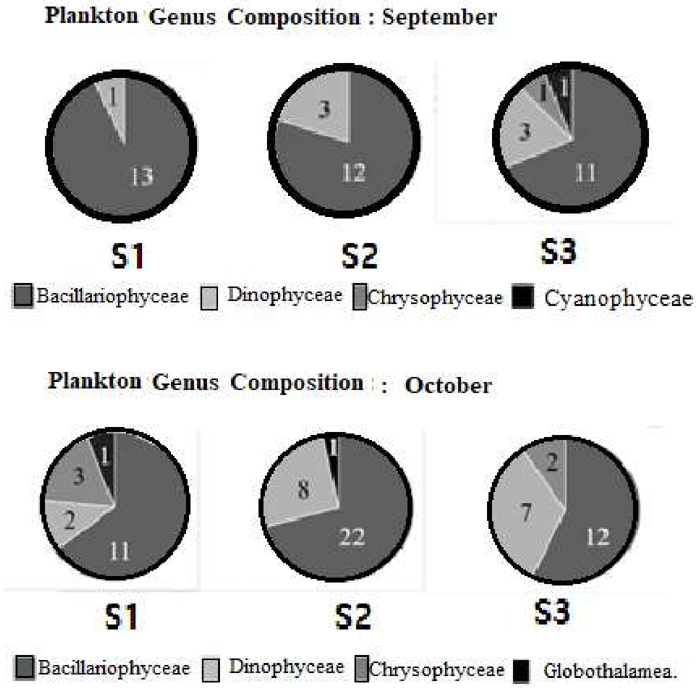

Fig. 2: Plankton genus composition.

growth and metabolism processes of phytoplankton and other organisms. Phosphate levels in FNC water and its surrounding area range from 0.11 to 0.56 mg/L, which fall within the scope of phosphate levels in marine water (0.00031-0.124 mg/L). Phosphate levels on the water surface are generally lower than those on the seafloor primarily because of phosphate consumption by phytoplankton (Patty 2013).

Phytoplankton Composition and Abundance

The phytoplankton found in FNC water and its surrounding areas mainly belongs to the classes of Bacillariophyceae, Dinophyceae, Cyanophyceae, Chrysophyceae and Globothalamea, and they are divided into 44 genera.

As shown in Fig. 2, in September, the phytoplankton in all sampling sites was dominated by Bacillariophyceae ranging from 11 to 13 genera. Other phytoplankton that were found with less number were Dinophyceae, Cyanophyceae and Chrysophyceae (1-3 genera). In October, a similar phenomenon occurred in Bacillariophyceae for its highest class found in all sampling sites. Phytoplankton, in the Bacillariophyceae class, is commonly found in marine waters and is characterized by a high level of adaptation,

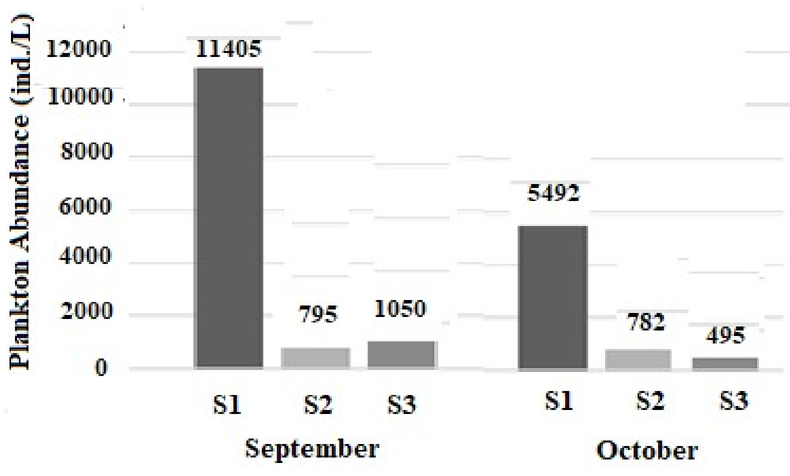

Fig. 3: Abundance of phytoplankton in site (S1) and surrounding FNC waters (S2 and S3).

Table 3: Phytoplankton ecological indexes.

Sampling Period	Sampling Site	H'	E	D
September	S1	1.60	0.83	0.25
	S2	1.47	0.76	0.30
	S3	1.97	0.86	0.16
October	S1	1.85	0.83	0.19
	S2	2.43	0.90	0.10
	S3	2.36	0.95	0.10

Notes: Shanon Diversity Index (H'), Evenness Index (E) and Dominance Index (D)

cosmopolitan nature, and wide distribution (Mann et al. 2017).

The abundance of phytoplankton in FNC water and its surrounding area ranged from 495 to 11,405 ind/L (Fig. 3). S1 in two different sampling periods, September and October, was classified as mesotrophic water with a moderate level of fertility, which is indicated by the phytoplankton abundance ranging from 2,000-15,000 ind/L (Iswanto et al. 2015). Meanwhile S2 and S3, in two sampling periods, were classified as oligotrophic water with a low fertility level indicated by the phytoplankton abundance ranging from 0 to 2,000 ind./L. The high abundance of phytoplankton in S1 was caused by the cultivating place for White Snapper (*Lates calcarifer*) with intensive feeding. Therefore, it resulted in high availability of organic material which could be consumed by phytoplankton. While at S2 and S3 in the two sampling periods, the abundance of phytoplankton was lower due to the ocean currents that distribute phytoplankton to the surrounding water (Font-Muñoz et al. 2017).

Phytoplankton Ecological Indexes

Diversity Index, Evenness Index and Dominance Index: Calculation of the phytoplankton ecological index includes the Shanon Diversity Index (H'), Evenness Index (E) and Dominance Index (D). As shown in Table 3, the phytoplankton diversity index (H') value in FNC water and its surroundings, in September, ranged from 1.47 to 1.97. In October, the phytoplankton diversity index value ranged from 1.85 to 2.43. In general, the phytoplankton diversity index value increased from September to October, which is classified as stable to very stable with moderate to very good aquatic environmental conditions (Wibisono 2005).

As shown in Table 3, the phytoplankton evenness index value ranged from 0.76 to 0.86 and from 0.83 to 0.95 in September and October, respectively. Overall, the phytoplankton evenness index value of FNC water and its surroundings was relatively high. If the E value is close to 1, it indicates that the level of uniformity in a community is high, and the number of individuals per species is evenly distributed (Kvalseth 2015). The phytoplankton dominance index value ranged from 0.16 to 0.30 and from 0.10 to 0.19 in September and October, respectively. It is classified as low, which indicates that there are no dominating phytoplankton species in FNC water and its surroundings (Wibisono 2005).

Saprobity Index: The saprobity value of water describes the pollution level in the water, measured by the content of nutrients and pollutants. Increasing nutrient content can cause phytoplankton blooms which result in water turbidity and decreased brightness. However, sufficient nutrient content will increase phytoplankton productivity, thereby enhancing the productivity of other organisms with a higher trophic level. Saprobity is measured using phytoplankton as an indicator because each type of phytoplankton is part of a certain saprobic group which will influence the saprobity value (Zahradkova & Soldan 2013, Canning & Death 2019).As shown in Table 4, the saprobity value of FNC water and its surroundings, in September, ranged from +2.8 to +2.36, which belongs to the Oligosaprobic category (Sagala et al. 2011). The Oligosaprobic phase is characterized by blue and clear water with high DO levels, a small number of bacteria in the water, pH- and DO-sensitive organisms, such as planarians, insect larvae, and aquatic moss (Barinova 2017). In addition, there is a breakdown process of organic materials by microorganisms in the water. Consistent with this finding, the data on DO levels in FNC water and its surroundings are classified as high (7.4-7.7 mg/L). In general, the pollution in FNC water and its surroundings in September was vague. This was due to ocean currents which evenly distribute the organic materials in the water (Indrayana et al. 2014).

Table 4: Results of Saprobic Index.

Sampling Period	Sampling Point	Saprobic Index	Saprobic Zone	Degree of Pollution
September	S1	+ 2.80	Oligosaprobic	Very light
	S2	+ 2.55	Oligosaprobic	Very light
	S3	+ 2.36	Oligosaprobic	Very light
October	S1	+ 1.40	β-Meso/ Oligosaprobic	Light
	S2	+ 1.94	β-Oligo/ Oligosaprobic	Very light
	S3	+ 1.27	β-Oligo/ Oligosaprobic	Light

In October, S1 showed water a saprobity value of +1.40, which was classified into β-Meso/Oligosaprobic with mild pollution. Furthermore, the sampling site of S2 was measured with the saprobity value of +1.94 which is categorized into ▯-Oligo/Mesosaprobic with an extremely light degree of pollution. Meanwhile, S3 was measured with the value of +1.27, which was categorized into β-Meso/Oligosaprobic with a light degree of pollution. In October, the quality of FNC water and its surroundings declined because of the accumulation of food residues when cultivating white sea bass. This decrease was inversely proportional to the DO level, with a value of 7.3-8.1 mg/L. This denotes that the organic materials causing the decline in water quality are relatively low because of the bacterial activity in oxidizing organic materials that are consumed (Hamzah & Trenggono 2014). Water belonging to the Mesosaprobic phase is characterized by transparent, slightly turbid, odorless, and colorless water (Barinova 2017).

Overall, FNC water and its surroundings are categorized as a suitable environment for aquatic organism life. Phytoplankton from the Bacillariophyceae class is found in all sampling points as part of the saprobity group. The presence of diatoms (Bacillariophyceae) at all stations indicates mild to moderate water pollution. The Bacillariophyceae class has a wide tolerance range for organic material pollution and serves as a bioindicator in moderate to heavy polluted water.

CONCLUSIONS

It can be concluded that the water quality at sea bass culture in Sendang Biru FNC is classified as Oligosaprobic to β-Meso/Oligosaprobic, which indicates light water pollution. Commonly found phytoplankton belong to the Bacillariophyceae class, with only a small number belonging to Dinophyceae, Cyanophyceae, Chrysophyceae, and Globothalamea classes. This result revealed that aquaculture using the FNC system may contribute the water pollution and regular biomonitoring is required.

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REFERENCES

Awaludin, A.S., Dewi, N.K. and Ngabekti, S., 2015. Saprobic coefficient of plankton in Universitas Negeri Semarang Reservoir (Indonesian: Koefisien saprobik plankton di Perairan Embung Universitas Negeri Semarang). *Indonesian Journal of Mathematics and Natural Sciences*, 38(2), pp.115-120. https://doi.org/10.15294/ijmns.v38i2.5780.

Barinova, S., 2017. Essential and practical bioindication methods and system for the water quality assessment. *International Journal of Environmental Science & Natural Resources*, 2(3), pp.1-11. https://doi.org/10.19080/IJESNR.2017.02.555588.

Berge, T.N., Daugbjerg, D., Andersen, D. and Hansen, P.J., 2010. Effect of lowered pH on marine phytoplankton growth rates. *Marine Ecology Progress Series*, pp.79-91.

Canning, A.D. and Death, R.G., 2019. Ecosystem health indicators—freshwater environments, in *Encyclopedia of Ecology* (Second Edition).

Dias, J.D., Simoes, N.R. and Bonecker, C.C., 2012. Net Cages in fish farming: a scientometric analysis. *Acta Limnologica Brasiliensia*, 24(1), pp.12-17.

Dresscher, T. and Mark, H., 1976. A simplified method for the biological assessment of the quality of fresh and slightly brackish water. *Hydrobiologia*, 48(3), pp.199-201. https://doi.org/10.1007/BF00028691.

Fachrul, M.F., 2007. *Bioecological Sampling Methods* (Indonesian: Metode Sampling Bioekologi). Published by PT. Bumi Aksara and Longman, Jakarta, Indonesia.

FAO, 2023. Water. Chapter 3: Estimates of water flow. Available at: https://www.fao.org/fishery/static/FAO_Training/FAO_Training/General/x6705e/F1.htm

Font-Muñoz, J.S., Jordi, A., Tuval, I., Arrieta, J.J., Anglès, S. and Basterretxea, G., 2017. Advection by ocean currents modifies phytoplankton size structure. *Journal of the Royal Society Interface*, 14, p.20170046. https://doi.org/10.1098/rsif.2017.0046.

Golterman, H.L., 2004. *The Chemistry of Phosphate and Nitrogen Compounds in Sediments*. Kluwer Academic Publishers, New York.

Hamzah, F. and Trenggono, M., 2014. Dissolved oxygen in Lombok Strait (Indonesian: Oksigen terlarut di Selat Lombok). *Jurnal Kelautan Nasional*, 9(1), p.21. https://doi.org/10.15578/jkn.v9i1.6199.

Hlavac, D., Adamek, Z., Hartman, P. and Masílko, J., 2014. Effects of supplementary feeding in carp ponds on discharge water quality: A review. *Aquaculture International*, 22(1), pp.299-320. https://doi.org/10.1007/s10499-013-9718-6.

Indrayana, R., Yusuf, M. and Rifai, A., 2014. The influence of surface currents on the distribution of water quality in Genuk Waters, Semarang (Indonesian: Pengaruh arus permukaan terhadap sebaran kualitas air di Perairan Genuk Semarang). *Journal of Oceanography*, 3(4), pp.651-659.

Indrayani, N., Sutrisno, A. and Agung, S., 2014. Saprobic-trophic index as an indicator of water quality in Kembang Kempis Wedung Dam, Demak Regency (Indonesian: Indeks trofik-saprobik sebagai indikator kualitas air di Bendung Kembang Kempis Wedung, Kabupaten Demak). *Diponegoro Management of Aquatic Resources Journal* (MAQUARES), 3(4), pp.161-168. https://doi.org/10.14710/marj.v3i4.7051.

Iskandar, R. and Fitriadi, S., 2017. Analisa Proksimat Pakan Hasil Olahan Pembudidayaan Ikan di Kabupaten Banjar Kalimantan Selatan. *ZIRA'AH*, 42, pp.65-68.

Iswanto, C.Y., Hutabarat, S. and Purnomo, P.W., 2015. Water fertility analysis based on plankton biodiversity, nitrate and phosphate in Jali River and Lereng River Keburuhan Village, Purworejo (Indonesian: Analisis kesuburan perairan berdasarkan keanekaragaman plankton, nitrat dan fosfat di Sungai Jali dan sungai lereng Desa Keburuhan, Purworejo). *Journal of Management of Aquatic Resources*, 4(3), pp.84-90.

Jaya, M.M., Budy, W. and Domu, S., 2017. Sustainability of tuna fisheries in Sendangbiru Malang District. (Indonesian: Keberlanjutan perikanan tuna di Perairan Sendang Biru Kabupaten Malang). *ALBACORE*, 1(1), pp.111-125. https://doi.org/10.29244/core.1.1.111-125.

Joseph, I., Joseph, S., Ignatius, B., Syda, R.G., Sobhana, K.S., Prema, D. and Varghese, M., 2010. A pilot study on culture of Asian seabass *Lates calcarifer* (Bloch) in open sea cage at Munambam, Cochin Coast, India. *Indian Journal of Fisheries*, 57(3), pp.29-33.

KLH, 2004. Seawater quality standard for marine life. The state of the Environment Minister's Decision No. 51 of 2004.

Kusumaningtyas, M.A., Bramawanto, R., Daulat, A. and Daulat, W.S., 2014. The water quality of Natuna coastal water during transitional season (Indonesian: Kualitas perairan natuna pada musim transisi). *Depik*, 3(1), pp.10-20. https://doi.org/10.13170/depik.3.1.1277.

Kvalseth, T.O., 2015. Evenness indices once again: critical analysis of properties. *Springerplus*, 4, p.232. https://doi.org/10.1186/s40064-015-0944-4.

Madireddy, S. and Brayboy, L., 2022. Effects of protein concentration in fish feed on physical and chemical water pollution. *Journal of Student Research*, 11(1). https://doi.org/10.47611/jsrhs.v11i1.2393.

Mann, D.G., Crawford, R.M. and Round, F.E., 2017. Bacillariophyta. In: Archibald, J.M., Simpson, A.G.B. and Slamovits, C.H. (Eds.) *Handbook of the Protists*, pp.205-266.

Nontji, A., 2005. *Nusantara's Marine* (Indonesian: Laut Nusantara). Published by Djambatan, Jakarta.

Nontji, A., 2008. *Marine Plankton* (Indonesian: Plankton Laut). Published by LIPI Press, Jakarta.

Nordin, R.N. and Pommen, L.W., Meays, C.L., 2009. Water Quality Guidelines for Nitrogen.

Odum, E.P., 1971. *Fundamentals of Ecology*. W.B. Saunders Company, Toronto.

Patty, S.I., 2013. Distribution temperature, salinity and dissolved oxygen in waters Kema, North Sulawesi. *Jurnal Ilmiah Platax*, 1(3), pp.148-157. DOI: https://doi.org/10.35800/jip.1.3.2013.2580.

Paytan, A. and McLaughlin, K., 2007. The Oceanic Phosphorus Cycle. *Chemical Reviews*, 107(2), pp. 563-576.

Pfeffer, E., 1990. The pollution of water by fish feeding [Article in German]. *Deutsche Tierärztliche Wochenschrift*, 97(7), pp.273-275.

Pilditch, C.A. and Grant, J., 1999. Effect of variations in flow velocity and phytoplankton concentration on sea scallop (*Placopecten magellanicus*) grazing rates. *Journal of Experimental Marine Biology and Ecology*, 240(1), pp. 111-136. https://doi.org/10.1016/S0022-0981(99)00052-0

Pourafrasyabi, M. and Ramenzapour, Z., 2014. Phytoplankton as bio-indicator of water quality in Sefid Rud-River-Iran (South Caspian Sea). *Caspian Journal of Environmental Sciences*, 12(1), pp.31-40.

Ruttenberg, K.C., 2004. The Global Phosphorus Cycle. *Treatise on Geochemistry*, 8, pp.585-643. https://doi.org/10.1016/B0-08-043751-6/08153-6.

Sadhu, N., Sharma, K.S.R., Praveen, N.D., Shoji, J. and Philipose, K.K., 2015. First result of culture of Asian seabass (*Lates calcarifer*, Bloch) in open sea floating net cages in India: Effect of stocking density on survival and growth. *Indian Journal of Geo-Marine Sciences*, 44(10), pp.1540-1544.

Sagala, E.P., 2011. Community Saprobic Index in determining the level of pollution in marine waters between the Benu River and Betet Island, Banyuasin Regency, South Sumatra Province (Indonesian: Indeks saprobik komunitas dalam menentukan tingkat pencemaran di perairan laut antara Sungai Benu dan Pulau Betet, Kabupaten Banyuasin, Provinsi Sumatera Selatan). *Maspari Journal*, 2(1), pp.11-18. https://doi.org/10.56064/maspari.v2i1.1125.

Samudra, S.R., Fitriadi, R., Baedowi, M. and Sari, L.K., 2022. Pollution level of Banjaran River, Banyumas District, Indonesia: A study based on the Saprobic Index of periphytic microalgae. *Biodiversitas*, 23(3), pp.1527-1534. https://doi.org/10.13057/biodiv/d230342.

Sartimbul, A., Larasati, A.A., Sari, S.H.J., Rohadi, E. and Yona, D., 2017. Variations in plankton communities and oceanographic parameters in pelagic fishing areas in South Malang Waters (Indonesian: Variasi komunitas plankton dan parameter oseanografi di daerah penangkapan ikan pelagis di Perairan Malang Selatan). *Journal of Fisheries and Marine Science*, 1(2), pp.55-64. https://doi.org/10.21776/ub.jfmr.2017.001.02.2.

Simanjuntak, M., 2012. Sea water quality observed from nutrient aspect, dissolved oxygen and pH in The Banggai Waters, Central Sulawesi (Indonesian: Kualitas Air Laut Ditinjau dari Aspek Zat Hara, Oksigen Terlarut dan pH di Perairan Banggai, Sulawesi Tengah). *Jurnal Ilmu dan Teknologi Kelautan Tropis FPIK-IPB*, 4(2), pp.290-303.

SNI, 1996. Indonesian National Standard No. 2715. Fish Meal as Raw Material for Feed (Indonesian: Tentang Tepung Ikan Bahan Baku Pakan).

SNI, 1998. Indonesian National Standard Procedure No. 03-4717. National Standard Procedure for taking plankton samples (Indonesian: Tata-pengambilan-percontoh-plankton).

SNI, 2005. Indonesian National Standard No. 6989. How to Test Phosphate Levels with a Spectrophotometer using Ascorbic Acid (Indonesian: Tentang Cara Uji Kadar Fosfat dengan Spektrofotometer secara Asam Askorbat).

SNI, 2011. Indonesian National Standard No. 6989. Methods for Testing Nitrate (NO3-N) with a UV-Visible Spectrophotometer with Cadmium Reduction (Indonesian: Tentang Cara Uji Nitrat (NO3-N) dengan Spektrofotometer UV-Visible secara Reduksi Kadmium).

Spellerberg, I.F. and Fedor, P., 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon–Wiener' Index. *Global Ecology & Biogeography*, 12(3), pp.177-179.

Szczerbinka, N. and Malgorzata, G., 2015. Biological method used to assess surface water quality. *Archives of Polish Fisheries*, 23(4), pp.185-196.

USEPA, 2021. Standard Operating Procedure for Phytoplankton Analysis. Available at: <https://www.epa.gov/system/files/documents/2021-12/lg401.v07-phytoplankton-analysis_rfa.pdf>.

Wibisono, M.S., 2005. *Introduction of Marine Science* (Indonesian: Pengantar Ilmu Kelautan). Published by PT. Gramedia Widiasarana Indonesia, Jakarta.

Yamaji, I., 1979. *Illustrations of Marine Phytoplankton of Japan*. Hoikusha Publishing, Osaka.

Yeanny, M.S., 2018. Phytoplankton Community as bio-indicator of fertility in Belawan river. *IOP Conference Series: Earth and Environmental Science*, 130, p.012030. https://doi.org/10.1088/1755-1315/130/1/012030.

Zahradkova, S. and Soldan, T., 2013. Saprobic System. In: *Reference Module in Earth Systems and Environmental Sciences*.