Phytoplankton distribution in Ranggeh River and its relationship with physicochemical parameters

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Abstract. Ranggeh River, located in Nagari Batang River - Agam Regency, is one of the natural habitats for native fishes of Lake Maninjau. Phytoplankton is a microorganism that has an important role in the aquatic ecosystem, as a primary producer in the food chain and to provide a food source for the higher organisms such as zooplankton and fish. The existence of phytoplankton in the river is influenced by physical and chemical factors. This study was aimed to reveal the correlation of the phytoplankton abundance and physicochemical parameters in Ranggeh River. The observations were conducted in February, March, and April 2019 at the upstream (SR 1, SR 2 and SR 3) and the downstream areas (SR 4 and SR 5) of Ranggeh River. The parameters observed were phytoplankton abundance and some water quality parameters. The phytoplankton community structure was analyzed by the ecological index. The highest and lowest abundance of phytoplankton was found in SR 4 and SR 1, respectively. Bacillariophyta has been recorded as the most dominant group (98.30% to the total phytoplankton population), followed by Chlorophyta (1.40%), Cyanophyta (0.27%), and Euglenophyta (0.04%). Based on the ecological index, the phytoplankton communities at SR2, SR 3, SR 4 and SR 5 are unstable, and there is a species that dominates namely the Navicula elegans, Navicula pupula and Synedra ulna from the Bacillariophyta group. According to values of phytoplankton abundance, total nitrogen, total phosphorus, chlorophyll-a, and diversity index, Ranggeh River was mesotrophic water.

1. Introduction
Ranggeh River is an important freshwater ecosystem in Nagari Batang Air - Agam Regency, this river is one of the natural habitats of Lake Maninjau native fishes. Changes in land use that occur around the rivers will affect the water quality and aquatic organisms, including phytoplankton. Phytoplankton is a microorganism that has an essential role in the aquatic ecosystem. As a producer in the food chain, they provide natural food for higher organisms such as zooplankton and fish. Fonge et al [1] mention that phytoplankton is an important primary producer and the base of the food chain in ecosystems.
Phytoplankton has a short life cycle resulting in fast response to environmental changes, therefore species abundance and composition indirectly indicate the water quality. Sharma et al [2] concluded that the distribution of phytoplankton in the freshwater ecosystem is influenced by physicochemical parameters, which are the major factors to control the dynamics and structure of phytoplankton (Hulyal & Kaliwal in Sharma et al [2]). Changes in the aquatic environment may influence the abundance of phytoplankton that one species can be more dominant than the others at short time.
intervals throughout the year [3]. Current velocity, erosion, and sedimentation are common phenomena in the river ecosystem affecting the life of aquatic organisms, including phytoplankton.

Studies on phytoplankton community in relation to physicochemical parameters have been performed in several rivers such as the Manna River in South Bengkulu [4], Bedog River in Yogyakarta [5], Surabaya Stream in East Java [6], and Baldi Stream in Garhwal Himalayas [2]. However, there has been no study on the phytoplankton community and physicochemical parameters in the rivers around Lake Maninjau, especially Ranggeh River. Ranggeh River is one of the rivers which become the habitat for native fishes of Lake Maninjau. However, human activities around the river are increasing like agricultural activities and the existence of settlements which will certainly affect the presence of biota in the river. Therefore this study was conducted to find out the relationship between phytoplankton abundance and physicochemical parameters in Ranggeh River. It is expected that the output of this study can contribute to the management of the river around Lake Maninjau in the context of preserving native fishes of Lake Maninjau.

2. Methods

Ranggeh River is in Nagari Batang Air – Agam Regency, West Sumatra Province which lies in the coordinates of 00° 20’ S and 100° 014’ E. The length of the river is 5.9 km. This river is used to irrigate rice fields in the surrounding sites where the condition of riparian vegetation has started to change due to plantation and agricultural activities.

Sampling was undertaken from February to April 2019. Five sampling sites on Ranggeh River, three in the upstream (SR1, SR2, and SR3), and two in the downstream (SR4 and SR5), were chosen representing the condition of the river (figure 1). In general, the land use surrounds the Ranggeh River are rice fields. SR1 is the boundary of forest areas, SR 2 is close to the paddy field, SR 3 is close to the settlement area where the water was flowing intermittent, SR4 is a pool area, and SR5 is about 30 meters from the river mouth flowing to Lake Maninjau (figure 1 and table 1).

![Figure 1. Sampling sites at Ranggeh River in February to April 2019.](image_url)

Dissolved Oxygen, pH, water temperature, total dissolved solids, and conductivity were measured in-situ using Horiba U50 water quality checker. Chlorophyll-a, Total Nitrogen, and Total Phosphorus were analyzed using the standard method [7]. For phytoplankton analysis, 20 L of water was collected and filtered through plankton net no 25 (mesh size of 53 μm) and preserved with 1% Lugol solution for analyses using the Sedgwick Rafter counting cell. Results were recorded in individuals per litter.
(individuals/L). The identification of phytoplankton was based on Prescott [8], Prescott [9], Scott & Prescott [10], Mizuno [11], Gell et al [12], and Bellinger & Sigee [13].

Table 1. Name of the site, position, and description of sampling sites at Ranggeh River.

| No. | Name of Site | Position          | Description                                                                                                                                 |
|-----|--------------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | SR 1         | S 00°20’34,0"    | It is an upstream part of the Ranggeh River, on the right is a rice field and the left is a forest. This river is the source of water for rice fields. Water discharge is relatively large, the condition of the base substrate is dominated by large and small rocks, forming small rapids. The condition of the water is still clear which reflects the upstream area. This site is approximately 500 meters from SR 1. Riverbed consists of large and small rocks, on the right and left of the river is the rice fields. The water flow is relatively small and the water looks a little turbid which is thought to come from agricultural areas.                                                                                       |
|     |              | E 100°014’19,0"  | This site is near the bridge and estimated at 700 meters from SR 2. Water discharge at this site is very small even dry out at certain times so that in some parts of the riverbed there are sandbars. most of the water is used for agriculture. On the right side, there are residential areas and the left side is rice fields. The bronjong building looks to hold back the flow of water which erodes the river banks.                                                                 |
| 2.  | SR 2         | S 00°20’33,4"    | Most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
|     |              | E 100°014’01,6"  | The right and left sides of this site are rice fields, the width of the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
| 3.  | SR 3         | S 00°20’31,9"    | Most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
|     |              | E 100°013’52,6"  | This site is near the bridge and estimated at 700 meters from SR 2. Water discharge at this site is very small even dry out at certain times so that in some parts of the riverbed there are sandbars. most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
| 4.  | SR 4         | S 00°20’50,3"    | Most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
|     |              | E 100°013’24,8"  | This site is near the bridge and estimated at 700 meters from SR 2. Water discharge at this site is very small even dry out at certain times so that in some parts of the riverbed there are sandbars. most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
| 5.  | SR 5         | S 00°20’51,0"    | Most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |
|     |              | E 100°013’09,0"  | This site is near the bridge and estimated at 700 meters from SR 2. Water discharge at this site is very small even dry out at certain times so that in some parts of the riverbed there are sandbars. most of the water is used for agriculture. On the right side, there are rice fields, and the river is only 1.2 meters, and the water discharge is relatively small. At this site, there are a few small pools. The water conditions are relatively clear and the riverbed is dominated by sand. This site is relatively protected by trees, but the edge of the river looks the former landsides.                                                                 |

3. Results and Discussion

3.1 Physicochemical parameters

Dissolved Oxygen (DO), pH, and water temperature are presented in Figure 2. DO values ranged between 4.68 mg/L and 8.57 mg/L and the value in the downstream area is lower than in the upstream area. Human activity in the downstream produces higher organic and inorganic compounds compared to the upstream, which require higher dissolved oxygen for the decomposition process. The pH value ranged between 7.03 and 8.57 and in the upstream area is relatively higher than the downstream area. Kristanto in Fauzia et al [5] stated that freshwater such as water mountains generally has alkaline pH value.

Although temperature fluctuations in the waters are not as high as in the air, temperature affects the life of aquatic organisms. Most aquatic organisms have little tolerance for temperature changes. Odum [14] and Wetzel [15] mentioned that temperature is one of the critical factors that control aquatic life in a headwater stream because of changes in temperature cause typical circulation patterns that can affect aquatic life. The lowest water temperature in Ranggeh river (21.0°C) is at SR1 (the
upstream area), and the highest (29.2°C) is at SR5 (the downstream area). The height of the land affects the temperature resulting in higher temperature in the lower altitude. Moreover, the downstream is more open area than the upstream that is covered by trees.

![Graphs of Dissolved Oxygen, pH, and Temperature at Rangge River in February, March, and April 2019](image)

**Figure 2.** Dissolved Oxygen, pH, and temperature at Ranggeh River in February, March, and April 2019 (no measurements were taken at SR3 during drought condition in March and April 2019)

Total dissolved solids (TDS) value ranged between 7.8 – 118.3 mg/L and the value in the downstream is higher than in the upstream areas. Higher human activity in the downstream compared to the upstream affect the TDS value in the waters. Fauzia et al [5] showed that the TDS content in the downstream area is higher due to aquaculture activities and the accumulation of dissolved organic and inorganic materials from the area above it. The conductivity value shows a similar trend as the TDS value, which ranged from 0.062 to 0.187 mS/cm.

The current velocity value ranged from 0.07 – 4.55 m/seconds. Current velocity at SR1 was higher than another sites, the riverbed in this site consists of large and small rocks, forming small rapids. Meanwhile, the current velocity at SR4 is lower than other sites at each sampling, SR4 is a pools area where the water looks calm.
Figure 3. Total Dissolved Solid, Conductivity, and Water Velocity at Ranggeh River in February, March, and April 2019.

Phosphorus and nitrogen are the two elements that are often limiting factors in water. Both of these nutrients can be a limiting factor for phytoplankton growth in unpolluted waters, and alone or together can increase phytoplankton’s productivity (Stockner and Shorteed in Murphy [16]). Chlorophyll-a is a pigment needed for photosynthesis and can describe the total phytoplankton biomass in waters (Gregor and Marsalek in Camara et al [17]). Observations in the Rangge River show the value of Total Nitrogen (TN) ranged between 0.271 and 0.590 mg/L, Total Phosphorus (TP) value ranged between 0.035 and 0.136 mg/L and Chlorophyll-a ranged between 0.314 and 8.788 mg/m$^3$ (figure 4). Based on the OECD standard [18], this value indicates that Rangge River is mesotrophic.
Figure 4. Total Nitrogen, Total Phosphorus, and Chlorophyll-a at Ranggeh River in February, March and April 2019.

3.2 Phytoplankton community structure and its relationship to physicochemical parameters

Four phylum and sixty-eight species of phytoplankton were recorded in Ranggeh River, Chlorophyta (37 species), Bacillariophyta (22 species), Cyanophyta (7 species), and Euglenophyta (2 species) (table 2). Maximum average abundance (8,330 individual.L⁻¹) of phytoplankton was observed at SR4 and the minimum average (42 individual.L⁻¹) was at SR1. The highest abundance of phytoplankton is from the Bacillariophyta group (figure 5). In general, the water condition of Ranggeh River in February to March 2019 was categorized as mesotrophic waters according to Lander in Larasati [19] with phytoplankton abundance value below of 15,000 individual.L⁻¹. The highest abundance occurred in March 2019 at almost all sites (SR 1, SR4 and SR 5) and the phytoplankton abundance was the highest at SR 4. The highest abundance of Phytoplankton at SR4 may be due to the lower current velocity at this site.

On the contrary, SR1 has a high current velocity which causes low phytoplankton abundance. Wickstead in Oktavia et al [6] stated that currents are very important in the distribution of plankton in the rivers, surface currents, and bottom waters. The pattern of phytoplankton abundance (figure 6) and TP is almost similar, which is the highest in March 2019. It seems that there is a relationship between phytoplankton abundance and phosphorus, as it has been known that phosphorus affects the growth of phytoplankton. Fonge et al [1] found that the abundance and diversity of phytoplankton were influenced by ambient physicochemical conditions, especially phosphorus concentration. The pattern of phytoplankton abundance and chlorophyll-a at Ranggeh River is almost similar, which is the highest in March 2019 and the value is relatively the highest at SR 4. Chlorophyll-a concentration reflected the phytoplankton biomass in Ranggeh River.
Bacillaryophyta has been recorded as the most dominant group, followed by Chlorophyta, Cyanophyta, and Euglenophyta. It contributed 98.30% to the total phytoplankton population of Ranggeh River, while Chlorophyta, Cyanophyta, and Euglenophyta contributed 1.40%, 0.27%, and 0.04%, respectively. Bacillaryophyta was also recorded as the dominant group in Manna River, South Bengkulu [4], Surabaya Stream, East Java [6], Bedog River, Yogyakarta [5], and Baldi Stream, Garhwal Himalayas [2]. Bellinger & Sigee [13] mentioned that Diatoms (Bacillaryophyta) are very abundant in both planktonic and benthic freshwater environments, where they form a large part of the algal biomass and are a major contributor to primary productivity. Bacillarophyceae is cosmopolitan phytoplankton, resistant to extreme conditions, adaptable, and has high reproductive power and a high tolerance for chemicals and nutrients (Smith in Dwirastina & Arif [4], [20],[1]). Bacillarophyceae often dominate in rivers with very high abundance because they can stick in the substrate adapt to low and high currents (Welch in Adriansyah et al [21]). It was also reported by Gasse et al in Harris [22] that the conductivity value strongly influences the dominance of diatoms (Bacillarophyceae) in waters. Navicula elegans, Navicula pupula, and Synedra ulna are the species with the highest abundance in the Ranggeh River. Adriansyah et al [21] also found that Navicula is phytoplankton with the highest abundance in Jawi River and Raya Dalam River, this shows that Navicula is adaptable and high tolerance to its environment (Patrick in Adriansyah et al [21]).
Figure 6. Average abundance of phytoplankton at different sites during the observation.

The second abundant division of phytoplankton recorded during the study was Chlorophyta, with a total of 37 species (table 2). The Chlorophyta observed was almost evenly distributed, with no dominated species. The lowest abundance of Chlorophyta was found in April 2019 and occurred at SR1 while the highest was at SR4 which occurred in March 2019. The third abundant division of phytoplankton was Cyanophyta and the highest density (18 individual.L⁻¹) of Cyanophyta was recorded at SR5, while the minimum densities (5 individual.L⁻¹) were found at SR1 and SR3. Euglenophyta contributed only 0.04% to the total phytoplankton abundance in Ranggeh River, maximum density (14 individual.L⁻¹) was recorded at SR4 and the minimum (1 individual.L⁻¹) at S2 and SR3.

3.3 Phytoplankton diversity
Diversity index, evenness index, and dominance index of phytoplankton in Ranggeh River ranged from 0.232 to 3.154, 0.022 to 0.774 and 0.154 to 0.954, respectively (figure 8). The results show that Ranggeh River has low to moderate phytoplankton diversity, uniformity between species in the community and that a dominant species at some sites. Some of the dominant species were *N. elegans* and *N. pupula* at SR 2, SR 3, SR 4, and SR 5 (February and March 2019) and *Synedra ulna* at SR 4 and SR 5 (March 2019) and SR 4 (April 2019). Phytoplankton diversity index at SR 1 was relatively higher compared to other sites, the species was evenly distributed (evenness index value is close to 1 [14]) and the dominance index value is close to zero indicating no dominant species [14]. The community structure at SR 1 is more stable than other sites.
### Table 2. Species Composition of phytoplankton in Ranggeh River during February, March, and April 2019

| Phytoplankton Composition | Bacillariophyta | Chlorophyta | Cyanophyta | Euglenophyta |
|---------------------------|----------------|-------------|------------|--------------|
| *Achnanthes taeniata*     | Actinastrum sp. | Anabaena sp. | Chroococcus sp. | Euglena acus |
| *Amphora ovalis*          | Ankistrodesmus falcatus | Chroococcus sp. | Merismopedia punctata |
| *Chaetoceros danicus*     | Cladophora sp. | Micocystis aeruginosa | Oscillatoria tenus |
| *Cyclotella* sp.          | Closterium | Micocystis aeruginosa | Oscillatoria princeps |
| *Cymbella turgida*        | Closterium calosporum | Micocystis aeruginosa | Spirulina sp. |
| *Diatoma* sp.             | Closterium ehrenbergii | Micocystis aeruginosa | Spirulina sp. |
| *Fragillaria* spp.        | Closterium gracilis | Oscillatoria tenus | Spirulina sp. |
| *Gomphonema* sp.          | Closterium gracilis | Oscillatoria tenus | Spirulina sp. |
| *Gyrosigma balticum*      | Closterium lanula | Oscillatoria tenus | Spirulina sp. |
| *Gyrosigma rhomboides*    | Closterium parvulum | Oscillatoria tenus | Spirulina sp. |
| *Hantzschia* sp.          | Closterium recticarinatum | Oscillatoria tenus | Spirulina sp. |
| *Melosira granulata*      | Closterium turgidum | Oscillatoria tenus | Spirulina sp. |
| *Navicula* sp.            | Coelastrum microporum | Oscillatoria tenus | Spirulina sp. |
| *Navicula elegans*        | Coeleochaete sp. | Oscillatoria tenus | Spirulina sp. |
| *Navicula pupula*         | Cosmarium decoratum | Oscillatoria tenus | Spirulina sp. |
| *Navicula radioxa*        | Cosmarium margaritatum | Oscillatoria tenus | Spirulina sp. |
| *Navicula rhyncocephala*  | Cylindrocapsa sp. | Oscillatoria tenus | Spirulina sp. |
| *Pinnularia* sp.          | Euastrum spinulosum | Oscillatoria tenus | Spirulina sp. |
| *Pinnularia gibba*        | Eudorina sp. | Oscillatoria tenus | Spirulina sp. |
| *Surirella elegans*       | Micrasterias alata | Oscillatoria tenus | Spirulina sp. |
| *Surirella robusta*       | Micrasterias foliacea | Oscillatoria tenus | Spirulina sp. |
| *Synedra ulna*            | Microspora sp. | Oscillatoria tenus | Spirulina sp. |
|                           | Pandorina sp. | Oscillatoria tenus | Spirulina sp. |
|                           | Pediastrum duplex | Oscillatoria tenus | Spirulina sp. |
|                           | Pleurotaenium sp. | Oscillatoria tenus | Spirulina sp. |
|                           | Scenedesmus acuminatus | Oscillatoria tenus | Spirulina sp. |
|                           | Scenedesmus dimorphus | Oscillatoria tenus | Spirulina sp. |
|                           | Scenedesmus quadricauda | Oscillatoria tenus | Spirulina sp. |
|                           | Spirogyra sp. | Oscillatoria tenus | Spirulina sp. |
|                           | Spirotaenia condensata | Oscillatoria tenus | Spirulina sp. |
|                           | Stauroastrum javanicum | Oscillatoria tenus | Spirulina sp. |
|                           | Stauroastrum punctatrum | Oscillatoria tenus | Spirulina sp. |
|                           | Stauroastrum sexangulare | Oscillatoria tenus | Spirulina sp. |
|                           | Stigeoclonium sp. | Oscillatoria tenus | Spirulina sp. |
|                           | Ulothrix sp. | Oscillatoria tenus | Spirulina sp. |
|                           | Ulothrix zonata | Oscillatoria tenus | Spirulina sp. |
|                           | Volvox aureus | Oscillatoria tenus | Spirulina sp. |
4. Conclusions
Bacillaryophyta is a dominant group in Ranggeh River, reaching to 98.20% of phytoplankton abundance. Based on the diversity, evenness, and dominance indexes, the phytoplankton community in Ranggeh River at most of the sampling stations were unstable and with some dominant species from the Bacillaryophyta group, *N. elegans*, *N. pupula*, and *S. ulna*. According to the values of phytoplankton abundance, total nitrogen, total phosphorus, chlorophyll-a, and diversity index, Ranggeh River is classified as mesotrophic.

5. References
[1] Fonge, Ambo B, Tabot P T, Mange C A and Mumbang C 2015 Phytoplankton community structure and physico-chemical characteristics of stream flowing through an agro-plantation complex in Tiko Cameroon *Journal of Ecology and the Natural Environment* 7 (5) pp 170–179 DOI: 10.5897/JENE2015.0515 [2] Sharma, Ramesh C, Singh N and Chauhan A 2016 The influence of physico-chemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: A case study. *Egyptian Journal of Aquatic Research* (2016), 42, 11 – 21 [3] Davis C C 1955 *The marine and freshwater plankton* (Michigan: Michigan State University Press) p 562 [4] Dwirastina, Mirna and Wibowo A 2015 Karakteristik fisika – kimia dan struktur komunitas plankton perairan Sungai Manna, Bengkulu Selatan *LIMNOTEK*, 22 (1) 76 – 85 (in Indonesian) [5] Fauzia, Zayanna A, Suhartini and Sudarsono 2016 Kualitas perairan di Sungai Bedog, Yogyakarta berdasarkan keanekaragaman plankton *Jurnal Biologi*, 5 (6) 50-61 (In Indonesian)
[6] Oktavia N, Purnomo T and Lisdiana L 2015 Keanekaragaman plankton dan kualitas air Kali Surabaya LenteraBio, 4 (1) pp 103-107. ISSN: 2252-3979 http://ejournal.unesa.ac.id/index.php/lenterabio (in Indonesian)

[7] APHA / American Water Work Association / Water Environment Federation 2012 Standard methods for examination of water and waste water 22nd ed, (Washington DC: APHA/AWWA/WEF) ISBN.0875532233 DDC:628.161

[8] Prescott G W 1951 Algae of the western Great Lakes Bulletin No 31 (Bloomfield Hills, Michc: Cranbrook Institute of Science) pp 946

[9] Prescott G W 1962 How to know the freshwater algae (Iowa: W.M.C. Brown Company Publisher) pp 348

[10] Scott A M and Prescott G W 1961 Indonesian Desmids Hidrobiologia XVII No 1 – 2 pp 132

[11] Mizuno T 1979 Illustration of the freshwater plankton of Japan (Osaka: Hoikusha Publishing Co. Ltd) pp 313

[12] Gell P A, Sonneman J A, Reid M A, Illman M A and Sincock A J 1999 An Illustrated Key to Common Diatom Genera from Southern Australia Identification Guide No. 26. (Thurgoona NSW: Cooperative Research Centre for Freshwater Ecology) pp 63

[13] Bellinger E G and Sigee D C 2010 Freshwater algae : identification and use as bioindicators (Oxford: John Wiley and sons, Ltd) pp 271 ISBN 978-0-470-05814-5

[14] Odum E P 1971 Fundamentals of Ecology (Philadelphia: W.B. Sounders) pp 574

[15] Wetzel R G 2001 Limnology 3rd ed (San Diego: Academic Press) pp 1005

[16] Murphy M L 1998 Primary Production In : Naiman R J and Bilby R E (eds.) : River Ecology and Management (New York: Springer-Verlag New York, Inc) pp 144 – 168

[17] Camara F R A, Lima A K A, Rocha O and Chellappa N T 2009 The role of nutrient dynamics on the phytoplankton biomass (chlorophyll-a) of reservoir-channel continuum in a semi-arid tropical region, Acta Limnol. Bras 21 (4) 431-439

[18] Ryding S O and Rast W 1989 The Control of Eutrophication of Lakes and reservoirs Man and Biosphere Series (Paris: UNESCO and The Parthenon Publishing Group) pp 314

[19] Larasati A 1985 Kelimpahan dan penyebaran fitoplankton di Bendung Curug, Kabupaten Karawang, Jawa Barat Karya Ilmiah (Bogor: Fakultas Perikanan, IPB Bogor) p 65

[20] Sachlan M 1980 Planktonologi (Semarang: Fakultas Peternakan dan Perikanan UNDIP) p 103 (in Indonesian)

[21] Andriansyah, Setawati T R and Lovudi I 2014 Kualitas perairan kanal Sungai Jawi dan Sungai Raya Dalam Kota Pontianak ditinjau dari struktur komunitas mikroalga perifitik Priobiont, 3 (1) 61 – 70 (in Indonesian)

[22] Harris G H 1986 The phytoplankton Ecology Sruicture Function and Fluctuation (New York: Chapman and Hall) p 384

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