Trophic status of the lacustrine zone around the dam site of Koto Panjang Reservoir, Riau Province, Indonesia

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Abstract. The aim of this study is to understand the trophic status of the lacustrine zone around the dam site based on the physical, chemical and biological data. The monitored indicators was water transparency, water temperature, nitrate and phosphate concentration, dissolved oxygen and phytoplankton abundance. The results showed that water quality parameters, temperature, transparency, CO_2, nitrate, phosphate and oxygen quality supporting the life of phytoplankton. The trophic status around the dam site reservoir PLTA Koto Panjang is mesotrophic to eutrophic. The activity of floating net cages donates organic matter to the water body that increases the nitrate and phosphate concentration. Further research is suggested concerning the content of organic material from activity of floating net cages by observing BOD5 concentration that describes the amount of organic matter in the reservoir.

Key Words: oligotrophic, water quality, phytoplankton, trophic status, fish net cage.

Introduction. The number of reservoirs in Indonesia amounts to about 324 and one of them is the Koto Panjang Hydroelectric Reservoir in Riau. The hydropower plant has an area of 12,400 ha built in 1992 and completed in 1997. Ecologically, at first the reservoir was flooded with nutrient content in low or oligotrophic waters. In time, the trophic status of these reservoirs became mesotrophic, eutrophic, and hypertrophic. The change of trophic status of this reservoir is determined by the activity in the reservoir border area and the activity in the reservoir body itself.

At present, one of the community activities in the reservoir border area is agriculture. In the Koto Panjang Hydroelectric Reservoir, the community conducts the fish maintenance of floating net cages (FNC) system which is concentrated around the dam site. The number of KJA plots operating in the Koto Panjang Hydroelectric Reservoir was 196 plots in 2003, 513 in 2006 and in 2009 were 900 plots (Siagian 2010). Furthermore, according to Simarmata et al (2013) the number of KJA is 1,100 plots, which showed an increasing number of the KJAs in the reservoir.

Increasing the amount of KJA could affect the quality of reservoir waters due to the waste load in the form of feed residues, feces and other excretions that cause the increase of organic material which can cause the increase of nutrients as nitrate and phosphate and lead to the abundance of phytoplankton. This phenomenon can lead to changes in trophic status of reservoir waters.

This trophic status needs to be considered, because a change in trophic status of a water body could lead to the mass death of cultivated fish. By knowing the trophic status of the waters of Koto Panjang dam this can be done approach in the management of reservoir for fish farming activities in sustainable way. The trophic status of the reservoir is thought to occur rapidly around the dam site because KJA activities are concentrated in the area. To see how much of change is in the trophic status around this dam site needs to be view the physical, chemical and biological characteristics.

Material and Method. This research was conducted from June to November 2015 in Koto Panjang hydroelectric dam, Kampar regency, Riau Province, Indonesia. Locations and sampling stations are presented in Figure 1. This study was conducted using non-experimental descriptive method. Research was conducted in the field and analysis of existing samples conducted in the field and in the laboratory of Fisheries University of Riau.

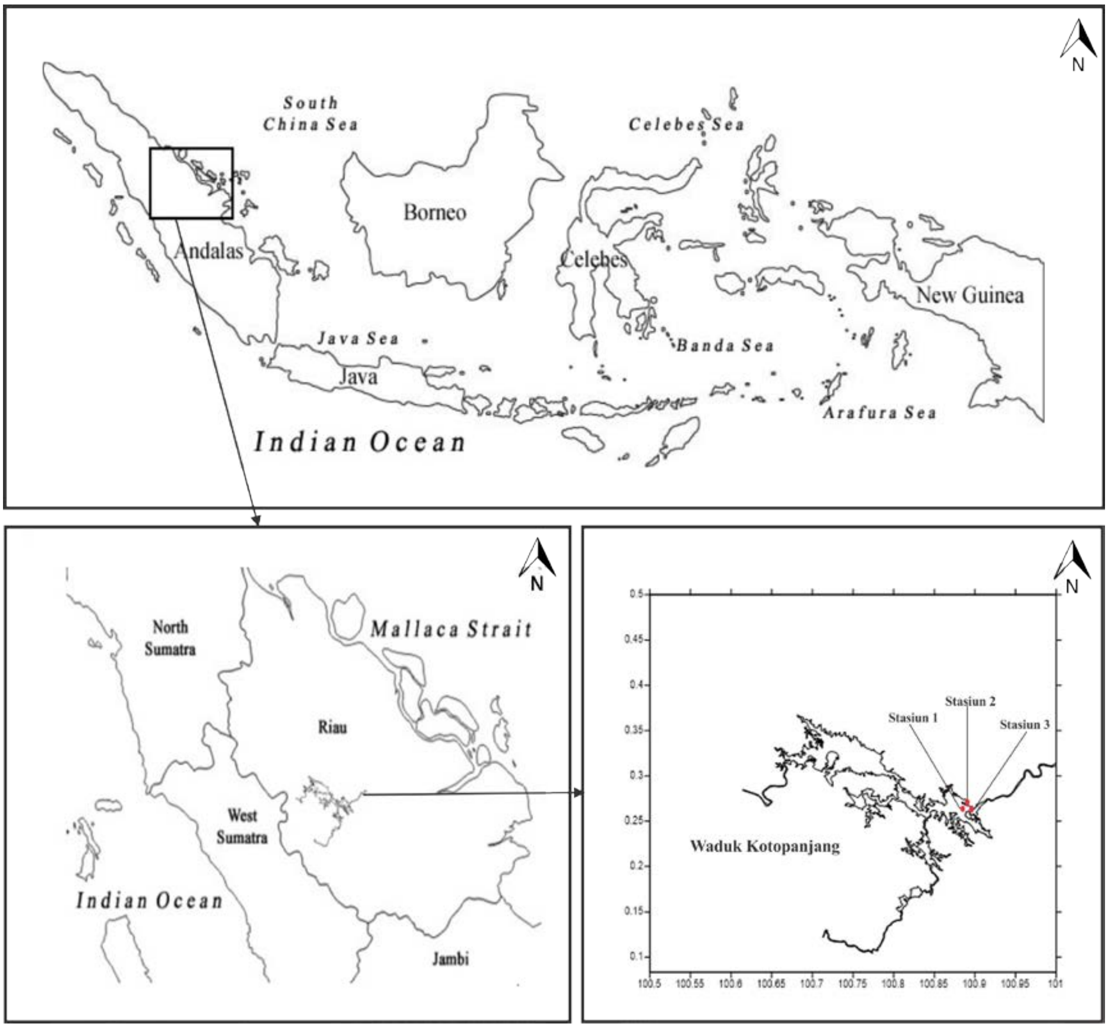

Figure 1. Map of reservoir.

The components tested are physical, chemical and biological qualities as parameters determining the trophic status of the water. Water quality parameters observed in the field was temperature, transparency, dissolved oxygen (DO), pH and carbon dioxide (CO_2). The concentration of nitrate, phosphate was analyzed in the Laboratory of Aquatic Productivity, Faculty of Fisheries and Marine Sciences, University of Riau. The biological parameters of phytoplankton were analyzed in the same laboratory as the nitrate and phosphate analyzer (APHA 2005). Site sampling consists of three stations and in each station with different depth (surface, 2 and 4 times from value of water clarity that was measured with secchi disc). This research was conducted in the field and in the laboratory and the process lasted for 5 months. Water sampling was taken in every 2 weeks from July to September 2015. Therefore water sampling and phytoplankton in the field was done as many as four replications. Water quality parameters (physical, chemical, and biological) observed are presented in Table 1.

Table 1

Water quality parameters, method and sample analysis during research

No.	Parameters	Unit	Methods	Measurements
		Physical		
1	Water temperature	^oC	Expansion	In situ
2	Clarity	cm	-	In situ
3	Water depth	m	Gravimetric	In situ
		Chemical		
1	pH	-	Color change	In situ
2	Dissolved oxygen	mg/L	Titrimetric / Winkler	In situ
3	Carbon dioxide	mg/L	Titrimetric	In situ
4	Nitrate	mg/L	Colorimetric	Laboratory
5	Phosphate	mg/L	$SnCl_2$	Laboratory
		Biological		
1	Phytoplankton	cell/L	Identification	Laboratory

Results

Water quality. The results of the water quality measurements in the Koto Panjang hydropower reservoir during the study are presented in Table 2. From Table 2 we can see that the transparency ranged from 198 cm to 255 cm, the temperature ranged from 29^{o}C to 31.7^{o}C, the oxygen from 4 mg/L to 7.17 mg/L, the recorded pH value was 5, carbon dioxide ranged from 4.49 mg/L to 11.48 mg/L, nitrate ranged from 0.02 mg/L to 0.28 mg/L and phosphate concentration ranged from 0.03 mg/L to 0.35 mg L.

From Table 2 we can see a decrease in temperature with increasing depth and there is temperature difference between the stations. The mean temperature in the present study was 31.7^{o}C. Cholik et al (1986) proposed an optimal temperature for aquatic organisms in the range of 25-32^{o}C, therefore the temperature conditions in this study are still suitable for living aquatic organisms. The mean transparency values found in the present study ranged from 164.5 to 205 cm. Such transparency is good enough for fish farming in KJA system, in accordance with the opinion of Suhadi (1989) who argued, that the minimum transparency for the cultivation in KJA system is 45 cm.

The mean oxygen concentration at the Koto Panjang hydropower area in the lacustrine zone around the dam site was 5.63 mg/L. There are several opinions regarding the requirements of DO concentration for fish culture. There are several opinions regarding requirements of dissolved oxygen concentration for fish culture. In Indonesia, the quality standard of DO is about >4 mg/L for FNC base on law number 82/2001 (Tatangindatu et al 2013) and recommended for good growth and production of some species such as parrot fish, goldfish, and carp fish. Compared the DO concentration obtained in the present study with the above opinions, the area of Koto Panjang hydroelectric dam lacustrine zone around dam site is feasible for fish farming.

The mean concentration of CO_2 during the study was 6.88 mg/L. Asmawi (1996) suggested the optimal CO_2 concentration for fish culture between 2 mg/L and 12 mg/L. So the concentration of CO_2 in this site has not endangered the cultivated fish.

Table 2

Mean water quality per station during research period

Station and Sampling point	Physical parameters				Chemical parameters				
	SD (cm)	Temp. (°C)	Depth (m)	Total Depth (m)	DO (mg/L)	pH	CO_2 (mg/L)	Nitrate	Phosphate (mg/L)
S_1 Surface		31.7	0		7.17	5.5	4.49	0.02	0.03
2SD (5.10 m)	255	31	5.1	40	5.85	5	6.49	0.04	0.07
4SD (10.20 m)		29	10.2		4.52	5	7.99	0.09	0.17
S_2 Surface		31.2	0		6.57	5.2	4.99	0.07	0.13
$S_2$2SD (3.96 m)	198	31	3.96	27	5.43	5	6.49	0.15	0.21
$S_2$4SD (7.92 m)		30	7.92		3.28	5	11.48	0.28	0.35
S_3 Surface		31.5	0		6.87	5.5	4.99	0.05	0.07
2SD (4.20 m)	210	31	4.2	28	5.44	5	5.99	0.09	0.12
4SD (8.40 m)		30	8.4		4	5	9.98	0.18	0.22

SD - Secchi Disk, S – Station, S_1 - Station 1, S_2 - Station 2, S_3 - Station 3.

The mean degree of acidity at the Koto hydropower reservoir, along the lacustrine zone around the dam site was 5.25. Concerning the pH value Asmawi (1996) suggests the range of 5-8, Pillay (1992) suggests in general for fish a range of 5-9, Parker (2002) reported that pH value of 4-6 will result a slow growth of fish and suggested an optimal pH for growth and fish production of 6.5-9. If we compare the pH of the waters from the present study with the above opinions it can be concluded that the pH range occurring in the lacustrine zone around the dam site is within the desired range.

The mean nitrate content considering all stations during the study was 0.12 mg/L. According to Goldman & Home (1983) water fertility based on nitrate concentration that is less fertile or oligotrophic is of 0.0-0.1 mg/L, medium fertile or mesotrophic water is of 0.1-0.2 mg/L and highly fertile or eutrophic water is o >0.2 mg/L). If the concentration of nitrate in this study ranged from 0.05 to 0.19 mg/L compared with the above opinions, the fertility rate of Koto Panjang hydropower reservoir around dam site is included in medium and high fertility category.

The recorded mean phosphate concentration during the study was 0.13 mg/L. Concerning phosphate concentration of the water, Goldman & Home (1983) grouping the fertility of waters over five levels: low or ultra-oligotrophic fertile (phosphate 0.000-0.020 mg/L), sufficient fertile or oligotrophic (phosphate levels 0.021-0.050 mg/L), medium or mesotrophic fertile (0.051-0.100 mg/L), excellent fertility or eutrophic (phosphate levels of 0.101-0.200 mg/L) and overly fertile or hypertrophic waters (phosphate levels 0.200 mg/L). If the phosphate levels in this study ranged from 0.1039 mg/L to 0.1465 mg/L compared with the above presented categories, the waters of the Koto Panjang Hydroelectric Reservoir around the dam site is classified in waters with good or eutrophic fertility levels.

Phytoplankton abundance. The types and abundance of phytoplankton found in each station during the study around the dam of Koto Panjang hydropower site were found four classes, Chlorophyceae, Chrysophyceae, Bacillariophyceae and Cyanophyceae. The composition and abundance of class-based phytoplankton at each station around the Koto Panjang hydropower dam site are presented in Figure 2.

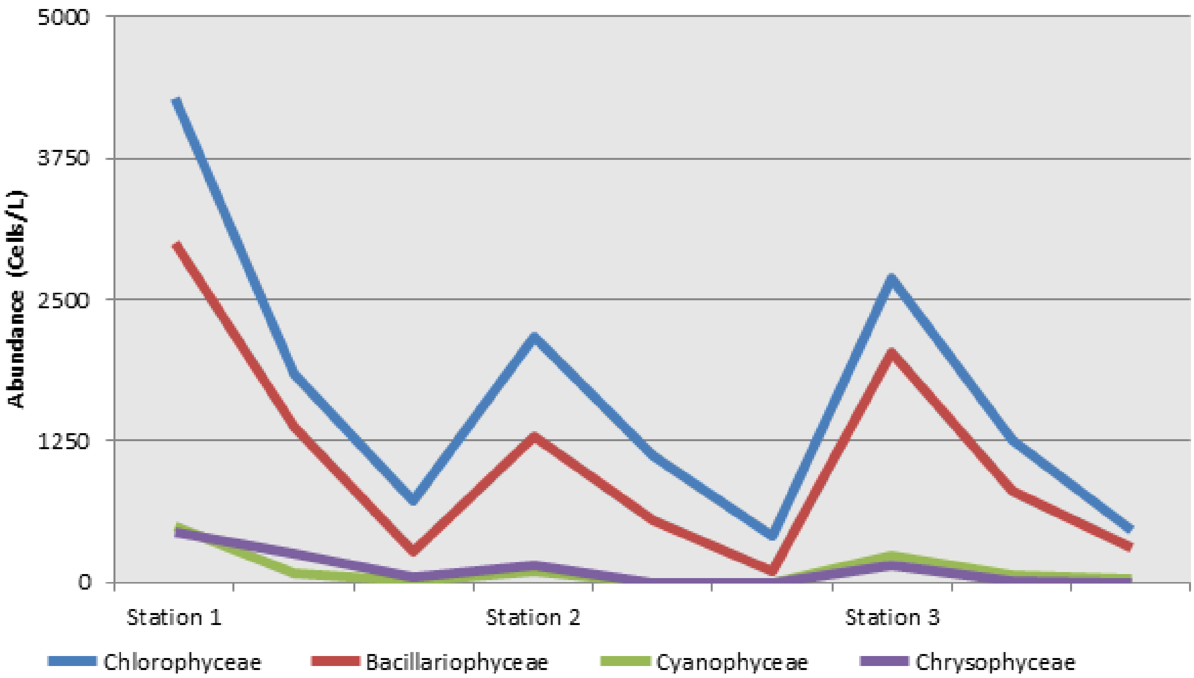

Figure 2. Composition and phytoplankton abundance (cells/L) per station. S – surface, 2 SD – 2x secchi disk depth, 4 SD = 4x secchi disk depth.

Figure 2 show that Chlorophyceae is more common than other classes; this is due to its young adaptability and rapid development. This species is a type of algae tolerant to relatively high temperatures, living colonized and grouped as stated Lukman in Salman (2012). The second class in terms of abundance was found to be the class. This is due to its tolerance to temperature, and high adaptability so that it develops quickly. According to Basmi (1999), Bacillariophyceae reproduces sexually and asexually, and contain chlorophyll a, chlorophyll c, fucoxantin and is able to live under no light conditions. The phytoplanktons of the Cyanophyceae and Chrysophyceae classes was found in low number because thee types are tolerant to certain temperatures and some types are able to bind N_2 from the air if in the water there is no nitrate. This is in accordance with the opinion of Hariyadi in Situmorang (2014) that the development of Cyanophyceae decreases when the water temperature increase.

The mean abundance of phytoplankton during the study at Station 1 was higher than at Station 3 and Station 2. The difference in phytoplankton abundance in these stations was due to different water transparency. Transparency at Station 1 was higher than in Station 3 and Station 2. This is in accordance with the opinion of Nybakken (1992) and Nurfadillah et al (2012) which states that, decreased transparency (availability of light) and nutrients will affect the process of photosynthesis and the development of phytoplankton.

Concerning the abundance of phytoplankton associated with the trophic status of the waters, according to Basmi (1999) are classified into oligotrophic (abundance <2,000 cells/L), mesotrophic (abundance 2,000-15,000 cells/L) and eutrophic (abundance >15,000 cells/L). The mean abundance of phytoplankton found around the dam of the Koto Panjang hydropower site during the study was 3,120 cells/L. Compared the obtained data with the literature standards our study sites falling into the mesotrophic waters category.

Trophic status. The indicator used to see the fertility rate occurring in a water body can be seen from the concentration of nitrate, phosphate, transparency and phytoplankton abundance. The trophic status of waters can be categorized into hypertrophic, eutrophic, mesotrophic, oligotrophic and dystrophic (Wetzel 2001). Several water quality criteria concerning the trophic status of waters can be seen in Table 3.

Table 3

The trophic status classification of waters

Parameter	*Trophic status*			*Sources*
	Oligotrophic	*Mesotrophic*	*Eutrophic*	
Transparency (m)	>6	6-3	3-1,5	Wetzel (2001)
N-NO_3 (mg/L)	<0.1	0.1-0.2	>0.2	Goldman & Horne (1983)
P-PO_4 (mg/L)	0.021-0.050	0.051-0.1003	0.101-0.200	Goldman & Horne (1983)
Plankton abundance (cell/L)	<2,000	2,000-15,000	>15,000	Basmi (1994)

To see the trophic status of Koto Panjang hydropower reservoir around the dam site in this study the parameters used was transparency, nitrate concentration, phosphate and phytoplankton abundance. Data on the measurement of transparency, nitrate concentration, phosphate and phytoplankton abundance is displayed in Figure 3.

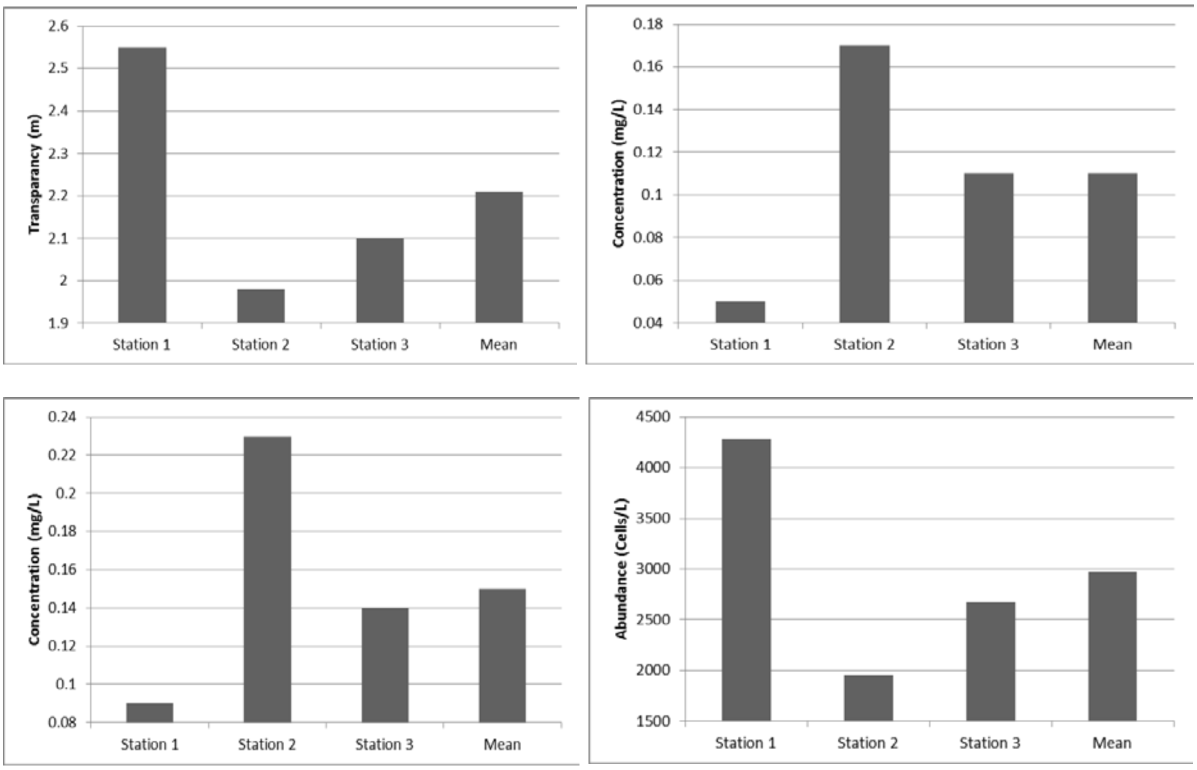

Figure 3. Transparency, nitrate, phosphate and phytoplankton abundance of the study site.

Figure 3 shows that transparency, nitrate, phosphate, and phytoplankton abundance are very different between station. In station one, near the input waters, transparency and phytoplankton abundance are very high. This is because water inputs from river provide plankton supply. Data's from Figure 3 and combined with Table 4, can be used to determine the trophic status of waters. Table 4 shows that according to the 4 parameters used, there is different trophic status in every station.

Table 4

The trophic status of Koto Panjang dam site

Parameter	*Station 1*	*Station 2*	*Station 3*	*Mean*
Transparency	Eutrophic	Eutrophic	Eutrophic	Eutrophic
Nitrate concentration	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
Phosphate concentration	Mesotrophic	Eutrophic	Eutrophic	Eutrophic
Phytoplankton abundance	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic

From the Table 4, we can see that transparency has the same trophic status in all 4 station. Based on the nitrate and phosphate concentration of Station 2 and Station 3, the trophic status is different compared to Station 1. The existence of differences in trophic status in this study on each station is suspected due to the differences in nutrient inputs in each station, especially nitrate and phosphate. In Station 1 the inputs of nutrients are from the river stream while and rarely KJA at Station 2 (solid KJA) and in case of Station 3 the nutrient input other than river flow are donated from fish farming activities from KJAs in the form of unconsumed feed and feces from aquaculture so that the nitrate and phosphate levels increase which causes trophic status to rise from oligotrophic to mesotrophic and from mesotrophic to eutrophic.

Viewed from the abundance of phytoplankton perspective, the trophic status of waters around the dam of Koto Panjang hydropower reservoir at Station 2 is oligotrophic while at Station 2 and Station 3 is mesotrophic. This is due to the fact that phytoplankton abundance is more influenced by transparency parameter than nitrate and phosphate concentration. Transparency at Station 2 is lower than at Station 1 and 3, but nitrate and phosphate concentration at Station 2 is higher, which causes the lower phytoplankton abundance at Station 2. Mujiyanto et al (2011) stated that the ratio of nitrate and phosphate is closely related to the abundance of phytoplankton in the waters.

From the mean value of the parameters determining the trophic status of the water in each station around the dam of Koto Panjang hydropower site, it is concluded that the trophic status of waters is included in the mesotrophic to eutrophic category. In researches concerning the trophic status of waters, it is advisable to look for methods which combine transparency, nitrate concentration, phosphate concentration and phytoplankton abundance or other parameters to produce a more accurate trophic index.

Conclusions. Physical (transparency), chemical (concentration of nitrate and phosphate) and biological (phytoplankton) indicators used to analyze trophic status indicate that KJA activity has an impact on water quality influencing the trophic status of Koto Panjang hydroelectric waters around dam site. Based on the indicators used, it is concluded that the trophic status of waters around the dam of Koto Panjang hydropower site is included in the mesotrophic to eutrophic category. Different parameters used show different trophic status, therefore it is suggested to find a method to determine the trophic status of waters by combining parameters as transparency, nitrate concentration, phosphate concentration and phytoplankton abundance or other parameters to produce a trophic index.

From the trophic status (mesotrophic up to eutrophic) of the waters around the dam site of the Koto Panjang hydropower plant, research results concluded that the KJAs activity contributes with organic materials to water bodies that affect the transparency, nitrate, phosphate and oxygen levels. It is advisable to analyze the ingredients content of the organic material from KJA activity, and to observe the concentration of BOD that describes the amount of organic matter content in the reservoir.

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