Plankton biodiversity based assessment for sustainable fisheries conservation in the Natural Recreational Park Dendam Lake, Bengkulu, Indonesia

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Abstract. Plankton biodiversity has been used as a bio indicator in reservoirs and stream waters to determine their water quality. This also brings us to understand the sustainability of their fish resources. This study aimed to assess the reservoirs condition by their water quality and plankton biodiversity and to determine the sustainability of their fish resources for conservation. Water quality and plankton composition and distribution (in water and fish digestive tract) were analyzed in the samples collected from the reservoir of Dendam Lake, Bengkulu, in February 2020. The water quality in Dendam Lake had the following average parameter values: a pH of 5.6, a dissolved oxygen of 3.57 mg L^{-1}, a biological oxygen demand of 5.03 mg L^{-1}, a chemical oxygen demand of 44.26 mg L^{-1} and a nitrate of 0.63 ppm. The phosphate was lower than 0.01 ppm, which is under the detection limit. A total of 24 genus of plankton were found in the lake. The biodiversity index of plankton was low: 2 sampling sources (water and fish guts) had a biodiversity index close to 1.5. In the fish digesting system there were found 27 genus of plankton. The same 5 plankton species were found in both sample types (from the lake water and from the digesting system of the fish): *Closterium* sp., *Oscillatoria* sp., *Tabellaria* sp., *Neupilus* sp., and *Draparnaldia* sp. The conclusion of this study is that in spite of the low biodiversity index of plankton in the lake, fish resources are still maintained if the relationship between water quality and plankton biodiversity (as fish diet resource) is well understood.
Key Words: phytoplankton, biodiversity, water quality, fish resources.

Introduction. The existence of lakes is very important in the ecological balance and in the water system (Ahmed et al 2015). In terms of ecology, the lake is an ecosystem consisting of water and aquatic life that is influenced by the balance of the surrounding metasystem. Dendam Lake is a water area located in Singaran Pati sub-district, Bengkulu, Indonesia, with a total surface of 88 hectares and about 53 hectares of water. Average rainfall ranges from 2,600 to 3,200 mm $year^{-1}$ with temperatures from 21 to 34°C (BKSDA 2019).

The biodiversity in lake ecosystems is affected by a number of human disturbances, due to increased nutrient loads, contamination, acid rain and invasion of exotic species. The main sources of damage and pollution of the river water quality are the industrial waste, municipal waste, household waste, clinical waste and oil. Human activity has caused ecosystems to experience pollution pressures that affect the water quality and the ecosystem composition of phytoplankton species (Nwonumara & Nkwuda 2018). Some studies show that long-standing threats to biodiversity such as eutrophication, acidification and contamination by heavy metals and organochlorines can be minor problems in the future (Bronmark & Hansson 2002).

The integrity of an aquatic ecosystem can be assessed by analyzing the physico-chemistry and the phytoplankton structure. Several studies show that the dominant and seasonal plankton will vary greatly in different water bodies, according to factors like the nutritional status, age, morphometrics and location. Therefore, plankton is often used as an indicator of the trophic state of the waters (Sampaio et al 2002). For example, microalgae of the type *Chlorella* sp. have the ability to live in polluted waters due to the phytohormone and polymine used for adapting to polluted environments (Nicziporuk 2012). Bio-indicators of pollutants are useful in predicting the extent of pollution (John et al 2003).

The biodiversity of plankton has been used as a bio-indicator in reservoirs and stream waters, in order to determine their water quality and to indicate the fish resources' sustainability, since plankton is the primary source of fish's diet. The aim of this study was to analyze the water quality condition of Dendam Tak Sudah Lake and identify micro-algae diversity in the lake at its current state. Since the status of the lake has changed from a nature reserve to a natural tourist park (BKSDA 2019), this makes it necessary to have data on the lake water biota with a new area status.

Material and Method

Study area. The Dendam Lake is located in Singaran Pati, in the heart of Bengkulu City. This lake has a geographical position at the coordinates of 3°47'45" - 3°49'01" south latitude and 102°18'07" - 102°20'11" east longitude and an altitude of 15 meters above sea level. The study was conducted in February and March 2020. Sampling was carried out at 8 location points (T1, T2, T3, T4, T5, T6, Ca1, Ca2) with a surface location (S) and a depth of 2 m (D).

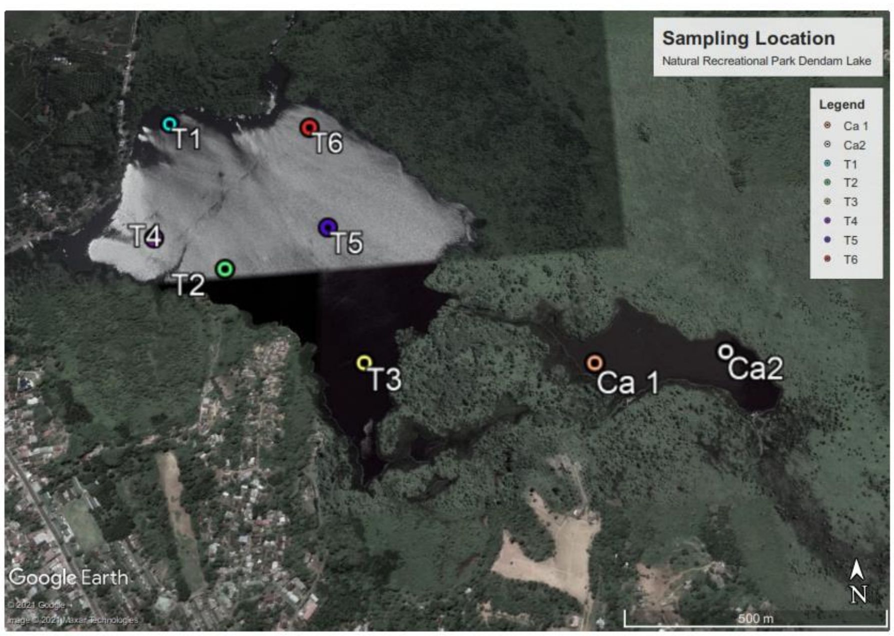


Figure 1. Map of sampling locations in the Natural Recreation Park Dendam Tak Sudah Lake, Bengkulu, Indonesia (source: Google Earth).

Water quality data. The water chemistry quality data collected were the power of hydrogen, dissolved oxygen, biological oxygen demand, chemical oxygen demand and concentration of phosphate and nitrate. Measurement of pH values was performed by dipping a pH meter into the water samples. The dissolved oxygen (DO) test was carried out by direct measurement using a DO Meter. Biology oxygen demand test (BOD) used the Winkler titration method. BOD measurements (in ppm) were carried out after an incubation period of 5 days and were determined by the following formula (APHA et al 2005):

$$BOD = n(DO_0 - DO_n)$$

Where:
n - number of incubation days;
DO_0 - DO on day 0 or beginning;
DO_n - DO on the n^{th} day or end of the test.

Chemical oxygen demand (COD) testing uses the reflux method by spectrophotometry, the principle of testing in organic and inorganic compounds especially those that are organic in a number of samples oxidized by $Cr_2O_7^{2-}$- in closed reflux produces Cr_3^+. Phosphate assessment use spectrophotometer method by ascorbic acid in water and wastewater samples in the range of 0.01 to 1.0 mg L^{-1} with a wavelength of 880 nm. Assessment of nitrates concentration in water is by spectrophotometric method with levels ranging from 0.01 to 1.00 mg L^{-1} NO_2-N.

Water physical quality assessment. Water physical quality assessment includes temperature, light penetration, Total Suspended Solid (TSS) and Total Dissolved Solid (TDS). The air, water surface and bottom waters temperature were measured. Measurement used a mercury thermometer inserted into the body of water for several minutes. The brightness of the waters was measured using a secchi disk. A piece of secchi was inserted into a body of water to a depth sufficient to hide the surface of the secchi disk. The distance to the secchi disk measured the level of the water light penetration. For the TDS and TSS tests, the water sample was filtered as much as 100 mL using a filter pipette. The filtered filtrate was used to measure the TDS content. Meanwhile, the solids retained on the filter paper were used to measure the TSS content. The calculation of TSS and TDS values required the following formula (Clesceri et al 1998):

$$TDS = \frac{(a-b) \times 1000}{c}$$

$$TSS = \frac{(a-b) \times 1000}{c}$$

Where:
a - cup mass and residue (filtered sample for TDS, and filtered residue for TSS) after heating 105℃;
b - mass of the empty cup after heating 105℃;
c - the sample volume used (100 mL).

Plankton and fish biodiversity data. Microalgae samples were taken using a plankton net with a mesh size of 45 (30-50) μm, a net diameter of the net of 20 cm and a length of the net of 30 cm. A total of 10 L of water was taken from each sampling point and passed into the plankton net. Filtered algal microorganisms were inserted into a 50 mL vial bottle and preserved with formalin and iodine lugol (Abhishek et al 2014). Samples were then identified in the laboratory of biology of UNIB. Fish diversity data were collected from the annual catches of fishermen in the area. The length, weight and abundance were measured for each sample. The biodiversity index was calculated for each sampling point, using the Shannon (1948) diversity index formula:

$$H = -\sum_{i=1}^{s} pi \ln pi$$

Where:
H '- Shannon-Wienner diversity index;
ln - natural logarithm;
pi - proportion of i-th species in the total community, equals to ni N^{-1}.

The dominance index of certain plankton species can be determined by using the Simpson dominance index formula (Simpson 1949)

$$C = \sum_{i=1}^{s} \left(\frac{ni}{N}\right) 2$$

Where:
C - Simpson dominance index;
Ni - number of individuals;
N - total number;
S - number of genders.

The level of species similarity from the sampling results was carried out using the formula for the species uniformity index (Sorensen 1948), as follows:

$$E = H'/log_2 S$$

Where:
E - species similarity index;
H' - species diversity index;
S - number of species found.

Plankton in fish digesting system. Data on fish diversity and the plankton diversity in their gut was gathered by collecting fish samples in different days and by dissecting the gut to collect samples of the ingested plankton. The fish was recorded by their length and the total of their weight. The plankton samples were sent to lab for analysis.

Results

Water quality parameter. From all of the sampling locations, the chemical quality of the waters was tested using the parameters in Table 1.

Table 1
Measurment of water chemistry quality at the surface of water and at a depth of about 2 m, in the Dusun Besar Lake's national recreation park

Parameter	*Location*	
	Water surface	*The depth of 2 m*
pH	5.663333	5.65
DO mg L^{-1}	3.596667	3.5525
BOD_5 mg L^{-1}	5.9775	3.786667
COD mg L^{-1}	29.86	65.8675
Nitrate ppm	0.577	0.725

The pH value of the lake ranged around 5. The most acidic pH was obtained at the location of the sampling point T6, whereas the pH at T3 had a higher value than in the other sampling locations. For the DO values, the T1 sampling location had a DO value of 4.8 mg L^{-1}. T5 had the second highest DO value after T1, with a concentration of 4.09 mg L^{-1}. T3 had the lowest DO value compared to other sampling locations. The highest DO values were obtained at the sampling location T1 with a BOD concentration value of 7.45 mg L^{-1}, while locations T2, T5, T6 and Ca1 had a BOD average of 5 mg L^{-1}. Ca2 had the lowest BOD concentration (3.74 mg L^{-1}). Sampling points T5 and T6 had the highest COD concentration, with a value of 52.15 mg L^{-1}. T2 and T3 had a concentration value of 31.62 mg L^{-1}. T4 had a COD value of 21.08 mg L^{-1}. The lowest COD value was recorded at T1, with a value of 10.54 mg L^{-1}. T3 sampling point had the highest nitrate level, of 0.628 ppm, compared to the other sampling locations. T5 had nitrate levels of 0.616. Low nitrate levels were observed at T4 and T2, of 0.54 and 0.52 ppm, respectively.

The analysis of the lake water quality based on the depth of the sampling location was also carried out to obtain the physical and chemical parameters. The Dendam Tak Sudah Lake had a pH value of 5.6 indicating acidic pH waters. The surface of the Dendam Lake waters had the same DO level as at a depth of 2 m, with a concentration of 3.5 mg L^{-1}. The BOD5 value at 2 m depth had a lower value, of 3.78 mg L^{-1}, while the BOD5 value at the surface of the lake was of 5.97 mg L^{-1}. The COD value at 2 m depth had a higher value compared to the surface of the Dendam Lake waters. The COD value at a depth of 2 m was of 65.3 mg L^{-1}, while at the surface it was of 29.8 mg L^{-1}. Phosphate levels were assumed to have a value below 0.01 ppm, the detection limit of the equipment in the lab. Nitrate levels at a depth of 2 m reached 0.7 ppm, a value higher than the 0.5 ppm recorded at the surface of the Dendam Lake.

The physical water quality parameters are shown in Table 2.

Table 2

Measurements of water phisical quality in the surface of water and at the depth of about 2 m in the national recreation park of the Dusun Besar Lake

Physical parameters	*Location*	
	Water surface	*The depth of 2 m*
Temperature (^{o}C)	29.66667	28.5
Light penetration (m)	0.708333	
TSS (mg L^{-1})	0.284667	0.26
TDS (mg L^{-1})	294	202.5

The highest temperature was 31°C at the point T1, which is on the surface of the water, while the lowest temperature was of 28°C, detected at a depth of 2 m, at T2D and T6D. The average temperature of the lake water was 29.2°C. Light penetration from all sampling points can reach 0.5 to 1 m into the waters except for Ca1. T4, T5 and T6 had light penetration values limited to 0.5 m, while at T2 and T3 light can reach 1 m from the water surface. At T1, light penetrated up to 0.75 m. TSS in waters reached 0.522 mg L^{-1} at T5, at a depth of 2 m from the surface, while the lowest concentration was at 0.03 mg L^{-1} at T3 at a depth of 2 m. TDS is an indicator of polluted water. TDS can be caused by organic and non-organic compounds, but in peat water TDS comes from organic material. TDS (ppm or mg L^{-1}) particles have a size of less than one nanometer. TDS can be found in all polluted water, such as industrial activity wastewater and peat water.

Plankton biodiversity. In the studied lake, biodiversity consisted of 24 species of plankton (Table 3).

Table 3

Plankton biodiversity analysis in the national recreation park of the Dusun Besar Lake

	Individual mL^{-1}											
	CA1S	*CA2S*	*T1S*	*T2S*	*T2D*	*T3S*	*T3D*	*T4S*	*T5S*	*T6S*	*T6D*	*Lake*
Total species	13	6	4	2	4	2	9	1	7	4	5	24
Total ind.	420	7.193	244	111	260	309	102	129	135	207	191	9.302
H'	1.492	0.137	0.193	0.097	0.737	0.042	1.305		0.707	0.515	0.526	0.753
E	0.323	0.951	0.930	0.961	0.618	0.986	0.430	1.00	0.707	0.750	0.767	0.632
C	0.403	0.053	0.096	0.097	0.369	0.042	0.412		0.252	0.258	0.227	0.164

S-surface; D-depth 2 m; H’-biodiversity index; E’-dominancy index; C-simmilarity index.

Most species were found in the Ca1 sampling location. The biodiversity index of the average sampling population was low. Most locations had a biodiversity index under 1.5. Their dominance index showed no significant values, while at the location T4P it showed just one species of plankton, *Cladophora*, that became dominant at that location. The similarity index showed that all sampling locations have a low score, of less then 0.5.

As shown in Table 4, eight fish species live in the waters of the Dendam Lake.

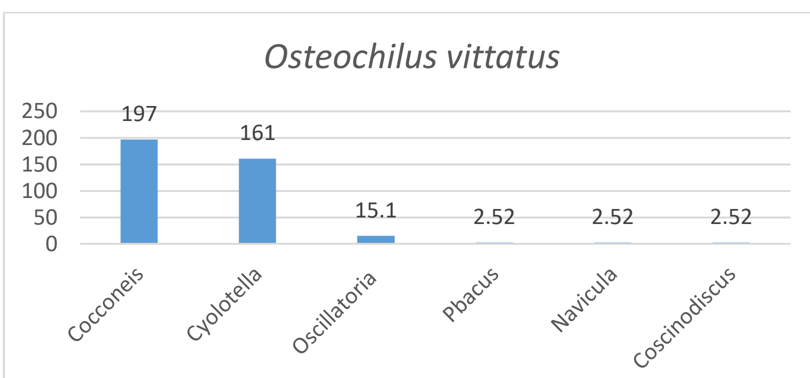
Table 4

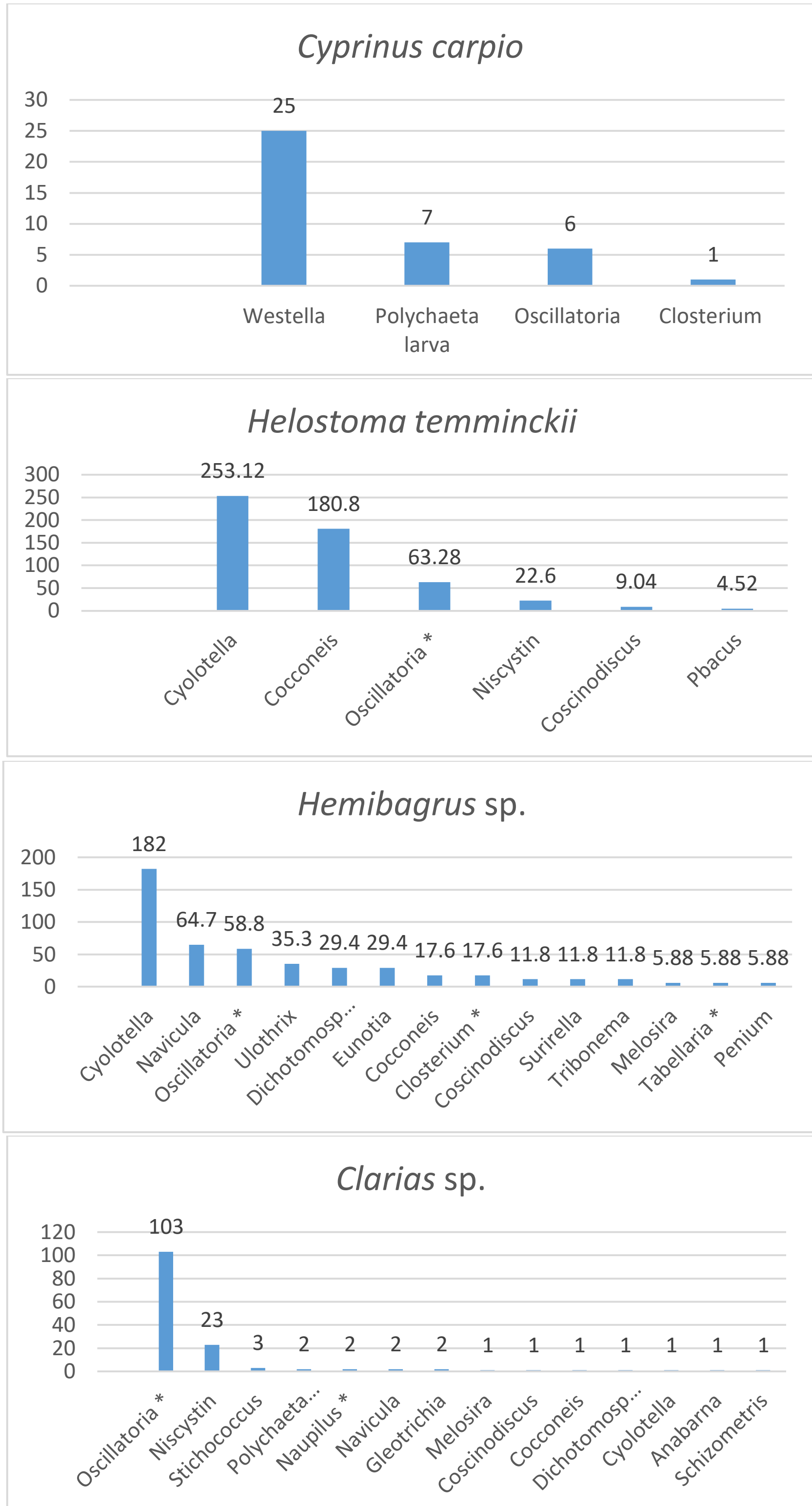
Fish diversity in the Dusun Besar Lake in the national recreation park

Local name	*Species*	*Abundance %*
Nila	*Oreochromis niloticus*	30.21
Tembakang	*Helostoma temminckii*	30.21
Palau	*Osteochilus vittatus*	5.21
Sengat	*Hemibagrus* sp.	12.50
Lele	*Clarias* sp.	4.17
Gabus	*Channa striata*	12.50
Patin	*Pangasius* sp.	4.17
Mas	*Cyprinus carpio*	1.04

The dominant species were *Oreochromis niloticus* and *Helostoma temminckii*.

Data of plankton in the fish gut is shown in Figure 1, with values fluctuating according to the fish feeding habit. Most of fish species consumed the *Oscillatoria* plankton species. Five genus of plankton were found in both collected data series (plankton biodiversity in the water and in the fish gut).





Cyprinus carpio
30
25
20
15
10
5
0
25
7
6
1
Westella
Polychaeta larva
Oscillatoria
Closterium
Helostoma temminckii
300
250
200
150
100
50
0
253.12
180.8
63.28
22.6
9.04
4.52
Cyolotella
Cocconeis
Oscillatoria *
Niscystin
Coscinodiscus
Pbacus
Hemibagrus sp.
200
150
100
50
0
182
64.7
58.8
35.3
29.4
29.4
17.6
17.6
11.8
11.8
11.8
5.88
5.88
5.88
Cyolotella
Navicula
Oscillatoria *
Ulothrix
Dichotomosp...
Eunotia
Cocconeis
Closterium *
Coscinodiscus
Surirella
Tribonema
Melosira
Tabellaria *
Penium
Clarias sp.
120
100
80
60
40
20
0
103
23
3
2
2
2
2
1
1
1
1
1
1
1
Oscillatoria *
Niscystin
Stichococcus
Polychaeta...
Naupilus *
Navicula
Gleotrichia
Melosira
Coscinodiscus
Cocconeis
Dichotomosp...
Cyolotella
Anabarna
Schizometris

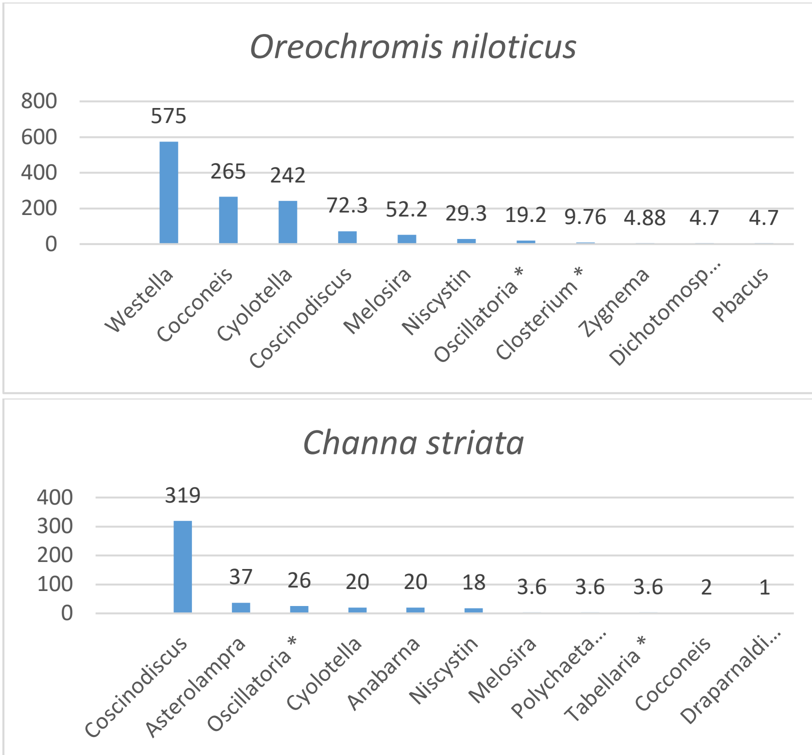


Figure 1. Plankton diversity collected from the gut of each species of fish samples.

Discussion

Water quality. The waters of Dendam Lake have the characteristics of peat waters because these waters are surrounded by peat swamps. From the observation, the area of Dendam Lake is about 53 ha or 9.11% of the conservation area. The surrounding land is a water catchment area and supplies water for Dendam Lake. In terms of layout, the waters of the lake are not in the immediate vicinity of peat forests, tourism roads and fishing activities. The waters of Dendam Lake are surrounded by swamps and peatlands, making it a lake with peat water conditions. Peat water in lakes induce pollution, as shown by blackish brown water, high dissolved solids and several other aspects. Peat water has a brown to deep black color caused by plant organic material that turns into peat, a high turbidity, a low pH value (less than seven) and high BOD and COD levels (Wosten et al 2006). The color of peat water that is brown to black is caused by the high content of organic substances (topsoil) dissolved in the form of humic acid and its derivatives (Mostofa et al 2013).

The water temperatures at the eight sampling locations in the lake did not show any significant differences. Water temperature was in the normal category, not dangerous to humans or to the environment, with values ranging from 29 to 31°C. The value of water light penetration impacts the diversity of aquatic plants in the waters and affects the high activity of water nitrification caused by non-photosynthetic activities that occur on the bottom of the waters. From the observations, light only penetrated up to 1 m from the surface of the water, which defines the zone of photosynthetic activity.

From the observations, the TDS of less than 1 nanometer in the waters of Dendam Lake have a value corresponding to a good water status. According to the Indonesian Government Regulation No. 82 (2001), if the TDS value exceeds 1,000 mg L^{-1}, it can be categorized as polluted. In addition, according to Bruvold et al (1969), drinking water has been rated by panels in relation to its TDS level as follows: excellent, less than 300 mg L^{-1};

good, between 300 and 600 mg L^{-1}; fair, between 600 and 900 mg L^{-1}; poor, between 900 and 1,200 mg L^{-1}; and unacceptable, greater than 1,200 mg L^{-1}. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste. Based on the observations, the TSS values were 277 and 334 mg L^{-1}. According to the Indonesian Government Regulation No. 82 (2001), the TSS value in water quality standards is less than 50 mg L^{-1}. The TSS value of the waters of Dendam Lake is above the established water quality standards. High value TSS can be found in all waters polluted by industry or peat waters, this is due to substances suspended in peat water in the form of mud, sand and organic and inorganic compounds (Petala 2006).

The results of pH analysis at the sampling locations showed that the mean value was below the water quality of 7.0-7.5. The low pH of the lake waters is caused by the impact of biodegradation activities that occur in the peat swamps around the lake waters. Dissolved oxygen in the waters of Dendam Lake indicates a moderately polluted condition. The majority of DO values are between 2 and 4.4 mg L^{-1}, which, according to Lee et al (1978), indicates a quality status as moderately polluted. The low concentration of BOD indicates that the organic material contained in water is mostlybiodegradable. COD levels in the lake waters are already at concentrations far below the established water quality around 2-4.4. According to Simon et al (2015), high COD levels are caused by household waste that is not managed properly before being discharged into the water, such as detergent waste and chemicals used in household activities. Phosphate levels in the waters of Dendam Lake are still far less fertile below 0.002 mg L^{-1}. This low phosphate concentration can be caused by a limited diffusion from the sediment. Sediment is the main storage place for the phosphorus cycle, occuring, generally, in the form of particulates that bind to hydroxides and iron oxides. Nitrate levels in the waters of Dendam Lake are still below safety limit of fertility in waters around 0.9-3.5 ppm (Lee et al 1978). The nitrate levels in the surface layer are mostly used or consumed by phytoplankton.

Plankton biodiversity. Plankton diversity in the waters of Lake Dendam had a very low value. From the observations, 6 plankton phyla were obtained with 3 genera. The most common genus was the Chlorophyta (green algae) group, but the greatest abundancewas obtained for the Ochrophyta (red algae) group. According to Nwankwo et al (2003) and to Silva (2005), several species from these dominant groups can detect environmental stress better than most fast-growing species, based on the physiological and behavioral flexibility.

From the observations, 8 locations (T1, T2, T3, T5, T6, Ca1, Ca2) were dominated by the genus Nitzschia. Nitzschia is a widely distributed diatom with a large number of species, some of which have important ecological benefits. This genus is mostly found in various types of inland, coastal and marine waters (Trobajo et al 2004). The high abundance of this species is due to the capacity to adapt to the physical and chemical factors of the environment in the waters. Several *Nitzschia* sp. are good indicators of heavy metal contamination (Tlili et al 2011), eutrophic and/or organic conditions (Martín et al 2010) and salinity (Rimet 2009).

Fish biodiversity. The diversity of fish in lake waters was dominated by *Oreochromis niloticus* and *Helostoma temminckii* species, each with a percentage of about 30.21% of the total fish population in the lake waters. This great abundance was due to their eating habit, indicating omnivorous species meeting their dietary needs from the nutrients of phytoplanktons and zooplanktons living in the waters. The plankton abundance did not reflect the abundance of fish at the bottom of the lake waters. The diversity of microalgae sampled from the digestive tract of fish living in the lake is an indicator useful for determining the sustainability of the fish populations in the waters of Lake Dendam, depending on the food web and on the fishing intensity.

Conclusions. Dendam Lake waters are still not very polluted, the main issue being the high levels of TSS in the waters. Other parameters have not shown signs of severe contamination. A major issue that might be experienced by the waters of Dendam Lake is the low abundance and low biodiversity of its aquatic biota, also impacting predators at higher levels of the food chain. In the future, more accurate and periodic data is needed regarding the condition of Lake Dendam's waters and of its biota.

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Conflict of interest. The authors declare no conflict of interest.

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