Conservative management of Lahor Reservoir based on eutrophication conditions due to fish farming and agriculture waste

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Abstract. The purpose of this study is to determine the condition of water quality, trophic status, abundance and type of phytoplankton, and pollution load, as well as to formulate a conservative effort for reservoir management based on Lahor Reservoir conditions in 2017. The data needed for water quality analysis are total P, NO₃-N, NO₂-N, NH₃-N, BOD, DO, TSS, and pH; hydrological and reservoir data such as rainfall data, the volume of the reservoir, reservoir catchment area, and Lahor reservoir outflow; as well as data on abundance and types of phytoplankton. The results of the water quality analysis of the Lahor Reservoir showed that it did not meet Class II water quality standards and trophic status, being eutrophic to hypereutrophic, which means the Lahor Reservoir has become polluted. The abundance of phytoplankton that occurs in the Lahor Reservoir exceeds the limit of the phytoplankton abundance that has been determined and is dominated by Microcystis blue-green algae. Therefore, the recommended efforts are bioremediation techniques, regulation of reservoir operation patterns, application of the Trophic Level-Based Aquaculture (TLBA) system, and introduction of rotifer zooplankton.

Keywords: trophic status, water purification, Lahor Reservoir, water quality.

1. Introduction

Lahor Reservoir is a reservoir that functions as a place of aquaculture, water supply to Sutami Reservoir, tourism, flood prevention, and irrigation water supply. Aquaculture activities can reduce the quality of Lahor Reservoir from the remaining fish feed that is not consumed by fish and from the waste produced by fish metabolism.

In addition, land use in the Lahor Reservoir is dominated by agricultural activities that can contribute to the burden of input in the form of organic and inorganic materials into the waters of the reservoir, which will affect the water quality of the Lahor Reservoir. The entry of organic and inorganic materials into the reservoir waters will spur the process of nutrient enrichment (eutrophication). Meanwhile, eutrophication can trigger excessive growth of certain types of phytoplankton, commonly known as algae blooms. The occurrence of algae blooms, if left unchecked, can disrupt the balance of the reservoir water ecosystem.

Therefore, in order to maintain the sustainability of reservoir waters, especially the Lahor Reservoir, and to benefit human interests, it is deemed necessary to assess the water quality condition of the Lahor reservoir and to formulate a conservative effort to manage the reservoir that can improve the quality of the Lahor Reservoir water based on the analysis of Lahor Reservoir water quality.
2. Material and Methods

2.1. Literature Study
The utilized literature is literature related to reservoirs, statistical tests, water quality, sampling, and Lahor Reservoir.

2.2. Data Collection
Secondary data was obtained from Jasa Tirta I and the Department of Public Works and Water Resources of Malang Regency, in the form of water quality parameter data such as NH$_3$-N, NO$_2$-N, NO$_3$-N, Total-P, Chlorophyll-a, Brightness, BOD, DO, TSS, and pH, as well as morphological and hydrological data of the Lahor Reservoir such as reservoir water volume data (V), reservoir surface area data (A), data (Qo). Primary data consisted of data on the type and abundance of phytoplankton in the waters of the Lahor Reservoir obtained through sampling on the field.

2.3. Preparation of Phytoplankton Sampling Tools and Materials
The tools used in sampling phytoplankton are a 25 µ size plankton net, a 5 L size bucket, a film bottle, life jackets, a drop pipette, black crackle, a cooler, ice cubes, and 1% lugol solution.

2.4. Technique of Phytoplankton Sampling
a) The plankton net was coloured by spraying using spray bottles throughout the surface of the plankton net with local water (water at the sampling point) by dipping it into the water until the entire surface was submerged.
b) The film bottle was attached to the end of the plankton net and tied.
c) A water sample was taken using a 5 L bucket and filtered using the plankton net (when the water was being filtered, the plankton net was shaken so that the plankton attached to the surface of the net can enter the film bottle).
d) Sampling was repeated at 4 other points near the sampling station, for a total amount of filtered water of 25 L for 1 station.
e) The plankton concentrate contained in the film bottle was then given a preservative, as 2 drops of 1% lugol using a pipette, and labelled with a sample identity.
f) Plankton samples that were labelled were inserted into a cooler containing ice cubes.
g) The samples were tested at the Hydrobiology Laboratory of the Faculty of Fishery and Marine Sciences of UB.

2.5. Sampling Points for Physical, Chemical, and Biological Parameters

![Figure 1](image-url)

**Figure 1.** Sampling Points for Physical, Chemical, and Biological
2.6. Data Testing
Testing utilized the F Parameters of Water Quality [1] and the RAPS Test for Rain Data [2].

2.7. Data Calculation and Analysis
a) The data obtained was classified based on wet and dry seasons, which refers to the season classification by the Meteorology, Climatology, and Geophysics Agency (BMKG).

b) The water quality data obtained was tested by a statistical test using the F test based on data that had been classified by season.

c) The obtained water quality data was compared with Class II water quality standards as outlined in Government Regulation No. 82 of 2001.

d) The results of the comparison of water quality parameters with Class II water quality standards were analysed.

e) The classification of the trophic status of Lahor Reservoir was analysed based on trophic status criteria of reservoirs by Ministry of the Environment Regulation No. 28 of 2009 [3].

f) The trophic status classification of the Lahor reservoir was determined.

g) The results of trophic status were analysed.

h) The types and abundance of phytoplankton were analysed.

i) The trophic status of the Lahor Reservoir based on the results of phytoplankton abundance according to the trophic status classification by Lander was determined.

j) The capacity of water pollutant load in the Lahor Reservoir was calculated.

k) Conservation efforts for reservoir water quality management in accordance with the water quality conditions of the Lahor Reservoir was determined.

3. Result and Discussion

3.1. RAPS Rain Data Test
Based on the RAPS Test table, it was found that for n = 12 has a value of:
Q/(n) 0.5 = 1.16 (95% chance), R/(n) 0.5 = 1.32 (95% chance). Then, Q/(n) 0.5 count < Q/(n) 0.5 table. Because the values of Q/(n) 0.5 and R/(n) 0.5 count are smaller than the values of Q/(n) 0.5 and R/(n) 0.5 table, the monthly daily rainfall data of the Karangkates station is still within consistent limits and the data is appropriate for subsequent analysis.

3.2. 2017 Season Classification
To mark the division of seasons, the BMKG uses the criteria of the amount of rainfall. The beginning of the rainy season is the first month with rainfall equal to or greater than 50 mm, while the beginning
of the dry season is the month where the rainfall is less than 50 mm. The length of the season is the number of 10-day periods from the beginning of the season to the end of the season [4].

| No. | Month       | \( H \) Month (mm) | \( H \) 10-day period (mm) | Limit \( H \) (mm) | Season Classification |
|-----|-------------|---------------------|-----------------------------|--------------------|-----------------------|
| 1   | January     | 464                 | 51                          | 50                 | Wet                   |
| 2   | February    | 283                 | 143                         | 50                 | Wet                   |
| 3   | March       | 143                 | 62                          | 50                 | Wet                   |
| 4   | April       | 256                 | 78                          | 50                 | Wet                   |
| 5   | May         | 30                  | 16                          | 50                 | Dry                   |
| 6   | June        | 23                  | 4                           | 50                 | Dry                   |
| 7   | July        | 58                  | 4                           | 50                 | Dry                   |
| 8   | August      | 2                   | 2                           | 50                 | Dry                   |
| 9   | September   | 29                  | 0                           | 50                 | Dry                   |
| 10  | October     | 77                  | 53                          | 50                 | Wet                   |
| 11  | November    | 328                 | 57                          | 50                 | Wet                   |
| 12  | December    | 189                 | 66                          | 50                 | Wet                   |

3.3. *F* Test of Water Quality Parameters for the 2017 Wet Season and Dry Season of Lahor Reservoir

Total P, \( \text{NO}_3\)-N, \( \text{NO}_2\)-N, \( \text{NH}_3\)-N, BOD, DO, TSS, PH are homogenous. From the above statement, it can be seen that the 2017 wet season and 2017 dry season water quality parameters met the variability stability test (*F* Test), which means that there was no significant difference from water quality parameter data or there was no difference between variants, and the water quality data is feasible to be used for analysis of water quality in the Lahor Reservoir.

3.4. Analysis of the Water Quality of the Lahor Reservoir in 2017

Based on the results of comparison analysis of water quality parameters and Class II water quality standards that refer to Government Regulation No. 82 of 2001 [5], the water quality parameters that did not meet class II water quality standards are \( \text{NO}_2\)-N, \( \text{NH}_3\)-N, BOD, and DO, for which the water quality parameters have the potential to cause pollution in the waters of the Lahor reservoir at depths of 0.3 m, 5 m, and 10 m in the wet season and dry season.

According to Effendi (2017) [6], nitrites are toxic for aquaculture because they can oxidize \( \text{Fe}^{2+} \). In this form the ability of the blood to bind oxygen is reduced. The mechanism of poisoning from nitrite is its effect on the transport of oxygen in the blood and tissue damage to the body of aquatic organisms. According Arifin *et al.* (2017), fish cannot tolerate very high ammonia concentrations, as this can interfere with the process of binding oxygen by blood. High levels of ammonia will also cause algae blooms, because ammonia is a nutrient that supports an increase in chlorophyll-a [7].

The high nutrient content in the reservoir results in higher levels of BOD in the water, which will cause the depletion of dissolved oxygen in the water. Low DO levels will cause a decrease in the strength of fish, affect how quickly fish eat, and decrease the metabolic process of fish in reservoir waters [8].
3.5. Calculation of Chlorophyll-\(a\) Based on Formulas

### Table 2. Trophic Status of Lahor Reservoir Based on Chlorophyll-\(a\) Parameters

| No. | Season | Location | Width (m) | O (%) | M (%) | E (%) | H (%) |
|-----|--------|----------|-----------|-------|-------|-------|-------|
| 1   | Wet 2017 | Middle   | 0.3       | 0     | 0     | 29    | 71    |
|     |         |          | 5         | 0     | 0     | 43    | 57    |
|     |         |          | 10        | 0     | 0     | 43    | 57    |
|     |         |          | 0.3       | 0     | 20    | 0     | 40    |
| 2   | Dry 2017 | Middle   | 5         | 0     | 60    | 0     | 40    |
|     |         |          | 10        | 0     | 20    | 0     | 40    |

### Table 3. Trophic Status of Lahor Reservoir Based on Brightness Parameters

| No. | Season | Location | Width (m) | O (%) | M (%) | E (%) | H (%) |
|-----|--------|----------|-----------|-------|-------|-------|-------|
| 1   | Wet 2017 | Middle   | 0.3       | 0     | 0     | 0     | 100   |
|     |         |          | 5         | 0     | 0     | 0     | 100   |
|     |         |          | 10        | 0     | 0     | 0     | 100   |
|     |         |          | 0.3       | 0     | 0     | 0     | 100   |
| 2   | Dry 2017 | Middle   | 5         | 0     | 0     | 0     | 100   |
|     |         |          | 10        | 0     | 0     | 0     | 100   |

Where O = Oligotrophic; M = Mesotrophic; E = Eutrophic; H = Hypereutrophic

Based on the results of the analysis of the trophic status of the Lahor Reservoir for various seasons and at various depths, it was found that the trophic status of the Lahor Reservoir is eutrophic tending to hypereutrophic, because most of the results of trophic status classifications by parameters of total P, total N, chlorophyll-\(a\), and brightness at depths of 0 m, 3 m, 5 m, and 10 m and the 2017 wet and dry seasons are high, which means that the condition of the Lahor Reservoir in 2017 is polluted, with high contamination. Nutrient levels in the eutrophic status are high in reservoir waters, whereas for the hypereutrophic status, the levels of elements and eutrophic processes are very high.

### 3.6. Analysis of Phytoplankton in the Lahor Reservoir

Based on the table above, it can be seen that at Station I (see Table 4), the upstream area was found to have 13 types of phytoplankton, which were dominated by the Microcystis phytoplankton with as many as 12,257,143 cells/litre with a percentage of 63.24% of the total phytoplankton abundance at station I. Meanwhile, Station II was also dominated by the Microcystis phytoplankton, with an abundance of 51,363,265 cells/litre and a percentage of 94.34% (Table 5).

Microcystis is a type of blue-green algae (Cyanobacteria) that commonly grows on the surface of the water. In blooming conditions, Microcystis can produce a toxin called microcystin, which is mainly released into the water when the cells die and break. Microcystin is highly toxic for both plants and animals, potentially causing death (Retnaningdyah C. et al., 2009). Thus, if Microcystis algae continues to grow, this will endanger the lives of fish in the waters.
Table 4. Abundance and Types of Phytoplankton at Station I

| No. | Genus     | Abundance (cell/L) | Abundance (cell/ml) | Abundance % |
|-----|-----------|--------------------|---------------------|-------------|
| 1.  | Anabaena  | 987755             | 988                 | 5.1         |
| 2.  | Microcystis| 1225714            | 12257               | 63.24       |
| 3.  | Pinnularia| 493878             | 494                 | 2.55        |
| 4.  | Chlorella | 1092517            | 1092                | 5.64        |
| 5.  | Staurastrum| 29932              | 30                  | 0.15        |
| 6.  | Closterium| 14966              | 15                  | 0.08        |
| 7.  | Merismopedia| 2828571          | 2829                | 14.59       |
| 8.  | Mesotaenium| 1152381            | 1152                | 5.95        |
| 9.  | Gloeocystis| 463945             | 464                 | 2.39        |
| 10. | Nitzschia | 14966              | 15                  | 0.08        |
| 11. | Ankistrodesmus| 14966          | 15                  | 0.08        |
| 12. | Neidium   | 14966              | 15                  | 0.08        |
| 13. | Scenedesmus| 14966             | 15                  | 0.08        |
|     | Total     | 19380952           | 19381               | 100         |
|     | Average   | 1490842            | 1491                | -           |

Table 5. Abundance and Types of Phytoplankton at Station II

| No. | Genus     | Abundance (cell/L) | Abundance (cell/ml) | Abundance % |
|-----|-----------|--------------------|---------------------|-------------|
| 1.  | Microcystis| 51363265           | 51363               | 94.34       |
| 2.  | Anabaena  | 987755             | 988                 | 1.81        |
| 3.  | Chlorella | 419047             | 419                 | 0.77        |
| 4.  | Pinnularia| 224490             | 224                 | 0.41        |
| 5.  | Merismopedia| 1242177         | 1242                | 2.28        |
| 6.  | Closterium| 14966              | 15                  | 0.03        |
| 7.  | Mesotaenium| 164626             | 165                 | 0.30        |
| 8.  | Scenedesmus| 14966             | 15                  | 0.03        |
| 9.  | Staurastrum| 14966             | 15                  | 0.03        |
|     | Total     | 54446259           | 54446               | 100         |
|     | Average   | 6049584            | 6050                | -           |

Table 6. Trophic Status of Lahor Reservoir Based on Phytoplankton Abundance

| No. | Literature | Station | Abundance (cell/ml) | Trophic status |
|-----|------------|---------|---------------------|----------------|
| 1.  | Lander     | I       | 19381               | 19381 > 15000  | Eutrophic     |
| 2.  | Lander     | II      | 54446               | 54446 > 15000  | Eutrophic     |
|     | Average    |         | 73827               | 73827 > 15000  | Eutrophic     |

Based on the calculation of the pollution load capacity with the hypereutrophic, eutrophic, and mesotrophic condition of the reservoir in the 2017 wet and dry seasons, it was found that the Lahor reservoir has the ability to handle or accommodate pollution loads without exceeding the specified water quality standards.
3.7. Recommendations on Conservation Efforts for Lahor Reservoir Management

Based on the analysis of the water quality of the Lahor Reservoir, it was found that the current state of Lahor Reservoir is contaminated by organic and inorganic materials that entered the Lahor Reservoir waters, as evidenced by the trophic status of the Lahor Reservoir being eutrophic to hypereutrophic, and analysis of phytoplankton abundance. Lahor tends to experience algae blooming because it is dominated by one type of phytoplankton from the genus *Microcystis*, which can produce a toxin that is harmful to fish life. Therefore, it is necessary to formulate conservation efforts to improve the water quality of the Lahor Reservoir, which include the following:

a) Reservoir Operation Pattern Settings

In the dry season, the movement or flow of water tends to be slow and the environmental conditions of the reservoir are also very supportive for algal growth due to warm temperatures and low winds; these conditions create an environment suitable for algal growth. Reservoir operations will help to improve water quality because they will increase the exchange of water between the main stream of the reservoir and the outlet of the reservoir, and thus the algae will move to deeper waters, preventing the algae from carrying out photosynthesis because there is no light in deeper waters. The presence of movements that cause a high current from the reservoir to the outlet will result in a higher dilution.

In this study, the hydrodynamic and water coolant models for the main stream of the reservoir and outlets were calibrated using CE-QUAL W2 software to find out the effect of reservoir operations on algae [9].

b) Application of TLBA (Trophic Level-Based Aquaculture)

In the trophic level cultivation system, the chart of fish production will be shaped like a pyramid. The number of fish that eat plankton, periphyton, and detritus (low trophic level) is far greater than the number of high-level trophic fish. In principle, all nutrient wastes of fish culture that are more abundant than nutrients retained into fish meat, are re-used for aquaculture. The utilization is performed by the addition of fish fry that eat plankton, periphyton, and detritus. These three natural food sources are mostly produced from the rest of the metabolism of pallet-eating fish. The composition of trophic fish production is low compared to the main commodity of pallet-eating fish, being 60% of waste-eating fish and 40% of pallet-eating fish.

TLBA is applied with a cultivation system that places the main and high economic value commodities (of a high trophic level) on floating net platforms, while their outer expanse contains low-level trophic commodities. According to the Directorate-General of Aquaculture, the types of fish suggested to be cultivated in floating net platforms that are of the high trophic level category are tilapia, pomfret, and jambal, while the fish types of mola, Java barb, milkfish, sharkminnow, and oscar are types that are effective for controlling pollution (Ministry of Maritime Affairs and Fisheries, 2016).

c) Introduction of Rotifer Zooplankton in Lahor Reservoir

Rotifers (*Rotifera sp.*) are a type of zooplankton that lives by preying on *Cyanophyta* phytoplankton (blue-green algae). The main foods of rotifers are phytoplankton and organic materials, especially those that settle at the bottom of the water (Isnansetyo and Kurniastuty, 1995 in Shinta, 2016). Brachionus type rotifers are very important in supporting aquaculture, especially as feed for fish and shrimp larvae (Artana, 2012 in Shinta, 2016).

In Lahor Reservoir, it is recommended to introduce rotifer zooplankton of the *Monogononta* class with the genus *Brachionus*, because in addition to being the largest class of rotifer zooplankton, it lives as a parasite in blue-green algae (Sheila Uschita *et al.*, 2015). Blue-green algae is the dominant type of phytoplankton in the Lahor reservoir.

The use of algae predators is more environmentally friendly and cheaper because in addition to not requiring the use of chemical substances, rotifers will also continue to breed and become natural feed for fish and shrimp tillers (Sinung, 2016). Rotifer culture can be obtained through collaboration with
the microbiology division of the Institute of Sciences (LIPI) or can be cultured with culture techniques.

d) Bioremediation technique
This effort utilizes in situ bacteria to reduce nitrates and inhibit growth of Microcystis. The bioremediation technique was carried out in the Sutami Reservoir by C. Retnaningdyah et al. in 2008 to suppress Microcystis blooms. Based on the results of the research, the bioremediation technique was capable of reducing nitrates by 80-85% and reducing Microcystis by 90-95%. The following are the steps for the bioremediation technique:

a. Isolation and manufacture of nitrate-reducing bacteria
   • Isolation of nitrate-reducing bacteria was carried out by making a series of dilutions with physiological salts of 0.85%; 6 isolates were used that amounted to 2 x 10^9 cells/ml, and each series of dilution was inoculated into a nitrate agar medium.
   • The utilized culture was a stock of 3 x 10^8 cell inoculums/ml; the inoculum was used for treatment.

b. Microcystis Exploration and Purification
   • Purification was carried out to maintain Microcystis cell conditions during filtration.
   • Preparation of Microcystis inoculum stock was performed by selecting cells under a microscope and aseptically inserting them into selective media to treat up to 3 x 10^5 cells/ml.

c. Effect of nitrate-reducing bacterial formulations on Microcystis growth rate
   • The culture technique was carried out by adding 3 x 10^8 cells/ml of nitrate-reducing bacteria and 3 x 10^5 cells/ml Microcystis culture into sterile water media for 15 days.
   • The parameters observed were the abundance of nitrate-reducing bacterial cells after taking a 4% formalin bacterial culture sample with 1 drop; Microcystis levels were calculated using a haemocytometer every 24 hours.

d. Effect of nitrate-reducing bacteria formulations on decreasing Microcystis phytoplankton levels in Lahor Reservoir
The addition of a 4 x 10^7 cell/ml nitrate-reducing bacteria was able to inhibit the growth of Microcystis in sterilized natural media after 6 days of incubation. The average abundance of phytoplankton decreased to 619 cells/ml at station I and 771 cells/ml at station II, where the initial abundance was 19,381 cells/ml at station I and 54,446 cells/ml at station II. The decrease in phytoplankton abundance in the Lahor reservoir will increase the trophic status of the Lahor reservoir to the mesotrophic level, where the level of nutrients present in the reservoir waters is moderate level and there is an indication of pollution, but still in the initial stages.

4. Conclusions
The condition of the Lahor Reservoir in 2017, in terms of water quality status, is affected by the water quality parameters. There are several water quality parameters that have the potential to cause water pollution, which are NO\textsubscript{2}-N, NH\textsubscript{3}-N, BOD, and DO; specifically, NO\textsubscript{2}-N 0-57% does not meet water quality standards, NH\textsubscript{3}-N 57-100% does not meet water quality standards, 100% BOD does not meet water quality standards, and DO 40-71% does not meet water quality standards at depths of 0.3 m, 5 m, and 10 m in the 2017 wet and dry seasons.

The condition of the Lahor Reservoir, in terms of trophic status, is eutrophic to hypereutrophic. This condition shows that the Lahor Reservoir is experiencing high eutrophication, which means that the reservoir water contains high levels of nutrients and indicates that the water has been polluted. Total P level of 40-86% indicates eutrophic status in the wet and dry seasons. Total N level of 20 - 71% indicates eutrophic status. Chlorophyll A level of 20-71% indicates hypereutrophic status. 100% brightness indicates hypereutrophic status.

The condition of the Lahor reservoir, in terms of phytoplankton, has an algae blooming condition, because in addition to the water condition being densely green, based on the results of the study, Microcystis phytoplankton was shown to dominate the reservoir waters. Microcystis phytoplankton dominated by 63.24% in station I and by 94.34% at station II compared to other types.
Based on the calculation of the capacity of the pollution load (DTBA) with the trophic status that has been determined are:

DTBA Hypereutrophic (2017 wet season) = 1,462,696 Kg P/wet season
DTBA Eutrophic (2017 wet season) = 378,655 Kg P/wet season
DTBA Mesotrophic (2017 wet season) = 379,608 Kg P/wet season
DTBA Hypereutrophic (2017 dry season) = 693,332 Kg P/dry season
DTBA Eutrophic (2017 dry season) = 298,346 Kg P/dry season
DTBA Mesotrophic (2017 dry season) = 21,856 Kg P/dry season

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