The impact of fish feed on water quality in Lake Cilala, Bogor Regency, West Java

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Abstract. Water quality in Lake Cilala has decreased due to fishery activity, which is now overgrowing. In 2016, fish cages were demolished since they caused eutrophication and sedimentation. There has yet a research on the impact of Lake Cilala aquaculture activity on water quality. This research was done to identify water quality in four sampling points, reflecting the fish cages distribution. Some parameters analyzed were temperature, TDS, TSS, pH, BOD, DO, phosphate, and nitrate. Besides that, the impact of fish feeds on water quality has also been analyzed based on conversion. Two water quality parameters exceeded the quality standard; total suspended solids (maximum value of 152 mg/L) and BOD (maximum value of 13.8 mg/L). The nitrogen released from the activity of fish feeding was 6.49 kg. Moreover, fish feces contributed to the nitrogen and phosphorus released by 7.03 kg and 32.82 kg consecutively. Therefore, the total nitrogen released was 13.53 kg. The highest total nitrogen concentration was solids in Lake Cilala sediment, not much-dissolved nitrogen in the water. Hence, aquaculture activity with a high number of cages in Lake Cilala affects the water quality.

1. Introduction
Various anthropogenic activities in and around ponds may cause pollution and sedimentation in the pond [1]. Water pollution carries health risks to the dense population in developing countries [2]. Water pollution in ponds also needs to be taken into account in water treatment. It is estimated that as much as 12,000 km³ of freshwater in the world has been contaminated, including lakes [3]. One of the water pollutions often found is caused by aquaculture activities. Aquaculture activities using floating cages were initially developed in Cambodia and are still often applied in Southeast Asian countries such as Cambodia, Indonesia, Laos, Thailand, and Vietnam [4]. The role of water in Indonesia has changed due to human activities affecting the water ecosystem and land modification, which functioned as a rainwater collection ecosystem [5]. Lake Cilala is located in Jampang Village, Parung Subdistrict, Bogor Regency, West Java. This lake originated from the water spring in the middle of the lake and from the running water and channel of Lake Kemang. The research conducted in 2013 showed that Lake Cilala could contain 900 units of cage sized 10 x 5 x 0.75 m³ [6]. The research also showed that the dissolved oxygen content in Lake Cilala was still ideal, approximately 4-6 mg/L [6]. In 2016, sedimentation and eutrophication occurred due to the high number of cages, resulting in cage cleaning and lake dredging. However, the number of fish cages currently cultivated by the locals is increasing and has become uncontrollable. The aquaculture activities are impacting water from the feed and material residual produced by the farming.
Fish produces organic material; thus, the amount of organic material will significantly impact the environment [7,8]. Aquatic animals' process causes organic particles dissociating and entering the water column as TSS [9]. Aquaculture activities provide waste input; hence this activity may enrich exogenous nutrients in the water [10].

This environmental impact is caused by the abundance of nitrogen and phosphorus released into the lake [11]. Nitrogen and phosphorus released into the water system may be caused by fish feed and feces [12]. A study showed that only around 20% of the fish feed used in aquaculture is eaten by fish, while the remaining 80% will become residual in water [13,14]. Fish feed contributes BOD in the water because of its high crude protein content [15,16]. The percentage of nitrogen and phosphorus in water originated from feces is 70% and 15% consecutively [17]. Another research also mentioned that feces from aquaculture activity would release 13% of nitrogen and 37% phosphorus into water [17]. However, the amounts of nitrogen and phosphorus from fish feces and residual feed are not only released in a body of water. Phosphorus and nitrogen concentrations can also be found in the water-sediment [18,19]. Almost 80% of phosphorus from aquaculture activity will settle in the water immediately [20].

This research discusses the impact of aquaculture activity on the water quality of Lake Cilala. This lake has experienced eutrophication that is suspected due to intense aquaculture activity seen from a large number of fish cages. This causes high pollutants released into the water due to the high number of fish. This research was conducted to observe the impact of fish feed from aquaculture activity on the water quality in Lake Cilala.

2. Method

2.1. Case study location and time period

Lake Cilala is a natural lake located in Jampang Village, Parung Subdistrict, Bogor Regency. Geographically, Lake Cilala is situated on the coordinate of 106°42’-106°43’ BT and 6°28’ LS. The water of Lake Cilala originated from the running water, Kemang Pond channel, and the water spring in...
the middle of the pond. According to the Bioregional Management of Jabodetabek on Profile and Management Strategy of Ponds, Swamps, and Lakes, the main water supplier of Lake Cilala is Lake Kemang channel, which is currently contaminated by plantation and domestic waste. The research location can be seen in Fig. 1. This research was conducted in November 2019-April 2020. A water sample was taken from four sample points in Lake Cilala, reflecting the distribution of fish cages and water streams.

2.2. Data collection and analysis
In supporting data analysis, the number of fish cages needs to be identified. Data on the number of cages was processed according to the site observation as primary data. However, due to the Covid-19 pandemic situation that makes it difficult to go to the site, the data was taken based on the digital calculation of online spatial map Landsat 8 of Google Earth with 2019 imaging data as secondary data.

Data on water quality was processed from the laboratory test result to check parameters comprising pH, temperature, total suspended solids, total dissolved solids, dissolved oxygen, BOD, nitrate, and phosphate. The data was processed by calculation and sorted out using Microsoft Excel.

The number of fish feed based on floating net cages population, was analyzed to determine the impact on water quality. The analysis was performed based on the conversion of fish feed into nitrogen and phosphorus in the water. Several conversions of the previous researches can be seen in Table 1. After the conversions were identified, a research analysis was done based on the literature review.

Table 1. Fish feed to nitrogen and phosphorus conversion.

| Calculation | Analysis Description |
|-------------|-----------------------|
| Residual fish feed | 20% of the total fish feed [14] |
| The number of feces generated | 260 gram every 1 kg of fish feed [21] |
| The number of phosphorus from the feces | 70% feces [17] |
| The number of nitrogen from the feces | 15% feces [17] |
| The number of nitrogen from the residual fish feed | 18% residual fish feed [22] |

3. Results and discussion

3.1. Water quality in Lake Cilala
To date, numerous floating net expansions have been performed. The existing research showed that the water capacity of Lake Cilala for fish cages is 130 tons fish/year [6]. This number indicates the maximum fish allowed to be produced to maintain the environmental sustainability and resources of Lake Cilala. Naturally, Lake Cilala can accommodate 3.77 tons of natural fish with the maximum capacity of cages. Water quality in Lake Cilala can be seen in Table 2.

Table 2. Water quality in Lake Cilala.

| Parameter | Unit | Quality Standard* | Water Quality A1 | A2 | A3 | A4 |
|-----------|------|-------------------|-----------------|----|----|----|
| Physical Parameter | | | | | | |
| Temperature | °C | ± 3 | 33.6 | 33.8 | 32.1 | 32.6 |
| TDS | mg/L | 1000 | 41.7 | 38.6 | 39.2 | 39.7 |
| TSS | mg/L | 50 | 152 | 129 | 115 | 41 |
| Chemical Parameter | | | | | | |
| pH | pH unit | 6-9 | 8.5 | 7.6 | 7.5 | 7.3 |
| DO | mg/L | 4 | 7.5 | 6.3 | 6 | 5.8 |
| NO₃ as N | mg/L | 10 | 2.43 | 2.06 | 2.07 | 2.75 |
| Phosphate** | mg/L | 0.2 | < 2.68 | < 2.68 | < 2.68 | < 2.68 |
| BOD | mg/L | 3 | 13.8 | 4.7 | 5.3 | 3.4 |
3.1.1. **Temperature.** The water temperature of Lake Cilala during sampling was between 32.1°C-33.8°C. This high temperature was caused by sampling time that was performed in bright daylight around 11.00 a.m. The high midday temperature is the time of photosynthesis for phytoplankton and aquatic plants. The natural growth of phytoplankton and aquatic plants will occur at an optimum temperature above 25°C [6]. During sampling, the water condition showed the occurrence of photosynthesis for some water organisms and plants that would affect some other parameters such as pH, BOD, and DO.

3.1.2. **Total Dissolved Solid (TDS).** The distribution of TDS concentration in four sampling points was between 38.6-41.7 mg/L. The TDS test result of Lake Cilala indicated that the water quality seen from this parameter met the quality standard of Indonesian Government Regulation Number 82 of 2001 on Water Quality Management and Water Pollution Control Class II (1,000 mg/L). The spatial or temporal trend of water quality cannot be identified from this parameter, but the highest TDS value was on A1 point.

3.1.3. **Total Suspended Solid (TSS).** The total value of suspended solids reflected the water condition seen from the organic and inorganic particle content in water. TSS concentration in Lake Cilala showed a far range of 41-152 mg/L. The only concentration of TSS that met the quality standard of 50 mg/L subject to the Indonesian Government Regulation Number 82 of 2001 on Water Quality Management and Water Pollution Control Class II on A4 point. The other sampling locations exceeded the standards. It could be found that aquaculture activity in Lake Cilala affects the water quality seen from the TSS. Aquaculture activity released residual fish feed and feces into the water, which increased the suspended solids material in water. Suspended solids contain high nitrogen, phosphorus, and carbon suspensions from the material decomposition process. It is in line with the reviewed literature that shows organic material decomposition will increase organic particles in the water column in the form of TSS [9].

3.1.4. **pH.** The pH value of Lake Cilala ranged from 7.3 to 8.5 during sampling. The sampling was performed at around 11.00 a.m. when the weather was bright and hot. As the previous temperature analysis, this condition is when photosynthesis occurs in organisms and aquatic plants in the research location. According to the sampling time, the increase of pH is in line with the literature study, where photosynthesis can increase the pH value of the waters due to intense sunlight. The existing condition still reflects the natural condition of the water's pH in general. However, the A1 sampling point was indeed having a high pH (8.5), almost reaching nine as the maximum limit of the water quality standards. Compared to the natural phenomenon, the pH value was within safe limits since the sampling was performed when photosynthesis occurred.

3.1.5. **Dissolved oxygen (DO).** Dissolved oxygen is oxygen in waters generated from air and photosynthesis by-product. The concentration of dissolved oxygen in Lake Cilala during measurement was ranging between 5.8-7.5 mg/L. Aquaculture activity in Lake Cilala did not directly affect the dissolved oxygen in the water. Dissolved oxygen will change if the aquatic plant's growth is excessive due to nutrient pollutants resulting from aquaculture activity. Therefore, it can be concluded that the water quality of Lake Cilala reviewed from the concentration of dissolved oxygen is still in good condition.

3.1.6. **Nitrate (NO₃).** Nitrate in water may cause eutrophication. The result showed that the nitrate concentration in Lake Cilala was ranging from 2.06-2.75 mg/L. This nitrate concentration follows the quality standard of Indonesian Government Regulation Number 82 of 2001 on Water Quality
Management and Water Pollution Control Class II. This value indicates that the water in Lake Cilala is in good condition. Low nitrate concentration in water justifies that aquaculture activity has yet contributed to the nitrate concentration. This sampling was performed in the rainy season in November 2019. Rainfall can dilute the nitrate concentration. In a temporal dynamic, nitrate concentration will be higher in the dry season when the temperature is higher, and rainfall is lower. Hence, this research concludes that aquaculture activity in Lake Cilala does not release high nitrate pollutants due to the low nitrate concentration.

3.1.7. Phosphate (PO$_4^{3-}$). The water quality test result for this parameter showed a minimum result in all sampling locations. The concentration was below the detector value, which was $< 2.68$ mg/L. The high number of fish cages should have escalated the phosphate concentration value. This high phosphate content was presumably resulted from the fish feed residual deposit. Previous research showed that the waste from fishery activity $> 60\%$ in phosphorus [12].

Nevertheless, the test result showed a low orthophosphate concentration. Previous research showed that at least 10% of the feed residual in water would immediately settle at the bottom of the water [12]. Moreover, a study also found that almost 80% of phosphor released from aquaculture activity will immediately settle in the bottom of the water [20]. In addition to the aquaculture waste settled in the bottom of the water, the waste is also released in water in dissolved phosphate. Dissolved phosphate in the form of orthophosphate is needed by plankton, algae, or aquatic plants. In the bright daylight, it showed the peak of photosynthesis during sampling so that orthophosphate was assimilated into algae. This phenomenon caused the orthophosphate to have a low concentration, even below the detector value. This is justified from previous research, which states that low concentration of orthophosphate could also be because of the direct dissolved phosphate absorption by water organisms, such as algae and bacteria, and/or adsorption into particles will settle as time passes by [12].

3.1.8. Biochemical oxygen demand (BOD). BOD value was ranged between 3.4-13.8 mg/L, reflecting a very high concentration in water. The high concentration of BOD exceeds water quality in the Indonesian Government Regulation Number 82 of 2001 on Water Quality Management and Water Pollution Control Class II. The highest concentration was in A1 point, which was reaching 13.8 mg/l. BOD's high concentration was due to the high content of crude protein of the fish feed, such as pellets [15]. Observing the intense aquaculture activity in Lake Cilala, this high BOD concentration also reflects the number of fish in the water. It is in line with research mentioning that more fish enable more organic material decomposition so that the BOD concentration will be high [8].

High BOD concentration corresponds to its relation with high TSS concentration. The water quality in Lake Cilala seen from the TSS concentration increases from A4 to A1 point. The same goes for the BOD concentration. It concludes the correlation between TSS and BOD, where the higher the TSS, the higher the BOD concentration will be. This result indicates the tendency between BOD and DO that is different from the existing theory. The existing theory said that the higher the BOD concentration, the lower the DO concentration. During data collection, the BOD concentration tended to get lower from A1 to A3, but the highest BOD concentration was at A4. The same goes for the DO concentration showing a tendency to get lower from A1 to A4 point. However, the DO concentration in Lake Cilala was well monitored, even though the BOD concentration was high. Such condition is influenced by the sampling time, which was at midday when aquatic plants and phytoplankton had photosynthesis. The photosynthesis results are glucose and oxygen, causing the dissolved oxygen concentration to increase at that time. It is supported by water concentration that was reaching alkaline at A1 point (pH = 8.5).

3.2. Impact of fish feed on water quality

The fish feed used by farmers in Lake Cilala were pellets and worms. The pellets usually bought by fish farmers were mass-produced fish feed. Pellets mostly contain protein, crude fiber, and oil because they are made from unvalued fish or fish that cannot be consumed, known as trash fish [16]. The research in Lake Cilala did not calculate the trophic index since the Chl-a parameter was not observed. However,
the research conducted in Lake Cilala was done to determine whether aquaculture activity can potentially impact water quality. Aquaculture activity released the highest nutrient from the residual fish feed, followed by the number of feces.

The research conducted by a brief interview with the farmers while observing Lake Cilala revealed the estimation of feeding to each cage amounting to 10 kg per month. Floating net cages with a total of 541 units became the calculation basis for the fish feed released into Lake Cilala. A total of 20% of fish feed are to be released into the cages as residual every day [14], which showed that the amount of fish feed released into the water is 36.07 kg. Nitrogen release from this fish feed residual amounted to 6.49 kg. The estimation of fish feces from this aquaculture activity was also calculated based on the number of the existing floating net cages. The number of feces released into the water was calculated as much as 46.89 kg. Fish feces contributed to the nitrogen and phosphorus release of 7.03 kg and 32.82 kg consecutively.

According to the existing calculation, the total nitrogen and phosphorus released into water from the feeding of 333.33 gr of fish feed per day per cage is 13.52 kg and 32.82 kg simultaneously, as seen in Fig. 2. The high concentration might increase the nitrate and phosphate content in water, potentially causing eutrophication. The potential of eutrophication would then be a concern for the next researcher. Nevertheless, this calculation does not directly reflect the NO$_3^-$ and PO$_4^{3-}$ concentration level discussed in the present study. The calculation result showed that the total nitrogen concentration in solids was released into the water.

![Figure 2](image)

**Figure 2.** Illustration of fish feed conversion to nitrogen and phosphorus.

The writer predicted that the high concentration of nitrogen in the sedimentation of Lake Cilala is not dominated by dissolved nitrogen in the water. This finding could be justified by the references showing that nitrogen concentration in water will be high if the bottom water and sediment have a reductive environment [14]. Therefore, Dissolved Inorganic Nutrient (DIN) containing 89% NH$_4^+$ and 11% (NO$_2^-$ + NO$_3^-$) can be found on the surface. Moreover, similar research mentioned that in summer, the sediment environment tends to be more reductive so that NO$_2^-$ and NO$_3^-$ are diffused from water to sediment due to the negative flux of NO$_2^-$ and NO$_3^-$. Because the ambient temperature is relatively high, it was then adopted by the increasing number of nitrogen in Lake Cilala to be found in the lake sediment. It is still unknown whether Lake Cilala has a high nitrogen-based nutrient circulation.

This research did not measure the sediment quality observed from the nitrogen and phosphorus parameter concentration. However, this research result showed the possibility of a high nitrogen and...
phosphorus concentration found in lake sediment. It is related to the calculation result indicating the high total concentration of nitrogen and phosphorus from the aquaculture activity in Lake Cilala.

The research mentioned that in addition to fish feces, residual feed contributed to the high concentration of phosphorus and nitrogen in sediment [19]. The literature review also mentioned that some aquaculture activities produce heavy metal in the sediment. Therefore, it can be concluded that nitrogen and phosphorus concentration from aquaculture activity affected by the excessive use of fish feed will be mostly found in the sediment of Lake Cilala. Further research on sediment quality needs to be conducted.

Aside from the nitrogen and phosphorus concentration, fish feed surely contributed to the other pollutant parameters, such as TSS and BOD. The water quality results in Lake Cilala showed a high TSS value. Due to the abundant residual fish feed having the same density as water, resulting in the floating residual fish feed. This material then became suspended solids in water as TSS. Other than TSS, BOD concentration in Lake Cilala also exceeded the quality standard. Fish feed was very influential in this concentration. The fish residual feed calculation of 39.02 kg per day contributed to the BOD pollution in water. It is because the type of feed used by farmers in Lake Cilala was pellets. Pellets, as described in the literature review, have high crude protein content. This high crude protein causes high BOD concentration [15].

4. Conclusion
There is a decrease in water quality caused by aquaculture activity in Lake Cilala. Two chemical parameters exceed the quality standard, namely TSS (maximum value of 152 mg/L) and BOD (maximum value of 13.8 mg/L). These two parameters reflect that the dominant impact of aquaculture activity is from residual feed release in water, also residual material produced by fish, such as feces. The high number of cages emphasizes that the fish feed released into Lake Cilala is considerably high. This contributes to release the suspended solid containing high nitrogen and phosphorus compounds, 13.5 kg, and 32.8 kg consecutively. However, nitrogen (in the form of nitrate/\(\text{NO}_3^-\)) and phosphorus (in the form of orthophosphate) compounds are low since most of them are in the form of Lake Cilala's sediment dissolved in water. Further research on the impact of fish feed on sediment quality still needs to be done.

Acknowledgements
This paper is supported and funded by International Indexed Publication Grant for Student Final Project (PITMA B) with NKB-1026/UN2.R3.1/HKP.05.00/2019 by the University of Indonesia 2019.

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