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Impact of Lapindo Muds in Aquaculture Ponds on Periphyton Growth

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Abstract: This study aimed to determine the abundance, diversity, and periphyton dominance in the pond using Lapindo mud that cultivated catfish of different sizes. The method used was descriptive quantitative, describing the relationship between the pool using Lapindo mud and fish cultivation of different sizes on the growth of periphyton on the walls of the pond. In this research, there were three different treatments: treatment A (100% Lapindo mud), treatment B (75% Lapindo mud), and treatment C (50% Lapindo mud). There were also three groups of catfish sizes: 4 cm, 6 cm, and 8 cm. The simple linear regression test showed that the age of the fish did not affect the growth of periphyton, while different concentrations of Lapindo mud influenced the growth of periphyton. In all ponds, the Cultivation Diversity Index was still relatively low. The results of periphyton diversity research in the polluted waters of Lapindo mud indicated the dominance index value and the highest abundance of Bacillariophyceae. The most common types of Bacillariophyceae were *Amphora* and *Diatoma*. The abundance of the genus indicate that they are easy to adapt to contaminated water areas.

Introduction

The hot mud of Lapindo is a semi-solid waste mixture containing crude oil material originating from the oil exploration activities by PT. Lapindo Brantas. The exploration and drilling activities are located in the Porong District, Sidoarjo, East Java. The eruption of hot mud from Lapindo began on May 29, 2006, and continues to date. The eruption discharge of mud reaches 120,000 to 135,000 m3/day. Additionally, there have been 116 other ventilation holes appearing in the last approximately four years, resulting in separated water from mud sediment ranging from 35,000 to 84,000 m3/day (1)

The Sidoarjo hot mud is a result of the overflow of mud eruptions in the Porong area, Sidoarjo. The overflow of Sidoarjo hot mud is located 10 km northeast of Mount Penanggungan, near the Banjarpanji exploration well, in the Reno Kenongo Village, Porong District, Sidoarjo Regency, East Java. The overflow of mud contains a significant amount of volcanic material accompanied by gas, hence the term "mud volcano" for such gas eruptions. This mud overflow disaster has been ongoing for nearly 7 years and has resulted in significant losses, especially for the residents of Porong, Sidoarjo (2).

The Lapindo mud has become a source of problems for livelihoods. On the other hand, researchers conduct experiments to explore information, whether positive or negative. Previous research, substituted cement with Lapindo mud in the context of volume to determine the most ideal mixture composition in terms of compressive strength and water absorption of solid concrete bricks (3).

Periphyton serves as a primary inorganic producer occupying a pivotal role in food formation within aquatic ecosystems, thus playing a crucial part in the survival of aquatic organisms. Besides being utilized as natural feed, periphyton can also serve as a bioindicator of water quality. Naturally, periphyton adheres and remains fixed to submerged substrates such as plant roots, rocks, wood, and other submerged objects, thereby exhibiting a tendency to accumulate more pollutants from those areas compared to other aquatic biota (4). Periphyton is one of the natural fish feeds and has been used in limited quantities for several fish species such as Tilapia (5). Periphyton forms on submerged substrates. Research on periphyton remains limited to date, primarily focusing on substrate variations and fertilization (6). The presence of periphyton is inseparable from the substrate it inhabits. Periphyton communities found on different substrates have the potential to generate distinct community structures. Environmental activities within the lake also influence periphyton growth. This underpins the need for further investigation into periphyton on Lapindo mud substrates in aquaculture ponds.

The input of organic materials and mud waste into the pond increase turbidity and pollution in that area. This affect the diversity of phytoplankton and periphyton therein due to uneven nutrient availability (7). Based on this description, it's important to study the diversity of periphyton in ponds that have different concentrations of Lapindo mud.

Experimental Section

Test Parameters

Testing of parameters is conducted by calculating the abundance of periphyton found in each pond and then determining the diversity index and dominance value. The calculation of periphyton abundance is based on the Equation 1 (8).

$$K = \frac{N \times At \times Vt}{Ac \times Vs \times As}$$ **Equation 1**

Where K = periphyton abundance (cells/cm2), N = number of periphyton observed, As = substrate area (cm2), At = cover glass area (mm2), Ac = sweep area (mm2), Vt = periphyton sample volume (mL), and Vs = observed sample volume (mL).

The Shannon-Wiener index is used to calculate species diversity index, uniformity index, and dominance index with the Equation 2 and 3 (9):

$$H' = -\sum \left(\frac{ni}{N}\right) ln\left(\frac{ni}{N}\right)$$ **Equation 2**

$$D = \sum \left[\left(\frac{ni}{N}\right)^2\right]$$ **Equation 3**

Where H' = Shannon Wiener diversity index, D = Simpson dominance index, ni = number of individuals of genus i, and N = total number of individuals of all genera.

Data Analysis

In this research, the method used is quantitative description and the analysis used to determine the effect of Lapindo mud concentration and fish size on periphyton abundance is simple regression analysis, and the explanation is in the description according to the actual incident.

Result and Discussion

Relationship between Fish Size in Aquaculture Ponds and Periphyton Growth

Based on the results of simple linear regression between the size of catfish and periphyton abundance (Figure 1), it was found that in ponds using 100% Lapindo mud (A) with different fish sizes, there is a negative linear relationship with y = 1680.15 - 86.07x and correlation coefficient (r) = 0.438.

This equation indicates that fish size influences 43.8% of periphyton abundance, while 56.2% is influenced by other factors. Similarly, in ponds using 50% Lapindo mud (C), a negative linear relationship was found with y = 2377.34 - 29.79x and correlation coefficient (r) = 0.057. This equation suggests that fish size only influences 5.7% of periphyton abundance, with 94.3% influenced by other factors. Ponds using 75% Lapindo mud (B) showed a positive linear equation, y = 855.38 + 88.21x, with a correlation coefficient (r) = 0.758. This indicates a strong relationship between fish size, with 75.8% influencing periphyton growth and 24.2% influenced by other factors.

From this data, it can be observed that the influence of catfish size on periphyton growth is minimal and uncertain. The different sizes of catfish still have some influence, albeit minimal. This is also related to previous report, where natural catfish food consists of plankton, small crustaceans, snails, worms, and mosquito larvae (10).

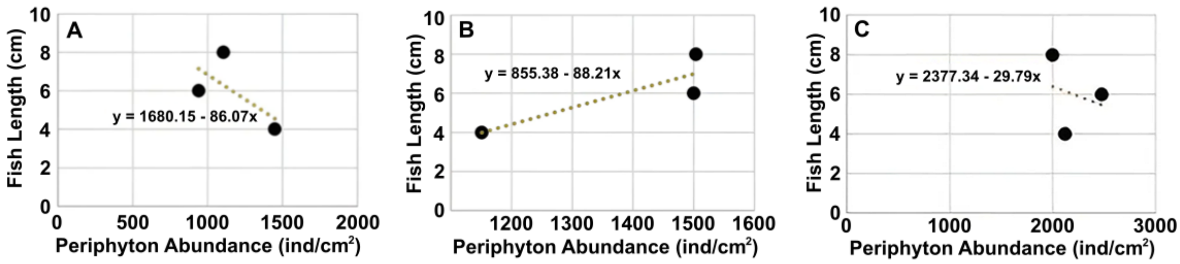

Figure 1. Relationship between periphyton abundance and fish size.

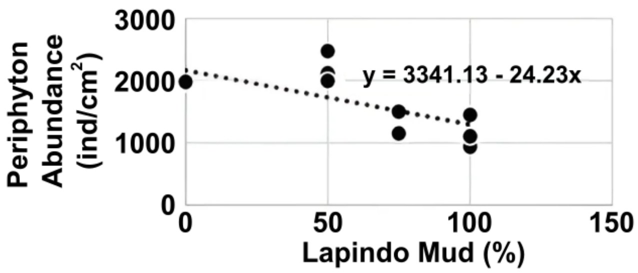

Figure 2. Relationship between periphyton abundance and pond wall treatment using Lapindo mud.

In the case of 100% Lapindo mud treatment (A), a moderate negative relationship (r = 0.438) suggests that increasing fish size tends to reduce periphyton abundance. This could be due to the presence of substances in the Lapindo mud that affect periphyton growth or nutrient availability in the water. Additionally, larger fish might actively consume more periphyton or cause greater water turbulence, hindering periphyton growth. While larger fish can grow under these conditions, there may be a limitation on periphyton abundance as a natural food source.

For the 75% Lapindo mud treatment (B), the data shows a strong positive relationship (r = 0.758), indicating that increasing fish size is associated with increased periphyton abundance. This composition might create a more balanced condition for periphyton growth, allowing larger fish to utilize periphyton as an additional food source. This situation is beneficial for aquaculture because the abundant natural food source can support the growth of larger fish.

In contrast, the 50% Lapindo mud treatment (C) reveals a very weak negative relationship (r = 0.057), suggesting that fish size has an almost negligible effect on periphyton abundance. This might be because a 50% composition does not adequately support periphyton growth or other factors such as water quality or competition with other microorganisms might dominate. This condition might not be optimal for aquaculture relying on periphyton as a primary food source, necessitating adjustments in pond management to ensure good fish growth.

Relationship between Lapindo Mud Concentration in Aquaculture Ponds and Periphyton Growth

Based on the results of simple linear regression between Lapindo mud concentration and periphyton abundance (Figure 2), it was found that in ponds using Lapindo mud, there is a negative linear relationship with periphyton growth, with the equation y = 3341.13 - 24.23x and correlation coefficient (r) = 0.851. This equation indicates that mud concentration influences 85.1% of periphyton abundance, while 14.9% is influenced by other factors.

Observations in each pond showed that periphyton types fluctuate. The presence of periphyton can serve as a bioindicator of changes in aquatic environments due to ecosystem imbalances caused by pollution (11). This is based on the fact that periphyton generally plays a significant role as a primary producer in aquatic ecosystems, has a short life cycle, and many species are sensitive to environmental changes.

The low diversity of periphyton is also observed in this study. Each treatment of Lapindo mud shows low diversity. Water pollution is caused by the entry of pollutants, which can be gases, dissolved substances, and particulates (12). This pollution can lead to a decrease in diversity or extinction of aquatic organisms such as benthos, periphyton, and plankton, disrupting aquatic ecosystems. Aquatic ecological systems have the ability to purify the environment as long as pollution remains within the carrying capacity of the environment.

The results of periphyton diversity research in waters polluted by Lapindo mud do not show dominance of the Bacillariophyceae class, but in each pond with different concentrations of Lapindo mud, there are species belonging to this class with the highest abundance. The most commonly found species of Bacillariophyceae are *Amphora* and *Diatoma*. The abundance of these genera indicates their adaptability to polluted aquatic environments. The genera *Oscillatoria*, *Navicula*, and *Nitzschia* have high tolerance to pollutants. Previous research showed that these genera are biological indicators in organically polluted waters (13). The phytoplankton in the lower reaches of the Musi River and found dominance of the genera *Oscillatoria* and *Diatoma* (Bacillariophyceae) in waters classified as 'moderately polluted' (14). The *Oscillatoria* sp. species are often found in environments with high organic nutrient content. *Navicula* and *Nitzschia* can be use as bioindicators of periphyton. The diatom species *Nitzschia*, has broad tolerance to organic pollution, and can act as an indicator in moderately to heavily polluted waters (15, 16). Each type of periphyton has an optimum limit for its environmental factors. An organism with high tolerance will be able to survive in polluted ecosystems, while those with low tolerance will perish. Based on this research, *Oscillatoria*, *Navicula*, and *Nitzschia* can survive in polluted water conditions, making them potential biological indicators for polluted waters.

Predation and competition play significant roles in this ecosystem. Larger fish may prey more on periphyton or other organisms competing with periphyton, leading to changes in the community of periphyton and other organisms in the pond. Additionally, larger fish are typically more active, resulting in more frequent stirring of mud and water, affecting the microenvironment where periphyton grows.

High periphyton abundance provides a sustainable natural food source for fish, reducing reliance on artificial feeds. Fish grown with natural food typically have better meat quality and are more resistant to diseases. Maintaining a balance between periphyton abundance and fish population is crucial for pond ecosystem health. Too much or too little periphyton can disrupt this balance and affect fish growth. The data highlights the importance of proper pond management, including the adjustment of mud composition, monitoring water quality, and managing fish populations to achieve an optimal balance between periphyton growth and fish growth.

Aquatic Environmental Factors

Based on the average temperature data in the experimental ponds using catfish (*Clarias* sp.) in groups 1, 2, and 3, the morning water temperature was 26°C. The average temperature during the day was 28.6°C, and in the afternoon, it was 26.4°C. With these average temperatures, it can be said that the water conditions are still within optimal limits. The optimal range of water quality for catfish farming is in the temperature range of 25–30°C (17), these temperatures are suitable for the growth of algae, especially *Diatoms* (20–30°C) and *Chlorophyta* (27–35°C), while *Cyanophyta* are more tolerant of higher temperature ranges (18).

Dissolved oxygen observations were conducted in the morning because photosynthesis stops at night, but respiration continues. The pattern of oxygen changes in water causes daily fluctuations in oxygen in the euphotic layer of water. The minimum oxygen levels in water occur in the morning (18). The average dissolved oxygen concentration from all treatments was 6.7 mg/L. Therefore, with dissolved oxygen levels exceeding 5 mg/L, the water is still within the normal range. Dissolved oxygen is essential for fisheries activities. A dissolved oxygen concentration of 5 ppm or more is necessary for catfish production. Periphyton acts as a primary producer by producing oxygen and is one of the producers of organic matter in rivers. Primary productivity is the amount of organic matter produced by autotrophic organisms with the help of sunlight (19).

The average pH value of the research ponds during the study ranged from 6.48 to 9.1, with an average value of 8.0, this range is within natural water conditions. Based on observations, the pH values obtained do not show significant differences. The pH value determines periphyton dominance in water and a good range for aquatic biota (18). Generally, blue-green algae live in neutral to alkaline pH and have a negative growth response to acid conditions (pH <6), while diatoms in neutral pH ranges support their species diversity (19).

The average nitrate concentration in each treatment was relatively high at 10.3 mg/L. The maximum allowable nitrate concentration in water is 10 mg/L (20). Nitrate concentrations in water exceeding 5 mg/L indicate pollution in the water. The high nitrate and nitrite levels are believed to be related to the application of Lapindo mud and agricultural activities.

Nutrient and oxygen levels are crucial for periphyton growth. Periphyton requires nutrients like nitrogen and phosphorus, and if Lapindo mud affects water quality by altering these nutrients, periphyton growth will be impacted. Additionally, oxygen levels are vital for both periphyton and fish. Mud that increases or decreases oxygen levels will directly affect these organisms.

The pH and temperature of the water, influenced by the Lapindo mud, are also critical for maintaining a balanced pond ecosystem. Extremes in pH can inhibit periphyton growth, while non-ideal temperatures can affect the metabolism of both fish and periphyton, leading to suboptimal growth conditions.

Conclusion

Based on the results of the research conducted, several conclusions were drawn. Catfish raised under treatments A, B, and C, with sizes of 4, 6, and 8 cm respectively, can survive and thrive in ponds with Lapindo mud added to the wall layers. Different sizes of fish have minimal impact on the presence of periphyton, while Lapindo mud in the ponds significantly influences periphyton growth, with the best growth observed in pond C, which had a 50% concentration of Lapindo mud. Periphyton with the highest dominance index belongs to the class Bacillariophyceae, with genera *Amphora* and *Diatom*. However, the overall diversity index of the cultivated ponds remains relatively low.

Declarations

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Contribution: Conceptualization, Data Curation, Formal analysis, Methodology, Writing - Original Draft.

Conflict of Interest

The author declares no conflicting interest.

Data Availability

The unpublished data is available upon request to the corresponding author.

Ethics Statement

Not applicable.

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Not applicable.

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