The growth of tilapia (*Oreochromis niloticus*) in floating cages treated with aquatic plants in a post coal mining void

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Abstract. Water quality improvement is essential for fish cultivated in ponds, since water quality problem may lead to the mortality of fish, especially in post coal mining void, which rely solely on rain for water exchange. One method to handle water quality problems is using aquatic plants. Some aquatic plants have capability of removing or destroying contaminants from the water. The objective of this study was to examine the effect of aquatic plants on water quality and fish growth. The experiment was conducted in a post mining void in Loa Bahu, Samarinda, East Kalimantan, using a randomized block design with 4 treatments (including control) and 5 repetitions. Three aquatic plant species, namely *Salvinia molesta*, *Pistia stratiotes*, and *Eichhornia crassipes,* were placed individually in fish cages. Every cage of 2 x 2 m was supplied with 80 (*Oreochromis niloticus*) and cultivated for 3 months. The results showed that the aquatic plants increased the dissolved oxygen concentrations and maintained water temperatures and pH levels. These plants were also able to decrease NO_2, NH_3, and H_2S. The growth rate of tilapia reared in cages with aquatic plants was significantly higher than in the control (without plants).
Key Words: phytoremediation, aquaculture, water quality, contamination, fishpond.

Introduction. Post-coal mining voids have been intensively used for aquaculture (Ashari et al 2019; Christian et al 2023; Maidie et al 2010; Triswiyana et al 2019) and have offered economic benefit for the farmers (Christian et al 2023; D'Souza et al 2004). Yet, after a while, the farmers start to experience mass deaths of their fish that eventually occur every year and become more frequent after some period of cultivation. The results of study conducted (Pagoray et al 2014) found that the sharp fluctuations of water quality such as dissolved oxygen, carbon dioxide, pH, ammonia, nitrite, sulphide and phenol, could possibly be the cause of the mass fish death. In addition, post mining void basically has low pH, low concentration of oxygen, and it is high in heavy metals contents (McCullough et al 2020; Blanchette & Lund 2016; Müller et al 2010).

The depletion of water quality in ponds can be overcome using various methods, including phytoremediation (Ng & Chan 2021; Qin et al 2016). Phytoremediation is a remediation technique that aims to restore the condition of an area that has been polluted, in a cost-effective way and efficiently (Wahwakhi et al 2017). Phytoremediation in aquatic ecosystem is the using of plants in order to maintain the water quality to make the aquatic environment healthy (Wang et al 2017). Various plants are used to remove, move, and/or destroy contaminants in soil and water (Khan et al 2022; Laghlimi et al 2015). In addition, plants can also be used as a provider of dissolved oxygen in the waters, and also function to absorb organic and inorganic materials in the waters (Eddiwan et al 2018; Ansari et al 2020).

Varies aquatic plants have been used to improve the quality of polluted water (Ghaly et al 2005; Putra et al 2015). A previous study showed the effectiveness of *Salvinia molesta*, *Pistia stratiotes*, and *Eichhornia crassipes* in reducing the overloaded nutrient in aquaculture ponds. Those plants species were also able to lower the heavy metals concentrations of contaminated water (Ali et al 2020) and of the fishpond in mining void (Lakra et al 2019). Preliminary research that was conducted in the void indicated that the phytoremediation process reduced the content of organic matter such as NO_2, NH_3, H_2S, and increased dissolved oxygen content (Pagoray & Ghitarina 2020). Based on this results, further trials were carried out with *S. molesta*, *P. stratiotes*, and *E. crassipes*, which affected the water quality and the growth of fish cultivated in post coal mining ponds, such as tilapia (*Oreochromis niloticus*). The objective of this study was to evaluate the effectiveness of *S. molesta*, *P. stratiotes*, and *E. crassipes* in improving the water quality in cages, by observing the growth of the fish reared in post coal mining void.

Material and Method

Experimental animal. The experiment was carried out in June 2023. Three hundred twenty (320) juvenile *O. niloticus*, with an average weight of 11.12–11.14 g and an average length of 9.04–9.08 cm, were used in this experiment. Fish were distributed evenly in 20 cages of 200 x 200 cm with a stocking density of 20 ind m^{-2} equal to 80 fish per cage. The fish were acclimated to the media for 1 week, prior to the commencement of the experiment, and they were feed at 5% of their biomass weight, 2 times a day.

Experimental and sampling protocol. This experiment used a Randomized Block Design (RBD) consisting of a control (without plant), 3 individual plant treatments and 5 repetitions. *S. molesta, P. stratiotes*, and *E. crassipes* were applied in separate cages that were already filled with fish. Each cage was filled with 250 g m^{-2} of plants or 1,000 g of plants per cage. The water from each cage was sampled prior to inserting the plants, every week. The fish (20% of total fish per cage) were sampled every two weeks to measure their growth (length and weight). The experiment ran for 2 months. The water quality parameters that were measured in this experiment were temperature, dissolved oxygen, nitrite, nitrate, ammonia, and H_2S).

Data analysis. The water quality data were compared with the quality standards based on the Regional Regulation of East Kalimantan Province No. 2 of 2011. Data on the growth of fish length and weight were collected, then analyzed by means of variance, in order to explain the differences between treatments; the DMRT test (Duncan multiple range test), one factor ANOVA p=0.005 and Bonferroni's post hoc analysis were used.

Growth measurement. Measurement of growth was performed (Effendie 1979) as follows:

$$W = Wt - Wo$$

Where:
W - absolute weight (g);
Wt- final average weight (g);
Wo- initial average weight (g).

$$L = Lt - Lo$$

Where:
L- absolute length gain (cm);
Lt- final average length (cm);
Lo- initial average length (cm).

Statistical analysis. All data were tested for assumptions of normality and homoscedasticity by the Bartlett's test and were arcsine-transformed when required. Comparisons between the nursery site at Tekek and natural reef at Renggis were conducted using a t-test. Variations between sampling months were compared using one-way ANOVA, followed by Tukey's post hoc test. Significance of differences was defined at $p<0.05$. Statistical analysis was performed using the MINITAB® software.

Results

Water quality. The water temperature in all media was consistent and showed no significant differences. However, it can be said that the water temperature in the media with *P. stratiotes* was slightly lower than the other media. There was no significant change in pH during the study despite carbon dioxide fluctuations. The concentration of carbon dioxide in Control treatment was significantly higher than in the treatment with plants. The lowest levels of carbon dioxide were found in the treatment with *E. crassipes*. Meanwhile, dissolved oxygen levels in the four treatments, during the study, ranged from 3.94 to 4.23 mg L^{-1} (Table 1). A higher dissolved oxygen level was detected in cages treated with *P. stratiotes* and *S. molesta*. Ammonia levels ranged from 0.45 to 0.49 mg L^{-1}; the lowest level was found in cages given *E. crassipes* and the highest level was in control treatment. The ammonia level in the control was significantly higher than in all plant treatments. In this experiment the range of nitrite levels was 0.005-0.006 mg L^{-1}.

Table 1

Average values of water quality parameters during the experiment in the fish cages of post coal mining void

Water quality parameters	*Treatment*			
	Control	*P. stratiotes*	*S. molesta*	*E. crassipes*
Temperature (°C)	29.64	29.16	29.14	29.25
pH	7.12	7.06	7.07	7.06
DO (mg L^{-1})	3.94^{b}	4.23^{a}	4.23^{a}	4.17^{a}
CO_2 (mg L^{-1})	9.11^{a}	8.62^{b}	8.47^{b}	8.21^{b}
NH_3 (mg L^{-1})	0.49^{a}	0.47^{b}	0.47^{b}	0.45^{b}
NO_2 (mg L^{-1})	0.005^{b}	0.006^{a}	0.006^{a}	0.006^{a}
NO_3 (mg L^{-1})	0.22^{b}	0.23^{b}	0.24^{a}	0.25^{a}
H_2S (mg L^{-1})	0.48^{a}	0.45^{b}	0.45^{b}	0.45^{b}

Growth performance. The results of experiments showed that plant administration had a very significant effect ($P<0.05$) on the average weight of the fish. This condition can be seen in Figure 1, where the pattern of weight gain of the fish that was not treated with plants was significantly lower than the weight of tilapia treated with plants.

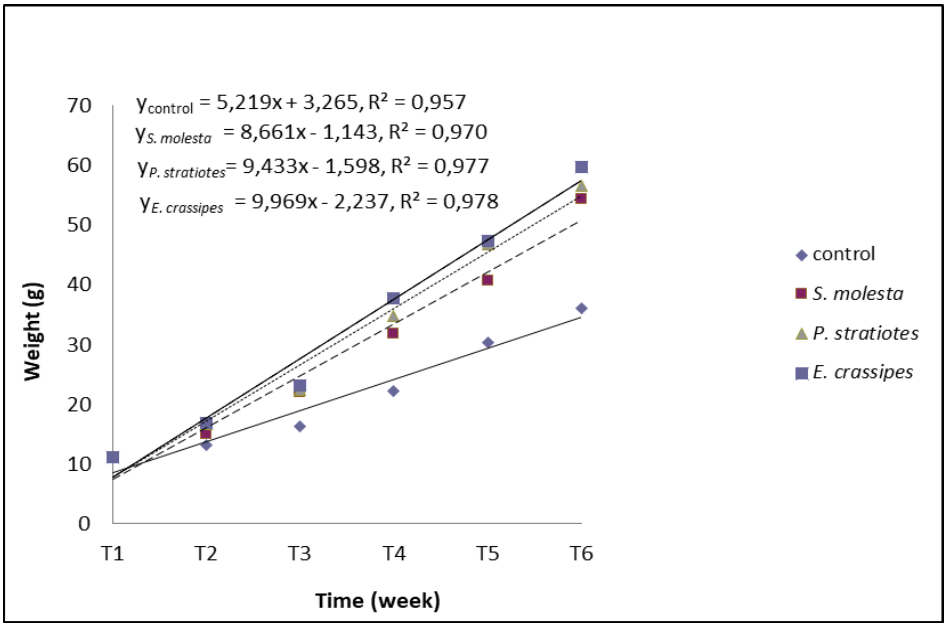

Figure 1. The average weight growth of *Oreochromis niloticus* reared in cages, in post coal mining void on different types of aquatic plants.

The highest weight average of tilapia was obtained in the cages with *E. crassipes,* with an average weight of 59.74 g per fish, followed by P. stratiotes with an average weight of 56.67 g per fish and *S. molesta* (K1) with an average weight of 54.36 g per fish. The results of the analysis showed that the treatment with plants in cages showed a better growth compared to the control. It is supported by that water hyacinth plant (*Eichhornia crassipes*) can reduce ammonia concentration by 81% within 10 days. Aquatic plants that applied in post-coal mining pond had a very significant effect ($P<0.05$) on the length of tilapia. This effect is very clear when compared to the control (without aquatic plants). Figure 2 shows that the pattern of the average length of tilapia with no treatment plant was slower than in the other treatments.

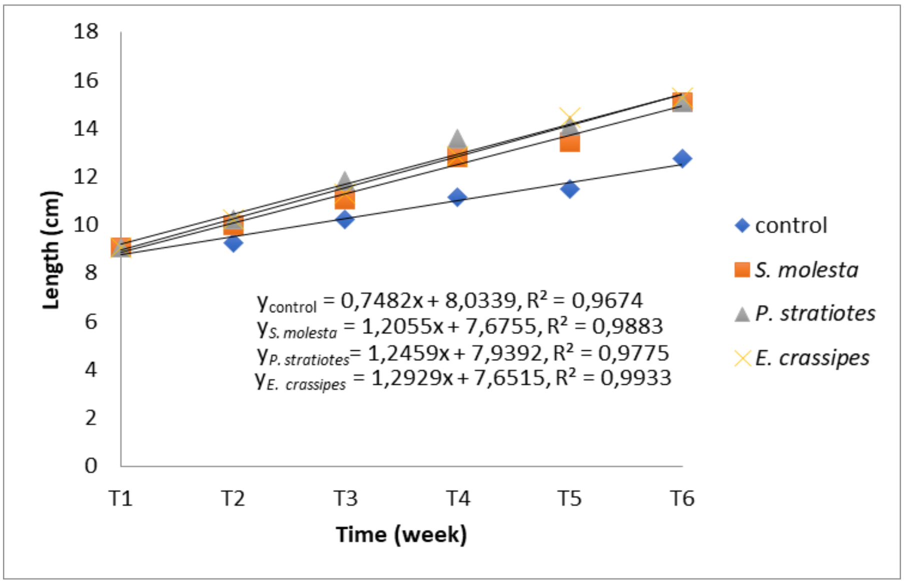

Figure 2. The average length of *Oreochromis niloticus* reared in cages of post coal mining pond in the treatment of different types of aquatic plants.

Discussion

Water quality. The leaf shape and structure of the stratified *P. stratiotes* causes the water surface to be somewhat protected from the sun (Eid et al 2016). High CO_2 levels often occur in post mining ponds used for fish cultivation in cages. The depletion of the dissolved oxygen's level may increase the harmful effect of high CO_2 level (Kumar Singh 2017). The optimum concentration of nitrogen nitrite for Tilapia is in the range of 0.02 – 0.12 mg L^{-1} (Cavalcante et al 2014). The highest nitrate level was found in cages that were given water hyacinth (*E. crassipes*), while the lowest was in cages that were not given plants and the one given *S. molesta*. Possibly, in control cages without plant, there was an increase in phytoplankton density, which plays a role in the formation of nitrogen. There was a significant difference of H_2S levels between the control and treatment cages. Yet, all cages with plant treatment showed similar values. Ammonia levels ranged from 0.45 to 0.49 mg L^{-1}; the lowest level was found in cages with water hyacinth plants (*E. crassipes*) and the highest level was in the control treatment. The ammonia level in Control was significantly higher than in all plant treatments

Growth performance. It is known that aquatic plants could improve the aquatic environment, as a trap of luxury uptake organic matter in eutrophic waters, which is able to absorb certain substances or nutrients in excess; aquatic plants also function as controllers and cleaners of pollution with heavy metals, pesticides, and oils (Hart & Oriakpono 2020). In addition, *E. crassipes* is also able to absorb organic compounds from a solution, reduce total suspended solids (TSS), and reduce biological oxygen demand (BOD) (Amalina et al 2022). Thus, these plants can help improve the aquatic environment which in turn has a positive impact on the average weight of Tilapia kept in cages, in post coal mining ponds (Maharani et al 2022).

When compared among the three types of aquatic plants, it appears that only fish in the cage with *E. crassipes* had significantly higher length compared to fish in the cage with *S. molesta* and *P. stratotes*. Fish cage with *E. crassipes* has the lowest ammonia level. Perhaps, it was affecting appetite of the fish, as stated by Shinde & Sukhdhane (2023) that increasing ammonia levels in the air causes reduced feed consumption in cultivation fish. Yet, all treatment plants have significant differences when compared to the control. There is a relationship between fish length and fish weight. According to Maimunah et al (2020), 52% of fish weight is influenced by body length, while the remaining 48% is influenced by other environmental factors, such as temperature, feed, age, and disease. According to Hidayat et al (2013), fish growth is influenced by several factors, internal and external; internal factors include heredity, disease resistance and ability to utilize food; external factors include physical, chemical and biological characteristics of waters.

Aquatic plants such as *P. stratiotes* and *S. molesta* can also be used for wastewater treatment (Mustafa & Hayder 2021). Other types of plants that can be used for phytoremediation are algae. Green algae can produce oxygen, which appears as tiny bubbles between the filaments. Compared to native plants, these invasive plants show a much higher efficiency in nutrient removal with high nutrient uptake capacity, fast growth rate, and large biomass production (Ankit et al 2022; Singh et al 2021). In tropical or subtropical areas, invasive plants such as *E. crassipes* and *P. stratiotes* are used in phytoremediation water systems (Ali et al 2020; El-Gendy et al 2005; Ugya et al 2019).

Conclusions. The current study demonstrates that water quality, especially DO, CO_2, NH_3, and H_2S, in cages with aquatic plants such as *P. stratiotes, S. molesta,* and *E. crassipes* improved significantly compared to the cage without plant. The fish in the cages with plants had a better growth. The fish in the cage with *E. crassipes* had significantly higher length compared to fish in the cage with other plants such as *P. stratiotes* and *S. molesta*. It can be concluded that although the three plants (*P. stratiotes, S. molesta,* and *E. crassipes*) show their capability in improving the water quality, yet *E. crassipes* proof to be more effective in the growth perspective. Therefore, during fish cultivation in mining voids it is recommended to use *E. crassipes* as phytoremediator.

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

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