Optimization on survival and growth rate of African catfish (*Clarias* sp.) using water spinach (*Ipomoea aquatica*)-based aquaponics system

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Abstract. The high rate of African catfish (*Clarias* sp.) consumption makes aquaponics system to be an alternative in overcoming the limitations of cultivated land. The decrease in water quality is caused by fish's excretion which can influence fish's life. Aquaponics system is considered able to improve this catfish growth process. This study analyzes the influence of water spinach (*Ipomoea aquatic*) density on the survival and growth rate of African catfish in an aquaponics system. This study involved 672 African catfish which were then divided randomly into four different groups, namely P0 (without any water spinach in the aquarium), P1 (20 pieces water spinach), P2 (30 pieces water spinach), and P3 (40 pieces water spinach). The amount of fish and its weight were measured, along with water spinach density and water quality (pH, dissolved oxygen, water temperature, and ammonia levels). The survival rate of the African catfish observed from group P0, P1, P2, and P3 were 26.7; 75.59; 80.95; and 88.69% respectively ($p < 0.05$). The specific growth rate were 0.79; 1.00; 1.12; and 1.15%, respectively ($p < 0.05$). Water spinach based aquaponics can optimize survival and growth rate of African catfish. These findings support the ongoing aquaponic system which is considered quite easy with water spinach. This study suggests further research on the optimal ratio of African catfish and spinach plants that are more specific.
Key Words: aquaponics, plant density, survival rate, specific growth rate, catfish.

Introduction. Easy and fast growth of African catfish (*Clarias* sp.) supports the high rates of consumption of this type of fish in Indonesia and other countries in Asia, Europe, Africa, and America (Direktorat Jenderal Perikanan Budidaya (DJPB) 2014; Wijaya et al 2014; Lucas et al 2019). The production of African catfish in Indonesia in 2012 was as many as 441,217 tons, and 543,461 tons in 2013, and is estimated to increase in the following years (DJPB 2014). African catfish can be bred on limited land with dense stocking seedlings (intensive breeding) (Abraham et al 2018). However, intensive breeding causes a decrease in the nutrients and oxygen concentrations in catfish pond water (Da et al 2015; Abraham et al 2018). The decrease in water quality is caused by the excretion of fish in the form of ammonia and urea which are toxic and disrupt the welfare of African catfish (Zidni et al 2013).

One alternative method is using an aquaponics system, which is able to reduce ammonia to nitrate by involving plant roots, oxygen, and bacteria. Water spinach plants are known to be effective in absorbing nutrients in water and can reduce up to 58% of nitrogen waste in fish farming (Setijaningsih & Suryaningrum 2015). Nitrogen and phosphates derived from fish excretion are needed by plant in the growth and formation of cells (Lucas et al 2019). This study was conducted to determine the effect of water spinach (*Ipomoea aquatica*) density in aquaponics system on the survival and growth rate of African catfish as a reference for more effective and efficient catfish breeding method.

Material and Method

Design and variables. This research used a complete randomized design. The study was conducted on February 19th until March 19th 2017 in Faculty of Fisheries and Marine, Universitas Airlangga, Surabaya, East Java, Indonesia. The independent variable in this study was the number of water spinach, and the dependent variables were the survival rate and growth rate of African catfish also the water quality such as water temperature, pH, dissolved oxygen (DO), and ammonia.

Sample. A total of 672 African catfish (*Clarias sp.*) with fork length of 4-6 cm (mean fork length is 4.6 cm) were used as the samples. African catfish were kept in 16 aquaria with 20 cm water height (17.5 liters) of PDAM (local water company) water and fed with pellets. Each group consisted of 42 African catfish in the beginning of the study. The calculation of stocking density was based on the formula of Suprapto & Samtafsir (2013), which is 400 to 2400 fish m^{-3}. Pellets contain protein content of more than 30%. Feeding dose was three times a day for 30 days as much as 5% of the body weight of the catfish. Fish were fed in the morning at 9 am, afternoon at 1 pm, and evening 5 pm (Khan et al 2009). The water spinach seeds were sown for about 2 weeks in planting medium in the form of rockwool as a place to attach water spinach and bacterial growing media. On the other side, ammonia concentration was measured using distilled water, ammonium chloride (NH_4Cl), phenol solution (C_6H_5OH), sodium nitroprusside ($C_5FeN_6Na_2O$), alkaline citrate solution ($C_6H_5Na_3O_7$), and 5% sodium hypochlorite (NaClO) (Badan Standardisasi Nasional 2004).

Materials. This research used a pump set for aquaponic recirculation (AT-105, Atman), pH meter (pen type PH-009, ATC), hose (1 meter type, Puso), digital scale (FEJ-5K, Quttro), fish nets (20 cm size, PAM), ruler (30 cm size, Butterfly), measuring cylinder (Class A 10 mL, Pyrex), DO meter (HI9146, Hanna), thermometer (Vivid Oval Broader Type, Safety), and spectrophotometer (10S-UV-Vis, Genesys).

Procedures. The aquaponic system placed a tray above the aquarium. The trays were contained water spinach according to the specified amount. The trays were equipped with inlet and outlet channels. The inlet channels directly connected with water pump to the tray. The outlet channels drain water from tray to the aquarium. Water was flowed using recircuation system. The water from cultivation process flowed to the tray as cultivation water resource. Each tray's size is about 35 cm long, 30 cm wide, and 10 cm high. This study distinguished the number of water spinach in each media. The details are P1 = 20 pieces, P2 = 30 pieces, P3 = 40 pieces and no water spinach in P0 (control) (modification of the method of Dauhan et al (2014)). This treatment was repeated 4 times. The 16 aquaria are about 35 cm long, 25 cm wide and 25 cm high (Figure 1).

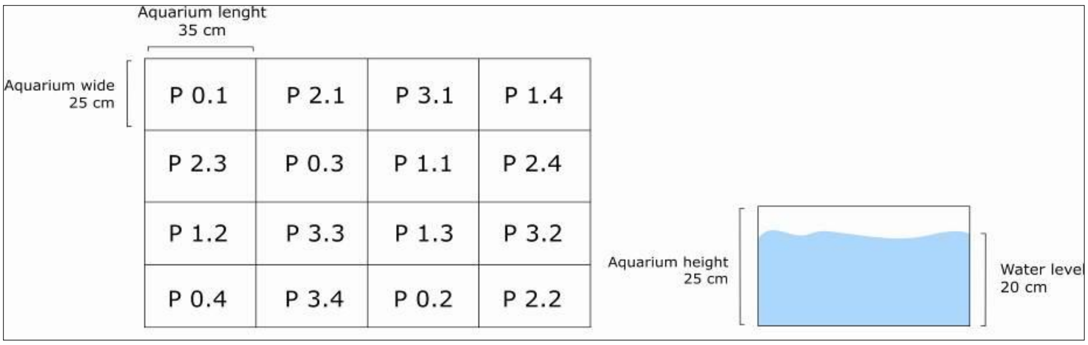

Figure 1. Aquarium map (first number in the name of aquarium means the group; second number means the repetition).

The main parameters observed in this study were the survival rate and growth rate of African catfish. Specific growth rate (SGR) is the rate of individual weight gain in percent per day using the formula (Mizanur & Bai 2014):

$$SGR = \frac{\ln W_e (g) - \ln W_s (g)}{d (days)} \times 100$$

where: SGR = specific growth rate (%/day);
We = mean of fish weight at the end of fish rearing (g);
Ws = mean of fish weight at the beginning of fish rearing (g);
d = total rearing days (day).

Whereas, survival rate of African catfish is measured using the modified formula of Effendie (1979) in Kordi (2009):

$$SR = \frac{N_t}{N_0} \times 100$$

where: SR = survival rate (%);
Nt = amount of fish in the end of fish rearing;
Nt = amount of fish in the beginning of fish rearing.

Other water quality parameters observed were the temperature, pH, ammonia, and dissolved oxygen (DO). They were analyzed every day at 06.00 am and 16.00 pm (ammonia observation was carried out every 7 days) using the SNI 06-6989.30-2005 procedure (Badan Standardisasi Nasional 2004).

Statistical analysis. The data obtained in this study were analyzed using variant analysis (ANOVA test). The analysis carried on using Duncan Multiple Test with a significant level 5% if there was a difference result between each group (Kusriningrum 2008).

Results. The data collected showed distinct result from each treatment given. In Table 1, African catfish in P3 group had higher growth in body weight compared to those in other groups, eventhough there was also an increase body weight observed in other groups. The total initial fish weight was between 42 and 45 g with same amount of fish in every group. The mean weight of fish before treatment is around 1 g. In the end of treatment, P0 group showed the worst weight increase and the smallest amount of fish in aquarium. There were only 4 fish in the aquarium with total final weight 10.87 g in the last treatment on first repetition. This means that there was no significant weight gain compared to the other groups.

Table 1

Data on the weight and number of fish

Group	*Repetition*	*Total initial weight (g)*	*The initial number of fish*	*Mean*	*Total final weight (g)*	*The final number of fish*	*Mean*
P0	1	42.04	42	1	10.87	4	2.71
	2	42.7	42	1.01	19.24	7	2.74
	3	44.69	42	1.06	39.17	14	2.79
	4	45.15	42	1.07	37.13	20	1.85
P1	1	43.71	42	1.04	113.51	37	3.06
	2	42.55	42	1.01	109.27	32	3.41
	3	45.55	42	1.08	84.04	26	3.23
	4	43.99	42	1.04	94.74	32	2.96
P2	1	42.1	42	1	110.7	37	2.85
	2	43.62	42	1.03	111.01	34	3.26
	3	42.95	42	1.02	115.58	36	3.21
	4	43.99	42	1.04	117.9	29	4.06
P3	1	45.33	42	1.07	137.03	36	3.8
	2	44.49	42	1.05	141.56	36	3.93
	3	44.65	42	1.06	144.33	38	3.79
	4	43.07	42	1.02	139.29	39	3.57

The increasing of fish weight was showed significantly on P1, P2, and P3. The mean weight of fish was 3 g in each repetition of P1, P2, and P3. Fish had weight enhancement of about 2 g each. Moreover, there was found a little number of dead fish on P1, P2, and P3. Table 1 showed that the final number of fish was around 30 in each repetition.

The collected data were then analyzed using ANOVA and Duncan's Multiple Range Test. The results of the analysis are presented in Table 2.

Table 2

Data of the effect of water spinach density on specific growth rate and survival rate

Group	*SGR±SD*	*SR±SD*	*P score*
P0	0.79 ± 0.28^{a}	26.7 ± 17.19^{a}	$p < 0.05$
P1	1.00 ± 0.12^{ab}	75.59 ± 10.71^{b}	$p < 0.05$
P2	1.12 ± 0.10^{b}	80.95 ± 8.47^{b}	$p < 0.05$
P3	1.15 ± 0.05^{b}	88.69 ± 3.57^{b}	$p < 0.05$

Note: SGR = specific growth rate; SR = survival rate. Different superscript in the same column shows that there is significant differences between each group.

The statistical analysis showed $p < 0.05$, which means that the density of water spinach plants significantly affect the catfish' survival rate. Based on Duncan's Multiple Range Test, there were differences between P1, P2, and P3 groups with P0 group (see Table 1). Figure 1 shows that the highest value of survival rate is found in P3 group, while the lowest survival rate is found in P0 group (control).

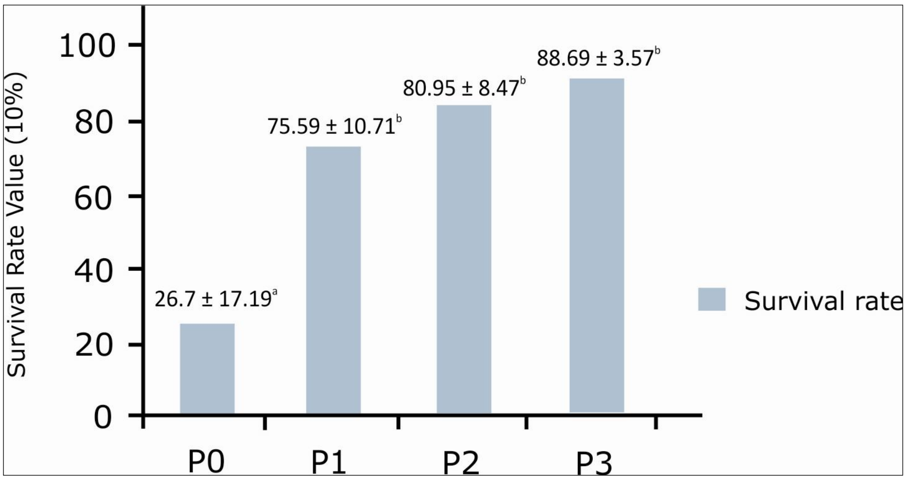

Figure 1. Mean value of survival of catfish (different superscript in the same column shows that there is a significant difference between each group).

Growth rate (specific growth rate). The ANOVA analysis showed the effect of the number of water spinach plants ($p < 0.05$) on the specific growth rate of catfish (see Table 1). There were differences observed between all groups on Duncan's Multiple Range Test. In Figure 2, the P3 group has the highest value of the mean SGR (1.15%), meanwhile the lowest value is found in P0 group (control) (0.79%).

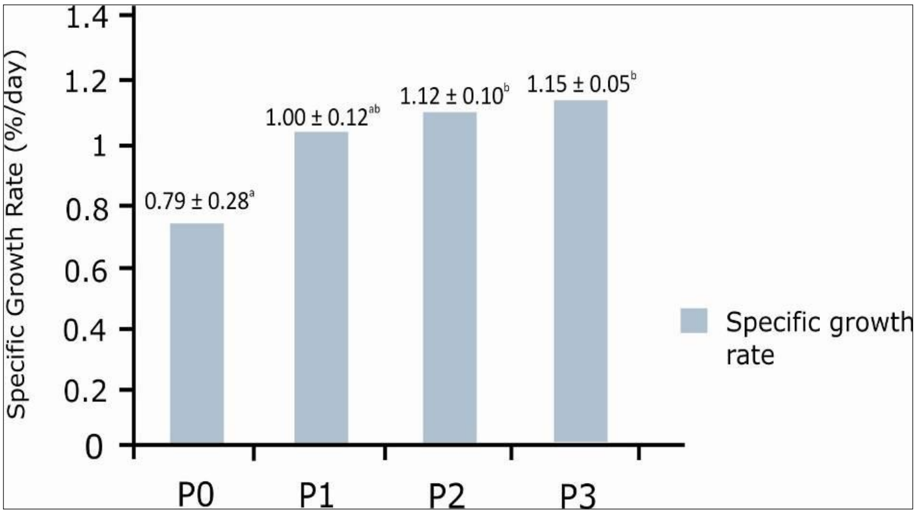

Figure 2. Mean value of specific growth rate of catfish (different superscript in the same column shows that there is a significant difference between each group).

Water quality. The water quality components are presented in Table 3. The range of DO values in P0 group was wider than that of the other groups. Similar to the range of water pH values, P0 had the widest range. In the temperature measurement, it was found that there were similarities in the temperature range of P0 and P2 with the smallest temperature range in P1. Furthermore, the highest ammonia level was found at P0 which showed the number of 1.023-9.330 mg L^{-1} and the lowest level was found in P3 (0.023-1.1 mg L^{-1}).

Table 3

Data of water quality of African catfish (*Clarias* sp.) in each group

Group	*DO (mg L^{-1})*	*pH*	*Temperature (^oC)*	*Ammonia (mg L^{-1})*
P0	3.29-6.70	6.1-8.4	27.8-29.9	1.023-9.330
P1	3.03-6.29	6.2-8.2	28.2-30	0.253-2.946
P2	3.20-6.19	6.1-8.1	27.9-30	0.1-0.792
P3	3.76-6.12	6.7-8.2	28.2-30.2	0.023-1.1

Discussion. Survival rate and SGR of fish are influenced by water quality in the cultivation process. Because of the catfish excretion through the osmoregulation process, 80-90% ammonia (N-inorganic), and around 10-20% of total nitrogen from feces and urine concentrate in the water (Wijaya et al 2014). Ammonia from excretion of fish that has not been reduced has an impact on its physiological system and triggers stress on the fish, which later is resulting death (Zidni et al 2013). Fish mortality was observed in each group during the study. The P0 group had the highest mortality compared to the others. In this study, high ammonia concentrations in P0 group (1,023-9,330 mg L^{-1}) was due to the absence of media such as plants which could help the process of breaking down the ammonia and other residual substances. Treatment in group P1, P2, and P3 indicated the process of decomposition of residual substances at catfish maintenance sites based on the number of water spinach plants given.

The number of African catfish placed in aquaponics system with more water spinach plants had higher survival and specific growth rates. Decomposition of ammonia into nitrate by water spinach improves sustainability of water quality (Wijaya et al 2014). Water would have 50% better quality if it flows through the rice field area (Da et al 2015). The re-circulation process by plants and fish in aquaponics system sustain water quality which greatly affects the survival and fish growth rate (Lisna & Insulistyowati 2015; Ngo Thuy Diem et al 2017). The optimum quality of water due to the plants density can also support the development of fish (Boxman et al 2018).

Water spinach also affected temperature, pH, and oxygen content of the experimental water. The temperature in each group ranged from 28 to 30^{o}C. The temperature range approaches the optimal temperature range in the fish maintenance process (Badan Standardisasi Nasional 2014). The pH and DO values are also within the optimal range (pH: 6-8; dissolved oxygen: 3-6 mg L^{-1}) (Iskandar 2016). The best media quality will affect digestive enzymes and metabolism that are effective in producing energy for fish growth (Zidni et al 2013). Several studies have shown that an aquaponic re-circulation system can inhibit the formation of fish food residues poison (Nuwansi et al 2017; Yildiz et al 2017).

In addition, the use of an aquaponic system is considered effective in processing nutrients for plants as a result of fish metabolism. Plants get around 26% of nitrogen produced by fish, and increasing amount of fish result in increasing amount of plant harvested (Reyes Lastiri et al 2016; Estrada-Perez et al 2018). Aquaponic systems have higher success rate compared to traditional aquaculture technique and they are able to preserve the water quality (Trang & Brix 2014). This system can also be applied as a sustainable ecosystem development and is suitable for small-scale industries (Makhdom et al 2017).

Conclusions. Based on the research that has been conducted, it can be concluded that the density of water spinach plants in an aquaponic system affected water quality which had a positive impact on the survival and growth of African catfish. The researchers found that the higher density of water spinach plants on the aquaponic system, the more metabolic waste material decomposed, which is profitable for the survival and specific growth rate of the African catfish.

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