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Research Article
Optimal Stocking Density of *Tilapia rendalli* (Boulenger, 1896) for Increased Growth in a Periphyton Based Aquaculture System

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Abstract
Background and Objective: A study was conducted at the National Aquaculture Center in Malawi to find the optimal stocking density of *Tilapia rendalli* to improve its growth in a periphyton based pond system. **Materials and Methods:** Growth was evaluated using specific growth rate, survival rate, yield and condition factor. These parameters were estimated from bi-weekly measurements of body weight (g) and total length (cm). Environmental conditions were monitored daily for temperature, dissolved oxygen, pH and chlorophyll a. **Results:** Ranges for mean weight gain (% day^{-1}), specific growth rate (% body weight day^{-1}), average daily weight gain (g day^{-1}), survival rate (%) and yield (kg ha^{-1} 42 day^{-1}) were 1.6-2.11, 1.8-3.3, 0.03-0.12, 68-85 and 5.18-7.54, respectively. Fish stocked at low stocking density (2 fish m^{-2}) showed higher values than the fish stocked at higher stocking density (3 fish m^{-2}). **Conclusion:** Low fish stocking density (2 fish m^{-2}) is optimal for increased growth of *Tilapia rendalli* in a periphyton based aquaculture system.

Key words: Periphyton, *Tilapia rendalli*, aquaculture, stocking density, Malawi

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Tilapia culture is practiced in many countries including developing nations where culture inputs are limited. Fish feeding is a major expenditure for fish farmers[1]. One alternative to improve tilapia production without the costly culture inputs is the use of periphyton-based system in which submersed hard surfaces are installed for periphyton development[2]. Interest in periphyton, a simple and cheap source of natural food for semi-intensively cultured pond fish, has increased in the last few decades[2,3]. Periphyton or aufwuchs is a composite of sessile autotrophic and heterotrophic aquatic biota that include both the attached forms such as algae, filamentous bacteria, attached protozoa, bryozoan, rotifers and also the free-swimming organisms[3,4].

In periphyton-based systems, substrates such as bamboos are fixed in shallow waters (e.g., ponds, lagoons, reservoirs etc.) to enhance the growth of periphyton[5]. Periphyton may contribute substantially to primary productivity especially in shallow freshwater ecosystems and thus provide an important energy input to both detritus and grazing food chains of the ecosystem[6]. Periphyton can partially or totally replace or complement supplemental feed in phytophagous tilapia ponds, without reducing fish yield but with considerable reduction in production cost[5]. Thus, periphyton-based aquaculture can be an excellent alternative to reduce production cost and allow an economically viable tilapia production, particularly in rural, resource limited regions in developing countries[5]. Furthermore, periphytons improves water quality because they are colonized by nitrifying bacteria which can act as biological filters thereby reducing the levels of toxic ammonia in water[7].

The fish's environment, of which stocking density and food availability are part has tremendous influence on growth performance of fish. In a system where natural food availability has been enhanced, such as a periphyton based system, fish densities of greater magnitude can be expected to be sustained[8]. However, optimal utilization of periphyton-based pond ecosystem depends on intricate balance between the density of periphyton substrates installed in the pond and the density of fish stocked[3]. Several studies have recommended use of periphyton-based systems to improve pytophagous tilapia production in Malawi and elsewhere[2,9-12]. However, the effects of varying stocking densities of fish have not been adequately considered. This study was intended to investigate the effects of varying fish stocking density on the growth performance of the phytophagous *Tilapia rendalli* in a periphyton based system. Information from this study will provide small scale fish farmers with knowledge on the best stocking density of *Tilapia rendalli* when rearing the fish in a periphyton-based system so that productivity is increased and production costs reduced.

MATERIALS AND METHODS

Culture facilities and design: The study was carried out in 6 ponds of equal size (200 m^{-2}) at National Aquaculture Center (NAC) in Zomba from January 31, 2014 to March 14, 2014. The experiment was laid out using a completely randomized design with two treatment and three replicates of each. Prior to the experiment, ponds were renovated, aquatic vegetation was removed and all small fish and other larger aquatic organisms were eradicated. The ponds were then filled to 1 m depth with water from the same canal. Inorganic fertilizer (NPK) with a composition of 23:21:0+4 sec was applied at an average rate of 3 g m^{-2} $week^{-1}$ during the culturing period. Bamboos were staked vertically into the pond bottom at a density of 0.18 poles m^{-2} (Fig. 1). The ponds

Fig. 1: One of the ponds of periphyton based system used in the experiment

were stocked with *Tilapia rendalli* at an average body weight (±SD) of 1.88±1.1 and 1.89±0.60 g for 2 fish m^{-2} and 3 fish m^{-2}, respectively.

Data collection and analysis

Environmental parameters: Environmental parameters including water temperature (°C), dissolved oxygen (mg L^{-1}) and pH) were monitored on site daily using water quality checkers (Hanna Instruments, models HANNA HI 9146 for DO and water temperature, HANNA HI 9125 for pH). Concentrations of periphytic chlorophyll a (chl-a, µg L^{-1}) were measured weekly. Periphyton samples were scrapped from bamboo poles using a scalpel blade from 1 cm^2 area at 30 cm depth. Periphytic algal samples were processed according to APHA[13]. After filtration with vacuum pump through a 47 mm GF/F, chl-a was extracted using acetone. The optical density was read at 630, 645, 663 and 750 nm using a Jenway spectrophotometer (model 6300, Japan) and results were corrected for phaeopigments by acidification. Chlorophyll a concentrations were calculated according to the equation of UNESCO[14]. Sampling was done between 9 and 12.00 h.

Fish growth parameters: Bi-weekly fish samples were collected by using fish traps, targeting 10% of the stocked fish in each fish pond. Individual body weight (g) and total length (mm) were measured using digital scale and measuring board, respectively. These measurements were used to estimate growth performance indices such as specific growth rate (% body weight day^{-1}), survival rate (%), mean weight gain (g), average daily weight gain (g day^{-1}), yield (kg ha^{-1} 42 day^{-1}), condition factor (K, g cm^{-3}) and percent mean weight gain (% day^{-1}) according to Eq. 1-7.

Specific growth rate (SGR) (% body weight day^{-1}) was determined according to equation:

$$\text{SGR} = \frac{\text{In (Wf)} - \text{In (Wi)}}{\text{Time (days)}} \times 100 \quad (1)$$

Survival rate (SR) was calculated with the equation:

$$\text{SR (\%)} = \frac{\text{No. of fish survived}}{\text{No. of fish stocked}} \times 100 \quad (2)$$

Mean weight gain (MWG %) was calculated using the equation:

$$\text{MWG (\%)} = \frac{\text{Wf} - \text{Wi}}{\text{Time (days)}} \times 100 \quad (3)$$

Average daily gain (ADG) was determined as:

$$\text{ADG (g day}^{-1}) = \frac{\text{Wf} - \text{Wi}}{\text{Time (days)}} \quad (4)$$

$$\text{Yield} = \frac{\text{Total biomass (kg)}}{\text{Area (ha)} \times \text{Culture period (days)}} \quad (5)$$

The value of the condition factor (K) was determined following the equation:

$$K = \frac{W}{TL^3} \times 100 \quad (6)$$

where, W is average body weight (g) and TL is total length (cm) of fish.

Mean weight gain (g) was estimated by:

$$\text{MWG} = \text{Wf-Wi} \quad (7)$$

where, Wf is final weight (g) and Wi is initial weight of fish.

Statistical analysis: Measured and estimated fish growth and environmental parameters were recorded in Microsoft Excel spreadsheets (Excel 2013). Mean and standard deviation (mean±SD) of each parameter was calculated for each treatment. Data exploration and analysis was done by using SPSS 16.0 for Windows As most data did not meet the assumptions of parametric t-test, the data were tested significant differences by using the non-parametric Mann Whitney test at 5% alpha level.

RESULTS

Environmental conditions: During the study period water temperature (°C), pH, dissolved oxygen (mg L^{-1}) and chlorophyll a (µg L^{-1}) ranged between 23-30.5, 6.9-8.3, 5.62-8.14 and 185-332, respectively. Temperature, pH and dissolved oxygen did not differ significantly between treatments ($p>0.05$). Figure 2 shows trends of water temperature and pH during the experimental period. Periphytic chlorophyll a differed significantly between treatments ($p<0.05$), with ponds containing fish stocked at a density of 2 fish m^{-2} showing higher chlorophyll a biomass than those containing fish stocked at 3 fish m^{-2} (Fig. 3).

Fish growth: Ranges for final body weight (g), mean weight gain (% day^{-1}), specific growth rate (% BW day^{-1}), mean

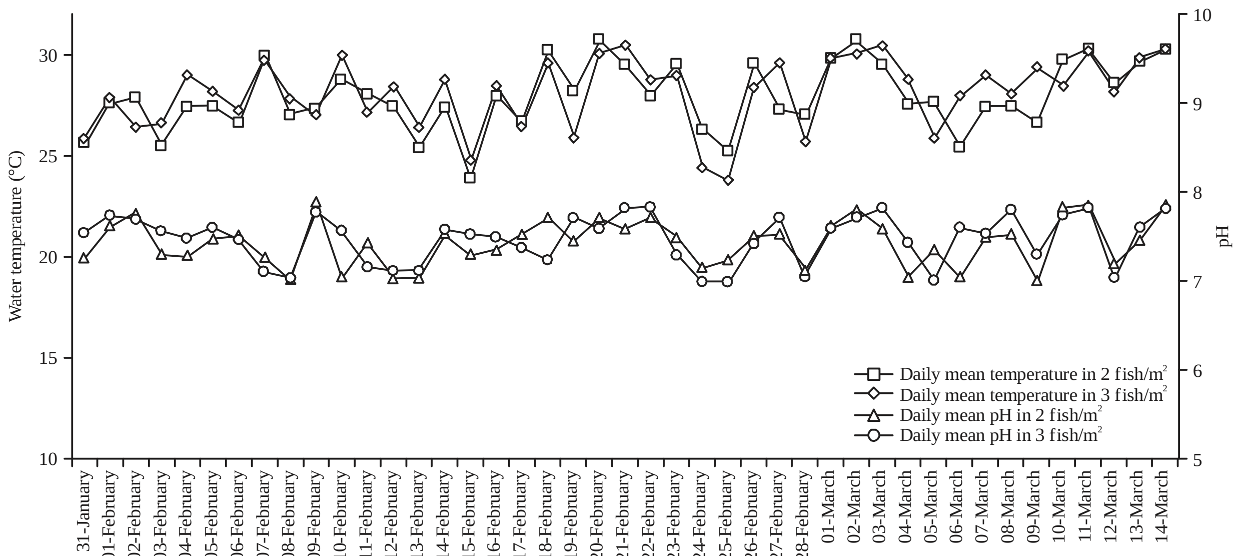

Fig. 2: Daily mean temperature and pH values in ponds stocked with *Tilapia rendalli* at different stocking densities

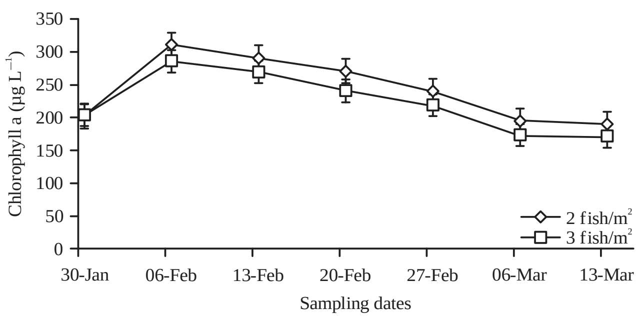

Fig. 3: Average chlorophyll a abundance in different treatments during the study period
Values are Mean±SE of three replicated ponds per sampling date

Table 1: Summary of fish growth parameters (Mean±SD) in the two stocking densities and associated p-values (Mann Whitney U test)

	Stocking density (No./m²)		
Parameters	2	3	p-value
Initial body weight (g)	1.80± 1.1	1.88±0.60	0.207
Final body weight (g)	5.60±4.8	4.40±3.3	0.038
Percent mean weight gain (% day^{-1})	9.05±2.5	6.00±2.1	0.025
SGR (% BW day^{-1})	2.70±0.3	2.00±0.1	0.041
Mean weight gain (g)	3.80±0.6	2.50±0.3	0.019
Average daily weight gain (g day^{-1})	0.09±0.02	0.06±0.01	0.022
Survival rate (%)	81.00±3	74.00±5	0.036
Yield (kg ha^{-1} 42 day^{-1})	7.48±2.2	5.18±1.0	0.024
K	2.28±0.16	2.13±0.09	0.110

weight gain (g), average daily weight gain (g day^{-1}), survival rate (%), yield (kg ha^{-1} 42 day^{-1}) and condition (k, g m^{-3}) were 4.2-11.2, 1.6-2.11, 1.8-3.3, 2.1-4.5, 0.03-0.12, 68-85, 5.18-7.54 and 2.04-2.46, respectively. Arithmetic means of these growth parameters differed significantly between treatment groups ($p<0.05$), with fish stocked at low stocking density (2 fish m^{-2}) showing higher growth rates than fish stocked at higher stocking density (3 fish m^{-2}) (Table 1). Condition factor did not differ significantly between fish of the two treatment groups ($p>0.05$) although it was higher in low density ponds.

DISCUSSION

The measured water quality parameters of temperature, pH, DO and chlorophyll a were within the acceptable range for proper tilapia growth[15,16]. Lack of significant differences in temperature, pH and DO between the treatments means that the fish were generally subjected to similar environmental conditions. However, significantly higher chlorophyll a biomass was observed in ponds containing fish stocked at lower than higher density. This finding is consistent with previous studies which suggested that higher grazing pressure exerted by fish on periphyton in ponds containing fish stocked at higher density can significantly depress periphyton biomass[17-19]. Dace fish grazing on periphyton has been found to decrease periphyton biomass[20]. Nile tilapia grazing on periphyton has also shown to depress periphyton biomass[21].

The present study shows that growth values of fish stocked at lower density (2 fish m^{-2}) were significantly higher than fish stocked at higher density (3 fish m^{-2}) in terms of mean weight gain (% day^{-1}), specific growth rate (% BW day^{-1}), mean weight gain (g), average daily weight gain (g day^{-1}), survival rate (%) and yield (kg ha^{-1} 42 day^{-1}). Similar studies of mullet fish reared in a periphyton based system have been observed[22]. Other tilapia species grown in periphyton based system have also shown higher growth when stocked at lower than higher density[7,9,23]. At lower fish stocking density, there is reduced competition for space and food resources resulting in better growth and survival rates and higher fish yields[24]. Higher periphytic chlorophyll a biomass in ponds stocked with fish at lower density indicate that these ponds contained sufficient food resources for the fish[18,19,24].

As this study was based on periphyton biomass samples collected from a single depth (30 cm) and measured only by pigment concentration, further studies are required where periphyton samples could be collected from different depths and their biomass evaluated using more metrics such as dry matter (DM) and ash-free dry matter (AFDM) biomass.

CONCLUSION

The results of the present study showed that there were significant differences in growth parameters and food availability (as chlorophyll a) between the two treatments. The study has demonstrated that lowering fish stocking density avails sufficient food resources and consequently increases growth performance and overall production of *Tilapia rendalli* in periphyton based systems. This study has discovered that a stocking density of 2 fish m^{-2} can be beneficial for increased growth and yield of *Tilapia rendalli* in a periphyton based aquaculture system.

SIGNIFICANCE STATEMENT

The findings of this study will help fish farmers to increase yields of *Tilapia rendalli* grown in periphyton based aquaculture systems which are widely acknowledged as effective and low cost models for increasing yields of phytophagous fish species in developing and resource constrained countries.

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