Stocking Density and Water Quality Effect on Growth Performance of Nile Tilapia Raised in Water Ponds in Dodoma City, Tanzania

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Abstract

Pond fertilization and stocking density consideration are two management practices used in pond fish farming to increase productivity. This study aimed to fill a knowledge gap in Dodoma by examining how different types of manure used for fertilization affect the water quality of ponds, as well as the effects of stocking density on the growth performance of Nile Tilapia. The effects of stocking density at 15, 30, and 100 individuals on the growth performance of tilapia fish (Oreochromis niloticus) in terms of weight and length gain were studied for one month (30 days). From day zero commercial powder feeds were applied at a rate of 9% of body weight. The pH, dissolved oxygen, and temperature of water fertilized with chicken and cow manure were all measured. The fourth week showed the best growth performance, with a length of 6.52±0.28cm and a weight of 3.43±0.36g at the large stocking density of 100 individuals per pond. Ponds fertilized with chicken manure had a significant effect in dissolved oxygen (10-14.20 mg/l) and pH (9.1-9.8) ($p<0.05$). Whereas, the more dissolved oxygen revealed a significant growth in fish in terms of weight ($p=0.01$). According to the findings of this study, low density and sufficient oxygen improved the fish growth performance. When applying manure for fertilization, it is critical to consider the different types of manure and how they affect water characteristics.

Keywords: Pond fertilization, manure type, growth performance, water quality

Introduction

Fish production is essential in improving food security Worldwide particulary in developing countries like Tanzania (Fletcher, 2021). The demand for aquatic food resources is increasing and will continue to increase over time due to population increase. For instance other reports shows that, the current demand of aquatic food worldwide is 131 million tons per year and is expected to raise to 204 million tons by 2030 (Joffrey *et al.,* 2021). Regardless of fish demand worldwide, yet in Tanzania, aquaculture farming is not exploited to its maximum potential. Findings by FAO, revealed that, Aquaculture is still primarily a part-time activity in the United Republic of Tanzania. The total number of people engaged in the aquaculture sub sector is approximately 17 100, with 14 100 employed in freshwater fish farming and approximately 3 000 engaged in seaweed farming (FAO, 2022). In addition, according with Fisheries Division, freshwater fish output is expected at 1 522.80 tonnes for tilapia, valued at US$ 1 327 637.30, while average productivity of rainbow trout was 7.0 tonnes in 2004, valued at US$ 18 308.63. 1 500 tonnes (dry weight) of seaweed are produced from the marine waters, but only for export, with earnings of US$ 209 241 (1 US$ = 1 147 TShs, ie, Tanzanian Shillings)(FAO, 2022).

Pond fertilization is act used by aquaculture farmers to increases the productivity of fish (Boyd, 2018). Different types of manures have been used in pond fertilization. Among the common manure used in fertilizations are: poultry and cattle manure (Boyd, 2018). Fertilization by using manure is applied so as to increase the productivity of phytoplankton which are used by fish as food (Chesser, 2022). The different contents of manure are anticipated to the water quality. However, little studies have been done to understand how the application of different manures could affect the water quality which are anticipated to have effects in the growth of fish. This study, addressed this challenge in Dodoma where the farmers are using different categories of manures to fertilize the pond.

Fish productivity has been influenced by different factors such as weather, feed and feeding, management practices, and species of fish raised. A study in Morogoro, Tanzania, showed that, the growth performance of tilapia fish was highly dependent of the species and the stocking density (Meiludie, 2013). Another study in Dodoma, revealed that, different type of feed provided to fish has great contribution on the growth performance (Ngongolo & Magendero, 2022). Little has been done on the effects of applying manure as pond fertilization of the water quality and productivity of fish. In addition, there is scanty information on the effects of stocking density on the growth performance of Nile tilapia (Oreochromis niloticus) in Dodoma.

This study focused at understanding the effects of applying different categories of manure to the pond on water quality. In addition, the study assessed the effect of stocking density, water quality of the growth performance of Nile tilapia (Oreochromis niloticus). The knowledge from this will help the farmers who are involved in fish production to maximizing the production at optimal pond fertilization, water quality and stocking density.

Materials and methods

Study area

The experiment was conducted at the College of Natural and Mathematical Science (CNMS), Department of Biology in the University of Dodoma. CNMS is having Aquaculture unit with ponds for raising fish for training and other purposes. Dodoma City is host to the University of Dodoma. Dodoma City is located in the country's center (6°10'23"S; 35°44'31"E), 455 kilometers west of the former capital, Dar es Salaam, and 441 kilometers south of Arusha, the birthplace of the East African Community. It is also 259 kilometers north of Iringa Municipality via Mtera. Dodoma has a semi-arid climate with relatively warm temperatures all year around. Although average maximum temperatures remain consistent throughout the year, average minimum temperatures drop to 13°C in July. The average annual precipitation is 570 mm, with the majority falling during the wet season between November and April, and the remainder falling during the dry season.

Source of experimental fingerlings

Species of Nile tilapia (Oreochromis niloticus) fingerlings used as experimental fishes were sourced from Ruvu fish farm hatchery in Coast Region, Tanzania mainland. The size of fingerlings used in the experiment was 0.17gm and 1.8cm in average. The fish fingerlings were packed in plastic bags filled with 1/3 water and oxygen and then transported in bucket. After arrival to college of natural and mathematical sciences fingerlings were acclimatized in hapa net placed in a plastic tank overnight before being stocked. Next day after acclimatization, early in the morning the fingerlings were stocked each replicate in its hapa net in which were already placed in experimental fish pond. The stocking densities of 15, 30, and 100 fish per pond were replicated in this study with the treatment of two types of manure: poultry and cow. Furthermore, the data was collected for four weeks, namely weeks 0, 1, 2, and 3. In each, stocking density category, two tanks were allocated for raising fish.

Experimental design and data collection on growth performance under varying stocking density

The experiment was conducted using fine mesh (1mm) hapa nets settled in the concrete fish pond with the size of one square meters ($1m^2$) for each replicate in each treatment. There was a total of six replicates that make a total of 290 fingerlings (Table 1). There were twice replicates for treatments of 15, 30, and 100 fingerlings stocked in $1m^2$. Thus, in each treatment there was a total of 30,60 and 200 fingerlings stocked in $1m^2$ (Table 1). The amount of feed used was 9% of body weight of individual fish. The quantity of feed for all fishes in each hapa net was calculated and weighed and divided into six potions and fed at a frequency of three times a day that is; morning at 8:00 am, afternoon at 12:00 pm and at 4:00 pm. The water exchange of the experimental fish concrete pond was changed once per week (on every Monday). About 10% of pond water was flashed away and replaced with fresh tap water.

Data collection

The fishes were grown for four weeks and data was collected for three weeks that is Weeks 0, week 1, week 2, and week 3 after stocking. The data were collected after an interval of seven days from 15 sampled fishes in each replicate on every Saturday. The data collected involved the measurement of length (cm) and weight (gm) of the fish were taken. Furthermore, during the data collection process, water samples for testing water quality (pH, dissolved oxygen, temperature) were collected and delivered to the biology laboratory at the University of Dodoma's College of Natural and Mathematical Sciences. During transportation to the laboratory, the water samples were kept cold in a cold box at 4°C. Water collection for testing water quality (pH and dissolved oxygen) was required to establish the relationship between water quality and fish growth performance.

Table 1: Illustration to show the experimental design of the study

S/n	Treatment (Stocking of Fingerlings)	Replication	Amount in each replicate (Fingerlings)	Total per treatment
1	15	1	15	30
		2	15	
2	30	1	30	60
		2	30	
3	100	1	100	200
		2	100	

Research design and data collection for water quality under different manure fertilization

Three tanks each with a total volume 1000 litres was used for experiment. In each tank, a total of 750 litres was filled in each tank and two categories of manures were added. In each tank, one type of manure was added. The type of manures involved in this experiment were chicken and cow manure. Two treatments involved the two categories of manure and one tank acted as control. The control pond was not added the fertilizer in it while the two tanks were treated with chicken and cow manure of 15 kg (one type of manure in each pond 15Kg). A total of 20 water samples were taken from each pond in the 4th and 7th day after applying the manure in each pond. This accumulated a total sample of 120 (n=60 in each sampling session/day). In each sample water quality in terms of dissolved oxygen, water temperature and water pH were measured. Water quality parameters measured in the laboratory included dissolved oxygen (DO) and pH (mg/L and pH, respectively). A HANNA HI9142 DO meter was used to measure dissolved oxygen, and a HANNA Combo HI 98129 multimeter was used to measure pH and temperature.

Data Analysis

The Shapiro-Wilk test for normality had $p<0.05$ thus suggesting that, the data are not normally distributed. In this case, the variation in growth performance of fish under different treatment was analyzed using non-parametric test. The non-parametric test used in this study was Kruskal Wallis statistical test and Mann-Whitney statistical test. The variation or difference was considered significant when the p-value was less than 0.05. Furthermore, to predicts the outcome of growth performance in terms of weight (gm) and other variables such as stocking density, water quality (dissolved oxygen (DO) and pH using a D.O meter (mg/L) and pH) and time interval from stocking (age in weeks), and total length on the increasing weight of fishes were analyzed using Multiple Linear Regression. $Yi= \beta 0 +\beta 1X1 +\beta 2X2+ \beta 3X3 + \beta 3X4 +\epsilon$

Where by:

- Yi is the dependent or predicted variable

(Weight (g))

- β0 is the y-intercept, i.e., the value of y when both x1, x2, x3 and x4 are 0.
- β1, β2, β3 and β4 are the regression coefficients representing the change in y relative to a one-unit change in x1, x2, x3 and x4, respectively. (In this case standard length (cm), Total length (cm), pH and Dissolved oxygen(mg/L) respectively.
- βp is the slope coefficient for each independent variable
- ϵ is the model's random error (residual) term.

Results

Growth performance of fish under varying stocking density

Stocking density of fish has significant association with the growth performance. The results revealed that, the stocking density week 0 (a time of installation), did not show significant variation in the growth performance ($p>0.05$). However, in the 1st, 2nd, and 3rd week, the growth performance significantly varied among the three stocking density categories ($p<0.001$) (Table 2 and 3). Stocking density and water quality in terms of dissolved oxygen (mg/L) was observed to have significant effect on the growth performance of fish in terms of weight (g) (Table 5).

Water quality under fertilization of different type of manure to the ponds

The use of various types of manure in the pond as a means of fertilization was shown to have a variable effect on water quality. For instance, pH and dissolved oxygen were higher in ponds applied with cow manure on both day 4 and day 7 than in ponds applied with chicken manure (Table 4). The water quality in terms of pH (Mann-Whitney U test statistic = 0.0003, p< 0.0001) and dissolved oxygen (Mann-Whitney U test statistic = 178.00, p< 0.0001) significantly varied between the cow and chicken manure (Fig. 1). When pH was used as an intercept in GLM, the p-value was 0.0001. A similar trend was observed for dissolved oxygen, with chicken manures (Estimate Std=15.63, S. E=5.92, t=2.64, p=0.01) outperforming cow manure (Estimate Std=4.18, S. E=0.69, t=-6.09, p=0.001) and the control (Estimate Std=1.93120, S.E=10.55, S.E=0.94, t=-11.21.

Discussion

Growth performance under varying stocking density

It was hypothesized that the growth performance would be low under high stocking density, which was not the case in this study. The growth showed a significant increase with the increase in stocking density. For instance, the stocking density of 100 fingerlings showed the highest growth rate compared to other stocking densities (15 and 30). This can possibly be explained by the allocated fingerlings with change in eating habits and activities in the pond. Perhaps the number of fingerlings assigned in the pond simply changed the feeding intake and growth through feeding consistency, swimming activity in the tank, and boldness. A Dutch study concluded that feeding consistency, tank swimming activity, and boldness during behavioral tests are related to feed intake and sole growth in captivity (Mas-Muñoz e*t al.,* 2011). Feeding has previously been reported as

Table 2: Average growth performance in each stocking density per replicate

S/n	Treatment (Stocking of Fingerlings)	Replication	Total number fingerlings	Total sample collected	Average weight (gm)	Average length (cm)
1	15	2	30	120	4.36±0.09	1.34±0.06
2	30	2	60	120	4.14±0.12	1.72±0.09
3	100	2	200	120	4.35±0.16	1.71±0.11
4	Kruskal-Wallis Test Statistic			2.36	3.85	
5	Probability (P-Value)			0.31	0.15	

Table 3: Average growth performance in each stocking density per replicate

S/n	Time interval in week	Treatments (Stocking density)	Average weight (Mean ± S.E gm)	Average length (Mean±S.E cm)
1	Week 0	15	1.73±0.05	0.16±0.01
		30	1.77±0.05	0.17±0.04
		100	1.82±0.08	0.18±0.01
	Kruskal-Wallis Test Statistic		2.08	2.65
	Probability (P-Value)		0.35	0.27
2	Week 1	15	3.02±0.08	0.51±0.01
		30	3.40±0.07	0.97±0.02
		100	4.02±0.04	1.05±0.02
	Kruskal-Wallis Test Statistic		50.82	45.456
	Probability (P-Value)		<0.0001	<0.0001
3	Week 2	15	4.54±0.07	1.31±0.02
		30	5.56±0.08	1.79±0.04
		100	5.52±0.04	2.37±0.04
	Kruskal-Wallis Test Statistic		41.38	59.993
	Probability (P-Value)		<0.0001	<0.0001
4	Week 3	15	4.94±0.04	1.77±0.02
		30	3.79±0.20	2.41±0.19
		100	6.52±0.04	3.38±0.04
	Kruskal-Wallis Test Statistic		80.80	71.60
	Probability (P-Value)		<0.0001	<0.0001

an important factor in the growth of fingerling in ponds (Ngongolo & Magendero, 2022).

Water quality under fertilization of different type of manure to the ponds

The application of different types of manure revealed a significant effect on water quality in the ponds. For example, in this study, it was clear that dissolved oxygen and pH varied among the ponds with different types of fertilization (poultry and cow manure). Other findings have shown that the application of chicken manure provides optimal dissolved oxygen. The optimal oxygen supply is recommended for the growth of ponds at DO>5 mg/L for good growth and reproduction of fish, in contrast to DO<3,

Table 4: Water quality under different categories of manure applied as in ponds for fertilization purposes

Day	Variables	Water Quality parameter		
	Treatment	pH	Dissolved Oxygen (mg/l)	Temperature (°C)
4	Cow manure	8.797±0.015	7.965±0.134	22.505±0.084
4	Chicken Manure	7.876±0.01	2.985±0.149	22.555±0.194
4	Control	9.839±0.099	10.45±0.23	21.335±0.103
7	Cow manure	8.886±0.053	5.676±0.302	23.371±0.111
7	Chicken Manure	7.986±0.054	5.337±0.327	20.874±0.321
7	Control	9.143±0.015	14.195±0.302	23.01±0.069

Table 5: The association existing between the weight with other factors such as water quality, stocking density, Standard length (cm) and Total Length (cm)

S/n	Variables	Classification	Coeff.	Std. err	t	p
		Intercept	-0.32	0.47	-0.68	0.50
1	Stocking density)	30	0.49	0.06	8.04	9.26e-15 ***
		100	0.93	0.06	14.82	<2e-16 ***
2	Week of stocking	Week 0	-0.14	0.46	-0.31	0.76
		Week 1	0.46	0.47	0.978	0.33
		Week 2	1.70	0.47	3.65	0.000296 ***
		Week 3	2.42	0.46	5.21	2. 95e-07 ***
		Intercept	-10.30	14.56	-0.708	0.48
3	Water quality	pH	-0.49	1.86	-0.26	0.79
		Dissolved oxygen (mg/L)	4.39	0.77	5.74	1.1e-07 ***

which is considered harmful to fish (Kaur *et al.* 2015). Kaur *et al.* (2015) reported that chicken manure was enough for pond fertilization. Its performance was observed to be sufficient for it performed better than the inorganic fertilizer (urea + SSP). The fertilization of ponds has been recommended in different parts of the world where aquaculture is practiced. It has been reported that pond fertilization by organic manure increases the production of aquatic organisms like fish and shrimp through increased food production (Boyd, 2018). The increase in food production is facilitated by the sufficient supply of nitrogen, phosphorus, and other plant nutrients to stimulate phytoplankton photosynthesis, which is the basis of the food web (Boyd, 2018). Chicken manure, as one of the manures with a high carbon concentration, is expected to produce and contribute significantly to plant photosynthesis (Boyd, 2018).

Growth performance under varying water quality

The effect of water quality is crucial in fish production. In this study, it was realized that water quality, specifically DO (dissolved oxygen), had a significant effect on fish growth performance.

Concurrently, the application of manure had an effect on the change in water quality. For instance, on day 7, the dissolved oxygen level was found to be between 5-7 mg/g for both cow and chicken manure, as recommended by Boyd (2018) and Kaur *et al* (2015). Another study found a similar finding whereby dissolved oxygen was significantly related to the growth performance of fish, which is interlinked with feed convention ration (Ngongolo & Magendero, 2022). Other findings revealed that, apart from turbidity, temperature, and food supply, other factors considered important for the growth of fish were dissolved oxygen (Soderberg, 2017). Also, pH has been reported to be among the water quality parameters that play a key role in the growth of fish in ponds. A study in Uganda showed that fish can become stressed in water with a pH of between 4.0 and 6.5 or 9.0 and 11.0. Fish growth is limited in water with a pH less than 6.5, and reproduction ceases and fry can die in water with a pH less than 5.0. The pH of pond water changes throughout the day due to photosynthesis and respiration by plants and vertebrates (Kaur *et al.,* 2015; Tumwesigye *et al.,* 2022). Furthermore, the study found that water quality parameters like temperature, pH, ammonia, carbon dioxide, and iron content had a significant effect on the weight and size of both tilapia and catfish (Tumwesigye *et al.,* 2022).

Conclusion and Recommendation

In this study, it was found that the growth performance of fish was associated with stocking density and water quality in the tank where the fish are kept. Although at a stocking density of 100 fingerlings, the growth rate was still higher than expected. This suggest that, more studies need to be done to understand what could be other factors which influence the growth performance from fish apart from stocking density. Furthermore, fertilization is essential for the growth of fish as it contributes to water quality improvement. Because fertilization for different chicken and cow manures had a significant effect on the improvement of dissolved oxygen (DO) in this study. The farmer must consider stocking density, water quality in the pond, and the type of manure used in the pond for better quantity and quality of fish production from aquaculture. We recommend more studies to be done in this area to understand the effects of stocking density in relation to feeding behavior, feed intake and determine other factors which could affect the growth performance of fish kept in the pond.

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