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Research Article

Growth and Economic Evaluation of Different Fish Species for Culture in Uganda's Mid Altitude Areas Using Local Feeds

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Abstract

Background and Objective: The East African high-altitude areas remain ecologically challenging to tropical native farmed fish species, the Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) yet the potential for cold-water fish culture is as well unexploited. This study describes the effects of environmental quality and local feed on the growth and economic performance of selected fish species for 5 months along the slopes of Mountain Elgon Uganda. **Materials and Methods:** Three earthen ponds each 200 m³ by volume were conditioned with hydrated lime at 0.1 kg m⁻³ for a week. The ponds were stocked with juveniles of Rainbow trout (*Oncorhynchus mykiss*), Nile tilapia and Mirror carp, averaging 1.5±0.1, 17.9±2.2 and 2.0±0.2 g (±SE), respectively. The fish were fed to satiation daily on 35% C.P local feed for 5 months. Water quality and growth data were collected daily and monthly, respectively. Performance parameters were computed and analyzed using univariate ANOVA and regression analysis in SPSS20. **Results:** There was a highly significant difference (p<0.001) in mean body weight gain (g/day) between Rainbow trout and the Nile tilapia (mean diff 0.0788, p<0.001) and Mirror carp (mean diff 0.087, p<0.001) and between Rainbow trout and the two species combined (mean diff 0.016, p = 0.006). The highest weight gain (4.8 g/day) overall was demonstrated by Mirror carp in the 4th month of growth. The mean relative condition (Kn) for respective species (p<0.05) were all <1. The Mirror carp was the most profitable, at Ugshs 4, 130, 463 (44.9%) of total revenue, while trout incurred over 92.1% (Ugshs -3, 974, 994.5) losses. Mirror carp demonstrated better economic viability with the experimental feed in the area, however, this can be much better with improved management. **Conclusion:** The observed growth patterns were consistent with temperature variation and feed quality, thus, Nile tilapia performed poorly due to low water temperature and Rainbow trout was worse due to poor feed quality that negatively influenced visibility and feed intake.

Key words: Fish species suitability, environmental conditions, suitable feeds, temperature variation

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

INTRODUCTION

Uganda is the largest producer of farmed fish in East and Central Africa, producing about 120,000 MT of freshwater fish species annually¹. This spectacular growth is particularly attributed to improved availability of requisite inputs such as skilled labour, feeds and fish seed mainly of tropical species². However, despite demonstrable growth, the development is more visible around the most urbanized central part of the country, located at a lower altitude, which is highly favourable to tropical farmed fish species. While the lower altitude areas continue to culture tropical species, over one-third of the country mainly around the slopes of mountain Elgon (Bugisu and Sebei) and the Ruwenzori-Kigezi sub-regions have lagged due to unfavourably low temperatures which do not support the growth of tropical fish species. The mid-high altitude sub-regions of Uganda experience water temperatures from 15-23°C, suboptimal for the culture of tropical species, African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*). Hence, for over six decades post the introduction of aquaculture, farmers in the mid-high altitude areas have suffered poor growth performances with tropical species. The Mirror carp (*Cyprinus carpio*) despite being cold tolerant and over six decades after its introduction in Uganda, is still not widely farmed due to a lack of sufficient quantities of seed and inadequate data about its growth performance in the mid-high altitude areas.

Similarly, the Rainbow trout (*Oncorhynchus mykiss*) was first introduced in Uganda in 1927 as an ecotourism and ornamental commodity initially stocked in River Sipi on the slopes of mountain Elgon^{3,4}. However, whereas, the captive stock established itself in the River Sipi, attempts to culture the species through aquaculture have not succeeded due to a lack of suitable feeds, lack of local seed and poor skills to handle the species adequately. This is contrary to what is happening in the neighbourhood in Kenya where the fish has largely succeeded in aquaculture due to available local seed and feed systems.

Uganda has several locally available fish feeds that have mainly been evaluated and succeeded in the culture of tropical fish species. Given the preferential feeding habit of Rainbow trout, mainly on animal-related diets and along the water column, sinking feeds would be more suitable, especially in earthen ponds where solid waste suspension is easily absorbed by the earth sediments⁵. The biggest challenge with sinking feed in earthen ponds, however, is the accumulation of dust suspension that limits visibility for species that feed on sight^{6,7}.

The purpose of this study, therefore, was to evaluate the suitability of three different fish species, Rainbow trout, Nile tilapia and Mirror carp for culture in earthen ponds using the local feed in a mid-altitude environment based on growth and profitability analysis along the slopes of mountain Elgon-Uganda.

MATERIALS AND METHODS

Study area: The study was conducted in earthen ponds located at Bulegeni Agricultural Research and Development Centre, Kamu Sub-County, Bulambuli District.

Experimental materials and design: Rainbow trout used in this study was obtained from Kiganjo trout hatchery (Republic of Kenya), while, the Nile tilapia and Mirror carp fingerlings were from local fish hatcheries in Uganda. Rainbow trout and Mirror carp were obtained at 30 days old post-hatch (dph), both averaging 1-2 g by weight. The Nile tilapia was 2 months old dph, weighing about 10 g on average. All the fish were acclimatized for a month on-site, on the experimental feeds before the start of the trials. The mean weight of the fish at the start of the experiment was 1.5 ± 0.1 , 17.9 ± 2.2 and 2.0 ± 0.2 g ($\pm$ SE) for Rainbow trout, Nile tilapia and Mirror carp, respectively. For each treatment, three earthen ponds, each measuring 200 m³ by volume were conditioned with hydrated lime at a rate of 0.1 kg m⁻¹ for a week to neutralize the culture environment and also to disinfect the ponds against predators and pathogens. Each experimental species was replicated in triplicates. At the beginning of the experiment, from each fish species, individuals were graded to the same size class to minimize variation in size. At stocking, a random sample of 50 fish was drawn from each replicate for extraction of the initial biometric total length (cm), total weight (g) dataset.

Rearing protocol: The experimental design was based on the growth of juvenile specimens of Rainbow trout, Nile tilapia and Mirror carp on locally made compound feed within a mid-altitude culture environment. Juvenile Nile tilapia (n = 2400), Mirror carp (n = 2400) and Rainbow trout (n = 2400) were divided into nine groups (three replicates for each species). Each fish species treatment was graded to a uniform weight range (mean live weight $\pm$ SE). The initial weights were 1.5 ± 0.1 , 17.9 ± 2.2 and 2.0 ± 0.2 g ($\pm$ SE) of Rainbow trout, Nile tilapia and Mirror carp, respectively. Each species was stocked at a rate of 4 fish m⁻³, comprising projected biomass carrying capacity $\pm$ SE of 2, 2 and 4 kg m⁻³ of Rainbow trout,

Nile tilapia and Mirror carp, respectively. All experimental units were restrained by a gillnet screen over the pond surface to protect the fish from bird predators.

Feeding management: Feeding using a powdered diet was by hand, thrice a day at 1000-1100 hrs, 1400-1500 and 1700-1800 hrs for first, second and third feeding, respectively, across all experimental treatments/units. All species were fed in response to satiation while, taking a record of the number of feeds used and the balance. For the 1st month of experimentation, all the species were fed a powdered diet. In the 2nd month, the fish were put on a transition diet format comprising a mixture of powder and a 1.5 mm diameter diet of the same feed type. From the 3rd month onwards, the stocks were weaned to a pelleted diet. The diet, according to the manufacturer was 35% crude protein. Feeding using a pelleted diet was thrice a day daily. Fish were not fed on sampling day to minimize building up stress factors and resultant mortalities in the system.

Water quality monitoring: Water quality was monitored daily in the morning before sunrise and at dusk in the evening. Parameters monitored included, water temperature, dissolved oxygen concentration, pH and turbidity. Dissolved oxygen, temperature and pH were monitored using a multi-parameter water quality test meter, model Eco-Sense DO200A. Turbidity was taken using a Secchi disk, reinforced with a metal plate having black and white alternate colour bands and a graduated cord handle for lowering and taking the readings. Reading for each parameter was taken from two locations (inlet and outlet of each pond).

Feed analysis: A proximate nutrient composition of the commercial feed used was carried out by Makerere University College of Agriculture, school of animal sciences, following the protocol of the Association of Official Analytical Chemists-AOAC⁸. The parameters analyzed included, moisture, crude protein, crude lipid, crude fibre and ash in Table 1.

Sampling procedure/biometric data collection: Fifty fish from each treatment/experimental unit were collected after every 30 days (1 month). Biometric data including length (L, cm) and weight (W, g) was collected for five consecutive months from 1st February to 30th June, 2018. This duration traverses the first phases of the dry (February to March) and wet (May to June) seasons in the area. Body weight was collected using a digital weighing scale model constant 14192-007R, while, the length was collected using a graduated measuring board.

Table 1: Proximate nutrient composition (%) of feeds used to feed Rainbow trout, Nile tilapia and Mirror carp

Component	Proportion
Dry matter (%)	91.6
Crude protein (%)	33.0
Crude fat (%)	8.8
Total ash (%)	7.7
Fibre (%)	10.3
Metabolizable energy (K calK ⁻¹)	2727.5

Data analysis: Data generated from each treatment replicates were pooled and analyzed per species/treatment. Growth, monitored by daily weight gain (DWG, g/day) and specific growth rates (SGR, (%) body weight/day) over the intervals between each sampling and the whole experimental period were computed using the formula⁹:

$$DWG = \frac{W_f - W_i}{t}$$

where, Wf and Wi are the mean final and initial fish body weight over time t.

Similarly, the specific growth rate for each treatment group was calculated¹⁰:

$$SGR \left(\frac{\text{Bodyweight gain (\%)}}{\text{Day}} \right) = \frac{\ln W_f - \ln W_i}{t} \times 100$$

Where:

lnWf = Natural logarithm of the mean final weight (g)

lnWi = Natural logarithm of the mean initial weight (g)

t = Time (days of growth) between lnWf and lnWi⁹

One-way Analysis of Variance (ANOVA) was used to test the difference in growth among species. Leven's F-test for homogeneity of variance (p<0.001) was used to test for differences among treatments. Tukey's Honestly Significant Difference (HSD) test was used to determine which specific pairs of treatments differed. To explore the effects of water quality on fish growth, the significance of the difference among treatments was estimated using the *post hoc* LSD Fisher test (p = 0.05). To compare conditions, the welfare of the fish among fish species and for the generation of predictive models of fish condition, the relative condition factor of each species, was calculated as the ratio of observed individual fish weight to the expected weight of an individual of a given length, applying the formula⁹⁻¹¹:

$$K_n = \frac{W_i}{aL_i^b}$$

Where:

W_i = Observed individual fish weight

L_i = Observed individual fish total length

a-b = Species-specific constants

These regression constants were obtained from the treatment length-weight relationship ($W = aL_i^b$) derived by pooling data generated from the respective treatment replicates in successive sampling months for the entire fish specimen in each treatment. Length and weight data were log-transformed to remove skewness and the resultant linear relationships were fitted by least square regression using weight as the dependent variable. Statistical analysis was done using SPSS for windows version 20 at a 0.05% level of significance^{12,13}.

RESULTS

The mean body weight ($\pm$ SE) at the start of the experiments was 1.5 ± 0.1 , 17.9 ± 2.2 and 2.0 ± 0.2 g for Rainbow trout, Nile tilapia and Mirror carp, respectively. There were no significant differences ($p > 0.05$) among replicates of the same treatments ($n = 3$, $p > 0.05$) throughout the experiments, hence, data for each species treatment replicates were pooled before analysis. The species showed different trends of growth response, to the experimental conditions. There was a highly significant difference ($p < 0.001$) in mean body weight gain (g/day) between Rainbow trout (mean diff 0.0788, $p < 0.001$) and Mirror carp (mean diff 0.087, $p < 0.001$). There was a significant difference in mean daily weight gain between Nile tilapia and Mirror carp but a highly significant difference between Rainbow trout and the other two species combined (mean diff 0.016, $p = 0.006$). The highest weight gain (4.8 g/day) overall during the experimental period was in the 4th month of growth by Mirror carp, while, no weight was gained by Rainbow trout in the 3rd month of experimentation. Overall, Rainbow trout grew much slower than Nile tilapia and the Mirror carp. The highest growth rate of 6% body weight/day was recorded with Rainbow trout at the beginning of the experiment. Rainbow trout grew at a reducing rate to zero in the 3rd month, before a slight increase in the 4th and 5th months, respectively. The Nile tilapia grew at a decreasing rate, declining from 2.5% body weight/day in the 1st month to 0.5% body weight/day in the 5th month. The Mirror carp, however, grew at an increasing rate from 3.3% body weight/day to 3.9% body weight/day in the 2nd month. This reduced to 1%, before an exponential increase and decline in the 3rd, 4th and 5th months, respectively in Table 2.

Table 2: Mean monthly specific growth rate (% body weight/day)

Mean monthly specific growth rate (body weight/day %)			
Month	Trout	Nile tilapia	Mirror carp
1	6.0	2.5	3.3
2	1.7	1.3	3.9
3	1.0	1.4	1.0
4	1.0	0.8	5.5
5	1.1	0.5	0.7

Table 3: Feed conversion ratio of Rainbow trout, Nile tilapia and Mirror carp during the experimental period

Feed conversion ratio by species (kg feed kg ⁻¹ fish)			
Month	Trout	Nile tilapia	Mirror carp
1	2.4	2.4	1.0
2	4.6	4.4	1.8
3	4.5	2.7	2.0
4	4.9	3.0	2.3
5	4.7	3.1	3.0
Average	4.2	3.1	2.0

Values computed for species at every month of growth

On average, Mirror carp achieved the highest growth rate, followed by Rainbow trout while the Nile tilapia achieved the least Fig. 1.

The mean body weight of Rainbow trout ($\pm$ SE) increased from 1.5 ± 0.1 - 36.0 ± 12.2 g in 5 months, while Nile tilapia and Mirror carp grew from 17.9 ± 2.2 - 162.5 ± 55.4 and 2 ± 0.2 - 268.9 ± 222.9 g, respectively, over the same period in Fig. 2.

The length-weight allometry among the species was also significantly different $F(2, 1886) = 65.8$, $p < 0.001$ as in Fig. 3a-c. The "b" constant for Rainbow trout ($R^2 = 0.892$) and Nile tilapia ($R^2 = 0.984$) were >3 (Fig. 3a and b), indicating these species were heavier than longer, characteristic of deeper and thicker fillets, capable of producing good carcass value on slaughter. The "b" constant for Mirror carp ($R^2 = 0.988$) was <3 , indicating the species were longer than heavier (Fig. 3c).

The mean relative condition factor (Kn) for the respective species at ($p < 0.05$) were 0.1 ± 0.02 , 0.2 ± 0.01 and 0.6 ± 0.1 , for Rainbow trout, Nile tilapia and Mirror carp, respectively in Fig. 4.

The worst (highest) average feed conversion values of 4.2 kg feed kg⁻¹ fish were in Rainbow trout treatment, implying that, to produce a kilogram of Rainbow trout fish using the same feed, one requires 4.2 kg feed under the same experimental conditions. The average feed conversion in Nile tilapia was 3.1 kg feed kg⁻¹ fish while that of Mirror carp averaged 2.0 kg feed kg⁻¹ fish produced in Table 3.

The mean values for water quality parameters (dissolved oxygen, temperature, pH and turbidity) are summarized in

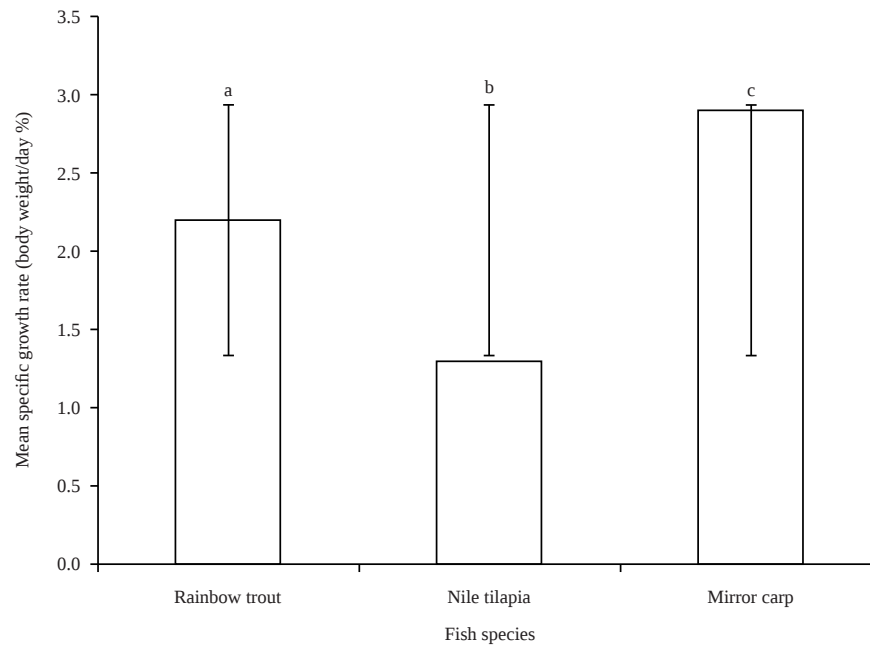


Fig. 1: Mean specific growth rate ($\pm$ SE) derived after pooling the data of replicate units of each Rainbow trout, Nile tilapia and Mirror carp treatment

Different letters above the bars indicate significant differences among treatments ($p < 0.05$)

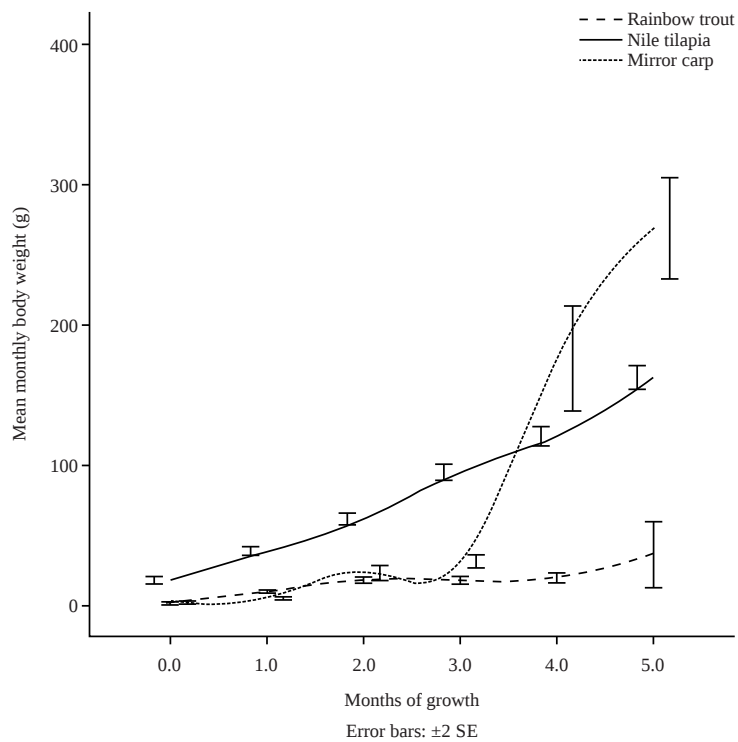


Fig. 2: Growths patterns and mean body weight of Rainbow trout, Nile tilapia and Mirror carp over 5 months growth period
Error bars are ($\pm$ SE) monthly mean weight of each species

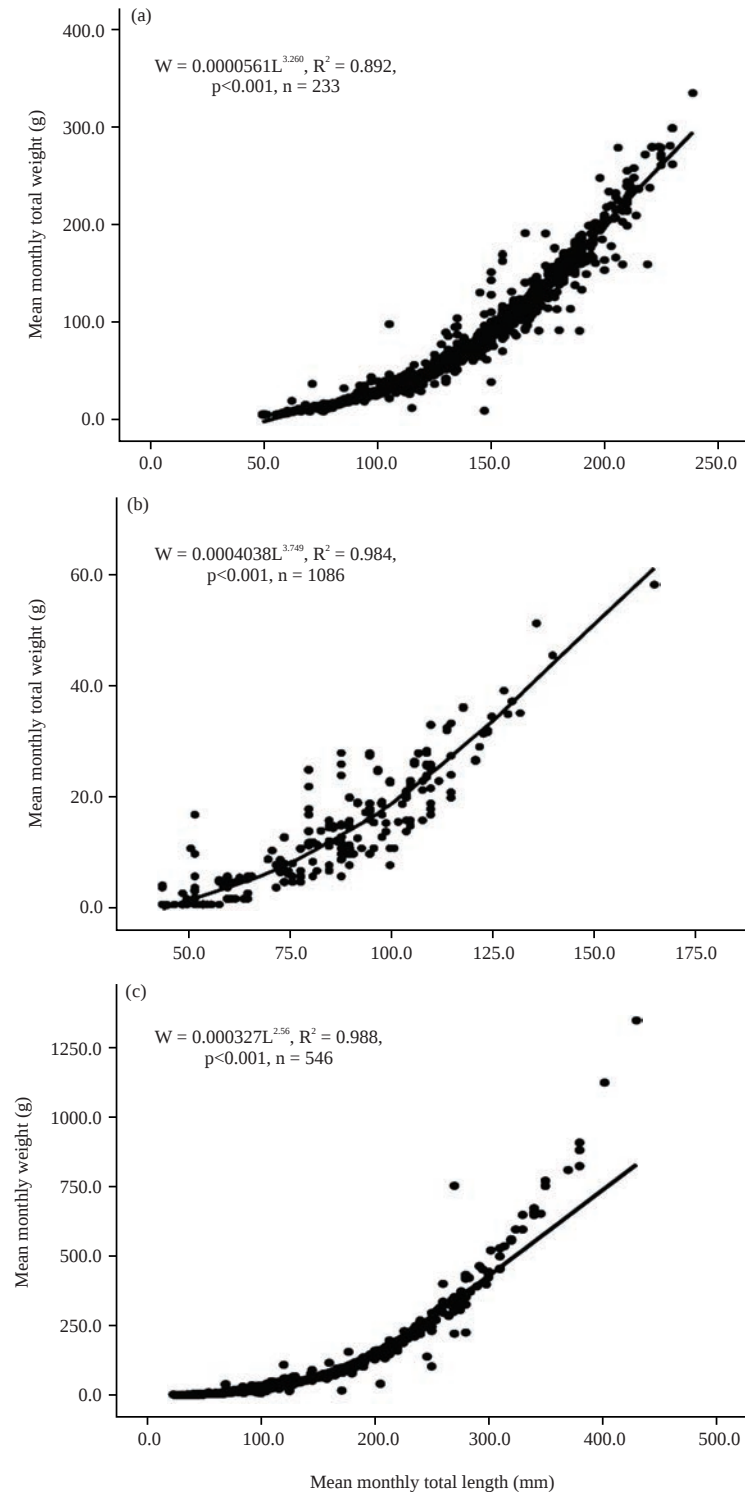


Fig. 3(a-c): Relationship between total weight (g) and total length (mm) for, (a) Rainbow trout, (b) Nile tilapia and (c) Mirror carp

Table 4. There was a significantly ($p < 0.001$) lower oxygen concentration of dissolved oxygen of $4.8 \pm 0.1 \text{ mg L}^{-1}$ in the Rainbow trout culture units compared to Nile tilapia and Mirror carp. Water temperature and turbidity in

Rainbow trout units were significantly ($p < 0.001$) different from Nile tilapia and Mirror carp units. There was no significant ($p > 0.05$) difference in pH levels across all treatments (Table 4).

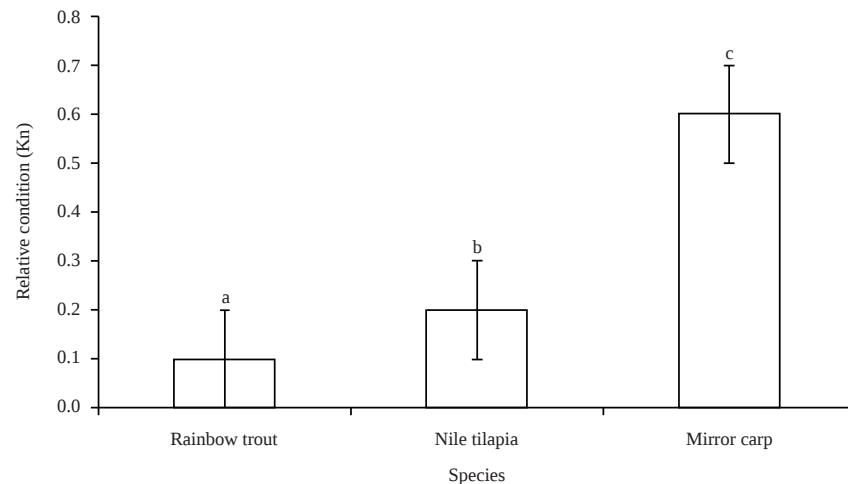


Fig. 4: Mean relative condition (Kn) (±SE) of Rainbow trout, Nile tilapia and Mirror carp

Different letters above the bars on each species indicate significant differences at $p < 0.05$

Table 4: Mean water quality parameters (±SE) recorded for the different experimental units of Rainbow trout, Nile tilapia and Mirror carp from 1-5 months of growth experiments at Bulegeni ARDC

Species	Water quality parameters			
	Dissolved oxygen (mg L^{-1})	Temperature ($^{\circ}\text{C}$)	pH	Turbidity (cm)
Rainbow trout	4.8 ± 0.1 (4.6-5.1) ^a	21.0 ± 0.2 (21.0-21.4) ^a	7.5 ± 0.0 (7.3-7.5) ^a	29.2 ± 1.0 (27.3-31.1) ^a
Nile tilapia	5.2 ± 0.2 (4.8-5.7) ^b	22.2 ± 0.1 (22.0-22.5) ^b	7.2 ± 0.1 (7.0-7.3) ^a	38.2 ± 1.9 (35.8-40.6) ^b
Mirror carp	5.3 ± 0.2 (4.9-5.5) ^b	22.0 ± 0.1 (21.9-22.3) ^b	7.3 ± 0.1 (7.4-7.4) ^a	38.5 ± 1.6 (35.4-41.5) ^b

a-b: Observations within columns significantly different, Figures in parentheses are ranges ARDC: Agricultural research and development center

Table 5: Economic analysis results for 600 m³ earthen pond culture of Rainbow trout, Nile tilapia and Mirror carp over 5 months of growth

Variables	UOM	Quantity	Rate (Ugshs)	Total amount (Ugshs)	Proportion of total operating costs (%)
Rainbow trout costs					
Feed	kg	898.8	3,550.0	3,190,562.5	38.5
Fish seed	Pieces	2,400.0	1,500.0	3,600,000.0	43.4
Operational expenses (casual labour, attendant)	Lump sum	5.0	300,000.0	1,500,000.0	18.1
Total operating costs				8,290,562.5	
Revenue (farm gate)	kg	215.8	20,000.0	4,315,568.0	
Gross profit				-3,974,994.5	
Nile tilapia					
Costs					
Feed	kg	1,082.2	3,550.0	3,841,668.0	63.4
Fish seed	Pieces	2,400.0	300.0	720,000.0	11.9
Operational expenses (casual labour, attendant)	Lump sum	5.0	300,000.0	1,500,000.0	24.8
Total operating costs				6,061,668.00	
Revenue (farm gate)	kg	1,069.0	8,500.0	9,086,610.5	
Gross profit				3,024,942.50	
Mirror carp costs					
Feed	kg	664.9	3,550.0	2,360,430.5	46.6
Fish seed	Pieces	2,400.0	500.0	1,200,000.0	23.7
Operational expenses (casual labour, attendant)	Lump sum	5.0	300,000.0	1,500,000.0	29.6
Total operating costs				5,060,430.50	
Revenue (farm gate)	kg	1,081.3	8,500.0	9,190,893.6	
Gross profit				4,130,463.1	

Seed constituted the highest cost component of 43.4% on Rainbow trout, while, 23.7 and 11.9% of the total operating costs were incurred in acquiring Mirror carp and Nile tilapia seed, respectively. About 63.4% of the total

operating costs were incurred on feeds for Rainbow trout, while, Nile tilapia and Mirror carp feed costs constituted 46.6 and 38.5%, respectively of the total operating costs.

In general, the Mirror carp was the most profitable, generating a gross profit of Uganda shillings four million one hundred thirty thousand four hundred and sixty-three (Ugshs 4,130,463) about 44.9% of total revenue. Nile tilapia generated Uganda shillings three million twenty-four thousand nine hundred and forty-two only (Ugshs 3,024,942.5) about 33.3% of the total revenue, while Rainbow trout incurred over 92.1% losses as over Uganda shillings three million nine hundred seventy-four thousand nine hundred ninety-four (Ugshs-3,974,994.5) less of the total revenue was incurred in Table 5.

DISCUSSION

The health, welfare and consequently the growth and economic returns of a fish farming enterprise are often directly dependent on the quality of the environment and inputs aimed to support the wellbeing of the stock. Thus, the water quality in which the fish are cultured and the feeds that the fish eat contribute immensely to fish growth and subsequent economic returns. Although different fish species are affected differently, comparative analysis of the effects of different environmental parameters generates momentum for the decision on candidate culture species in a given locality. This study demonstrates how the growth of Rainbow trout, Nile tilapia and Mirror carp was affected by water quality and local feed. In particular, the Rainbow trout was significantly affected by both feed and water quality. Being highly carnivorous, the low protein and fat contents of 33.3 and 8.8% were below the physiological requirement of ≥ 40 and $\geq 15\%$ required by Rainbow trout¹⁴. The highest proportion of the feed was made of non-nutrient components, thus, the dry matter was 91.6% contrary to its nutrient requirement. The low quality of feed affected intake and generated high levels of suspended solids along the water column, significantly reducing visibility and increasing high waste content that exhausted dissolved oxygen and increased turbidity in the culture units. Dissolved oxygen and turbidity were not within the optimum ranges for the commercial culture of the species and as a result, growth rates were low, daily weight gain was minimal and the fish experienced very poor conditions below 0.5. Whereas, the water temperature and pH remained within optimum levels for Rainbow trout culture, the cause of low oxygen levels and high turbidity was a result of poor quality of the experimental feed compared to the nutrient requirements of the species (Table 1).

Despite the feed, quality is within the requirement for the Nile tilapia and Mirror carp, the Nile tilapia growth performance was moderate. The final average weight was 162.5 ± 55.4 from 17.9 ± 2.2 g in 5 months. Daily weight gain,

specific growth rate and condition were equally moderate. This result is much lower for Nile tilapia culture under regular tropical weather (temperature) conditions. For example, Ondhoro *et al.*¹⁵, observed a mean weight of 311.5 ± 114.6 g and a condition of 2 at the water temperature of 25°C using the same feed. The ecological difference between the two studies is the variance in water temperature which in this study, was below the physiological requirement for Nile tilapia culture. Numerous studies show that Nile tilapia grows faster under the optimum water temperature range of $25\text{--}30^\circ\text{C}$, provided other growth requirements such as feed are optimal thus, water temperature below 25°C is stressful, slows the growth and prolongs the production period¹⁶⁻¹⁸.

Measured environmental conditions were all within the range of requirements for Mirror carp culture, however, mean body weight, 268.9 ± 222.9 g, condition of 0.6 etc., indicate the species did not reach its full growth potential. Moreover, its length-weight relationship was <3 , an indication that individuals were much longer for their body weights. The standard error of ± 222.9 g, reveals a very large size variation among the Mirror carp stock during the experiment. These variations often arise due to discrepancies in the initial size of individuals at stocking and irregular feed distribution that encourages the development of extreme growth cases commonly known as shooters¹⁹. A comparison of size distribution at stocking and harvest shows that the phenomenon emerged during the experiment. There was uniform size distribution at the beginning of the experiment (2.0 ± 0.2 g). It has been observed that once size variation emerges within the system, bigger-sized individuals become more aggressive and territorial against the smaller-sized group widening the size gap among individuals and thus at harvest, farmers attain variable sizes. Territoriality and aggressive feeding behaviour have been observed with species such as African catfish (*Clarias gariepinus*) Eurasian perch (*Perca fluviatilis*)²⁰. Other than irregular feed distribution in the culture systems, wide size variation also emerges from the fluctuation in water temperature between day and night that affect the fish's metabolic activity²⁰. It has been demonstrated further that in species like Mirror carp that are non-cannibalistic, size variation arises due to intraspecific competition for limited supply resulting in the disproportional acquisition of food that ultimately leads to differential growth rates among individuals of the same cohort^{21,22}. Similarly, Luo *et al.*²³, demonstrated the positive relationship between growth and food consumption in flounder. In some species such as flatfish and cyprinids in general, size variation is a result of differential rates in feed consumption, aggressiveness and intraspecific competition under conditions

of food scarcity. On the other hand, although feed was supplied to the species to satiation, unconcealed acts of aggression have been reported with several species including Mirror carp and Nile tilapia in which large individuals openly chase the smaller counterparts from the feeding site²⁰.

The experimental species responded to the experimental conditions differently and therefore, growth differed across the three species. Of more importance, is that each growth trend corresponded to a response variable, thus, while, the Nile tilapia and Mirror carp were mainly affected by environmental variables, the Rainbow trout mainly suffered the consequences related to the quality of feeds used which led to change in water quality and ultimately leading to low mean body weight/biomass. Examining the resultant biomass per species, comparative economic analysis reveals increased profitability with stability and an increase in growth parameters.

The highest biomass was obtained with Mirror carp which was also the most profitable enterprise followed by Nile tilapia. The Rainbow trout generated no profit due to poor growth rates, low daily weight gain and consequently low biomass. Direct effects of fish growth/biomass on profitability have been demonstrated by various authors, at different levels for different species. Abou *et al.*²⁴, observed positive relationships among gross returns, fish growth and total biomass, emphasizing that higher biomass leads to higher returns in tilapia production. The faster fish grows, the shorter the time it takes for it to attain somatic maturity and marketable size, hence faster growth helps farmers minimize expenses on culture inputs such as feeds, labour and prophylactic agents, thereby improving the profitability of the enterprise^{24,25}. Improved growth rates are also of importance in maximizing cohort frequency aiding farmers to stock and harvest from their ponds in at least two production cycles annually²⁶.

CONCLUSION

Results from this study indicate that Mirror carp fed on current feed was more viable and operations should be intensified with an improved management system during warm months. The gap in Mirror carp growth was demonstrated by the "b" constant <3. The Nile tilapia was moderately profitable, however, it might be unreliable due to fluctuation in water temperature conditions which slow down tilapia growth.

The observations contribute baseline information for the development of aquaculture management policy and

technical guidelines such as appropriate species selection based on environmental suitability and feeding chart for Uganda mid-altitude sub-regions.

SIGNIFICANCE STATEMENT

The study revealed that Mirror carp is the most suitable species for culture in Uganda's mid-altitude environment and that using local feeds, its farming is commercially viable provided management practices are optimized. That Nile tilapia is unsuitable for culture in the mid-altitude environment under natural conditions. Its culture is only viable under the modified environmental condition as is the case with Rainbow trout which requires better feeds than what was used during the experiment.

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