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Critical analysis of the growth performance of three fish species; Mirror carp (*Cyprinus carpio*), Nile tilapia (*Oreochromis niloticus*) and Sharp toothed African catfish (*Clarias gariepinus*), cultured in earthen ponds in Kigezi region South-western Uganda

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Abstract
Fish farming is important for increasing the national income and improving nutrition in the densely populated Kigezi region which has demonstrated a high level of malnutrition. This study was conducted in South Western Highlands of Uganda to evaluate the growth of three fish species in earthen ponds. Fingerlings and fries were stocked, 3 fish m^{-3} with an average body weight, 2.8 g of Nile tilapia, 1.7 g African catfish and 0.17 g Mirror carp under monoculture. Under poly-culture, stocking was at 1:3. Feeds were administered *ad libitum* daily. Fish performance and water quality data were determined monthly. Analysis of variance and paired samples t-tests were used to analyse data. Results indicated that Growth rates and average body weights of Nile tilapia and Mirror carp in Kabale and Kisoro was higher and significantly different ($p<0.05$) from Kanungu. Food conversion ratio for fish in Kanungu was higher compared to Kabale and Kisoro. Fish species under poly-culture systems generally had higher growth rates and body weights than those under monoculture systems. Water quality in the current study did not hamper fish growth. Our results can demonstrate that all the three fish species are suitable for culture in the zone.

Keywords: Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Mirror carp (*Cyprinus carpio*), earthen pond, fish performance.

1. Introduction
Global consumption of fish has been doubled since 1973, and the developing world has been responsible for nearly all of this growth [1]. The tradition and major source of fish globally is the capture fisheries. It is important to note that capture fisheries has remained stagnant and in some countries declined/collapsed as a result of mainly population pressure. The major hope of sustainably retaining this important diet (fish) in the global community is through aquaculture development and expansion.
The aquaculture industry has been expanding and in 2010, and the production reached to 60 million tonnes, excluding aquatic plants and non food products, with an estimated value of US$ 119 billion [2]. The levels of aquaculture production globally remain imbalanced over years across continents as well as countries, with Asia accounting for over 89% of the world aquaculture production [3, 4]. The least developed countries (LDCs) mostly from the Sub-Saharan and Asia, remain very insignificant in terms of the share of the world aquaculture production. The major aquaculture producers in Africa are Egypt (919,585 tonnes), Nigeria (200,535 tonnes), and Uganda (95,000 tonnes) [2]. Although, Uganda ranks third in terms of aquaculture production at a continent level, its performance is far below the first and second countries. This significantly shows a big gap to bridge on aquaculture development in Uganda.
Some statistical figures and grey literature indicate rapid growth of the enterprise (aquaculture) in Uganda. However, based on the experience of the EU study on aquaculture in 2011, there is no reliable source of aquaculture production statistics in Uganda [5, 4]. [5] further report that, as of 2010/2011, there was only one large-scale commercial farm in full operation, Source of the Nile (SoN), based in Jinja-Uganda which was able to produce 300 tonnes of fish in 2011 from

both cages and ponds.

Although Uganda's aquaculture industry is dominated by earthen pond production systems, the enterprise has not picked to the expectation of farmers despite heavy inputs [9]. This is mainly as a result of low technologies in pond culture [9]. As one of the measures of improving the sector, of recent, there has been a promotion on diversification of aquaculture for instance cage farming as an alternative production systems by Government of Uganda, foreign and private organizations [6]. This has seen other sizable commercial fish farms (cages) for instance the Chinese cage farms on Lake Victoria established for research and a demonstration centre, but also managed as a commercial enterprise (personal observation).

The progress of fish farming (pisciculture) in Uganda is mainly pronounced in the central region. The current development of the sector, aquaculture, in the central region is engineered by consistent research and equipped extension staff, supported by various donor projects such as Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Aquaculture for Food Security, Poverty Reduction and Nutrition (AFSPAN), Strengthening Aquatic Resource Governance (STARGO), United States Agency for International Development (USAID), European Union (EU), Fisheries Investments for Sustainable Harvest – USAID Project (FISH), Livelihoods and Enterprises for Agriculture Development-USAID Project (LEAD), Chinese government, African Development Bank (ADB), Food and Agriculture Organization (of the United Nations (FAO), World Bank, Ministry of Agriculture Animal Industry and Fisheries (MAAIF), National Agricultural Research Organization (NARO), Uganda Investment Authority (UIA), Lake Victoria Fisheries Organization (LVFO), Private sector; Uganda Huaqiao Fisheries Company ltd, SoN, Sustainable Commercial Aquaculture for Poverty Alleviation (SCAPA), Green Fields, Walimi Fish Cooperative Society (WAFICOS), and Non-governmental Agencies; UAOGRESCUE-Faith Project [5, 4]. In the other regions of the country for instance the South Western Highlands Agro-Ecological Zone (SWHAEZ), Kigezi, the industry is regarded as a myth. It must be noted that although the sector has been in existence for over six decades as of 2010 [7], little or no major work regarding research has surfaced in the region.

Fish farming in SWHAEZ is characterised by mainly pond fish culture of less than 600 m^2 and 90% of fish farmers practice subsistence farming [7]. However, recently investment in cage culture has started on a few lakes (personal observation). With technical backstopping from Kachwekano Zonal Agricultural Research and Development Institute (KAZARDI) there is potential of fish farming in the Kigezi region.

The traditional cultured fish species since the 1950s include; Nile tilapia (*Oreochromis niloticus*) and Mirror/Common carp (*Cyprinus carpio*), and later on African catfish (*Clarias gariepinus*) [7, 8]. Previous culture trials on African catfish and Carp in the zone are speculated to have promised, although aquaculture has drastically remained at a subsistence level. This was largely due to lack of quality seed and technical expertise in fish breeding [8]. Supply of fish seed was mainly from farmer to farmer and which hampered the expansion of the aquaculture sub-sector [8]. Furthermore, although the government under the NAADS programme provided extension workers, they also lack hands-on experience and confidence in fish culture and are therefore unable to appropriately advise the farmers [9].

The relevance of fish farming in the general context of urgent need for income generation, enhanced food security and improved nutrition, is greatly strengthened by the fact that the sector is not a new venture. The enterprise is desired and has been relatively tried by many farmers but with no success. Interest, aquatic resources and demand in local diets are high and if farmers would be guided technically, the sector would serve as a model and substantial benefits would accrue in terms of nutritional welfare and income generation to the communities in the zone. It is against this background that the current study was conducted to evaluate the performance of the three commonly cultured fish species in the zone. The results from the study would generate concrete information for both current and prospecting farmers on the choice of fish species to culture in SHWAEZ and align proper management practices in a move for revamping the sub-sector in the zone.

2. Materials and methods

2.1. Fish seed

Three fish species; Nile tilapia, Sharp toothed African catfish and Mirror carp, were cultured in earthen ponds. Although stocking rates were uniform (see below), the total number of the fish species stocked varied from pond to pond and from District to District depending on the pond sizes and volumes of water. In total, the number of Nile tilapia stocked was 5,964, Mirror carp 3,714 and African catfish 5,964. Mirror carp and African catfish were acquired from a commercial fish farm in Masaka (Central Uganda) and transported to experimental sites in oxygenated air tightened plastic bags. Juvenile Nile tilapia were sourced from Lake Albert–Hoima, acclimated and reared at a commercial farm in Kanungu District (SWHAEZ) from where Nile tilapia seed was acquired. Collection of Nile tilapia seed from Lake Albert was done to avoid related impacts of inbreeding of Nile tilapia reared for long in ponds [10]. All related animal rights were observed and respected prior to the experiment and during experimental execution.

2.2. Experimental sites/locations and fish stocking

The study was conducted in earthen ponds in three Districts of the zone; Kabale, Kisoro and Kanungu. The three Districts were selected because of varying climatic conditions especially when we considered Kihihi for Kanungu. On the other hand, Rukungiri District was left out partly because; its climatic conditions are similar to those of Kanungu-Kihihi, Kabale and Kisoro Districts [11, 12, 13, 14]. Before stocking, all the ponds were limed as indicated by [15]. Stocking rate was uniform, $3m^{-3}$, in all the ponds. At stocking, the average individual weights (g) of fish were; 2.8 g, 1.7 g and 0.17 g for Nile tilapia, African catfish and Mirror carp respectively. In case of poly-culture, a ratio of 1:3 for African catfish with Nile tilapia and Mirror carp with Nile tilapia was stocked. Poly-culture was conducted in Kanungu and Kabale Districts only. This was dictated upon by the availability of ponds. All the three fish species were stocked in Kisoro and Kanungu districts, each species replicated twice and a total of 12 ponds were stocked. In Kabale, only two species, Mirror carp and Nile tilapia, were stocked and also replicated twice. The reason for this experimental imbalance was due to lack of experimental facilities in Kabale. The experimental sites were managed by farmers. However, prior to the experiment, the farmers (experimenters) were trained in basics for general fish farm management including record keeping and administration of the feeds. Water losses due to seepage, evaporation and or quality deterioration were regularly monitored and compensated when need arose.

2.3. Experimental design
Feeds were offered *ad libitum* (apparent satiation), fed 3 times daily by hand for duration of approximately 30 minutes, at (9.00, 12.30 and 16.00) during the day at 10% body weight. The ration and feeding frequency was always adjusted monthly depending on average change in mean weights. However, it must be noted that, feeding duration and frequency were dictated by fish's response to feeds. The amount of feeds administered was determined by standard methods according to [16] and [17]. Uniform and complete formulated floating pellets (35% CP) fish feeds, from Ugachick Kampala were used in the study. The experiment ran for seven months.

2.4. Water quality parameters
Water quality samples were collected monthly and analysed for Temperature, pH, Nitrite (NO_2), ammonia (NH_3), hardness ($CaCO_3$) before fish sampling. Temperature was measured *in situ*, with an immersion thermometer. Due to lack of equipment and other logistics, dissolved oxygen (DO) unfortunately was not taken; however, this was taken care of daily by physically observing the water. For instance, when temperatures were high, water would be flashed. The rest of the parameters were measured using LaMotte Model AQ-3Fresh Water Aquaculture Combination Kits from procured from Palin Diagnostics Uganda-Kampala.

2.5. Data collection
Fish species were sampled on a monthly basis to determine growth performance parameters [18, 19, 20, 21, 22, 23]. The following parameters were recorded:

- Growth rate (GR) = $\frac{Wt-W0}{t}$; Where, Wt is the final weight (g) at time t, W0 is the initial weight (g) at time 0 and t is the culturing time in days
- Feed conversion ratio (FCR) = $\frac{Total\ feed\ given\ (g)}{Total\ weight\ gained\ (g)}$
- % Survival rate (%SR) = $100 - \frac{Ni-Nf}{Ni} \times 100$, where Ni is the initial number and Nf is the final number of fish
- Feed given to individual fish (Fi) = average mean weight ×% feed rate × total number of fish (g)

2.6. Statistical analysis
Data were expressed as mean ± Standard error. Homogeneity of variance of the means was tested with Levene test while normality was tested with PP plots and Kolmogrov-Smirnov test [24]. Performance/growth rate parameters of the fish species were compared at experimental site-wise (per District) and between Districts, while water quality parameters were compared between Districts only. One-way Analysis of Variance (ANOVA) followed by Tukey tests for multiple comparisons, were formed for fish performance per Districts (Kisoro and Kanungu) and between the three Districts. However, comparisons in Kabale experimental site alone were done with Paired Samples t-test. These statistical analyses were performed with the aid of SPSS software version 17 for windows. Significance minimum level was established at 0.05.

3. Results
3.1. Growth performance parameters
General performance of the fish species and feeds utilised between Districts are illustrated in Table 1. Results from this indicated that, the effect of a District did not have an effect on the SR of all the fish species between the Districts. Similarly, there was no significant difference ($p>0.05$) in the performance (GR and FCR) of Catfish between Kisoro and Kanungu. GR of Nile tilapia (0.4436) in Kanungu was significantly lower than GR of Nile tilapia in Kisoro (0.9886) and Kabale (0.7214). Also, GR of Mirror carp (0.4114) in Kanungu was significantly lower ($p<0.05$) than that of Kisoro (0.8121) and Kabale (0.8714). GR of Nile tilapia and Mirror carp between Kisoro and Kabale were not significantly different ($p>0.05$). FCR of Nile tilapia in Kisoro was the least (0.2636) and significantly different ($p<0.05$) from the two other Districts of Kabale, (0.7214) and Kanungu (0.9843). In general, Kanungu District had higher values of FCR especially for Nile tilapia and Mirror carp than in Kisoro and Kabale. On average, Nile tilapia and Mirror carp in Kabale consumed more feeds than in Kisoro and Kanungu. On the other hand, consumption of feeds by Catfish between Kanungu and Kisoro did not differ significantly ($p<0.05$).

Table 1: General performance of fish species between Districts

Performance	Fish species	Kabale	Kisoro	Kanungu
GR (g^{-d})	Nile tilapia	0.7214^a±0.2217	0.9886^a±0.0586	0.4436^b±0.4004
FCR	Nile tilapia	0.7214^a±0.2217	0.2636^b±0.0586	0.9843^a±0.4004
% SR	Nile tilapia	99.8929^a±0.0569	99.9512^a±0.0408	99.9927^a±0.0073
Fi	Nile tilapia	17.8786^a±3.4951	8.1529^b±1.4057	12.3214^b±4.5255
GR (g^{-d})	Mirror carp	0.8714^a±0.175	0.8121^a±0.3928	0.4114^b±0.1452
FCR	Mirror carp	0.4429^a±0.1088	0.6686^a±0.2042	1.8464^a±0.85031
% SR	Mirror carp	100^a±0.00	100^a±0.00	99.9854^a±0.0146
Fi	Mirror carp	15.05^a±3.0925	7.2771^b±0.963	9.3214^b±0.963
GR (g^{-d})	African catfish	------------------	0.5864^a±0.1282	0.6086^a±0.1305
FCR	African catfish	------------------	0.65^a±0.1321	0.7157^a± 0.1650
% SR	African catfish	------------------	100^a±0.00	100^a±0.0000
Fi	African catfish	-------------------	12.6893^a±1.8152	14.5429^a±4.3634

Values are Means ± Std. Error. Mean values within rows with the same superscript letters are not significantly different (P>0.05)

Fish species' average body weight data per District are presented in Figures, 1, 2 and 3. For the case of Kabale and Kanungu, Fish species were compared under both monoculture and poly-culture systems. In Kabale, average body weights of Mirror carp and Nile tilapia under monoculture systems progressively did not differ significantly ($p>0.05$) although Mirror carp varied slightly towards and at harvest (figure 1a). On the other hand, when the body weight of Nile tilapia poly-cultured with Mirror carp was compared with Nile tilapia mono-cultured, it was revealed that towards and at harvest, average weight of poly-cultured Nile tilapia was higher and significantly different ($p<0.05$) from that of mono-cultured Nile tilapia (figure 1b). On the other hand, when Mirror carp was poly-cultured with Nile tilapia, the final weight of Mirror carp poly-cultured was lower and significantly different ($p<0.05$) from that of Mirror carp mono-cultured (figure 1c).

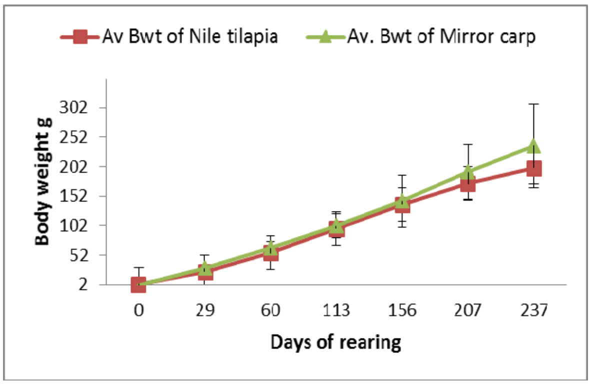


Fig 1a: Comparison of body weights of fish species under mono-culture systems in Kabale. *Plots are Means ± Std. Error*

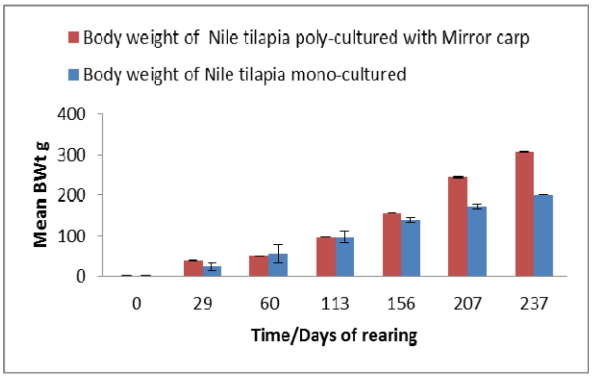


Fig 1b: Comparison of body weights of fish species under mono and poly-culture systems in Kabale. *Bars are Means ± Std. Error*

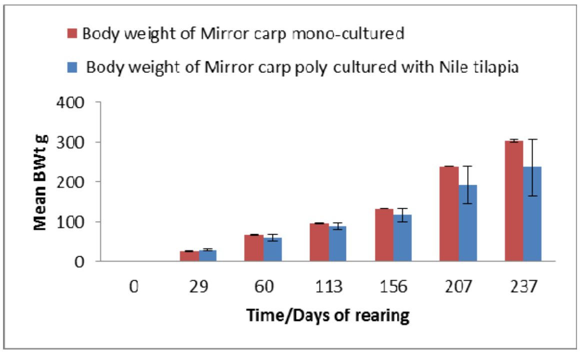


Fig 1c: Comparison of body weights of fish species under mono and poly-culture systems in Kabale. *Bars are Means ± Std. Error*

In Kisoro, we did not have poly-culture systems implying that all the fish were confined individually in their rearing facilities/ponds. Results from this site revealed that, the average body weight of Nile tilapia was higher and significantly different from African catfish and Mirror carp ($p<0.05$). Average body weights of African catfish and Mirror carp were not significantly different ($p>0.05$) over time, although varied slightly at harvest (Figure 2).

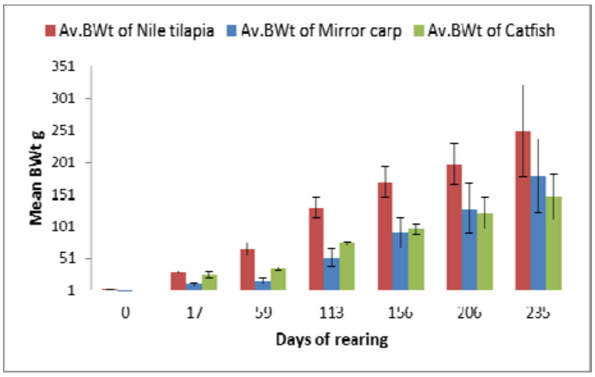


Fig 2: Comparisons of body weights of fish species under mono-culture systems in Kisoro. *Bars are Means ± Std. Error*

In Kanungu District, body weights of fish species under mono-culture systems varied over time (Figure 3a). Generally, the body weights of the fish species cultured under monoculture systems in Kanungu District did not differ significantly ($p<0.05$) over the culturing period, although minor variations were observed. On the other hand, when the body weight of Catfish poly-cultured with Nile tilapia was compared with Catfish mono-cultured, it was observed that the weight of poly-cultured Catfish was much higher (2063.95±61.05) and significantly different ($p<0.05$) from the lower weight (187±87.7) of mono-cultured Catfish (figure 3b). On a similar trend, when the weight of Nile tilapia poly-cultured with Catfish was compared with Nile tilapia mono-cultured, gradually the weight of mono-cultured Nile tilapia was observed to be higher and varied significantly ($p<0.05$) from poly-cultured Nile tilapia. However, towards and at harvest, poly-cultured Nile tilapia increased weight progressively higher than mono-cultured Nile tilapia and differed significantly ($p<0.05$) at harvest (Figure 3c).

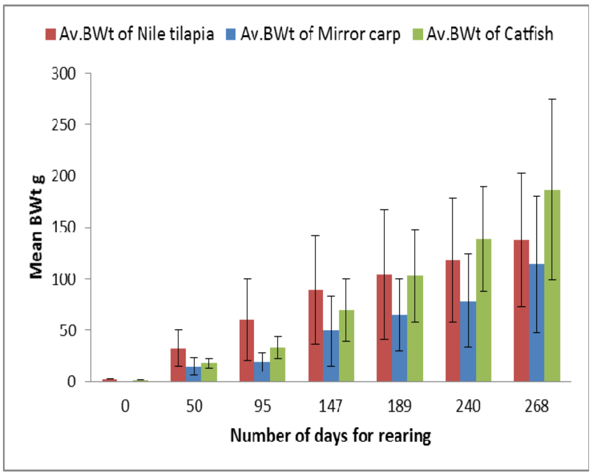


Fig 3a: Comparisons of body weights of fish species under mono-culture systems in Kanungu. *Bars are Means ± Std. Error*

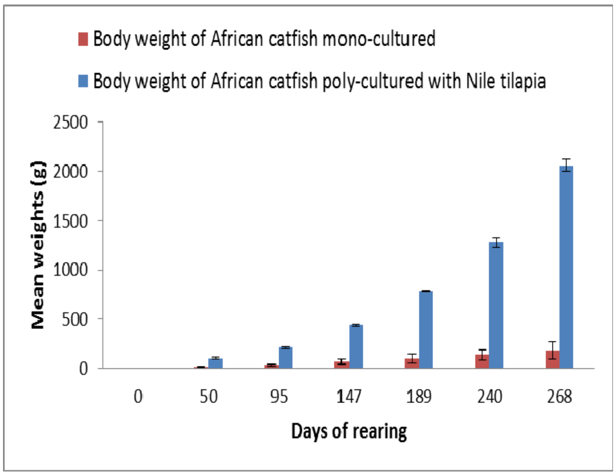


Fig 3b: Comparisons of body weights of fish species under mono and poly-culture systems in Kanungu. *Bars are Means ± Std. Error*

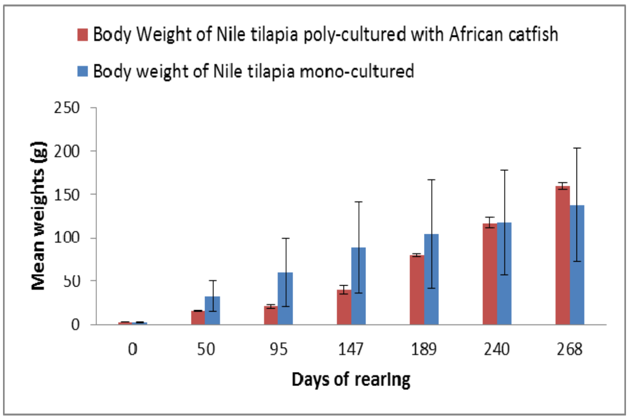
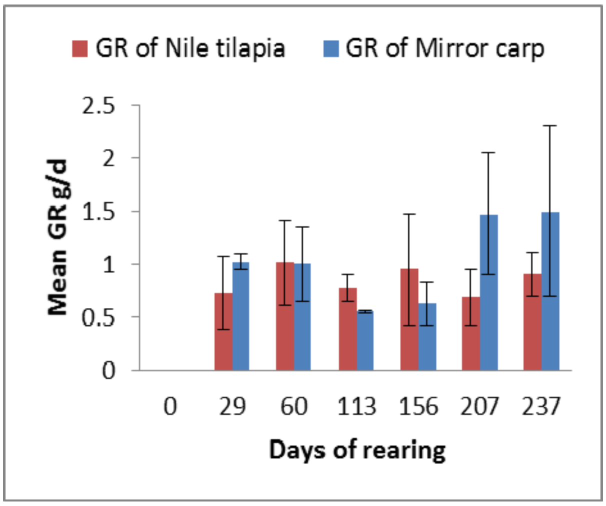
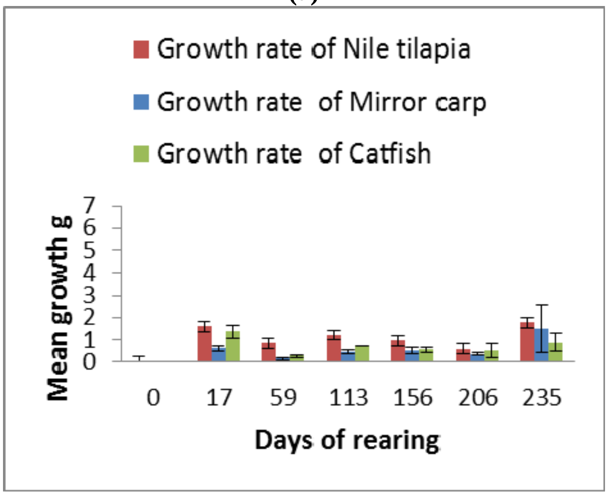


Fig 3c: Comparison of body weights of fish species under mono and poly-culture systems in Kanungu. *Bars are Means ± Std. Error*

Other performance parameters (GR, FCR, and SR), of fish species per District are presented in Figures, 4, 5 and Table 2 respectively. In Kabale District, GR of Nile tilapia and Mirror carp were not significantly different (p>0.05) although slight variations occurred (Figure 4a). GR of Nile tilapia, Mirror carp and Catfish in Kisoro varied overtime (Figure 4b). At 17 rearing days, GR of Catfish and Nile tilapia were observed higher and not significantly different (p>0.05) but significantly different (p<0.05) from the GR of Mirror carp. At 59 rearing days, GR of Nile tilapia was significantly different from Mirror carp and Catfish. Although the GR of Nile tilapia at days 59 declined, the decline in GR of Mirror carp and Catfish was much felt and differed significantly. From rearing days, 113 up to harvest 235, the GR of Nile tilapia differed significantly (p<0.05) from Catfish and Mirror carp, Catfish and Mirror carp did not differ significantly (p>0.05), (Figure 4b). On a similar trend, in Kanungu District the GR of fish species under monoculture systems did not differ significantly (p>0.05) over the rearing period. On average, FCR of all the fish species were recorded to be less than 2 in the Districts of Kabale and Kisoro (Figure 5a & b), apart from Kanungu where the highest FCR of 5 was recorded (Figure 5c). In Kabale, initially FCR of Nile tilapia was observed higher (2) and significantly different (p<0.05) from Mirror (0.4). However, from days 60 to 237, at harvest, FCR for all fish species were observed to be lower than 1 (Figure 5a). In Kisoro, the highest FCR was observed at 1.7 for Mirror carp, but was not significantly different (p>0.05) from that of Catfish, but significantly different (p<0.05) from that of Nile tilapia. Nile tilapia in Kisoro recorded the least FCR almost throughout the culturing period, apart from the period at harvest. In Kanungu FCR of Nile tilapia and Mirror carp were not significantly different (p>0.05) from each other, but significantly different (p<0.05) from Catfish (Figure 5c). Generally, Catfish in Kanungu recorded the least FCR throughout the culturing period (Figure 5c). It must be noted that, at rearing days 156 in Kabale, 189 and 268 in Kanungu, FCRs were zero because during those periods, there were no feeds.



(a)



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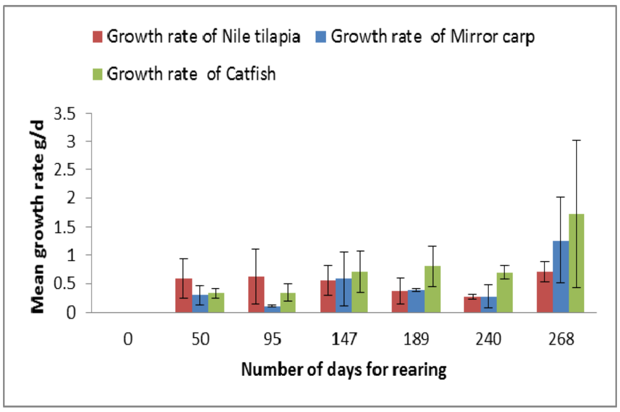
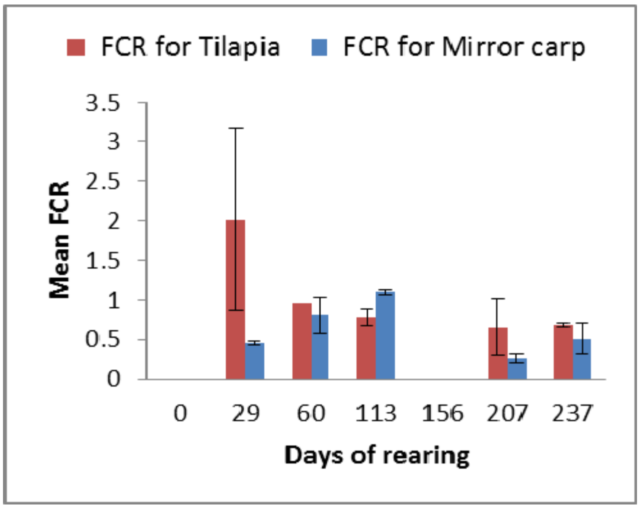
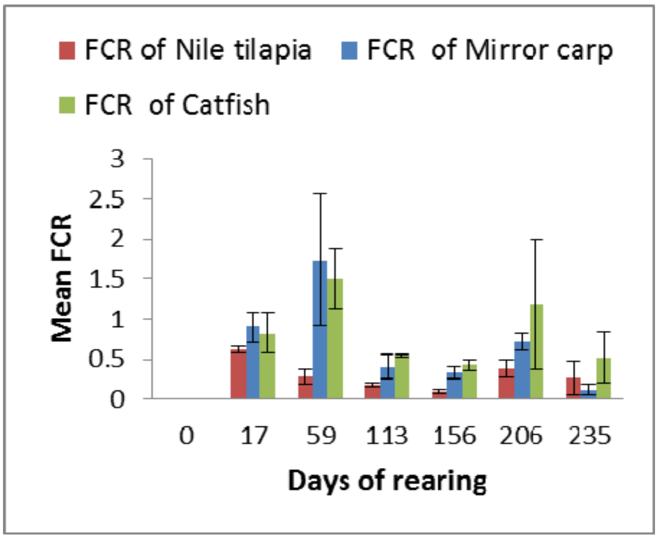


(c)

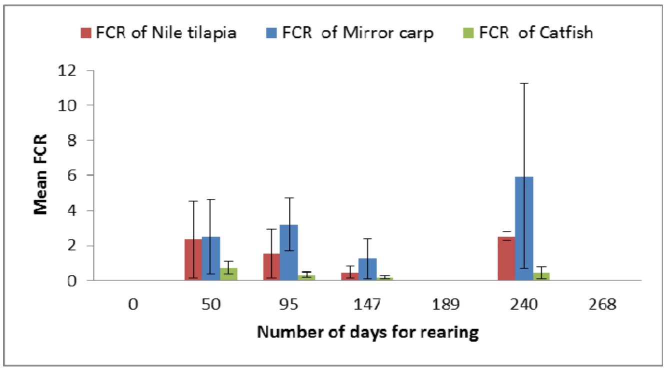
Fig 4: Growth rates of fish species in (a) Kabale, (b) Kisoro and (c) Kanungu



(a)



(b)



(c)

Fig 5: FCR of fish species in (a) Kabale, (b) Kisoro and (c) Kanungu

Bars are Means ± Std. Error. Gaps indicate days when there were no feeds.

Survival Rates (SR) between the fish species per District are presented in table 2. Although Nile tilapia in all the Districts and Mirror carp in Kanungu experienced some minor variations in SR, in all the Districts, SR was high for all the species and did not differ significantly ($p>0.05$).

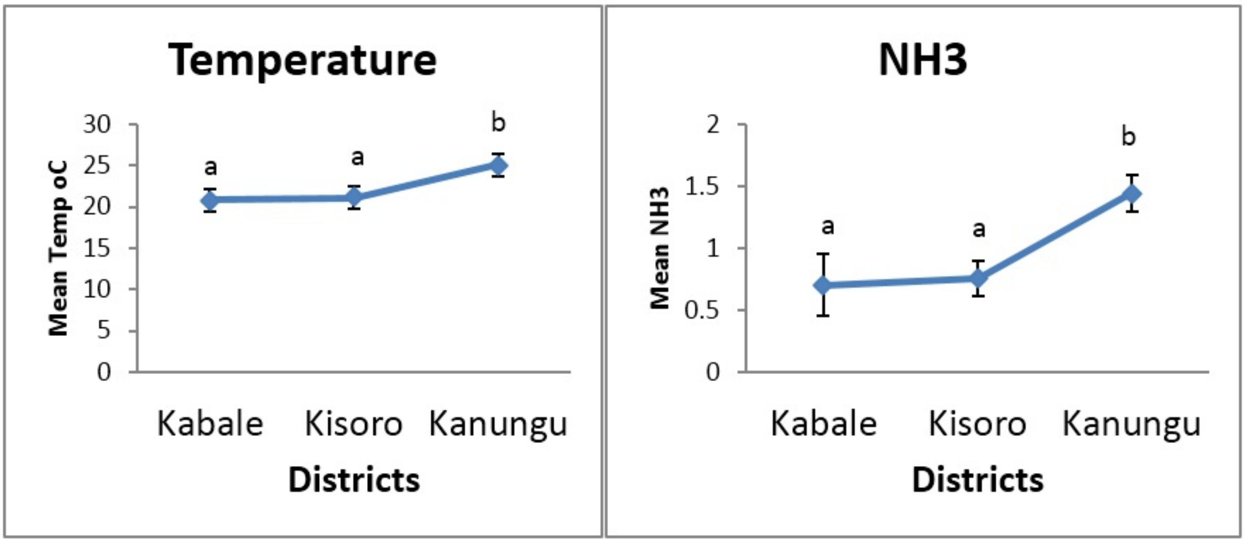
Table 2: Survival rate of the fish species per Districts

Fish species	Kabale	Kisoro	Kanungu
Nile tilapia	$99.8929^{a}\pm0.057$	$99.9512^{a}\pm0.041$	$99.993^{a}\pm0.007$
Mirror carp	$100^{a}\pm0.00$	$100^{a}\pm0.00$	$99.985^{a}\pm0.015$
African catfish	----------------	$100^{a}\pm0.00$	$100^{a}\pm0.000$

Values are Means ± Std. Error. Means within columns with the same superscript letters are not significantly different ($P>0.05$)

3.2. Water quality parameters

Variations in water quality; temperature, ammonia (NH_3), pH, carbon dioxide (CO_2), nitrite (NO_2), and calcium carbonate ($CaCO_3$) between Districts' experimental sites are presented in figure 6.



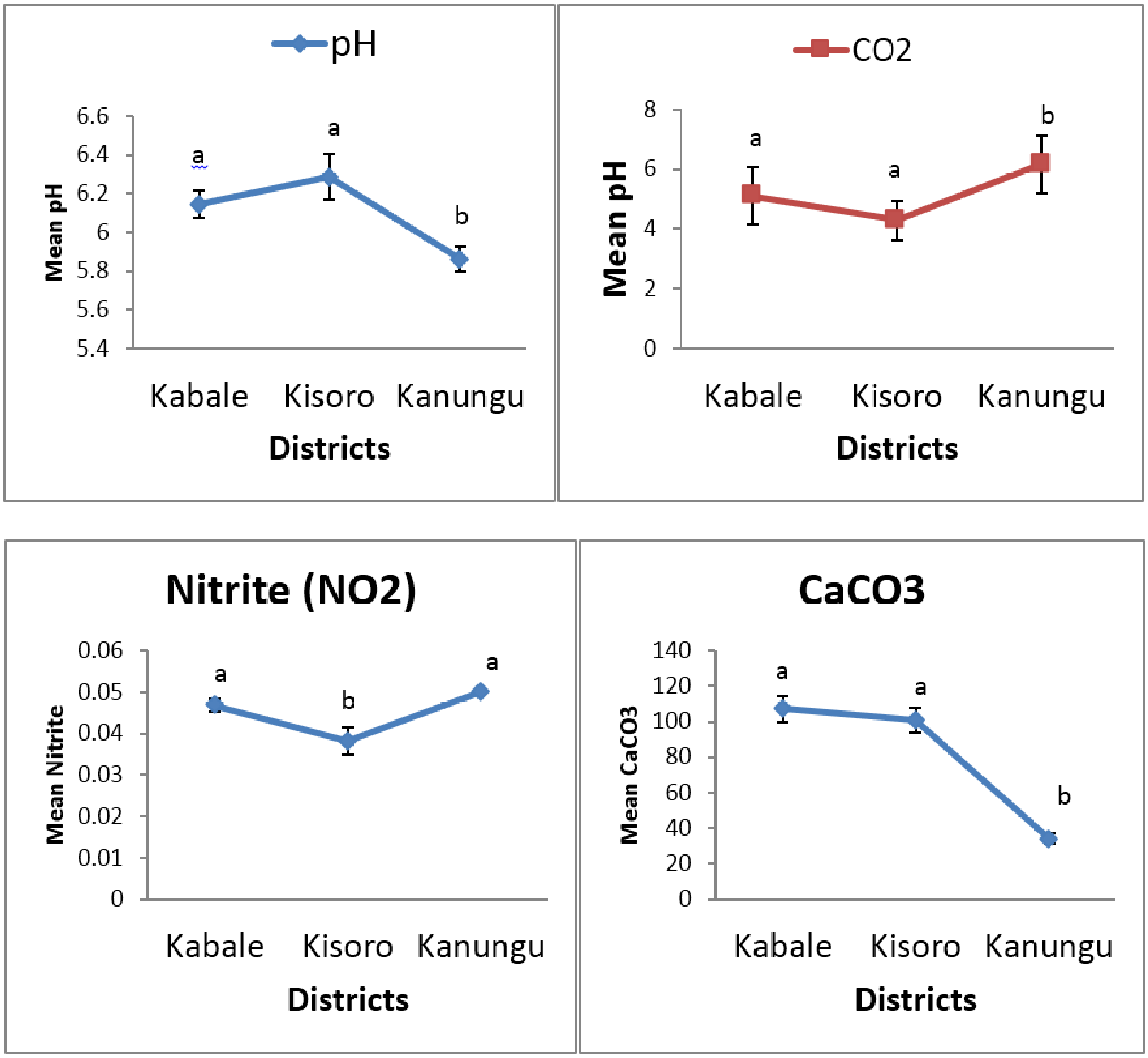


Fig 6: Pond water quality parameters between Districts.

Similar superscript letters indicate no significant difference at p>0.05

Temperature, NH_3, and CO_2 were observed lower in Kisoro and Kabale and significantly different ($p<0.05$) from higher values recorded in Kanungu. Contrary, pH and $CaCO_3$ were observed to be higher in Kabale and Kisoro and significantly different ($p<0.05$) from lower values recorded in Kanungu. On the other hand, when accumulation of nitrite in ponds was considered, results indicated that, Kisoro had the least amounts of nitrite and significantly different ($p<0.05$) from higher values in Kanungu and Kabale (Figure 6).

4. Discussion

Generally, growth performance and insignificant mortalities of the three fish species obtained from the current study confirm the suitability of the species for culture in the zone despite the alleged cold conditions. In the current study, there was no major effect of the District/sub-ecological zone to the performance of the fish species in the zone. For instance, GR and FCR of African catfish between the Districts of Kisoro and Kanungu did not vary. This suggests that, despite the variations in the environmental conditions (especially temperature) between Kanungu-Kihihi and Kisoro Districts, African catfish can thrive well in the two sub-regions. It is important to note that, in the current study, pond water temperatures in Kanungu-Kihihi were always around 24-25 ^{0}C much higher than 20-21 ^{0}C of Kisoro. The current findings suggest that a temperature range of 20-25 ºC uniformly affects the performance of African catfish in earthen ponds. These results are in line with those of [25] who found a good growth trend of Catfish in a similar temperature range. On the other hand, Nile tilapia and Mirror carp had their GR/performance impacted on by District. Performance of Nile tilapia and Mirror carp in Kabale and Kisoro was better and higher than in Kanungu. These results were contrary to our expectations. While in Kanungu-Kihihi temperatures were observed higher than in Kisoro and Kabale, GR of the species were expected higher in Kanungu-Kihihi than in both Kabale and Kisoro. Our expectations were in line with the explanations from [19, 26, 27] who elaborated that, a water temperature of around 25 ºC is one of the most important factors influencing the growth rate of most tropical fish species under culture systems. However, the best reason as to why this discrepancy appeared in performance (GR and FCR) of Nile tilapia and Mirror carp in

Kanungu-Kihihi was related to management. Although water quality during the current study was in the permissible ranges for fish growth, it was observed that ammonia and its related nitrite was higher in Kanungu than in Kisoro and Kabale. Major sources of ammonia are from fish excretion through gills and faeces and feeding rate [28]. It seemed that feeding rates in Kanungu were unusual and as a result, total ammonia accumulated in the ponds. Ammonia in ponds can be tolerated by fish if it is less than 4 mg/l and nitrite if less than 1.5 mg/l [29]. Although these ranges may not be toxic and lethal to fish, they can retard the growth rates and increase FCR of fish [28, 29]. FCR values for fish species between the Districts of the zone in the current study were all observed below 2. Our FCR results are recommended by [20] who elaborated that FCRs of less than 2 are considered good for fish growth. FCR is based on the weight gain of the test subject divided by its intake of a particular food protein during the production cycle. FCR is widely used for evaluating the quality of proteins in feed and also used as an indicator of protein quality and quantity in the fish's body [23, 30]. Because fish feeds are always expensive, FCR is an important indicator and can be used to determine if feeds are being utilised by fish as efficiently as possible. In the present study, our FCR concur with the findings of [31, 32, 33, 30, 23, 34, 25] who got FCRs of less than 2. The lower and important FCR values obtained in the current study manifests the importance of feeding Nile tilapia, catfish and Mirror carp at 10% satiation coupled with feeding by response in high altitude areas.

Every fish farmer would prefer to culture fish species that achieve a reasonable table weight/size at harvest and in a short production cycle. Fish growth response/performance varies from species to species due to differences in feeding habits, environmental conditions, fish size at stocking and general farm management [35]. In the current study, different fish species with different trophic levels were studied. Generally, fish species that were mono-cultured exhibited lower weights than those in poly-culture in both Kabale and Kanungu (except Kisoro where there was no poly-culture). In Kabale, average body weights and GR of Nile tilapia and Mirror carp under monoculture systems did not vary significantly. Similarly, in Kanungu the average body weights and GR of Mirror carp, Nile tilapia and African catfish under monoculture systems did not vary. Contrary in Kisoro, Nile tilapia's average body weight and GR was higher than for Mirror carp and African catfish. The observed insignificant variations in the average body weights of fish species under monoculture systems in Kanungu and Kabale suggest that a holistic view of general management options and environmental conditions favoured the fish species equally. This means that, there was an equally exploitation of the available resources in the systems/ponds by species.

In Kisoro, final weight of Nile tilapia was recorded to be $249.75^{a}\pm70.85$ higher than for both Mirror carp ($189.95^{b}\pm56.85$) and catfish ($147.3^{b}\pm35.8$). Previously, a lot have been stipulated (unpublished information) that Nile tilapia cannot perform in the zone due to low temperatures/cold conditions in the region. Because of this, emphasis has always been put on culturing Mirror carp and African catfish. However, our findings are contrary. Possible explanation for our results relies on the pond water quality where Nile tilapia was housed in. It was strange that at stocking, all the ponds were not fertilised, however after some time during the rearing cycle, Nile tilapia ponds in Kisoro were found all green (Plate 1). On investigation, it was revealed that, those ponds were naturally fertile. Note that it was also a coincidence for Nile tilapia stocked in those ponds. This implied that, in addition to supplementary feeding, Nile tilapia enjoyed enough and a variety of feeds in the systems compared to both Catfish and Mirror carp. Also it seems that, the kind of feeds (floating pellets) used in the current study, could have hampered the sufficient feeding of Mirror carp and African catfish, although they can adopt feeding on surface. Mirror carp and African catfish feed mainly on bottom, benthic feeders [36, 4]. [36] Further reported that Carp are omnivorous and prefers feeding on bottom in search of benthic organisms. However, this calls for further study to evaluate the performance of carp and African catfish using sinking and floating pellets. African catfish's low performance in monoculture systems in Kisoro and Kanungu may have been attributed to undernourishment. This is in accordance to [37, 4] who reported that, because catfish is equipped with a wide array of anatomical adaptations for feeding, and being a slow moving omnivorous/predator, it is supposed to feed on a variety of food items ranging from minute zooplankton, complete supplementary feeds and to fish of its own length or 10% of its body weight.

Plate 1: Nile tilapia pond water (green water- above) in Kisoro and other fish ponds (clear water-below)

In Kabale, integration/poly-culture of Nile tilapia with Mirror carp, improved the performance of Nile tilapia in terms of body weight better than under monoculture systems. Contrary, the integration/poly-culture of Mirror carp with Nile tilapia did not improve the performance of Mirror carp in terms of body weights than under monoculture systems. On the other hand, the integration of Nile tilapia and African catfish in Kanungu, improved greatly the performance in terms of body weight of African catfish than under mono-culture systems. Despite the poly-culture of Nile tilapia with African catfish improving the the performance of African catfish greatly, this interaction did not favour the performance of Nile tilapia over time, although significant variations (Nile tilapia gaining more weight under poly-culture) were observed at harvest. The current results concur with those of [38, 39, 40, 41]. Nile tilapia, Mirror carp and African catfish differ in feeding habits and occupy different trophic niches in ponds. Nile tilapia occupies and feeds from the water column while Mirror carp occupies and feeds at the pond bottom. This synergy influences maximum utilisation of all available natural feeds as well as the supplementary feeds and hence better growths/weights [39]. This kind of interaction, also maintains good water quality ideal for better fish growth [42]. [40] Further stress that, poly-culture of fish species in ponds involving Nile tilapia, acts as a ‘‘sanitary fish’’ to improve water quality and hence stimulate fast growth rate and health of the fish in the production system. On the other hand, poly-culture of Nile tilapia and African catfish did not stimulate the high growth rates/weight of Nile tilapia in Kanungu contrary to our expectations, although African catfish performed very well. Better weights of catfish were related to abundant feeds from both supplementary and some from predation. It is important to note that, in ideal situations, African catfish would have predated upon many young ones/fry of tilapia to avoid competition for resources and paved way for better growth rates of both Nile tilapia and catfish in the ponds, which was not the case. Also from our results, the insignificant mortality rates especially for Nile tilapia could have been related to low predation pressure by African catfish. Our results are contrary to those of [41] who found out that Nile tilapia gained 44.6% more weight when poly-cultured with catfish as a result of the predator thinning out many young ones of Nile tilapia to avoid competition of resources. Possible reason for this unexpected weight gain of Nile tilapia could have been attributed to the size/gape and number of the predator (catfish) at stocking in the present study. Small/limited gape size of the predator (catfish) has been given by [43, 44, 45], as a major factor affecting predation efficiency of catfish on to Nile tilapia. This could be one of the reasons why there was no control of the prolific breeding nature of Nile tilapia and hence leading to low unexpected weights of Nile tilapia in the current study. Also in the current study, because there was sufficient supplementary feeding, the predator concentrated on the exogenous feeds and could not thin out tilapia fry from the pond. This is also emphasized by [46] who reported that; African catfish predation is sufficiently effective only in semi-intensive pond culture systems where fish are fed on mainly natural feeds in the system. Furthermore, at stocking, the size of African catfish was significantly smaller than Nile tilapia which could have hampered the predation pressure. This is explained by [41] that, when small catfish are poly-cultured with relatively bigger Nile tilapia, catfish will not be aggressive enough to effectively prey upon tilapia reproduction to reduce densities. It is important to note that, better growth rates of Nile tilapia in the zone were expected in Kanungu District because of favourable conditions especially temperature for Nile tilapia performance as reported by [41, 47, 48], in comparison to Kisoro and Kabale. The unexpected low weights of Nile tilapia in Kanungu were largely dependent upon management.

It is must be noted that, Carp burrow/dig in the banks in search for food items and therefore, in the current study, it was always hard to get the fish during sampling. This could have biased our data for Mirror carp. This also implies that, the species may pose some difficulties for farmers to culture especially in earthen ponds as for instance three ponds may gradually turn into one big medium lake!

Pond water quality parameters; temperature, total ammonia (NH_3), pH, CO_2, Nitrite (NO_2) and calcium carbonate (CaCO3) were within the permissible limits and suitable for fish culture as reported by; [49, 15, 50, 51]. In most fish culture production systems, especially ponds, when fish is reared in a pond for more than one month, the uneaten feeds tend to induce primary production and water quality deteriorates. This was not observed in the current study. Our findings indicate that, the crop/ fish species had an effect of the primary productivity in the water column due to natural feeding habits of the species under the current study. This elaboration is in line with the findings of [52], who reported that stocking of carp in ponds was most efficient in controlling microcystis blooms and increasing water clarity.

5. Conclusion

Finally, based on the results from the present study, Nile tilapia, Mirror carp and African catfish are ideal and relevant candidate fish species for culture in the Kigezi region. For better results from Nile tilapia and Mirror carp, poly-culture system of these species is paramount as they promote maximum utilisation of the food resources (both supplementary and natural) in the pond production system. However, the digging nature of Mirror carp into the pond banks should be noted as this can be detrimental to the culture systems. On the other hand, poly-culture of Nile tilapia and African catfish is encouraged, however in order to enhance better growth rates for both species, the size and number of African catfish at stocking should be considered. Monoculture of Nile tilapia in the zone is a potential when it is practiced by pond fertilisation in conjunction to supplementary feeding.

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