Evaluation of yields and growth performance of Nile tilapia (*Oreochromis niloticus*), with ningu (*Labeo victorianus*) and African catfish (*Clarias gariepinus*) in earthen ponds in Kenya

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Abstract

Hunger and malnutrition remain amongst the most devastating problems facing the majority of the world's poor and needy, more so in Africa. Polyculture of Nile tilapia, African catfish and *Labeo victorianus* is considered a management strategy with the potential to increase yields and profitability of tilapia farming and at the same time to reduce malnutrition in Sub-Saharan Africa. For its ready adoption, however, more information, particularly on stocking ratios and ideal densities of different species, is required to successfully transfer this technology to farmers. Accordingly, in a 150-day experiment, mixed-sex Nile tilapia (*Oreochromis niloticus*) were co-stocked with either African catfish (*Clarias gariepinus*) or Ningu (*Labeo victorianus*) in six 120 m^2 earthen ponds (1.0 m depth). The mean weights at the start of the study were 5g, 5g and 50g for Tilapia, Catfish and Ningu, respectively. The Nile tilapia were stocked with each of the two other species at a density of 4 fish per m^2 in a ratio of 3:1 (Tilapia: Catfish or Ningu). Fish were offered a 30% protein feed and the ponds fertilized fortnightly with chicken manure, urea and DAP. Mean daily growth rates, final weights, and yields of tilapia after 150 days were significantly ($P<0.05$) higher in the tilapia/catfish treatment. Gross and net yields varied significantly between the treatments with the highest yields being observed in the tilapia /catfish stocking ratio.

Keywords: Polyculture, mixed-sex tilapia, Catfish, Labeo

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Introduction

Hunger and malnutrition remain amongst the most devastating problems facing the majority of the world's poor and needy with nearly 30% of 6.1 billion people suffering from one or more of the multiple forms of malnutrition (FAO, 2003). It is a fact that global population demand for aquatic food products is increasing, despite declining catches (FAO, 2006). Coincidentally, the contribution of aquaculture to the total global fisheries landings has been increasing from a mere 5.3% in 1970 to an estimated 43 % in 2004 (FAO, 2006). From an activity that was primarily Asian, aquaculture is developing, expanding and intensifying in almost all regions of the world except sub Saharan Africa (FAO, 2006). It is therefore no surprise that the contribution of aquaculture to the global fishery from East Africa has remained static at 0.005% (Oenga *et al.*, 2005). This is not withstanding the fact that the global contribution of tilapia, a group of species native to East Africa, has increased worldwide from less than 0.05 million mt in 1970 to 1.3 million mt in 2000, growing at an annual rate of 13.5% (annual percent rate - APR). *Oreochromis niloticus* is the dominant species of the 77 species of tilapia cultured worldwide; the cultivation of this species has shown an APR of 16 (1970 - 2000), and has been used in over 87 countries world -wide. In Lake Victoria, *Lates niloticus* has been the major commercial species, with catfish as the second most important species in aquaculture production.

Aquaculture in East Africa has remained a subsistence activity among the rural fish farmers (Oenga *et al.*, 2005). In Kenya alone there are over 7,500 small-scale fish farmers, with 10,731 fishponds covering a total area of 167.8 ha (Aloo and Ngugi, 2005). The numbers have however been fluctuating over the years with the highest being recorded around the mid-1970's. This is despite aquaculture in Kenya having a great potential to meet the high demand for fish. This potential can be realized if emphasis is placed on developing culture technologies for indigenous species such as *Labeo*, and by increasing production efficiencies, yields and profitability of aquaculture operations. Special attention should be paid to species with already established high consumer acceptance in the region such as Tilapia, African catfish and ningu (*Labeo victorianus*).

Polyculture of tilapia with other fish species such as ningu and African catfish increases productivity by utilizing more efficiently the ecological and feed resources within a pond, without a corresponding increase in the quantity of supplemental feed (James and McGinty, 1989). This is because these fish species have different feeding habits and different habitat preferences thus increasing the maximum standing crop of a pond by allowing a wider range of foods and pond volume to be utilized (Lutz, 2003). While *Labeo victorianus* is an indigenous bottom feeder and an omnivore, catfish feed on vegetative materials, aquatic invertebrates, small fish, and detritus (Pillay, 1990) both leading to an increased pond productivity when used in combination with Nile tilapia (Oenga *et al.*, 2005).

Polyculture of Nile tilapia, African catfish and *Labeo victorianus* is considered a management strategy with the potential to increase yields and profitability of tilapia farming in Sub-Sahara Africa. This production strategy is not commonly practiced in Africa, however, because the social and economic factors associated with it are not yet understood or appreciated by fish farmers. Only limited research has been done on the yield and growth performance of the tilapia-catfish and tilapia-*Labeo* combinations in polyculture (Omondi *et al.*, 2001). In Kenya, farmers still lack reliable information pertaining to aspects such as stocking ratios, species combination, yield and growth performance of Nile tilapia with the different species polyculture.

This study was designed, therefore, to evaluate the yields and growth performance of *Oreochromis niloticus* with *Labeo victorianus* and *Clarias gariepinus* in polyculture at 3:1 stocking ratios using earthen ponds in order to provide the information needed on the value of the technology for commercial fishery.

Materials and Methods

The study was carried out at the Agai site where the fish were stocked in ponds and reared for 120 days. This fish farm is located in Rachuonyo District, Nyanza Province, Kenya, and Lake Victoria basin. The District has a population of 307,126 of which 145,793 are male and 161,333 are female. The area experiences a tropical climate with annual temperatures ranging from 25.5° C to 30.8 ° C. The Ningu (*Labeo victorianus*) was fished from the River Mara which is located at a different site (see Fig.1).

The experiment was carried out in 6 earthen ponds (three ponds for each treatment) each with a size of 120 m^2 and an average depth of 1.0 m. Prior to the start of the experiment, the ponds were drained, and left to dry for 10 days to eradicate any fish and other aquatic macrofauna. They were then limed with agricultural lime ($CaC0_3$) at the rate of 2.5 tonnes ha-1 prior to fertilization. The ponds were filled with water up to 40 cm in depth and fertilized with 5 kg P ha -1 wk-1 and 20 kg N ha -1 wk-1 (Egna & Boyd, 1997) using Diammonium Phosphate (DAP; 18% N, 40% P) and Urea (46% N).

Fig. 1. River Mara catchment basin adapted from Mara basin website.

After four days the level of water in all the ponds was raised to 1 m and the fish were introduced. The same quantity of fertilizer was added to the ponds fortnightly for the duration of the experiment. Organic chicken manure was also added at the rate of 0.2 tonnes ha -1 wk-1 before stocking. After stocking, the water inlets and outlets were closed to prevent entry of unwanted fish and escape of experimental fish. Water lost by evaporation was replaced weekly in order to maintain the same level of water through the experiment.

The experiment consisted of two treatments, consisting of mixed sex *Oreochromis niloticus* stocked with either *Clarias gariepinus* or *Labeo victorianus* in a density of four fish per m^2 in a ratio of 3:1. Each treatment was replicated three times and allocated to each of the six $120m^2$ earthen ponds at Agai- Kenya, in a random manner using the software package Minitab (version 13). Treatment 1 was Tilapia stocked with African catfish and treatment 2, the Tilapia stocked with Ningu (*Labeo victorianus*). *Oreochromis niloticus* and *Clarias gariepinus* fingerlings of average 5 g were obtained, transported, acclimatized before being introduced into the fertilized earthen ponds. *Labeo victorianus* were fished from R. Mara (Fig. 1) using electro-fishing apparatus, acclimatized in the same river for two days in a cage before being transported to the culture site at the Agai, within the Lake Victoria catchment (Fig. 2).

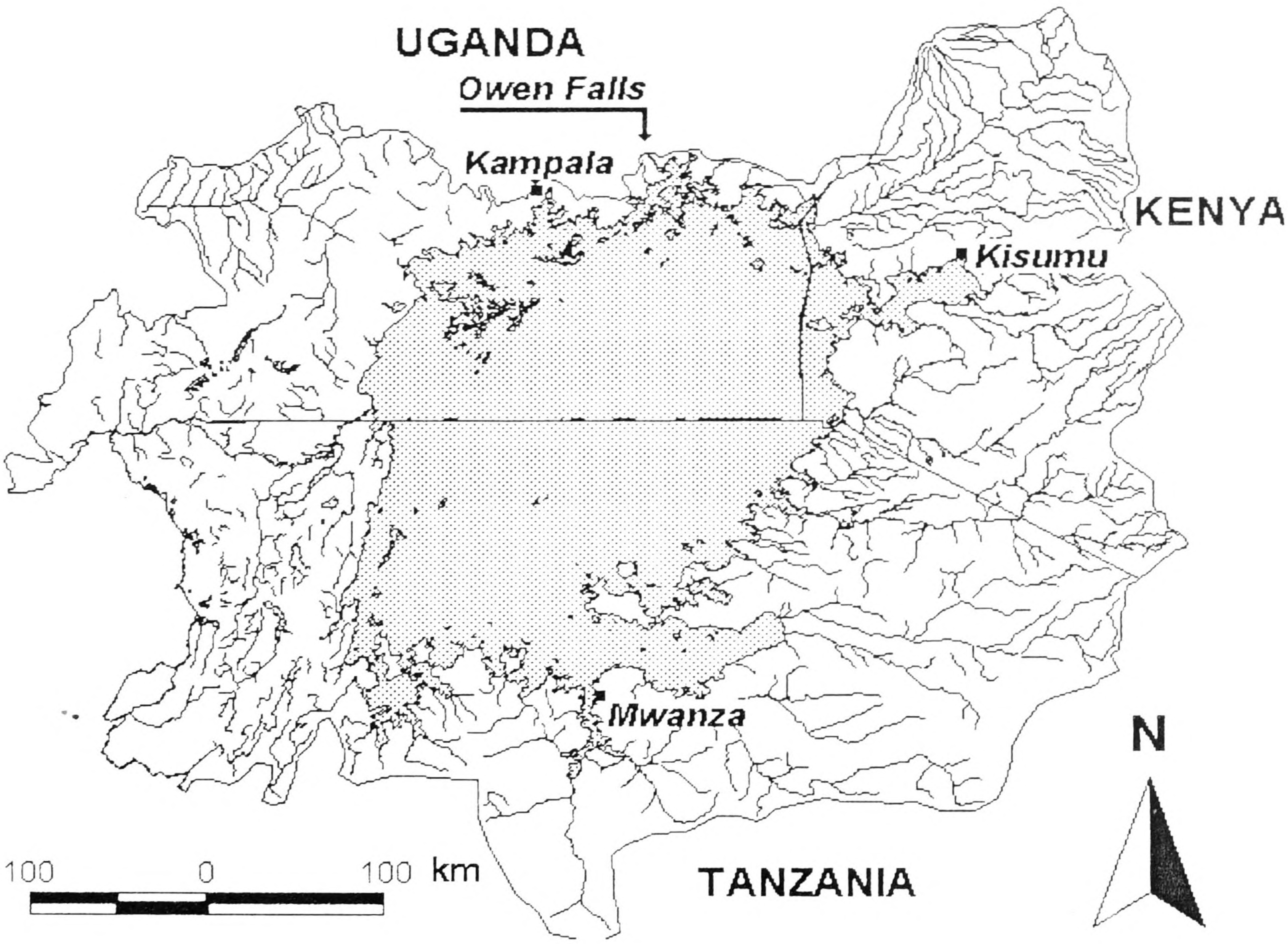

Fig. 2. The Lake Victoria catchment basin

During stocking the fish were randomly scooped up in batches of twenty alternately. The introduction of *Clarias gariepinus* and that of *Labeo victorianus* was done 30 days after the Tilapia to allow the latter to gain some weight and hence avoid being predated by the African catfish. The fish feed used in all the ponds consisted of a mixture formulated to contain 30% crude protein with *Caridina nilotica,* Rice bran and Cassava as the main ingredients. This feed was added at a rate of 5% body weight per day, equally divided between morning (10:00 hours) and afternoon (16:00 hours) feedings; adjustments for weight gain were carried out fortnightly after sampling the fish.

At the start of the experiment, thirty fish from each species were randomly sampled, and their total lengths and wet weights recorded. Thereafter, fish were sampled by seining at 2-week intervals and the fish were then weighed using an electronic balance (Shimadzu, EB-620SU 0.1 g sensitivity). At the end of the experiment, ponds were drained and all fish harvested and weighed to the nearest 0.1 g. The growth variables were calculated from these measurements as follows:

Net Fish Yield (NFY) = Total Weight of fish harvested - Total weight of fish introduced

Net Annualized Production (NAP) = (NFY 365)/ (Pond surface area growth period in days)

Growth rate (gd-1) = NFY/Growth period in days

The following water quality parameters were monitored: Total ammonia nitrogen (TAN) according to APHA (1995), Dissolved oxygen (DO) using an oxygen meter (YSI model 550A, Yellow Spring Instruments, USA), Temperature, pH (pH meter), and Secchi-disc depth. Water temperature was measured twice daily (8:00 and 16:00 h) at a depth of 25 cm.

Percent data were arcsine transformed before analysis. Fish growth, survival and yield data were analyzed by analysis of variance (ANOVA) using MINITAB software. Duncan's multiple range tests (DMRT) was used in the comparison of treatment means with statistical significance set at a probability level of 0.05 (Zar, 1984).

Results and Discussion

The growth performance of Nile tilapia, African catfish and *Labeo victorianus* in terms of initial weight, final weight, growth rate, survival rate and fish yield are shown in Tables 1 and 2. Mean final weight at harvest of tilapia was significantly ($P<0.05$) higher in treatment 1 (Table 1) and was reflected in the other calculated parameters.

Table 1. Mean weights, growth rates and yield for *O. niloticus* in the two treatments.

Variable	Treatment 1 (Tilapia /Catfish)	Treatment 2 (Tilapia/Ningu)
Stocking wt (g)	$5^{a} \pm 0.52$	$5^{a} \pm 0.57$
Final wt at harvest (g)	$147.72^{b} \pm 1.43$	$115.68^{a} \pm 1.48$
Gross yield (tonnes/ha)	$4.12^{b} \pm 0.57$	$3.47^{a} \pm 0.59$
Net yield (tonnes/ha)	$3.95^{b} \pm 0.36$	$3.32^{a} \pm 0.37$
NAP (tonnes/ha/yr)	$9.61^{b} \pm 0.83$	$8.08^{a} \pm 0.85$
Survival (%)	$93.00^{a} \pm 1.42$	$92.67^{a} \pm 1.33$
Growth rate (g/d)	$0.95^{b} \pm 0.44$	$0.74^{a} \pm 0.36$

Means in a row with dissimilar superscripts are significantly different ($P<0.05$).

The mean final weight of catfish was 45.87 g (Table 2) while that of Ningu was 102.64 g. Fish yields between the treatments were significantly different ($P<0.05$) with Treatment 1 giving the highest yield. Tilapia yields ranged from 8.08- 9.61 ton/ha/yr (Table 1) while that of catfish was 1.13 ton/ha/yr and that of Ningu 1.25 ton/ha/yr (Table 2). The combined yield of tilapia with catfish and with Ningu and their relative contribution to the net fish production are shown in Fig. 3. Total net annual yield obtained were 10.74 and 9.33 tonnes/ha/yr for Treatment 1 and 2 respectively (Fig. 3). The growth trend curves for tilapia with catfish and Ningu are shown in Fig. 4. There was a high initial growth rate of fish in all treatments up to day 30. The curves then separated from day 30 onwards with a distinctly higher growth trend being observed in Treatment 1 for tilapia.

Table 2. Mean weights, growth rates and yield for *C. gariepinus* and *L. victorianus* in the different treatments. NAP-Net annual production.

Variable	Treatment 1 (catfish)	Treatment 2 (Ningu)
Stocking size (g)	$5^{a} \pm 1.02$	$50^{b} \pm 0.73$
Final wt at harvest (g)	45 .87 ± 1.96	102.64 ± 0.88
Gross yield (ton/ha)	0.42 ± 0.43	0.91 ± 0.39
Net yield (ton/ha)	0.35 ± 0.41	0.41 ± 0.40
NAP (ton/ha/yr)	1.13 ± 0.64	1.25 ± 0.57
Survival (%)	91±1.25	89±1.46
Growth rate (g/d)	0.34 ±0.42	0.44 ±0.47

Means in a row with different superscripts are significantly different (P<0.05)

Table 3. Mean water quality parameters (+SE) for Treatments 1 and 2.

Variable T	reatment1 (Tilapia with catfish)	Treatment 2 (Tilapia with Ningu)
Morning temperature (ϒC)	24.9 ±1.4	24.7± 2.0
Afternoon Temp (ϒC)	30.4 ± 1.9	30.7± 1.8
Morning DO (mg/l)	5.7 ±1.7	5.3 ±1.6
Afternoon DO (mg/l)	10.2 ± 2.4	10.4 ± 2.1
Morning pH	9.3 ± 0.4	9.3 ± 0.5
Afternoon pH	10.1 ± 0.5	10.1 ± 0.5
TAN (mg/l) 1	.6 ± 0.1	1.6 ± 0.2
Secchi-depth (cm)	15.7 ±3.7	14.1 ± 4.1

Values in the same row with the same superscripts are not significantly different (p = 0.05); SE = Standard error of the mean

DO – Dissolved oxygen, TAN – Total ammonia nitrogen

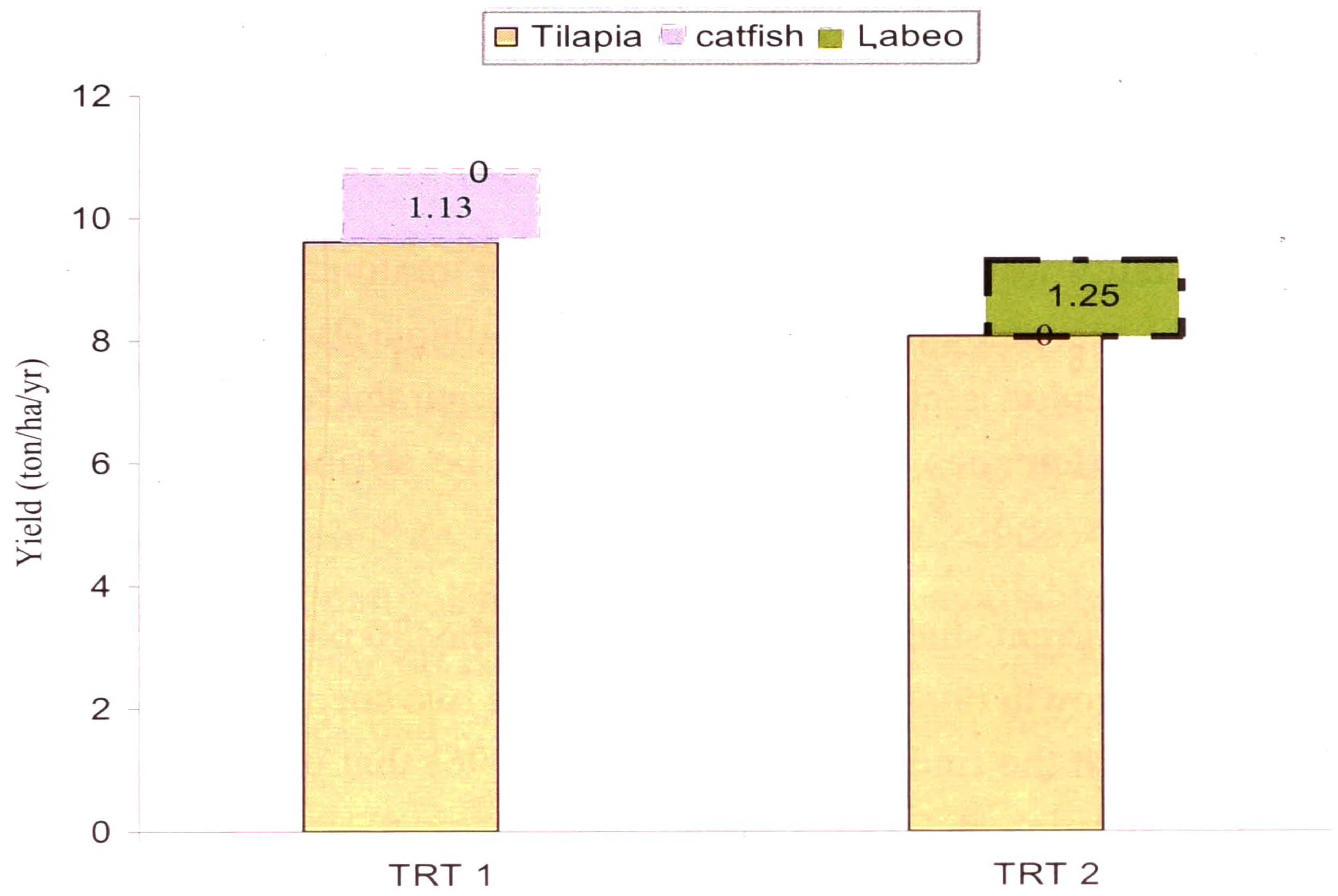

Fig. 3. Relationship between Net Annual Production (NAP) of *O. niloticus*, *C. gariepinus* and *Labeo victorianus*. The total annual yield for *Clarias* and *Labeo* is presented in each graph.(TRT = Treatment).

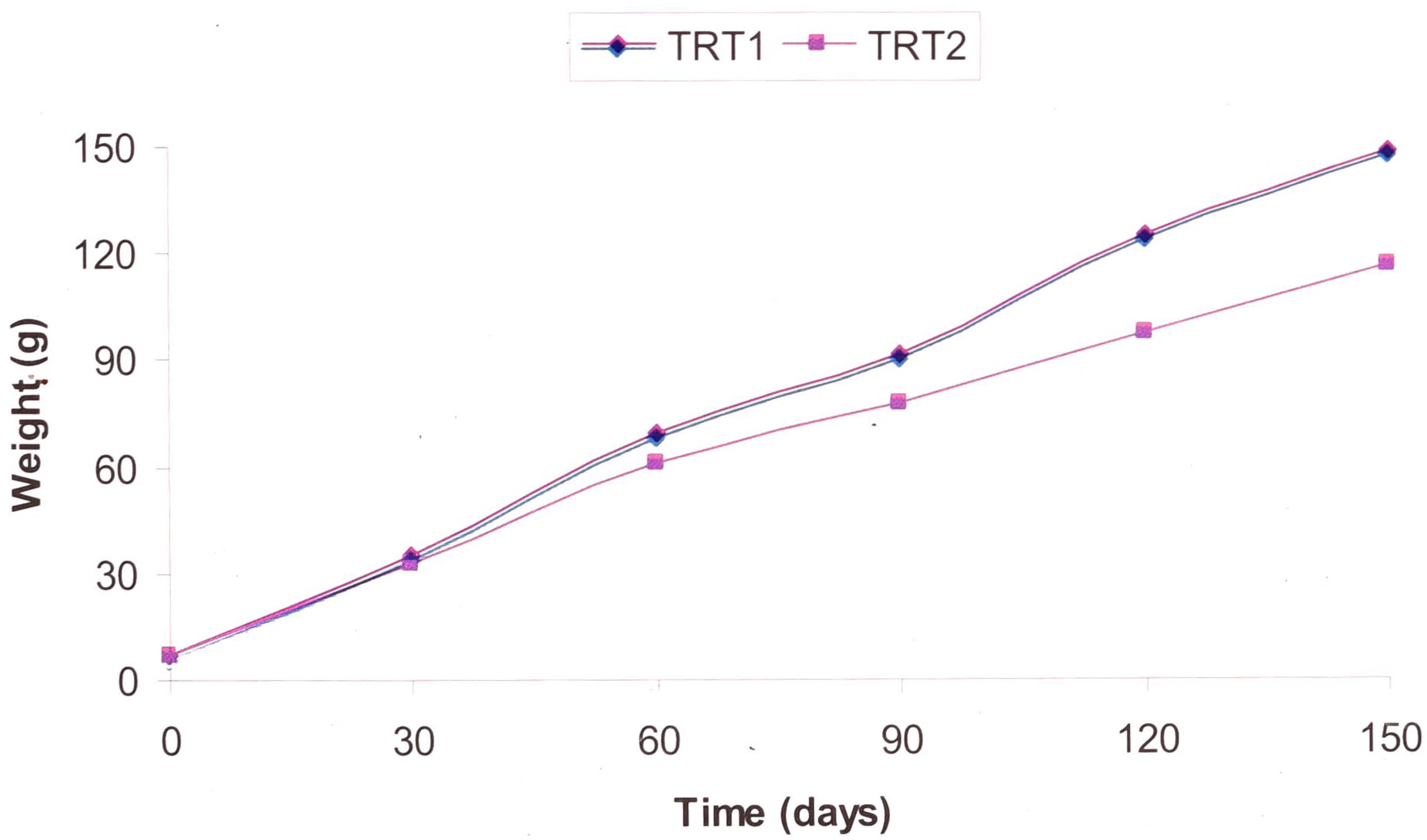

Fig. 4. Growth trends for *Oreochromis niloticus* co-stocked with catfish (TRT 1) and *Labeo* (TRT 2) for 150 days.

The growth rate in the two treatments ranged between 0.74 and 0.95 g/d for tilapia and 0.34 and 0.44 g/d for catfish and Ningu respectively with no significant differences (P>0.05) being observed within each species.

Values for water quality were no different between the treatments (P>0.05) and were, moreover, within the accepted limits for culture of Nile tilapia (Boyd and Tucker, 1992). From these observations it is clear that water quality parameters were similar in all ponds and that the differences in fish species could be attributed, therefore, to the treatment combinations.

Growth trends in the current study indicated that up to day 30 post stocking, there were no differences in the growth rates in tilapia between the two species combinations. This observation agrees with the findings of Nyanchiri (2006) that initial growth of fish is similar until certain limiting factors in the water body begin to retard growth. It was also apparent that after day 30, tilapia growth rates differentiated according to the species combination. Tilapia in the tilapia-catfish polyculture grew faster than that in the tilapia-*Labeo* combination treatment. One possible reason for the higher growth elicited in the tilapia-catfish polyculture treatment may have been due to predation by catfish on tilapia recruits. The reduction in numbers could in turn have the reduced competition between the fingerlings for the feed which was provided according to the originally stocked tilapia adults. The reduced competition and increased availability of feed could have arrested the sexual maturation in the tilapia with the energy resources from the feed that would normally be used in development of gonads and eggs being shunted into somatic growth (Turner and Robinson, 2000; Rad *et al.*, 2006). Normally, the high fish densities in the ponds as a result of numerous recruits in the tilapia – *Labeo* polycuture would result in the tilapia sacrificing growth to maintain reproductive capacity as the supply of food becomes insufficient (Coward and Bromage, 1999; Gines *et al.*, 2003).

The catfish must have also gained nutritionally by feeding on the tilapia recruits resulting in the observed accelerated growth. Tilapia recruits are rich in nutrients and are easily digestible to the catfish. This is supported by Yong-Selem *et al.*, (2006) who showed that *C. gariepinus* fingerlings stocked with tilapia brood fish preyed on the tilapia recruits and thus grew faster, survived better and withstood higher stocking densities than those in ponds without catfish. In treatment 2, *Labeo* being bottom feeders (Oenga *et al.*, 2006) may have continuously disturbed the pond water, thus reducing the feeding efficiency of tilapia (Nyanchiri *et al.*, 2006) and leading to the reduced growth of tilapia in the tilapia-*Labeo* combination. Another possible reason for the slow growth of tilapia observed in treatment 2 could be the increased competition for the feed given to the fish by both species. Similarly, the increased number of recruits as a result of the prolific breeding of tilapia and lack of predation by Labeo could have resulted in increased competition for the limited resources in the pond, thus reducing their growth.

Within the first 30 days, the growth rate of *Labeo* was the lowest among the 3 species of fish. This may be because they had been fished from a river and were thus in the process of acclimatizing to the environment of a static water body (pond). In the river ecosystem, moreover, being an omnivore (Oenga *et al.*, 2006) they must have been feeding on a variety of natural feeds which were not available the pond. The high growth rate of catfish after 60 days of stocking could be attributed to the fact that, tilapia having bred by then had produced recruits on which the catfish could prey.

Tilapia–catfish combination recorded significantly higher final weight at harvesting than the tilapia-*Labeo* combination. One reason for the higher production could be a better species combination which may have resulted in a more complementary utilization of all the food sources in the ponds - the supplemental feed as well as the natural food especially phytoplankton and zooplankton. Artificial food given to fish in earthen ponds can be directly eaten or can supply nutrients through decomposition by bacteria, fungi and protozoa. Water quality parameters in the culture of labeo and catfish were not significantly difference (P>0.05). This agrees with the findings of Nyanchiri (2006) who found out that in mixed tilapia polyculture, water quality parameters did not change significantly with the different fish species.

The interaction between the fish and organisms used as food is of utmost importance in polyculture. It is only a correct combination of ecologically distinct species at the optimal densities can utilize the available resources efficiently, due to the maximization of synergistic fish-fish relationships and minimization of antagonistic ones (Milstein, 1992). The African catfish and the Nile tilapia have different feeding habits and habitat preferences (Lutz, 2003) and hence fit the above requirements. *C. gariepinus* is an omnivore with a preference for animal protein and small fish although it also feeds well on artificial foods. *O. niloticus* in general is an herbivore and a detritivore and also readily accepts artificial food. The high production in Tilapia-catfish polyculture treatment could be attributed to the availability of both the supplemental (including tilapia recruits) and natural food in the ponds. Unlike catfish which feeds across the water column, *Labeo* is mainly a bottom feeder preferring to feed on the supplied and natural food at the bottom of the pond, a reason for the reduced production in the tilapia –*Labeo* polyculture.

Despite the higher growth rates of tilapia in the tilapia–catfish polyculture, however, it should be noted that catfish attained a lower yield (1.13 tonnes/ha/yr) in this treatment than *Labeo* in the other (1.25 tonnes/ha/yr).

This differences in production may be attributed to the initial stocking sizes; catfish were introduced at a much lower weight (5g) compared to *Labeo* (50g). At relatively small sizes, fish are fragile and thus prone to disease, predation and handling stress arising from both stocking and subsequent sampling which may have lead to reduced growth rates. The findings in this study, however, recorded no significant differences ($P>0.05$) in the growth rate between Catfish and Ningu so that the difference in the tilapia yield could be entirely attributed to the species used to combine with tilapia. The total fish yield of *Oreochromis niloticus* ranging from 8.08 to 9.61 tonnes/ha/yr was higher than that reported by Moehl (1999) though comparable to production reported by other workers (Bard *et al.*, 1976, Sumonu-Ogumodede, 1988, Fagbenro, 2000, De Graaf *et al.*, 1996) in tilapia –catfish polyculture. The disparities in equivalent yields are however accounted for by the relative variations in the quality and quantity of the supplemental feed, feeding regimes, initial stocking sizes of fish, ponds sizes used and pond fertilization rates used.

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