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Full Length Research Paper

Effect of repeated partial cropping on population dynamics and yield of *Oreochromis niloticus* (L.) during polyculture with *Heterobranchus longifilis* (Val.)

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The effect of repeated cropping of half the number of young and large adults on productivity and dynamics of *Oreochromis niloticus* was investigated during polyculture with *Heterobranchus longifilis*. Mixed-sex, large-sized and young adult tilapia of 841±0.3 g and 841±0.23 g were cultured with 40 catfish fingerlings in triplicate 36 m^2 earthen ponds in 1 and 2 treatments respectively. At the 4th, 6th, 12th, 26th and 32nd week, cropping was done in treatment 2 and the weights of the crop were used to enrich supplementary feed, by displacing an equal weight of ingredients in treatment 1. Realized supplementary feed crude protein level was 12.9 and 18.3±5% in treatments 1 and 2 respectively. Feeding was at 1% body weight thrice daily. Weight data were analyzed with ANOVA and t-test. Surplus production of *O. niloticus* from treatment 2, calculated as sum of periodic harvest + final harvest minus final harvest in treatment 1, was 249±25 g per week. Treatment 2 had significantly higher *H. longifilis* harvest mean weight and growth rate (percentage per day) (p<0.01), with densities (p<0.05). It also has higher numbers of zooplankton and phytoplankton species, cyanophyceae and diatoms, as well as *O. niloticus* size susceptible to catfish predation. Chlorophyceae dominated the phytoplankton in both treatments. The implication of tilapia surplus production for catfish-tilapia polyculture is thus discussed.

Key words: *Oreochromis niloticus*, partial harvest, population dynamics, compensatory growth, standing crop, surplus production, food availability, earthen pond.

INTRODUCTION

Majority of fish farmers in Nigeria are small-holder (semi-intensive) (Ayanda, 2003; Ayinla, 2007) and they practice catfish-tilapia polyculture. This system of catfish grow-out faces the problems of excessive tilapia reproduction and inefficient catfish predation (Van Weerd, 1995). Excessive reproduction of tilapia is often regarded as a setback for the system, since it results in the production of large quantities of small sized individuals, which have very low market value. Such ponds rapidly attain carrying capacity on account of tilapia biomass. This situation usually favors the proliferation of small sized individual tilapia with the attendant depression of recruitment into the large size classes. At harvest, 28 to 70% is composed of fingerlings (Lovshin et al., 1990). To achieve effective predation, high stocking densities of catfish are required (De Graaf et al., 1996). This results in small-sized catfish that fetches low prices. At low stocking densities catfish may therefore require assistance to gain sufficient nutrition from the tilapia in order to have significant individual sizes. Periodic biomass reduction by partial cropping of fingerlings is among the methods used in dealing with this proliferation (Fortes, 2005). Partial harvests of *Oreochromis niloticus* have so far focused on the removal of fry and fingerlings.

The idea of cropping another class of size of the tilapia population to increase the weight by which the biomass is reduced was tested in this study. The reduction was expected to induce a growth response in compensation which at first will intrinsically increase tilapia production

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from the system. The surplus production could potentially be a source of sustainable supply of protein for feed supplementation, since the system also faces the problem of supplemental feed quality. Tilapia has relatively low market value. Its use in the production of a species with much higher market value led to a 6- fold increase in the market value of the tilapia, and an 18-fold return on the marginal expense incurred. Low-value species can be used to produce high-value species (Funge-Smith et al., 2005).

The objective of this paper therefore, is to examine the effect of the repeated cropping of a section of the large adult sizes of *O. niloticus* on its production and population structure during polyculture with *Heterobranchus longifilis*, in earthen ponds.

MATERIALS AND METHODS

Pond preparation and husbandry conditions

The experiment was conducted in two treatments and three replicates, in the fish farm of the Michael Okpara University of Agriculture, Umudike, Nigeria. Experimental units were earthen ponds of 9 x 4 x 1.5 m dimensions. The ponds were cleared, limed with CaO at the rate of 6 kg/pond, and 500 g fermented chicken droppings were applied. Water was sourced from a perennial stream. Water level was constant at about 0.8 m at the inlet end and 1 m at the outlet end in all ponds was maintained by regular refreshment. This was done in order to eliminate the introduction of variable rates of production of fry and fingerlings between ponds as a result of differing depths (El-Sayed et al., 1996; Msiska and Costa-Pierce, 1997). Pond oxygen, temperature and pH were measured electronically with Hanna micro-processor meters twice daily in the morning (between 8 and 9 am) and in the afternoon (between 1 and 3 pm). All ponds were fertilized weekly with 500 g chicken dropping fermented for three days. Liming was done at the rate of 100 g/week with CaO.

Stocking

O. niloticus was categorized into four size classes as follows: large (> 15 cm total length); medium (10 to 14 cm total length); small (3 to 9 cm); and fry (< 3 cm total length).

A total weight of 841±0.3 g and 841±0.23 g mixed sex of *O. niloticus* was stocked in treatments 1 and 2 respectively. This comprised eight large (total weight 480 g) (3 males and 5 females) and 7 medium (2 males, 5 females) (total weight 360 g) individuals. Each pond was also stocked with 40 *H. longifilis* with mean weight of 5 g. The ponds were thereafter drained, re-filled and assigned treatments. The water inlet was screened with mosquito netting to prevent entry of wild tilapia. All large and 50% of medium sized individuals were taken from the ponds of treatment 2 at the 4th week. This scheme was adopted in order to leave the population with some sexually mature members while removing those that had become ecologically inefficient on account of attainment of large adult size. At the size range designated medium (10 to 14 cm total length), *O. niloticus* has attained sexual maturity. Bolivar et al (1993) put the size at attainment of sexual maturity for the species at 10 cm. De Graaf et al (1999) reported a sexually mature female at 8.7 cm. Periodic cropping was repeated at weeks 6, 12, 20, 26, and 32. At the 6th week, samples of 5 catfish fingerlings were taken from each pond for stomach content examination, to establish predation on tilapia.

Feeding

Supplemental feed

Both treatments were fed supplementally. Treatment 1 feed wascompounded as is commonly done, with 46.5% wheat bran, 46.5% brewery waste, 5% blood meal, and also with cassava flour used as binder at 2% inclusion level. Treatment 2 feed was compounded by displacing an equal weight of ingredients with tilapia harvested from the respective ponds. Feed crude protein content was 12.9% in treatment 1, and 18.3±5%, with 25.86±2% of it contributed to harvested tilapia in treatment 2.

Natural food

Zooplankton and phytoplankton densities were monitored. Ten litres composite water samples from each pond were filtered through a 100 µm mesh sieve. The plankton filtered was counted using a Sedgwick-Rafter counting chamber and expressed as per litre of water. At the end of the experiment, phytoplankton abundance was determined after centrifuging of composite 10 L water samples. Two weeks after stocking, five fish were taken from each replicate for stomach content analysis.

Data collection and analysis

The ponds were drained at weeks 4, 6, 12, 20, 26, and at the end of culture at week 32. The *O. niloticus* was enumerated and weighed. Data were collected on *O. niloticus* weight and number (except fry size class), as well as phytoplankton and zooplankton density. *O. niloticus* specific growth rate (% day^{-1}) was calculated as:

Specific growth rate:

$$\text{SGR} = \left(\frac{\text{In FBW} - \text{In IBW}}{\text{Days}}\right) \times 100$$

Where FBW is the Final body weight (g), IBW is the Initial body weight (g), and In
is the natural logarithm (Goda et al, 2007).

$$\text{Total productivity of } O.\,niloticus \text{ (g)} = \sum \text{Weight } O.\,niloticus \text{ cropped (g)} + \text{Weight } O.\,niloticus \text{ at harvest (g)}$$

Surplus production of *O. niloticus* was calculated as:

$$\text{Surplus } O.\,niloticus \text{ production} = \left[\left(\sum \text{Weight } O.\,niloticus \text{ cropped in treatment 2}\right) + \left(\text{Weight } O.\,niloticus \text{ at harvest in treatment 2}\right)\right] - \text{Weight of } O.\,niloticus \text{ at harvest in treatment 1}$$

Data were compared between the treatments using the t-test in the TTEST Procedure of the SAS(1995) (SAS Inc. Cary NC USA).

RESULT

O. niloticus production and population dynamics

Total tilapia productivity in treatment 2 was 7158±319 g.

Table 1. Total production of *Oreochromis niloticus, Heterobranchus longifilis* mean weight and specific growth rate (% day^{-1}) in earthen ponds operated: (a) under a conventional polyculture system involving predator-prey relationship between *H. longifilis* and *O. niloticus* with supplemental feeding (treatment 1) (b) with mean weekly removal 249±25 g *O. niloticus* from partial harvest of the small sized adult and complete harvest of large sized adult size classes (treatment 2), during a 32-week culture period. Values are means (±SD) from three replicates. * - p<0.05, ** - p<0.01, ****-0.0001.

Parameter	Mean weight (g)	SGR (% day^{-1})	Total production (g)	Feed protein content (%)
Treatment				
1	357.3±29.4	0.38±0.02	2506±265	12.9±0.16
2	653±28.9	0.59±0.03	7158±319	25±5±4.92
Significance	**	**	****	*

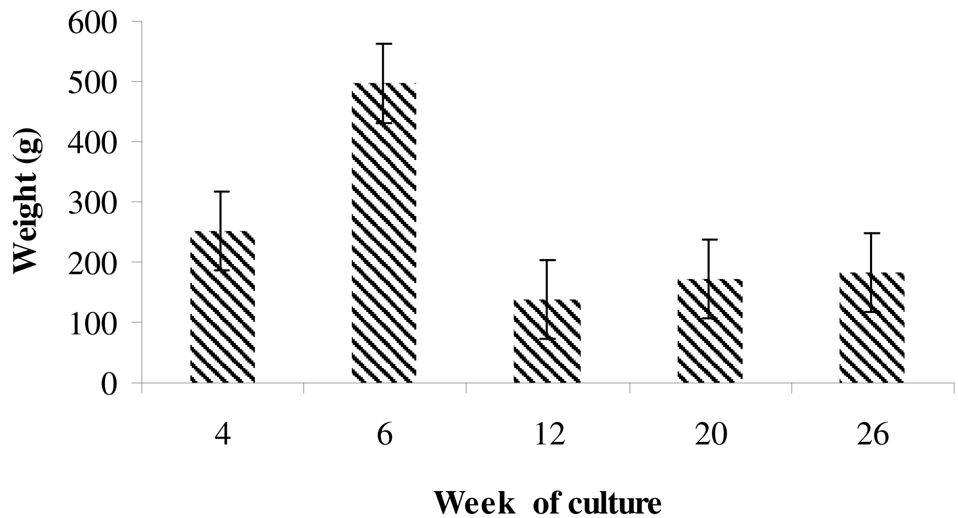

Figure 1. Weight (g) of >10 cm *Oreochromis niloticus* harvested from earthen ponds operated with periodic removal of 50% of the 10 to 14 cm and 100% of >14 cm size classes, over a 32-week culture period. Values are means (±SE) from three replicates.

This was significantly higher than in treatment 1 (p<0.0001) (Table 1), and represents a mean surplus production of 249±25 g for each of the 32 weeks of culture, which was cropped for supplemental feed enrichment. The weight of *O. niloticus* cropped decreased over the period (Figure 1). The dynamics of *O. niloticus* weight is given in Figure 2. By the second sampling, the weight removed had been over-compensated for. The weight in treatment 2 continued to decrease, though remaining higher than in treatment 1 until week 26. The dynamics by number, of the various size classes is given in Figures 3 to 6. The number in the cropped size classes maintained the same proportions with treatment 1 (Figures 3 and 4). The fry size class was the most numerous followed by the small, medium and large size classes in both treatments. There was no noticeable effect of the partial harvest procedure on the fry size class. The most dramatic effect of the partial harvest procedure was seen in recruitment into the small size class in treatment 2. The dynamics of the various size classes of *O. niloticus* are given in Figures 2 to 5.

H. longifilis growth

Two weeks after stocking and at mean weight of 17.6±2.7g and 19.8±16 in treatments 1 and 2 respectively, the stomach of catfish in all ponds had recognizable fish flesh, bones, scales, water bugs, and feed as part of the contents of the stomach. Overall catfish specific growth rate and harvest mean weight were significantly lower in treatment 1 (p<0.05). The specific growth rate during culture was highest in treatment 2 in weeks 6 and 12 (Figure 6), sustaining a higher mean weight up to harvest (Figure 7 and 8).

Plankton and water quality

Data on plankton density are given in Table 2. Zooplankton density was significantly higher in treatment 2 than treatment 1 (p<0.05). Treatment 2 had higher zooplankton diversity than treatment 1. The number of species of phytoplankton was higher in treatment 2, but

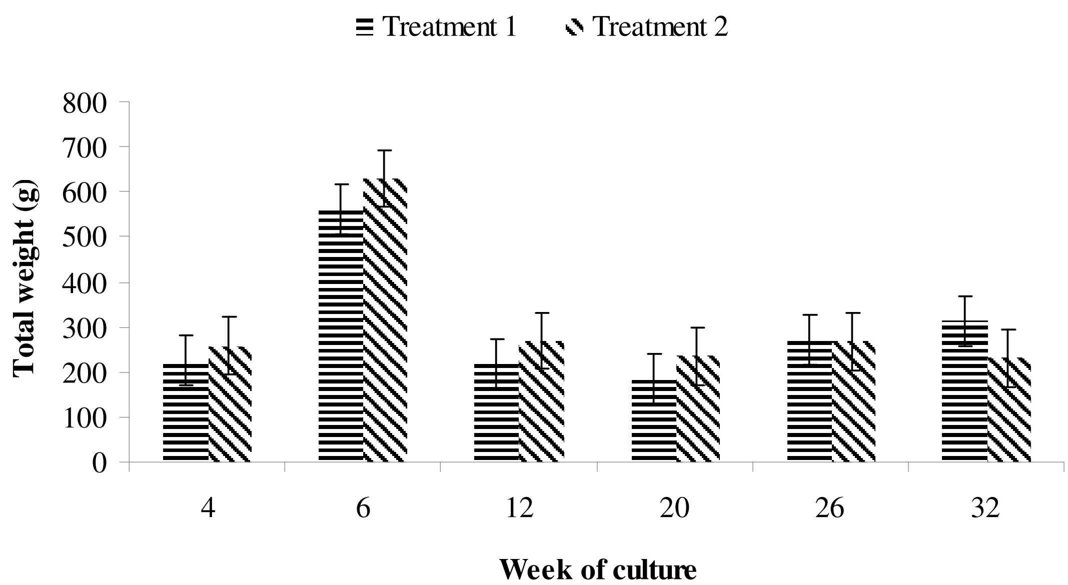

Figure 2. Total weight (g) dynamics of *Oreochromis niloticus* in earthen ponds: (a) under normal predator-prey relationship with *Heterobranchus longifilis* (treatment 1) (b) with a mean weekly removal of 249±25 g *O. niloticus* from partial harvest of the 10 to 14 cm and total harvest of >14 cm size classes (treatment 2) over a 32-week period of polyculture with *H. longifilis*. Values are means (±SE) from three replicates.

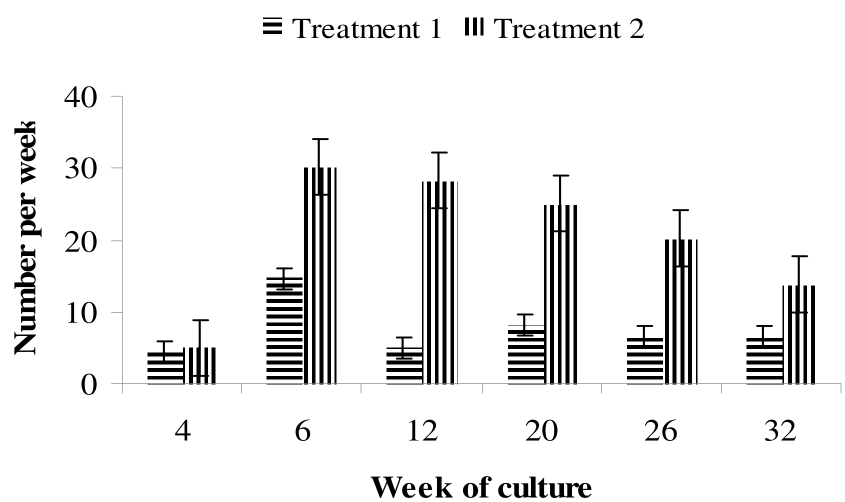

Figure 3. Dynamics of weekly abundance of small (3 to 9 cm) *Oreochromis niloticus* in ponds initially stocked with 7 sub-adult and 8 adult individuals (a) under normal predator-prey relationship with *Heterobranchus longifilis* (treatment 1) with removal of 50% of 10 to14 cm and 100% of >15 cm *O. niloticus* at 4th, 6th, 12th, 20th, 26th, and 32nd weeks (treatment 2) during polyculture. Means (±SE) are from 3 replicates.

the density per species was more uniform in treatment 1 than in treatment 2. Though the dominant phytoplankton species in treatments 1 and 2 at the end of the experiment were small-sized chlorophyceae (*Volvox* in treatment 1 and *Chlorella* in treatment 2), large-sized cyanophyceae and diatoms (*Oscillatoria* and *Synedra*) were relatively scanty, but were significantly higher in treatment 1 than treatment 2. Data on physico-chemical parameters are given in Table 3.

DISCUSSION

The sampling scheme adopted in this study was aimed at

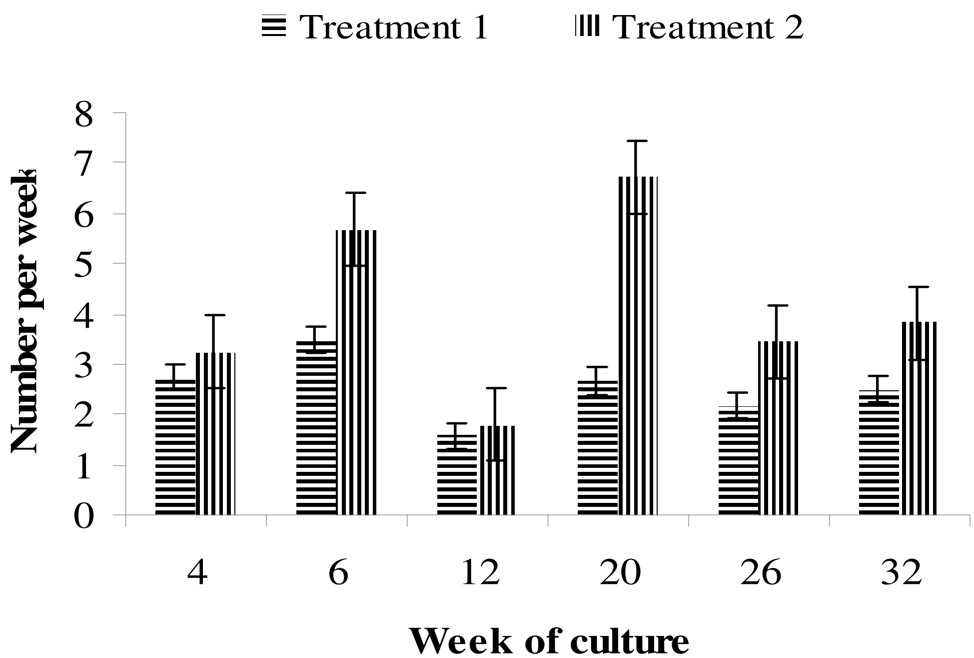

Figure 4. Dynamics of medium (10 to 14 cm) *Oreochromis niloticus* in ponds initially stocked with 7 sub-adult and 8 adult individuals (a) under normal predator-prey relationship with *Heterobranchus longifilis* (treatment 1) (b) with periodic removals of 50% 10 to 14 cm and 100% of >15 cm *O. niloticus* at the 4th, 6th, 12th, 20th, 26th and 32nd weeks (treatment 2), during polyculture. Means (±SE) are from 3 replicates.

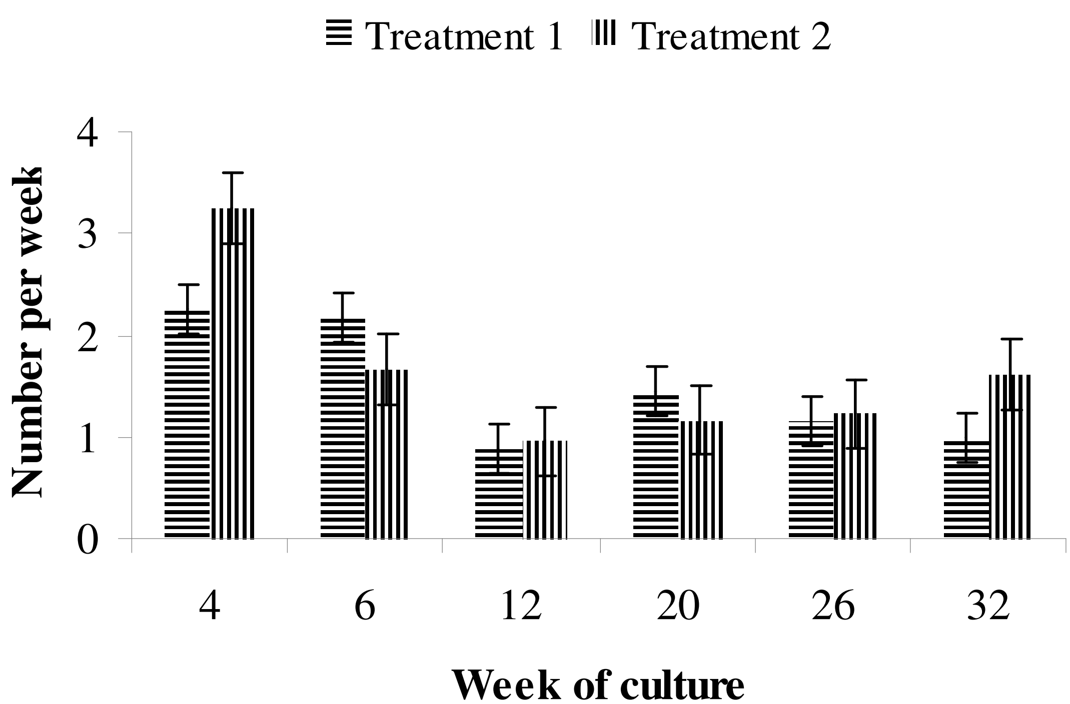

Figure 5. Dynamics of weekly abundance of medium (>15 cm) *Oreochromis niloticus* in ponds initially stocked with 7 sub-adult and 8 adult individuals: (a) under normal predator-prey relationship with *Heterobranchus longifilis* (treatment 1) (b) with periodic removal of 50% 10 to 14 cm and 100% of >15 cm *O. niloticus* at 4th, 6th, 12th, 20th, 26th, and 32nd weeks (treatment 2) during polyculture. Means (±SE) are from 3 replicates.

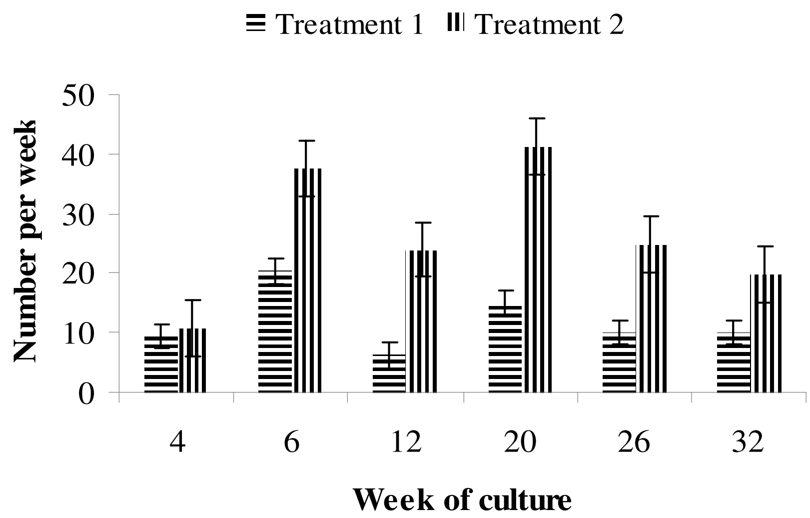

Figure 6. Dynamics of total number of *Oreochromis niloticus* (>3 cm total length) in ponds initially stocked with 7 sub-adult and 8 adult individuals (a) under normal predator-prey relationship with *H. longifilis* (treatment 1), (b) with removal of 50% 10 to 14 cm and 100% of >15 cm *O. niloticus* at 4th, 6th, 12th, 20th, 26th, and 32nd weeks (treatment 2) during polyculture. Means (±SE) are from 3 replicates.

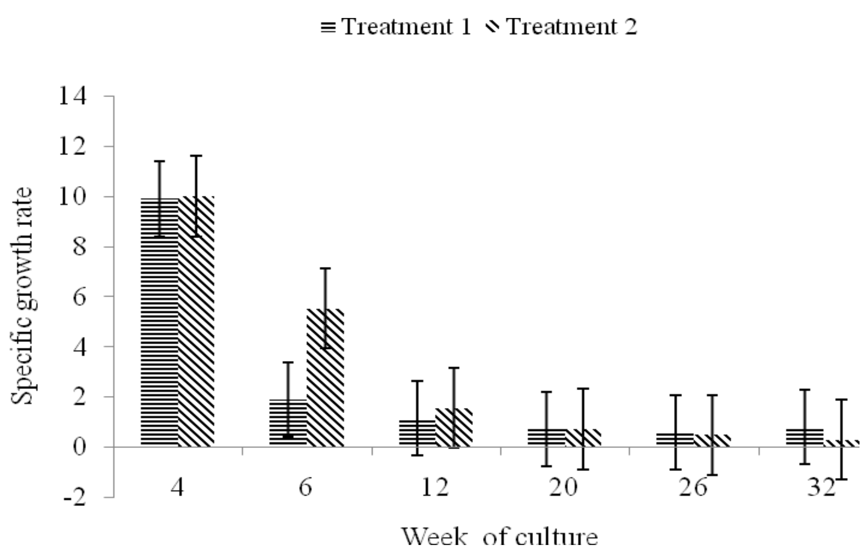

Figure 7. Specific growth rate (% day^{-1}) of *Heterobranchus longifilis* in earthen ponds operated: (a) under a normal predator-prey relationship with *H. longifilis* with supplemental feeding (treatment 1) (b) with periodic removal of 50% of the 10 to 14 cm and 100% of >14 cm size classes (treatment 2), during a 32-week culture period. Values are means (±SE) from three replicates.

achieving a significant reduction in the *O. niloticus* biomass in the ponds, without interfering with their recruitment ability. At the end of week 4, the first partial cropping was done in treatment 2. By the 6th week, the weight of *O. niloticus* in treatment 2 had once more exceeded that in treatment 1. This trend was observed up to week 20. At week 26, the weight of *O. niloticus* in the two treatments was equal, despite the removals in treatment 2. The replacement is explained by the significantly higher specific growth rates observed in treatment 2 (Table 1). These observations agree with what is known of surplus production in fish stocks. This has the central

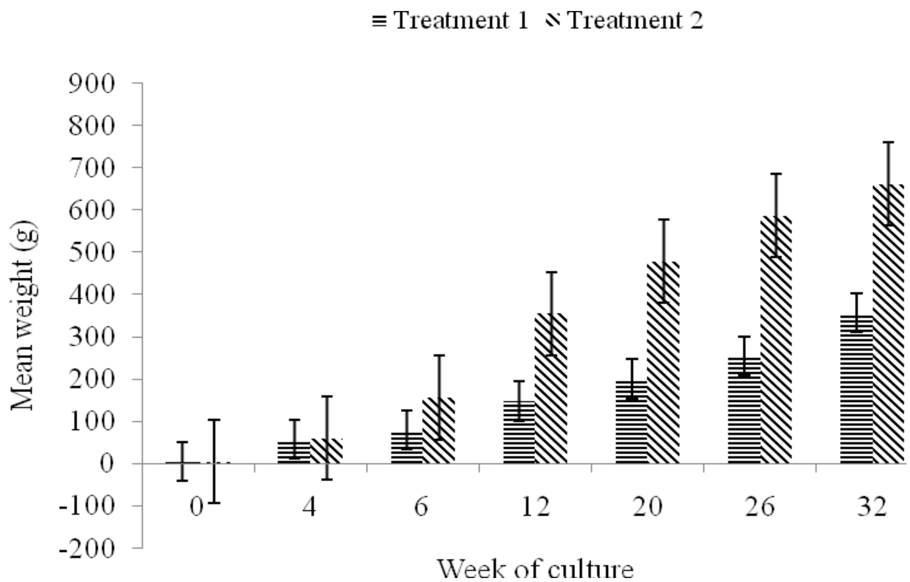

Figure 8. Weight (g) of *Heterobranchus longifilis* in earthen ponds operated: (a) under a normal predator-prey relationship with *H. longifilis* with supplemental feeding (treatment 1) (b) with periodic removal of 50% of the 10 to 14 cm and 100% of >14 cm size classes (treatment 2), during a 32-week culture period. Values are means (±SE) from three replicates.

assumptions that: at large stock sizes, reproductive rates and stock growth rates are slowed by self-regulating mechanisms; removals from the stock (resulting in a greater difference between stock size and carrying capacity) subject it to higher rates of growth as it tries to reduce this difference through increased individual growth and recruitment rates. This effect was enhanced in this study by the removal of the relatively ecologically inefficient large adult sizes.

Partial cropping exerted its influence on the dynamics and structure of the *O. niloticus* population by the interplay between standing crop and biomass. The procedure had a dramatic effect on biomass of *O. niloticus* because the weight removed constituted an average of 55% of total weight, and also on density but to a much lesser extent, as the number removed was small relative to the total number of tilapia. Thus both biomass-dependent and to a lesser extent, density-dependent factors of *O. niloticus* population dynamics may have been activated.

Biomass reduction has been found to have a positive effect on tilapia growth and yield (Someren and Whitehead 1959; Diana et al, 1988; Lorenzen 2000; Vromant et al, 2002). As both species do not compete for food, the removal of the large-sized tilapia may not have affected the catfish biomass by reducing competition for food. The influence may have been indirect, because the procedure led to the production of more fry and superior supplemental feed for consumption by the catfish.

According to Hogendoorn and Koops (1983), interspecies competition between *Clariaslazera* and *Sarotherodon niloticus* is absent in pond polyculture of both species. Therefore, the interaction between the catfish and tilapia in this study may have been restricted to the production of higher numbers of smaller-sized individuals, and the use of large size adults to enrich supplemental feed.

The most remarkable effect of the procedure was in the small size class. There were significantly higher total numbers in treatment 2 than treatment 1, which was higher by almost 3 times in some cases, resulting in more competition for food and space resources (Odum 1959). This agree with the report of Hepher and Pruginin (1982) that repeated removal of the adults results in an increased spawning activities in tilapia, with the production of progressively smaller individuals. While this may be unwanted in polyculture targeting tilapia production, the effect in this study may have been to make more tilapia available for consumption by the catfish as natural food. With the biomass reductions (low start-off weights) that occurred at each cropping, more food became available, inducing a compensatory growth response in treatment 2. The production of *O. niloticus* was increased by 2.9 times of the production from similar sized ponds subjected to the same fertilization rates, thereby increasing the efficiency of natural food utilization and consequently system productivity.

Compensatory growth response is a phenomenon in which fish fed restrictedly exhibit faster than normal growth rates with the return of favourable conditions, opening the prospect of increasing the growth rates

Table 2. Zooplankton density (number/litre), phytoplankton species diversity and density (number/litre, values given in 10^3) in earthen ponds used for the polyculture of *H. longifilis* and *O. niloticus* for 32 weeks: (a) under a normal predator-prey relationship with supplemental feeding (Treatment 1) (b) with periodic removal of 50% of the 10 to 14 cm and 100% of >14 cm size classes (Treatment 2). Values are means (±SE) from three replicates. * - p<0.05, ** - p<0.01, unindicated - p>0.05.

Species	*Volvox*	*Chlorella*	*Oscillatoria*	*Scenedesmus*	*Havicula*	*Synedra*	Total phytoplankton	No. phytoplankton species	Total zooplankton	No. of zooplankton species
Treatment										
1	126±10	22±5	58±6	6±0.29	62±4	87±8	304±89	11±0.2	698±33	7
2	28±2	266±9	2	4±1	4±1	21±9	945±95	15±0.5	1190±8	10
Significance	*	**	**		*	*	*		**	

Table 3. Physico-chemical characteristics of earthen ponds used for the polyculture of *H. longifilis* and *O. niloticus* for 32 weeks: (a) under a normal predator-prey relationship with supplemental feeding (treatment 1) (b) with periodic removal of 50% of the 10 to 14 cm and 100% of >14 cm size classes (treatment 2). Values are means (±SD) from three replicates, calculated over the 32 week period.

Treatment	Parameter					
	Temperature (°C)		pH		Dissolved oxygen [(Saturation (%)]	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
1	31.7±2.1	25±1.0	6.7±1.1	8.3±1.7	66±5	131±10
2	30.3±1.9	24.8±1.7	6.94±1.6	7.9±1.9	68±4	127±14

fish in aquaculture (Weatherley and Gill, 1981; Ali et al., 2003). Compensatory growth response has been observed in pond-farmed tilapia. Tilapia growth exhibits plasticity in ponds, being arrested in ponds that had reached carrying capacity, but resuming when removed to ponds that were below carrying capacity (Someren and Whitehead, 1959, Lorenzen, 2000). In this study, compensatory growth fully compensated for the weight, and over-compensated for the number of *O. niloticus* cropped. Total productivity of *O. niloticus* within the 32 weeks period is 287% the production in treatment 1. This represents a weekly surplus production of 249±25 g per 36 m^2 pond. It seems that this response was mediated through the rapid recruitment of fry into the small size class.

Catfish-tilapia polyculture is the semi-intensive method of choice in catfish grow-out in Nigeria (Ayinla, 2007). The objective of this model of polyculture is for the catfish to prey on the tilapia to grow. The tilapia is stocked primarily to serve as a natural food source for the catfish. One of the major problems faced by this grow-out system is the inefficient predation of the catfish, which requires stocking at high densities of 8,300 catfish/ha for this food source to be fully utilized as seen in the complete control of recruitment (De Graaf et al. 1996). At this catfish stocking density, there may not be enough tilapia for significant catfish individual growth and stunting also results. On the other hand, only 725 *Parachanna obscura* were needed to achieve the same effect (De Graaf et al. 1996). The use of this species may be limited by the availability of its fingerlings and market acceptance. At low stocking densities, catfish may therefore require assistance to gain sufficient nutrition from the tilapia. This will be achieved if the cichlid is harvested maximally but on a sustainable basis and used to feed the catfish supplementally. The second problem is the quality of supplemental feed. High quality feeds are too expensive for the system, accounting for 62% of cost of production (Ofor, 2007). In Nigeria, the supplemental feed for this system is made from low quality agricultural by-products, due to the high cost of the alternatives, caused by competition from many users (Ayinla, 2007). The test procedure has the otential to alleviate these problems. The *O. niloticus* cropped can be used to enrich supplemental feed that is fed to the system. It has been shown that this practice will not place the farmer at any disadvantage in terms of *O. niloticus* yield.

The observations on the effect of the procedure on plankton composition are explained by the findings of Figueredo and Giani (2005). Stocked into reservoirs in Brazil, *O. niloticus* selectively fed on larger sized phytoplankton (cyanobacteria and diatoms), resulting in the proliferation of small-sized or mucilaginous colonial chlorophyceans (Figueredo and Giani, 2005). *O. niloticus* stomach contents in Lake Victoria have been found to be composed of Cyanophyceae (53.6%), diatoms (19.7%, aquatic invertebrates (mainly Copepoda, Cladocera and Rotifera)(12.9%) and green algae (Chlorophyceae) 6.2% (Getabu, 1994). The absence of cyanophytes in rice farms led O. niloticus to switch to detrital aggregates, rather than feed on chlorophyceae, the dominant algal group (Chapman and Fernando, 1994). Also, the presence of *O. niloticus* was found to result in a 70 and 270% increase on nitrogen and phosphorus availability. The higher numbers of tilapia in treatment 2 may have resulted in nutrient recycling to a greater extent than treatment 1, making the ponds of treatment 2 more productive of zooplankton, which were then consumed less preferentially.

Conclusion

Catfish-tilapia polyculture faces the problems of ineffective predation of the tilapia by catfish, consequent catfish low production, and low quality of supplemental feed. The periodic harvest of all large adult and half of small adult *O. niloticus* as was done in this study, directly increased catfish production by providing more *O. niloticus* in the vulnerable size class for catfish predation, and indirectly by increasing overall *O. niloticus* production leading to a surplus production that was used to enrich supplemental feed introduced into the system. Further studies are needed to determine the influence of length of time interval between harvests, on surplus production of *O. niloticus*.

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