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Indigenous fish species a panacea for cage aquaculture in Zambia: A case for *Oreochromis macrochir* (Boulenger, 1912) at Kambashi out-grower scheme.

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Abstract
In Zambia there has been limited attempt to culture indigenous fishes in cages; therefore their suitability for cage culture is not proven. Until then, Nile tilapia remains the fish culture species of choice in cages. Despite its superior comparative growth performance, Nile Tilapia is exotic to the Zambian aquatic system and this poses great environmental concerns. In this trial pioneered at Kambashi Bream Fisheries, an attempt was made to monitor the growth performance of an indigenous fish species (*Oreochromis macrochir*) commonly known as long fin bream from the Cichlidae family. 4,000 fingerlings were stocked in each of the 3 x 50 m^3 cages and fed formulated diet for 240 days between March and October 2013. Fish grew from 3.0 g to 353 g (±0.0104 SE).Analysis of variance on the final weight of trial fish showed no significant differences ($P>0.05$).The trial proved *O. macrochir* as a suitability alternative candidate fish for cage culture on Lake Bangweulu.

Keywords: *Oreochromis macrochir,* Indigenous, Candidate, Cage aquaculture

1. Introduction
Zambia currently produces 85,000 tonnes of fish per year against an estimated demand of 145,000 tonnes [1]. It is further estimated that approximately 6,000 tonnes of fish is currently being imported annually from China, India and Zimbabwe. However, cage farming in Zambia is attracting a lot of interest, even if production statistics is scanty. The country has the potential to increase fish production by 300% by 2030 owing to an influx of both smallholder and commercial cage culture entrepreneurs. The current production from Lake harvest of Zimbabwe is landing 10 tons of fresh *Oreochromis niloticus* at the Lusaka Market on daily basis. There are more large scale commercial companies that are in the process of commencing cage farming in Zambia [2].
Although suitability of a fish species for aquaculture and cage culture in particular depends on many criteria related to marketability, availability, culture adaptability and stress tolerance.
Marketability is the first consideration in selecting a species for culture because the last step in a successful culture operation is to sell fish at a profit. In Zambia, species of fish to be used in Cage Culture is selected in compliance with the regulations pertaining to species translocations between watersheds [2]. The use of *Oreochromis niloticus* has however been allowed despite it being exotic and this will sooner or later generate environmental debates and concerns.
Kambashi smallholder out-growers scheme, a community based cage Aquaculture project situated in Chilubi District of the Northern Province of Zambia has taken a paradigm shift; championing a pilot program on the use of indigenous fish species of *Oreochromis macrochir* (commonly known as long fin Bream) in 50 m^3 cages (5m x 5m x 2m) on lake Bangweulu. The lake which is exclusively in country and is not shared with neighboring countries has in the recent past experienced a collapsing fishery with fish stock catches declining from 12kg/100m net in 1984 to less than 2 kg/100 m of net in 2009 [3]. The lake however is oligotrophic (low in nutrients) and therefore suitable for cage aquaculture. The Kambashi scheme has therefore seized with this opportunity to venture into the cage aquaculture sector to demonstrate an environmental friendly and social best aquaculture practice in the country. When fully scaled up Kambashi smallholder aquaculture scheme targets an annual fish production of 900 tones of local breams. The project will also assist in offsetting the large

deficit of affordable fish within Zambia and also contribute significantly to the development of the rural economy of Chilubi District through provision of new jobs to the hosting community. The project was a local community initiative to improve food security and nutrition for its people through cage fish farming, the Government of the Republic of Zambia and the local church fully supported the piloting.

2. Materials and Methodology

2.1 Experimental design and stocking

The trial was carried out on Lake Bangweulu from March through October 2013. One thousand two hundred (1,200) brood stock of *Oreochromis macrochir* were recruited from Lake Bangweulu using 13 mm seine net. One thousand (1000) fish of average weight 400g (± 0.012 SE) were segregated according to males and females and stocked into two separate holding ponds of 400 m^2 (20 m x 20 m) each. The fish were fed a 40% protein rich diet for one month (December, 2013). To commence fingerling (fish seed) production, the brood stocks in the ratio, 1 male to 2 females were then relocated into 20 breeding ponds (10 m x 10m each) and stocked at the rate of 0.5 fish/m^2.Each breeding pond was stocked with 50 brood stocks.

Fry was collected from breeding ponds, graded through 3.2 mm mesh material to remove fish that are >15 mm, and required swim up sized fish were taken into hapas (woven made net used for holding fish fry in water) for sex reversal . Stocking densities of 2000 fish/m^2 was used while water exchange in the hapas was facilitated to maintain good water quality. 17 α methyl testosterone fortified powdered feed (fish meal), containing 40% protein was administered at the rate of 20 percent body weight per day and gradually decreased to 10 percent by the end of a 4week sex-reversal period. Rations were adjusted daily, and feed administered four times per day. Feeding strategy allowed for feed to float avoiding waste and settling at the bottom of the hapas. Sex-reversed fry reached an average of 0.4 g after 4 weeks. The fry were then moved into grow out ponds fed on 40% protein rich ration until they reached fingerling size.

Twelve thousand (12,000) fingerlings were translocated from the land based hatchery and stocked equally (4000 fish/cage) into 3 square floating cages on the lake, each cage measuring 50 m^3 (5 m x 5 m x 2 m). The fingerlings were stocked at a density 80 fingerling m^3 with an average initial weight of 3.00±0.01 g. The cages were made of High Density Polyethylene (HDPE) plastic pipes framed and weld together in a square shape. The cages were buoyed by kaylite material tacked inside the pipes. The fish were grown for 8 months (March to October) inside the 8 mm mesh net bagged to the plastic frame of the cage while the fish were protected from predators by the use of a second outer HDPE net of 22 mm mesh size. The smaller nets were eventually removed from the cage in week 9 leaving the predator net to facilitate flow of more oxygenated water through the cages and also avoided bio-fouling created in the smaller meshed nets.

2.2 Water Quality

Water quality parameters (temperature, dissolved oxygen, pH, ammonia, transparency) were monitored to ensure water quality remained well within limits recommended for Tilapia in all the cages. Water temperature and dissolved oxygen were measured every other day. A multi-parameter water checker (Hanna model, HI 980) was used to record parameter readings.

2.3 Feeding regime in cages

Floating feeds sourced from Tiger Animal Feed Limited were administered to the fish. Fish were fed 4 times a day throughout the production cycle based on body weight. The initial feeding rate of 4-5% of their body weight per day was used which gradually reduced to 3% as fish grow, and finally reduced to 2% of body weight per day as fish approached market size. Different feed of varying dietary protein levels (crumbles-40%, fingerling pellets-38%, grower-35% and finisher -30%) was administered according to the successive growth stages of the fish in the cages.

2.4 Sampling and Harvesting

Twice every month 50 fish were randomly sampled from each of the 3 cages. To remove fish during sampling, the cages were partially lifted out of the water and fish captured with a dip net. Fish samples were counted, weighed then treated in 2% of iodated salt bath to avoid fungal infections and then returned into their respective cages for further growth. The sampled fish were measured for individual weight Periodic sampling helped to determine average fish weight enabling feed rate adjustments. After 240 days of trial, fish in all the three cages were harvested and weighed separately.

2.5 Data entry and statistical analysis

All data were entered into Microsoft excel spreadsheet and later exported to Statistical Package for the Social Sciences (SPSS) 12.0 version of windows for statistical analysis. A One-Way ANOVA was used to analyze the data. Data that did not meet the ANOVA assumptions were transformed by log as described by Pallant [4]. Duncan Multiple Range Test (DMRT) was used to determine significant differences between treatment means at α = 0.05

3. Results

3.1 Water quality

Water quality parameters remained in acceptable ranges during the 240 days of production cycle. There were no significant differences (P>0.05) in the water parameters observed across the 3 cages. Temperature ranged between 22.8 ºC ± 0.05 to 23.0 ± 0.03. Dissolved oxygen (DO) concentration averaged 6.5 mg/L. Values of pH ranged from 7.53 ± 0.06 in cage 1 to 7.56 ± 0.04 in cage 3. Ammonia averaged 0.016 ± 0.01 mg /L and were not significantly different (P>0.05) in all cages (Table 1).

Table 1: Water quality parameters from 3 cages of 50 m^3 size each during 240 days of experimental period for *O. macrochir* (Mean ± SE)[1]

Cage No.	Temperature	DO (Mg/L)	pH	Ammonia (Mg/L)	Secchi Reading
1	22.8 ± 0.05	6.50 ± 0.02	7.53 ± 0.06	0.016 ± 0.03	5±0.01
2	22.9 ± 0.02	6.50 ± 0.04	7.55 ± 0.03	0.017 ± 0.03	5±0.02
3	23.0 ± 0.03	6.48 ± 0.03	7.56 ± 0.04	0.016 ± 0.01	5±0.01

[1]Means were not significantly different (P> 0.05).

3.2 Fish Growth

The sex reversed (all male) *Oreochromis macrochir* gained weight of 350.95 g ±0.35 during the 240 days of production cycle and there were no significant differences (*P*>0.05) among the 3 cages. The food conversion ratio of 1.57±1.04 showed no significant differences (*P*>0.05) while survival percentage recorded no significant differences across the 3 cages (Table 2)

Table 2: Final mean body weights, weight gain, weight gain/day and feed conversion ratio (FCR) of *O. macrochir* raised in 3 x 50 m^3 cages for 240 days (Means ± SE)[1]

Parameters	Cage No.		
	1	2	3
Initial mean weight (g/fish)	3.00±0.01	3.00±0.01	3.00±0.01
Final mean weight (g/fish)	354±0.012[a]	353±0.014[a]	355±0.015[a]
Weight gain (g/fish)[2]	350.95±0.35[a]	350±0.30[a]	351.9±0.32[a]
Weight gain/day (g/fish)[3]	1.46±0.01[a]	1.45±0.01[a]	1.46±0.01[a]
FCR[4]	1.57±1.04[a]	1.56±1.10[a]	1.56±1.09[a]
Survival (%)[5]	99.65±0.77[a]	99.80±0.60[a]	99.75±0.75[a]

[1]Means in the same row with same superscripts are not significantly different (*P*>0.05). Data represent means of 50 fish/cage.
[2]Weight gain (g/fish) = final mean weight- initial mean weight.
[3]Weight gain/day = (final mean weight - initial mean weight)/ (days)
[4]FCR: feed conversion ratio = Total dry food offered (g)/weight wet gain (g).
[5]Survival (%) = Final number of fish/Initial number of fish x 100

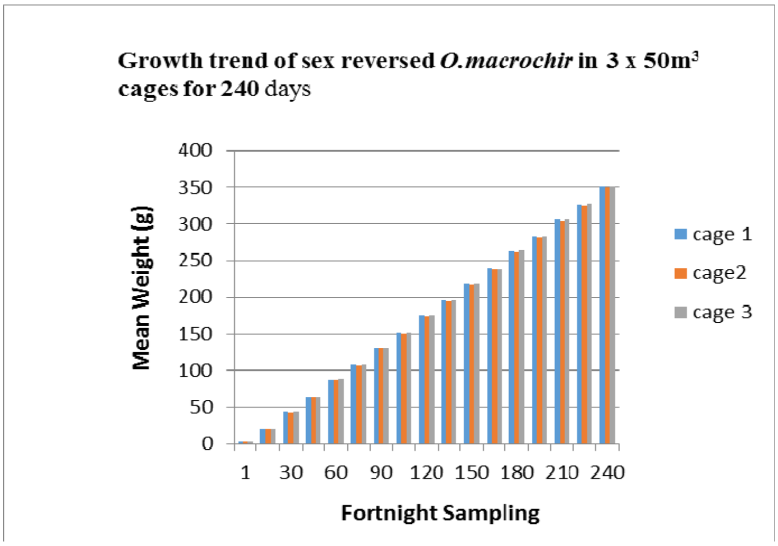

Fig 1: Growth trend by mean weight of sex reversed *O. macrochir* raised simultaneously in 3x 50 m^3 cages for 240 days (*n*= 120)

Fig 2: *Oreochromis macrochir* raised from the Kambashi cages in 240 days, weighing 350 g and total length of 28 cm

4. Discussion
The results of this trial confirmed that *Oreochromis macrochir* is suitable for cage culture. The male mono-sex trial fish used grew to an average of 350 g from 3 g in 240 days without significant differences (*P>0.05*) across the cages, despite the trial traversing 2 cold months of May and June. Similar experiments elsewhere by Gaber *et al.* [5] on monoculture of *Oreochromis niloticus* reared in cages for 7 months between May and November in 2012 gained weight by 274g. Growth is a function of, among other things both the nutritional quality and the rate of consumption [6], the fish in the trial recorded average Food Conversion ratio (FCR) of 1.56 indication of better growth performance and proves to be a suitable candidate for cage culture. According to Goddard [7] poor FCR (>2) sometimes indicates wider problems including occurrence of disease in stock. Stickney [7] observed that FCR values can actually be less than 1 in water systems where there is natural food. The current trial has shown *Oreochromis macrochir* is equally efficient in the utilization of artificial diet and therefore recorded a better growth performance Vis- avis FCR. Community involvement in cage culture practices such as regularly cleaning of the mesh of the net cages to exchange water for entry of natural foods also contributed to better FCR.

According to physicochemical parameters of water obtained, the level of DO (6.5 mg/l) was above 5 mg/L and water temperature averaging 23 ^{0}C, in all cages, which are ideal ranges for warm water fishes [8]. The water pH of 7.5 across the cages was within the limits for the growth of many tilapias [9, 10]. Secchi disk reading of 5, implied that the Lake is oligotrophic i.e. it has a very low nutrient level and is an environment that offers suitable conditions for cage culture.

5. Conclusion
This project is economically, environmentally and socially justified. Economic justification rests on its contribution to fish food production to the extent of replacing the current level of fish imports in Zambia. It is socially acceptable because it will provide employment to a number of persons that are currently unemployed. The fish species of *Oreochromis macrochir* which is the project fish is suitable to the environment as it is already present in the natural environment of the Lake. The sustainability of aquaculture in the country squarely lies on the use of locally sourced input resources such as the use of indigenous fish such as *Oreochromis macrochir* to replace the exotic species which are normally invasive and compromise the environment. Use of indigenous fish species is in tandem with the best aquaculture management practices. This experiment proved that *Oreochromis macrochir* is an economically viable fish species to advocate for in cage fish farming in Zambia particularly on Lake Bangweulu.

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