REPRODUCTIVE BIOLOGY OF MOUTH-BROODING TILAPIINES IN THE KAFUE FLOODPLAINS

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ABSTRACT

Invasive alien species have become a serious threat to the biodiversity of ecosystems of the world. Globally, the threat to biodiversity due to invasive species is considered second only to habitat loss. Invasive species are thus a serious impediment to conservation and sustainable use of global, regional and local biodiversity.

This study concentrated on the reproductive biology of the Oreochromis species in the Kafue Floodplains, which is part of the Kafue River stretching from Itezhi-tezhi to the Kafue Gorge. Specific objectives for this study were to compare reproductive strategies i.e. egg size and Gonadosomatic Indices of the introduced Oreochromis niloticus and the local breams, Oreochromis andersonii and Oreochromis macrochir.

Oreochromis niloticus is an invasive species that has been reported to cause a reduction in abundance of fish which are closely related to it due to its highly competitive nature. In this study, the egg sizes were noted as longest in Oreochromis niloticus measuring 1.825 ± 0.1892mm followed by Oreochromis andersonii with 1.696 ± 0.3117mm and Oreochromis macrochir had the smallest, which measured 1.4483 ± 0.777mm. The Gonadosomatic Index was highest in Oreochromis niloticus at 1.034 ± 0.0816 followed by Oreochromis macrochir with 0.918 ± 0.1332 and Oreochromis andersonii with 0.783 ± 0.0107. In all three species, the females had a higher Gonadosomatic Index than the males and the fish in the ripe gonad maturity stage also showed a higher Gonadosomatic Index value than the other stages.

Though only six months of data were collected for Gonadosomatic Indices, distinct spawning peaks for all three species were noted as November and January for Oreochromis andersonii, October and December for Oreochromis macrochir and November through December and March for Oreochromis niloticus.

From the results, it can therefore be concluded that larger egg sizes and high Gonadosomatic Index of Oreochromis niloticus compared to the other mouth-brooding tilapiines, Oreochromis andersonii and Oreochromis macrochir contribute significantly in giving it a competitive advantage. It is therefore recommended that the introduction of Oreochromis niloticus into the Zambian river systems be revised based on the findings from this study.

Key words: *Tilapiines, Reproduction, Gonadosomatic index, Kafue Floodplains.*

INTRODUCTION

The Kafue River is one of the major fisheries of Zambia ranking fourth amongst the fisheries in the country according to records from the Department of Fisheries, Zambia. Cichlids (Breams) are an important family in the Kafue River and have two lineages, haplochromines and tilapiines. The tilapiines are commercially more important and are used in aquaculture in the country. *Oreochromis andersonii* (Castelnau, 1861) and *Oreochromis macrochir* (Boulenger, 1912) are mouth-brooding tilapiines naturally found in the Kafue Floodplain. Since the introduction of *Oreochromis niloticus* (Linnaeus 1758), the species appears to have thrived, replacing the indigenous mouth-brooding tilapiines (Shwanck, 1994). This could be due to its larger egg sizes and higher gonadosomatic indices.

A review of the available literature indicates that wherever the climate is suitable, the *Oreochromis niloticus* has clearly demonstrated a propensity to establish and thrive on introduction (Shipton, *et al.,* 2008). In 1982, *Oreochromis niloticus*, together with *Oreochromis aureus*, Israel Tilapias, were imported from the University of Stirling in the U.K. to Mazabuka in the Kafue catchment area by the Zambia Sugar Company for aquaculture purposes and *Oreochromis niloticus* had a higher success rate than *Oreochromis aureus*. The stock of *Oreochromis aureus* at the Sugar Estate did not breed well, hence it declined and died out by 1990 while that of *Oreochromis niloticus* was successfully established (Shwanck, 1994) and latter escaped into the wild (into the Kafue Floodplains). This introduction was based only on arguments of economic expectation by the company (Audenaerde, 1994). The introductions of both *Oreochromis niloticus* and *Oreochromis aureus* were done without authorisation from or notice to the Department of Fisheries.

Outside Africa, *Oreochromis niloticus* was introduced in Japan from Egypt in 1962 (Tweddle and Wise, 2007) and later it was introduced in Thailand in 1965, and from Thailand it was introduced in the Philippines. According to Canonico (2005), there has been severe decline of native fish population in the areas where *Oreochromis niloticus* was introduced in the wild such as in Lake Alaotra in Madagascar.

The fish under study possibly differ in reproduction strategies with the *Oreochromis niloticus*. The latter having larger egg sizes and gonadosomatic indices thereby increasing its survival ability and giving it higher survival chances compared to the indigenous mouth-brooding tilapiines of the Kafue Floodplains. The exploration of the reproductive biology of the *Oreochromis* species in this study is significant as a way of generating baseline data that can be used to compare the reproductive potential of the various species of *Oreochromis* in the Kafue floodplains. There appears to be differences in the reproductive and growth potentials of the indigenous and exotic *Oreochromis* spp. in Zambia. Assessing the egg length and noting the differences in the Gonadosomatic Indices of the mouth brooders (*Oreochromis andersonii*, *Oreochromis macrochir* and *Oreochromis niloticus*) in the Kafue floodplains will help in our understanding of the reproductive strategies of the species.

The general objective of this study was to assess the reproductive strategies of the *Oreochromis niloticus* and compare them with those of the local mouth-brooding tilapiines of the Kafue floodplains, *Oreochromis andersonii* and *Oreochromis macrochir.*

The hypotheses being tested in the study were: that there was no significant difference in relative egg sizes; and that there was no significant difference in Gonadosomatic indices (GSI) of the *Oreochromis andersonii, Oreochromis macrochir* and *Oreochromis niloticus* in the Kafue Floodplains.

It was expected that results of this study provide the background information required for policy framework formation regarding fish species in the Kafue floodplains by the government of Zambia.

METHODOLOGY

Study area and sampling stations

The Kafue Flats lie between latitudes 15° 30' and 16° 0' South and longitudes 26° 05' and 26° 10' East. This is between Itezhi-tezhi and the Kafue Town a distance of 380 km. The flood plains cover an area of 7,680 square kilometres. Three stations were selected for sampling to represent the different habitats identified in the Kafue Floodplains. The habitats included the riverine, swampy and lagoon areas as shown in the map in Figure 1.

Station I, Kasaka (Latitude, 15°47'11"S; Longitude, 28°12'50"E), is near the Kafue-Mazabuka road bridge and is typical of the river habitats of the Kafue. It is characterised by relatively fast running water as the river slopes into the Kafue Gorge. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. The natural dissolved oxygen concentration is normally near saturation (Cowardin, 1979).

SAMPLING SITES- KAFUE FLOODPLAINS

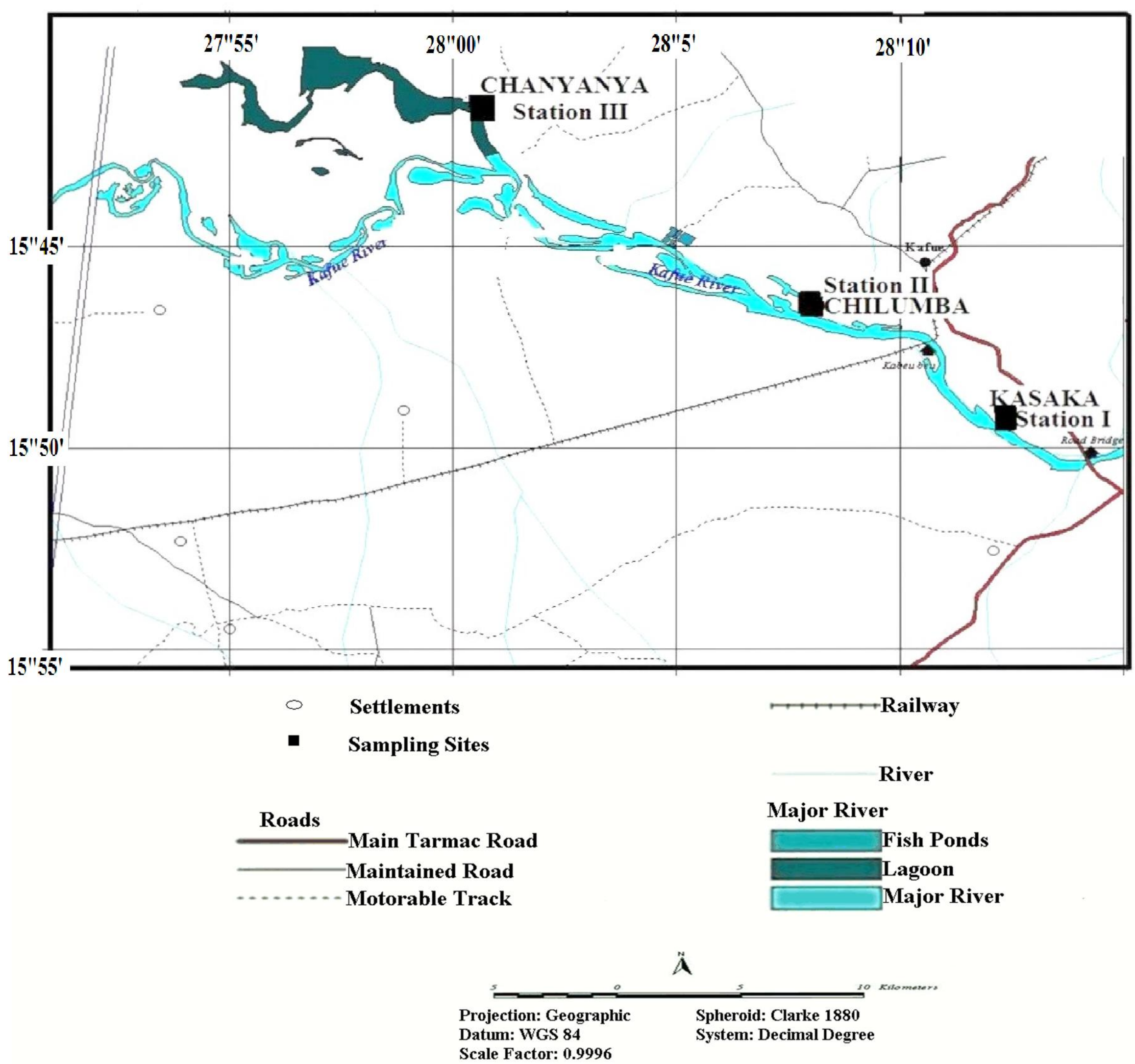


Figure 1: Lower Kafue floodplains showing sampling stations used in this study (Shwanck, 1994).

Station II, Chilumba (Latitude, 15°47'12"S; Longitude, 28°10'42"E), is along the river and is bounded on the landward side by aquatic vegetation and characterized by still water. This station is typical of the swampy areas of the flood plains. It is characterized by an unconsolidated bottom with scrubs and shrubs in the aquatic bed (Cowardin, 1979).

Station III, Chanyanya (Latitude, 15°42'40"S, Longitude, 28°00'42"E), is a lagoon on the banks of the Kafue River characterised by low gradient and slow water velocity. The substrate consists mainly of sand and mud. Oxygen deficits may sometimes occur in the area (Cowardin, 1979).

Sampling Design

Three sites (Stations I, II and III) were set for the collection of fish samples. At each site fish sampling by gill netting was done for three consecutive nights each month from October 2010 to March 2011. This fish sampling design was similar to that used by the Department of Fisheries of Zambia in their routine Gill Net Surveys.

Sampling Procedure

Fish samples were collected from the selected sampling sites of the Kafue River using a panel of gillnets of mesh sizes indicated in Table 1 according to the Gill Net Survey Manual, Department of Fisheries, Zambia (2008) in order to sample both large and small fish.

Fish samples were collected, mid-month, for three consecutive days at each station. The nets were set between 16:00 hours and 18:00 hours and hauled between 6:00 hours and 7:00 hours the following day.

Data Collection

The fishes caught were identified using standard keys (Skelton, 2001) for the species being studied and verification by pictures and detailed published description. The lengths in millimeters (total and standard) were measured using a standard 30cm fish measuring board. The weight (in grams) of the fresh fish specimens was read on a standard electronic scale.

Egg size measurement

The ovaries were collected from each of the female fish and were preserved in Gilson's fluid modified by Simpson (1951). The eggs were then stored in labelled jars indicating the fish species. The eggs were cleaned by decanting the Gilson's fluid and replacing it with water. The sizes of the eggs for the different species were determined by measuring the diameter of 30-40 randomly selected eggs per female along two axes using a calibrated eye piece micrometer under a binocular microscope. This was done in fish of the same gonad development stage i.e. the Ripe stage (Bagenal, 1978).

Fish Gonad Examination

The sex of each fish specimen was determined by examination of the gonads. The state of the gonads was identified based on the Nikolsky (1963) classification of the fish gonad maturity stages as summarized in Table 2.

Table 1. Mesh sizes of nets used in sampling fish

Unit	**Mesh Sizes**											
Mm	25	37	50	63	76	89	102	114	127	140	152	165
Inches	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5

Table 2. Fish Gonad stages as described by Nikolsky (1963)

Maturity stage	**Gonad state**	**Description**
I	Immature	Young individuals which have not engaged in reproduction; gonads of very small size.
Q	Inactive	Sexual products have not yet begun to develop; gonads of very small size; eggs not distinguishable to the naked eye
A	Active	Eggs distinguishable to the naked eye; a very rapid increase in weight of the gonad is in progress; testes change from transparent to pale rose color.
R	Ripe	Sexual products ripe; gonads achieved maximum weight.
K	Ripe-running	Sexual products are extruded in response to very light pressure on belly; weight of gonads decrease rapidly.
S	Spent	The sexual products have been discharged; genital aperture inflamed; gonads have the appearance of deflated sacs, the ovaries usually containing a few left over eggs and the testes some residual sperm

Gonadosomatic index (GSI) for each fish was calculated as the weight of the gonads relative to the total body weight, expressed as a percentage (deVlaming *et al.,* 1982).

$$GSI = GW/BW \times 100$$

where GW and BW are gonad and body weight (in grams) respectively.

Data Analysis

Egg sizes of the Oreochromis species

The mean egg length and width of the three species were compared using ANOVA (Statix 9) to determine whether or not there were significant differences in the size of the eggs among the species. Where there were significant differences in egg length or width among the *Oreochromis* species, comparison of means using the Bonferroni test was used to determine which of species had egg sizes that were significantly different from one another.

GSI variations in the Oreochromis species

Length and GSI variation in Oreochromis species

To note whether there was any dependence of GSI on somatic growth, a correlation analysis was done using Statix 9. The nature of the relationship and the equation to summarize it were computed. The significance of the regression or relationship was tested using ANOVA (Statix 9).

Mean GSI variation among Oreochromis species

GSI of the *Oreochromis* species were compared for significant differences. This was so as to note which species had the highest mean GSI and to determine if there were any significant differences among the species. GSI of the females and males of each of the species were also determined and differences were tested for significance using ANOVA (Statix 9). The mean GSI of the females in the different gonad maturity stages were compared among the species and differences were tested for significance using ANOVA (Statix 9). Where ANOVA revealed significant differences in GSI among the measured parameters i.e. species, sexes and gonad maturity stages, comparison of means using the Bonferroni test was then used to determine which of these parameters were still significantly different from one another.

Mean GSI monthly variation
The GSI peaks of the three *Oreochromis* species were note from October 2010 to March 2011. The differences were analysed for significance using ANOVA using the Statix 9 software. Where there were significant differences in GSI according to ANOVA, comparison of means using the Bonferroni test was used to determine which months were still significantly different from one another.

RESULTS

Egg sizes

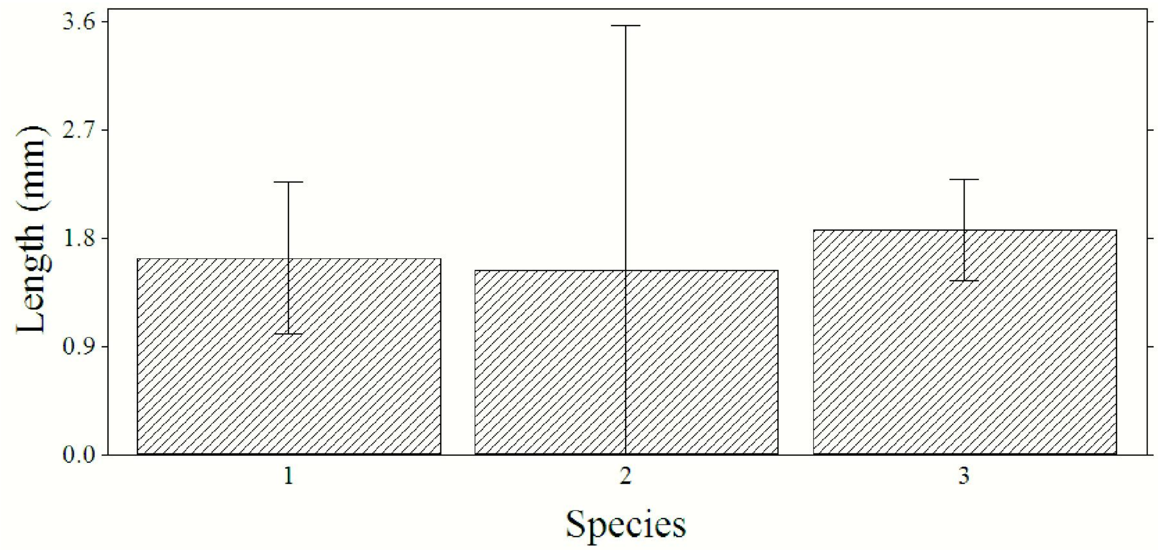
A total of 23 fish had their eggs analysed and the egg length of the species under study showed that *Oreochromis niloticus* had the longest eggs followed by *Oreochromis andersonii* and *Oreochromis macrochir* had the smallest (Table 3).
However, statistically, there were no significant differences ($F_{2,26}$ = 0.19; p = 0.8265 > 0.05) among the lengths of the eggs of all three species and the coefficient of variation was 46.77 percent (Table 3).

The egg width of the species under study also showed that *Oreochromis niloticus* had the widest eggs followed by *Oreochromis andersonii* and *Oreochromis macrochir* had the smallest (Table 3). However, statistically, there were no significant differences ($F_{2,26}$ = 0.73; p = 0.4938 > 0.05) in width among the eggs of all three species and the coefficient of variation was 49.21 percent (Table 3).

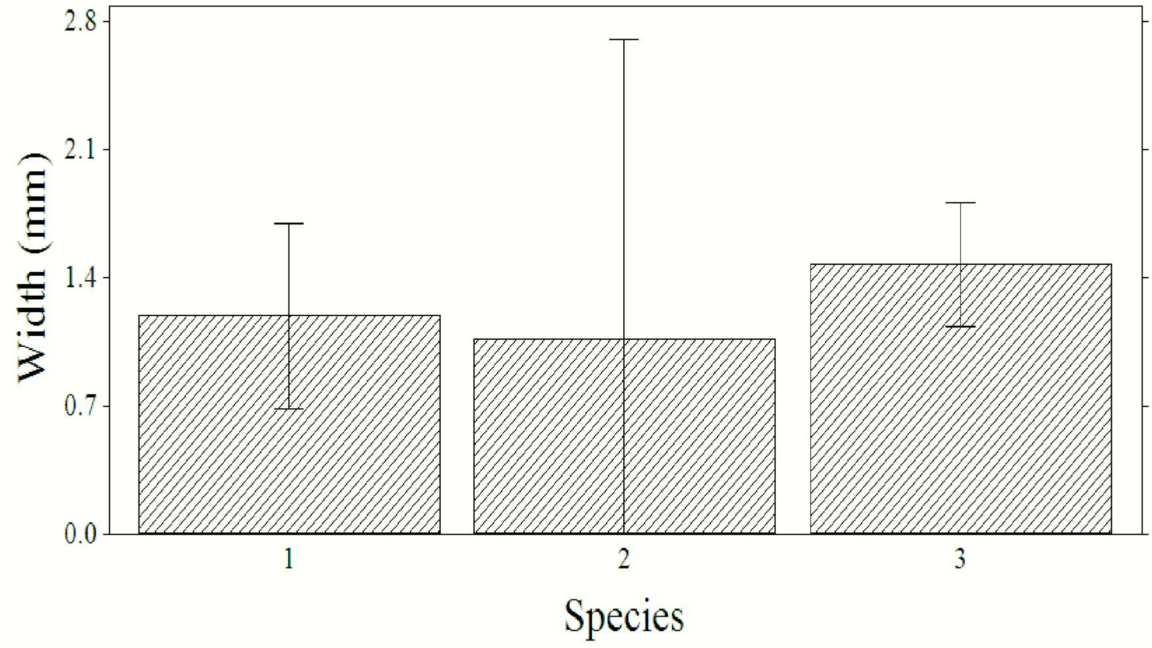
The egg sizes showed some numerical differences in the values with *Oreochromis niloticus* having the highest values of length and width (1.825mm x 1.450mm). *Oreochromis macrochir* had the lowest value of egg length and width and variations with their respective confidence intervals have been shown in Figures 2 and 3.

Table 3. Mean length and width of *Oreochromis* species of the Kafue Floodplain

Species	**Length (mm)**	**Width (mm)**
Oreochromis andersonii	1.696 ± 0.3117	1.178 ± 0.2501
Oreochromis macrochir	1.534 ± 0.4762	1.067 ± 0.3821
Oreochromis niloticus	1.825 ± 0.1892	1.450 ± 0.1518



1-Oreochromis andersonii 2-*Oreochromis macrochir* 3-*Oreochromis niloticus*
Figure 2. Mean egg length (mm) of the mouth-brooding tilapiines of the Kafue Floodplains.



1-Oreochromis andersonii 2-*Oreochromis macrochir* 3-*Oreochromis niloticus*

Figure 3. Mean egg width (mm) of the mouth-brooding tilapiines of the Kafue Floodplains.

GSI variation in the *Oreochromis* species

Length and GSI variation in the female Oreochromis species

Fifty nine fish were analysed for GSI. It was noted that there was a significant positive linear correlation between the length of the fish and the GSI in *Oreochromis andersonii* females which showed a regression of GSI = -2.8447 + 0.0174Length (r^2 = 0.3516; SD = 0.6759; $F_{1,13}$ = 8.59; p = 0.0117 < 0.05). As the fish grew longer, the GSI of the fish also increased as illustrated in Figure 4.

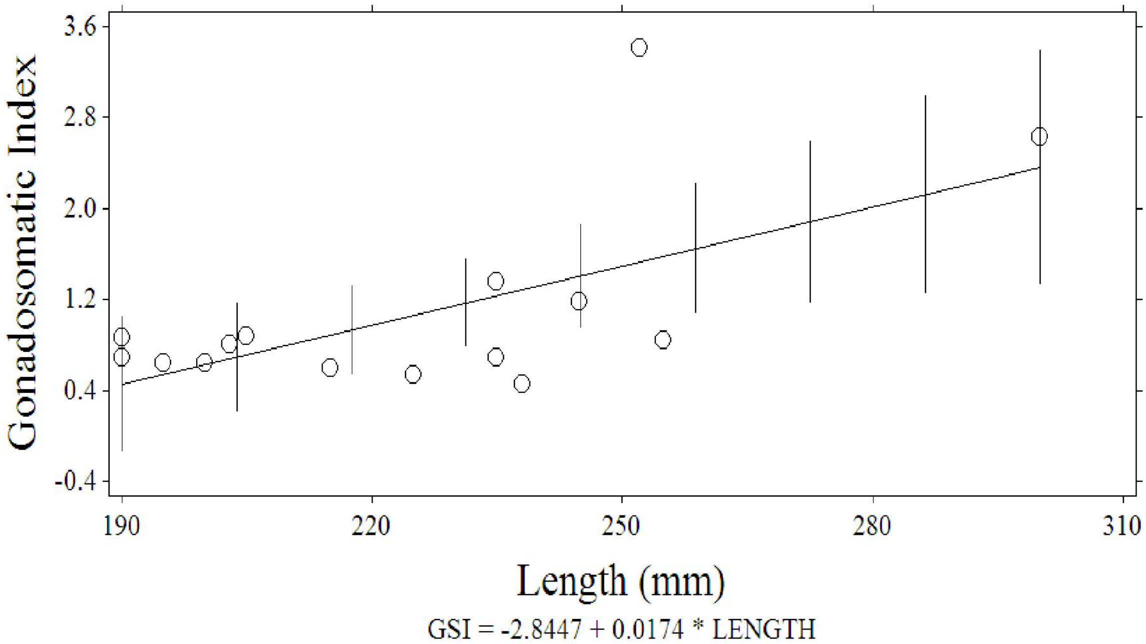


Figure 4. Mean length (mm) variation of *Oreochromis andersonii* females with GSI

Oreochromis macrochir females showed negative correlation between its length and the GSI with a regression (Figure 5). However the regression was noted as insignificant. GSI = 2.3033 - 7.42E-03 * Length (r^2 = -0.0370; SD = 0.2356; $F_{1,10}$ = 0.61; p = 0.4538 > 0.05).

The negative correlation (Figure 6) between length and the GSI of *Oreochromis niloticus* females was not significant and the regression was noted as GSI = 1.9044 - 1.29E-03 * Length (r^2 = -0.0457; SD = 1.0772; $F_{1,21}$ = 0.04; p = 0.8451 > 0.05).

Mean GSI variation among Oreochromis species

The GSI means among the different species were not significantly different ($F_{2,127}$ = 1.88; p = 0.1574 > 0.05). The species with the highest mean GSI value, however, was *Oreochromis niloticus* followed by *Oreochromis macrochir* and *Oreochromis andersonii* (Table 4).

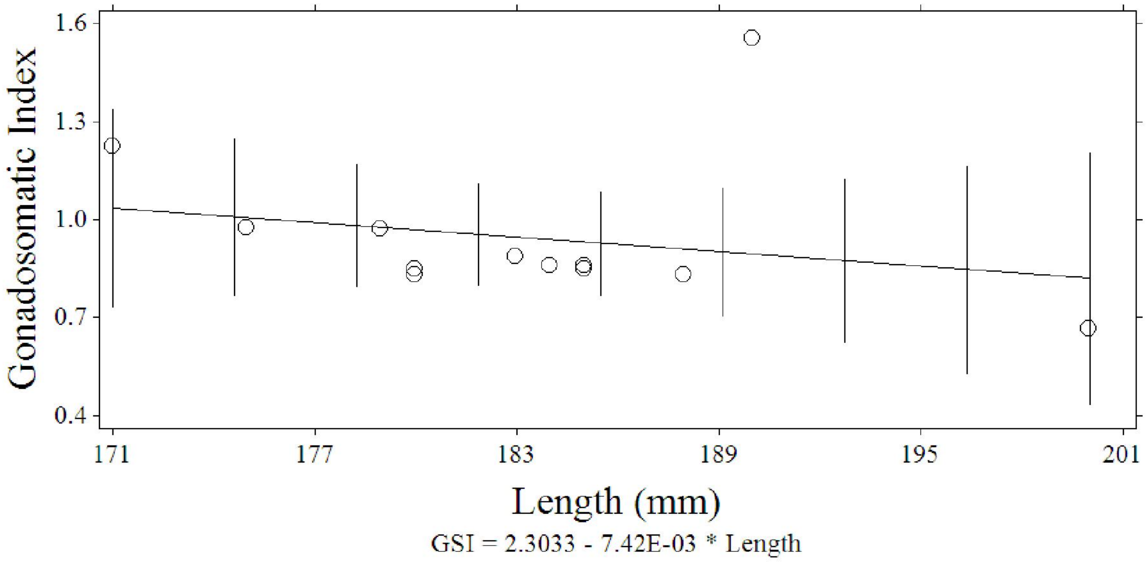


Figure 5. Mean length (mm) variation of *Oreochromis macrochir* females with GSI

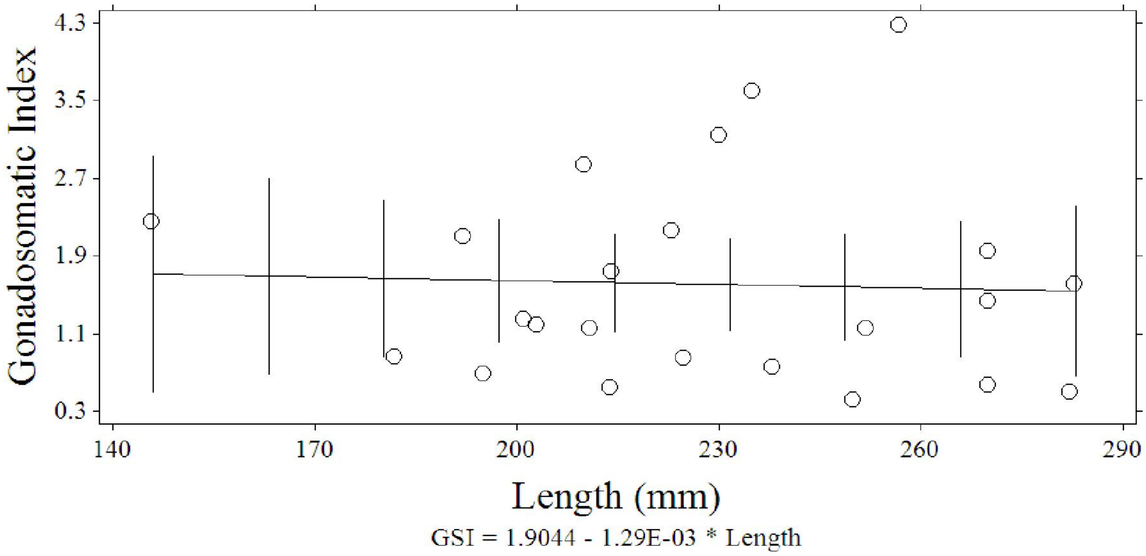


Figure 6. Mean length (mm) variation of *Oreochromis niloticus* females with GSI

Table 4. Mean GSI variation among *Oreochromis* species (± Standard Error)

Species	Mean	Male	Female
Oreochromis andersonii	0.783 (± 0.0107)	0.623 (± 0.0511)	1.072 (± 0.2223)
Oreochromis macrochir	0.918 (± 0.1332)	0.891 (± 0.0767)	0.944 (± 0.2485)
Oreochromis niloticus	1.034 (± 0.0816)	0.712 (± 0.0415)	1.608 (± 0.1795)

Oreochromis macrochir showed the highest mean GSI in its males followed by *Oreochromis niloticus* and the least was noted in *Oreochromis andersonii.* The differences between *Oreochromis macrochir* and *Oreochromis andersonii* were significant but the mean GSI of *Oreochromis niloticus* did not differ from that of *Oreochromis macrochir* and *Oreochromis andersonii* ($F_{1,77} = 4.24$; $p = 0.0179 < 0.05$). The mean GSI values for the males of each species are as summarized in Table 4.

There was no significant difference in the mean GSI of females in the different species ($F_{2,47} = 3.02$; $p = 0.0584 > 0.05$). However, females mean GSI was numerically higher in *Oreochromis niloticus* followed by *Oreochromis andersonii* and lastly *Oreochromis macrochir.*

Within the species, it was noted that differences occurred in the mean GSI for males and females. *Oreochromis andersonii* showed significant differences in the mean GSI between males and females of ($F_{1,40} = 7.48$; $p = 0.0093 < 0.05$) and so did *Oreochromis niloticus* ($F_{1,62} = 26.07$; $p = 0.0000 < 0.05$). *Oreochromis macrochir* showed no significant difference in the mean GSI between the two sexes ($F_{1,22} = 0.21$; $p = 0.6546 > 0.05$).

There was a difference in the mean GSI with change in gonad maturity state. This was significant in *Oreochromis niloticus* ($F_{3,19} = 5.66$; $p = 0.0000 < 0.05$) and *Oreochromis macrochir* ($F_{3,8} = 8.05$; $p = 0.0084 < 0.05$) which when comparison of means was carried out showed the ripe stages with a significantly higher mean as summarised in Table 5. There was no significant difference in the mean GSI in the females of *Oreochromis andersonii* ($F_{3,11} = 1.33$; $p = 0.3140 > 0.05$).

There were no significant differences in the mean GSI for the Immature, Inactive and Active states of gonad maturity in all three species (*Oreochromis andersonii;* $F_{2,8} = 0.71$; $p = 0.5213 > 0.05$, *Oreochromis macrochir;* $F_{2,7} = 0.82$; $p = 0.4783 > 0.05$ and $F_{2,10} = 0.22$; $p = 0.8042 > 0.05$ for *Oreochromis niloticus*).

In all three species, the Ripe gonad state showed the highest mean GSI and variation were further depicted in Figure 7.

Table 5. General mean GSI variation with stage of female gonad maturation for the mouth-brooding tilapiines of the Kafue floodplains.

Species	Immature (I)	Inactive (Q)	Active (A)	Ripe (R)
Oreochromis andersonii	0.721 (± 0.4676)	0.649 (± 0.4049)	1.142 (± 0.4049)	1.687 (± 0.4049)
Oreochromis macrochir	0.880 (± 0.0676)	0.941 (± 0.0605)	0.774 (± 0.0957)	1.550 (± 0.1353)
Oreochromis niloticus	0.745 (± 0.8236)	0.907 (± 0.4755)	1.045 (± 0.2745)	2.411 (± 0.2604)

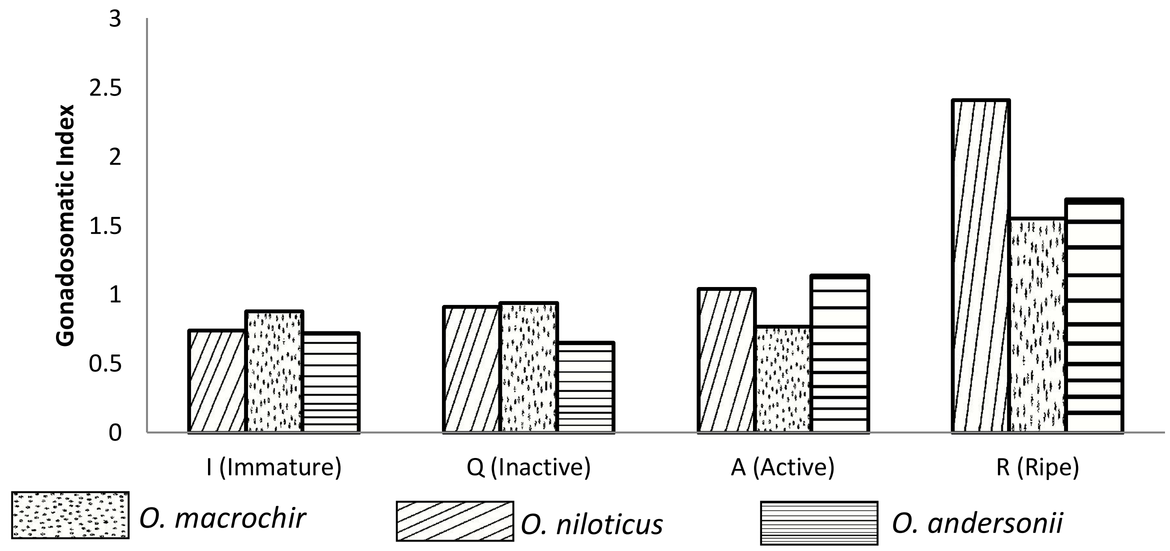


Figure 7. GSI variation among species, sex and gonad maturity states for the Mouth-brooding tilapiines of the Kafue floodplains.

Mean GSI monthly variation

There was a significant difference in the mean GSI of *Oreochromis niloticus* through some months from October 2010 to March 2011($F_{3,60}$ = 10.02; p = 0.03 < 0.05). Comparison of means using the Bonferroni test revealed that the GSI peaks noted in November (1.419 ± 0.1632) through December (1.205 ± 0.3054) and in February (1.050 ± 0.1999).

There was a significant difference in the GSI of *Oreochromis macrochir* in during the sampling period from October 2010 to March 2011 ($F_{3,60}$ = 10.02; p = 0.0000 < 0.05). Comparison of means using the Bonferroni test revealed that the peaks were in October (1.550 ± 0.1531) and December (1.334 ± 0.0884).

There was no significant difference in the GSI of *Oreochromis andersonii* through the different months form October, 2010 to March 2011 ($F_{4,37}$ = 2.45; p = 0.0633 > 0.05). However the highest GSI values were noted in November (1.387 ± 0.2964) and in January (1.161 ± 0.2096) as noted in Figure 8.

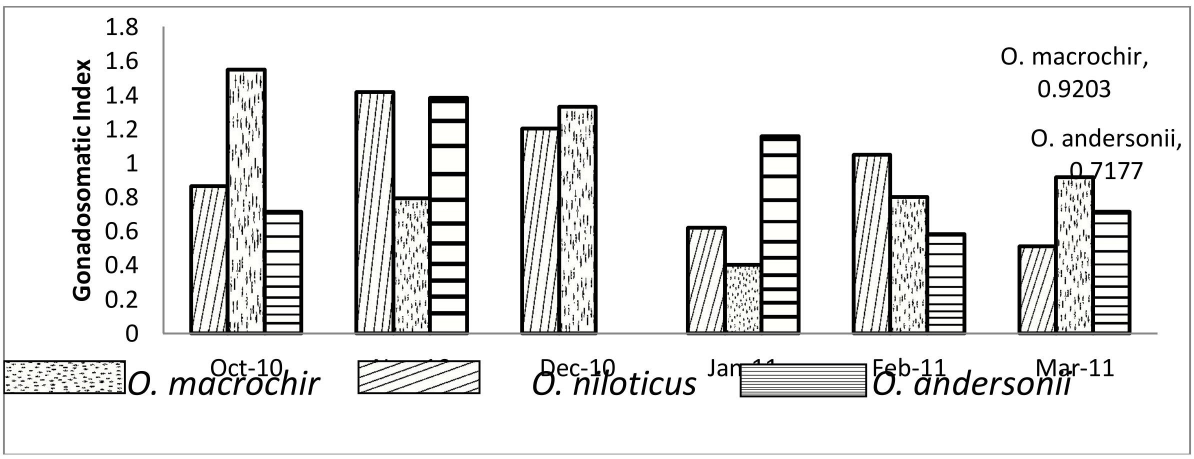


Figure 8. Monthly variation of GSI for the mouth-brooding tilapiines of the Kafue floodplains.

DISCUSSION

Egg Sizes

The egg size is restricted in range compared to the adult body sizes but comparison of egg sizes among fish stocks is an important aspect of noting differences in the reproductive characteristics of fish (Sargent *et al*., 1987). FAO (2005a) observed that the egg size of the genus *Oreochromis* species is not constant in every species and it varies greatly within the season. Within the species, there were varied sizes of eggs in fish of the same length and also in individual fish.

Though there was no significant difference in the egg sizes at 0.05 probability, *Oreochromis niloticus* had the largest egg sizes, which measured 1.825 x 1.450mm length by width, numerically, giving it an advantage for juvenile survival. Bigger eggs producing bigger larvae are likely to be an adaptive advantage allowing increased juvenile survival if food supply is limited or variable (Sargent *et al,* 1987). Payne and Collinson (1983) noted that *Oreochromis niloticus* eggs measured 1.94 – 2.95mm in the length and Tweddle who sampled from the Nile delta reported egg length of 3.0 - 3.5mm. The values noted in this study were lower than both values those from the Nile.

Kefi *et al.,* (2010) compared egg sizes of the same three *Oreochromis* species in a controlled experiment and also noted no significant difference in the egg sizes. They, however, pointed out that *Oreochromis macrochir* had the longest eggs (1.830mm) followed by *Oreochromis niloticus* (1.780mm) while *Oreochromis andersonii* (1.601mm) had the smallest. This could have been due to the fact that the resources such as food were controlled and therefore competition was not a factor as the study was undertaken under aquacultural conditions.

The low abundance of *Oreochromis macrochir* could be due to its small eggs that may account for the reduced juvenile's survival and ultimately its low abundance (Sargent *et al,* 1987). The lower values of egg length and width imply that the juveniles of *Oreochromis macrochir* had reduced food reserves compared to *Oreochromis andersonii*. The mortalities between hatching and time at juvenile stage (t_j) can be reduced if the yolk sacs do not run out of supply fast. In this study, *Oreochromis niloticus* had the longest and widest eggs giving it a competitive advantage.

GSI Variations in the *Oreochromis* species

Length and GSI variation in Oreochromis species

Peters (1963) noted that the size of spawning females is related to size of eggs that they carry and ultimately GSI. Results of this study show that there was a significant positive linear correlation between length and GSI in females of *Oreochromis andersonii.* This is in agreement with the findings of Shandge *et al.,* (2011) who found a positive correlation between the increases in GSI with higher length groups in the freshwater catfish *Notopterus notopterus* in India.

Oreochromis macrochir and *Oreochromis niloticus* females showed an insignificant negative correlation between their lengths and GSI with GSI = 2.3033 - 7.42E-03 * Length and GSI = 1.9044 - 1.29E-03 * Length respectively. This correlation was however noted as insignificant in both the females of *Oreochromis macrochir* and *Oreochromis niloticus* with $p > 0.05$ as correlation probability in both species implying that not all the changes that occurred in GSI were due to increase in fish length. Multiple factors such as nutrition and environmental conditions could have caused such a decline in GSI in the older (fish in higher length groups) females of the two species. Redding and Petino (1993) noted that seasonal environmental changes though less extreme in the tropics could cause a change in gonad weight. *Oreochromis* *niloticus* was noted to reproduce slowly at temperatures of 21 - 24 degrees Celsius and increased between temperatures of 25 - 30 degrees Celsius. In other literature monthly variation in GSI due to fish size was considered to be very small, because fish length did not vary significantly among months (ANOVA, $p > 0.05$) (Gomez *et al.,* 2005).

Mean GSI variation among Oreochromis species

Prior to spawning, the ovaries of the gravid females swiftly increase in size and these result in high GSI values in the months of spawning. The proportion of energy that goes to spawning females is vital for ensuring an increase in the number of offspring. Numerically, *Oreochromis niloticus* had the highest mean GSI value of 1.034 ± 0.0816 among the *Oreochromis* species. *Oreochromis niloticus* females had the highest mean of 1.608 ± 0.1795 which did not significantly differ with the 1.34 ± 0.01 that was obtained by Komolafe (2007) in Opa reservoir, Nigeria.

Oreochromis andersonii had the lowest GSI of 0.783 (± 0.0107) but when the females were compared, it showed a higher mean of 1.072 (± 0.2223) than that of females of *Oreochromis macrochir* which had GSI value of 0.944 (± 0.2485). The means of GSI for *Oreochromis andersonii* were significantly different between the males which had GSI equal to 0.623 (± 0.0511) and females whose GSI was 1.072 (± 0.2223). It therefore can be noted that the females of *Oreochromis andersonii* allocate more energy to reproduction compared to *Oreochromis macrochir* and could also be due to the fact that female gonads are relatively heavier than male gonads. The GSI showed a steady increase through the maturity stages. The increase in weight of the gonads is reason for such an increase, the ripe stage being the peak.

Mean GSI monthly variation

Under natural conditions, reproduction in fish is timed by changes in the external environment (Barnabe, 1994: Bromage, 1995). In most teleosts, spawning periods appear to be adjusted to environmental factors such as temperature and rain so that they are suitable for rearing offspring (de Vlaming, 1974).

In the present study, GSI was only observed in six months from October 2010 to March 2011 which only include the hot season characterised by dry and wet periods. However, the GSI values were greatly varied with the change from dry to rainy seasons and were also noted to be dependent on the availability of food. The GSI peaks for *Oreochromis niloticus* were noted in November through December (Figure 8) which were characterised by the increased rainfall and relatively warm temperatures. In other literature (Lowe McConnell, 1958), *Oreochromis* niloticus was found to breed throughout the year and slightly higher in the wet season in the East African waters and in Mexico, it was noted that the GSI mean values of both sexes of *Oreochromis niloticus*, varied significantly among months (ANOVA, $p < 0.05$) (Gomez *et al.,* 2005).

Oreochromis andersonii had its highest GSI peaks in November and March (Figure 15) which are warm and are characterised by increased rainfall compared to October which was when *Oreochromis macrochir* had its highest GSI peak (Figure 8). Most Tilapiines breed in warm and/or rainy periods due to the increase in phytoplankton biomass creating favourable conditions for the offspring to grow better and survive (Admassu, 1996).

Oreochromis macrochir has high GSI values which peaked in October (Figure 8) which is generally characterised by low rainfall, high temperatures and low phytoplankton biomass and December. According to Marshall (1979) who worked on *Oreochromis macrochir* in Lake Mcilwaine, presence of phytoplankton helped in growth of juveniles. Therefore, though *Oreochromis* *macrochir* focuses a lot of energy on spawning, the juveniles are born into conditions that are unfavourable and the weight of female ripe gonads were low indicating that the proportion of energy that goes to spawning females is reduced and thus decreasing the potential to spawn in high numbers.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Oreochromis niloticus has a high Growth Performance Index which has been noted in its high asymptotic length and faster growth rate than the local mouth brooders. The species also has been noted to have the largest eggs giving its juveniles a survival advantage.

The Gonadosomatic Index has been noted as highest in *Oreochromis niloticus* which breeds under more favorable conditions such as during high rainfall and temperature and allocates more energy to reproduction compared to *Oreochromis andersonii* and *Oreochromis macrochir. Oreochromis niloticus* has the potential to be successful in terms of survival and may displace the other mouth brooding Tilapiines in the wild.

Oreochromis niloticus has the potential to dominate the ecosystem of the Kafue Floodplains and is a threat to the Floodplains fish diversity. The replacement of the local Tilapiines by *Oreochromis niloticus* in the Kafue Flats threatens the sustainability of the Kafue Floodplain Fishery in that it seems to be displacing other Tilapiines. This will reduce the overall fish diversity of the area. In this situation, fishery management authorities in Zambia should review policies relating to fish species introduction and endeavour to prevent the spread of *Oreochromis niloticus* to other fishery areas.

Recommendations

- A survey on spread of the *Oreochromis niloticus* in the Kafue Floodplains could be conducted so as to note how far the spread is. There should be proper guidelines in the Fisheries Act and the regulations in Zambia regarding fish species introductions including the spread of *Oreochromis niloticus* to other water bodies where it has not been introduced.
- Such regulations should be supported by the policy position on fisheries and aquaculture development. The choice of fish species for aquaculture is recommended as *Oreochromis andersonii*.
- The growth rates and egg sizes are important factors in assessing competitive advantages with closely related species when introductions are considered and should be part of the consideration for allowing or rejecting an introduction of exotic fish species.

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APPENDICES

Appendix A.1 Fish species caught in gill nets at the Kafue Floodplains caught between October, 2010 and March, 2011.

Species	Common name
Cichlidae	
Callochromis stappersii (Boulenger, 1914)	Redspot callochromis
Oreochromis andersonii (Castelnau, 1861)	3-spotted bream
Oreochromis macrochir (Boulenger, 1912)	Green head tilapia
Oreochromis niloticus (Linnaeus, 1758)	Nile tilapia
Pharyngochromis acuticeps (Steindachner, 1866)	Zambesi kurper
Pseudocrenilabrus philander (Weber, 1897)	Southern mouth brooder
Sargochromis carlottae (Boulenger, 1905)	Rainbow bream
Sargochromis codringtonii (Boulenger, 1908)	Green bream
Serranochromis angusticeps (Boulenger, 1907)	Thin face largemouth
Tilapia rendalli (Boulenger, 1896)	Red breasted bream
Tilapia sparrmanii (Smith 1840)	Banded tilapia
Characidae	
Brycinus lateralis (Boulenger, 1900)	Striped robber
Claridae	
Clarias ngamensis (Castelnau, 1861)	Blunt tooth catfish
Cyprinidae	
Labeo cylindricus (Peters, 1852)	Red eye labeo
Barbus sp.	
Hepsetidae	
Hepsetus odoe (Bloch, 1794)	Kafue pike
Mochokidae	
Synodontis macrostigma (Boulenger, 1911)	Large spot squeaker
Synodontis macrostoma (Skelton and White, 1990)	Large mouth squeaker
Synodontis sp.	
Mormyridae	
Marcusenius macrolepidotus (Peters,1852)	Bulldog
Petrocephalus catostoma (Günther, 1866)	Northern Churchill
Petrocephalus wesselsi (Kramer & van der Bank,2000)	Southern Churchill
Schilbeidae	
Schilbe intermedius (Rüppell, 1832)	Butter barbell, Silver catfish