

# Growth and Mortality of Mouth Brooding Tilapiines of the Kafue Floodplain Fishery, Zambia

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## Abstract

Growth and mortality of *Oreochromis andersonii*, *Oreochromis macrochir* and *Oreochromis niloticus* of the Kafue Floodplain fishery were investigated between September, 2015 and November, 2015. This study was aimed at investigating the growth and mortality of mouth brooding tilapiines of the Kafue Floodplain fishery. Three stations that represent the major ecological habitats of the Kafue Floodplain fishery were selected. These were: Kafue Road Bridge (swamp), Namalyo (lagoon) and Kakuzu (riverine). Fish specimens were collected using gillnets that were set in the evening and hauled the next morning. Length measurements were taken from each fish specimen using a fish measuring board. Weight was measured using a kitchen balance to the nearest one gramme. One-way Analysis of Variance was performed on all quantitative data using Statistix 9.0 software. *Oreochromis niloticus* showed the largest growth coefficient (k) of 0.22 while *Oreochromis macrochir* had the smallest growth coefficient of 0.10. *Oreochromis andersonii* had a growth coefficient of 0.11. Exploitation ratios in the Kafue Floodplain fishery were found to be below the optimum value (0.5) except for *Oreochromis macrochir* (0.7). *Oreochromis andersonii* had an exploitation ratio of 0.3 while *Oreochromis niloticus* had an exploitation ratio of 0.4. This implies that the decrease in fish catches in the Kafue Floodplain fishery cannot be attributed to over-fishing but may be due to natural mortality.

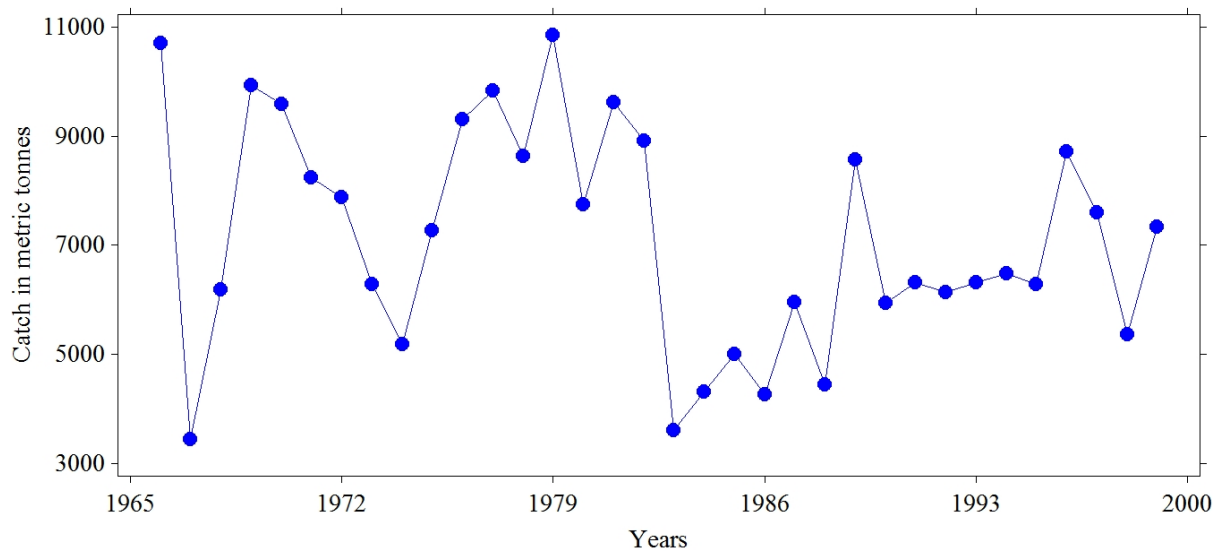
**Key words:** Exploitation; growth; mortality; Kafue Floodplain fishery.

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## 1. Introduction

The Kafue Floodplain is an important fishery in Zambia ranking fourth after Lake Tanganyika, Lake Bangweulu and Lake Kariba in terms of fish output. The Kafue Floodplain fishery is located in the Kafue Floodplains on the Kafue River between the Itezhi-tezhi dam and the Kafue Gorge dam, covering an area of 6,500km<sup>2</sup> [1]. There are Fifty-five known fish species in the Kafue Floodplain fishery, of which Twenty-three are of commercial importance. Cichlids account for eighty percent of all economically important fishes in the Kafue Floodplain fishery [1]. Total fish catches from the Kafue Floodplain fishery have been reducing gradually and the fishery seems not to be recovering from decreasing fish catches (Figure 1). For instance, in 1966 the Kafue Floodplain fishery produced a total catch of 10,709 metric tonnes but in 1980 this fishery recorded a total catch of only 7,741 metric tonnes [2]. Reasons for the decline in fish harvests have not been properly understood and investigated.



**Figure 1:** Fish catches from the Kafue Floodplain fishery from 1965 to 2000 [2]

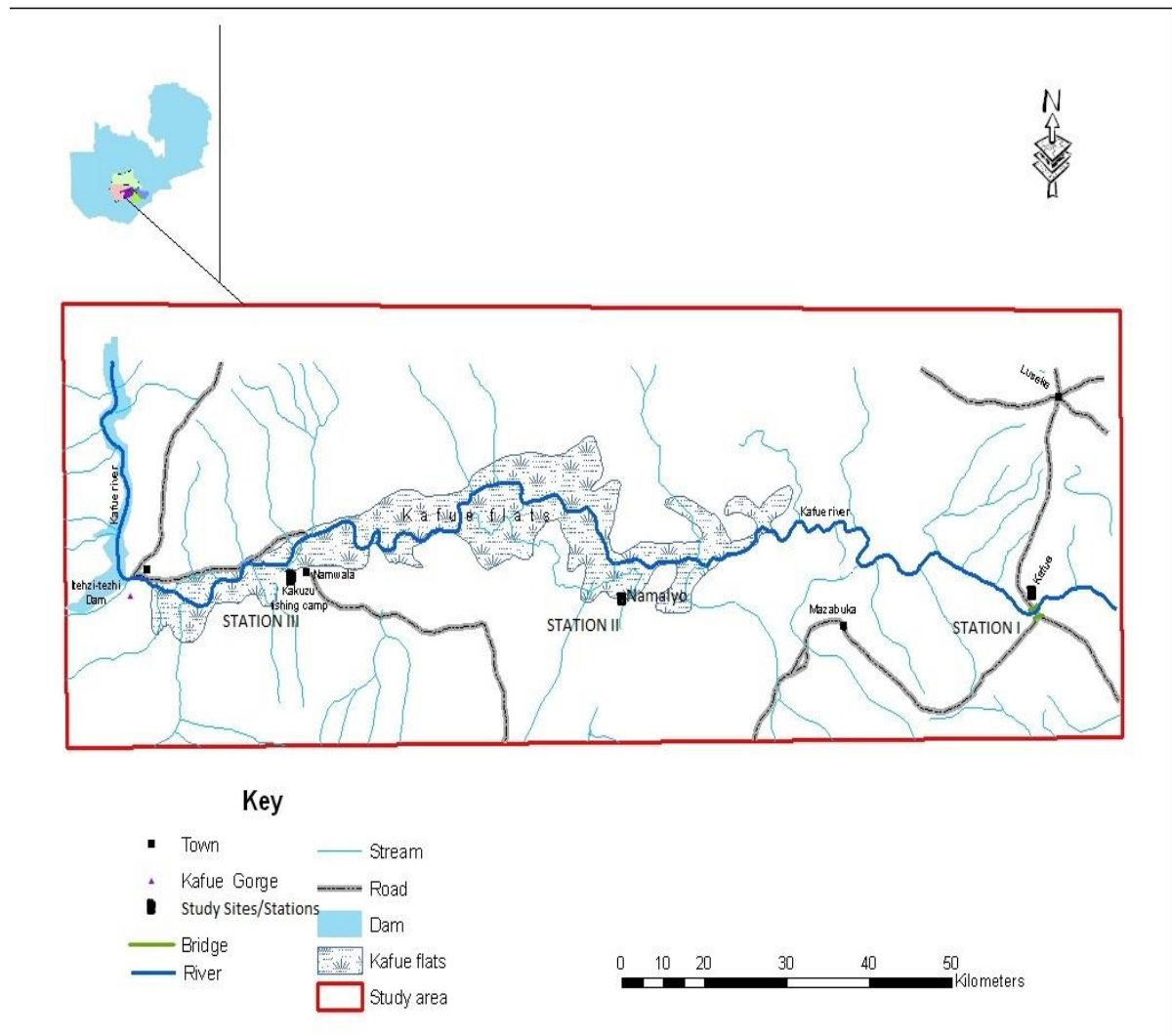
The possible explanation to the decrease in *Oreochromis* fish catches from the Kafue Floodplain fishery is that the average water levels in the Kafue Floodplains have increased due to the construction of dams at Kafue and Itezhi-tezhi [3]. The other explanation to the decrease in fish yields from the Kafue Floodplain fishery can be attributed to the increase in fishing pressure [4]. The general objective of the study was to investigate the growth, mortality and exploitation of mouth brooding tilapiines of the Kafue Floodplain fishery. It is expected that the study will help to know whether or not there is over-exploitation of *Oreochromis niloticus* in the Kafue Floodplain fishery.

## 2. Materials and Methods

### 2.1. Study area

This research was conducted in the Kafue Floodplain fishery (Figure 2) which is located about 50 Kilometres south from Lusaka, the capital city of Zambia. Three stations that represent the study area were selected: Kafue

Road Bridge (station I), Namalyo (station II) and Kakuzu (station III). These stations represent the different ecological habitats in the Kafue Floodplain fishery. Station I is the lower part of the Kafue River at a grid reference of 15°50'218"S and 28°14'110"E. It had still water and many hydrophytes ranging from submerged, floating and emergent types. Station II had a grid reference of 15°50'185"S and 28°14'126"E. This station is representative of a lagoon. It was characterized by low gradient and low water velocity. It was a typical Floodplain with high deposition of debris. Station III was within latitude 15°50'166"S and longitude 28°14'149"E. It is the upper part of the Kafue River. Kakuzu was characterized by relatively fast running water [5].



**Figure 2:** Location of the study sites within the Kafue Floodplain fishery.

## 2.2. Sample collection

Fish samples were collected from the selected sampling study sites using a fleet of gillnets of the mesh sizes ranging from 25mm to 190mm (Table1) according to methods described in the Gillnet survey Manual [1]. Gillnets of different mesh sizes were intended to catch fish specimens of different sizes.

**Table 1:** Mesh sizes of gillnets used in fish sampling

Mesh size (mm)	25	37	50	63	76	89	102	114	127	140	152	165	178	190
Mesh size (inches)	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5

Fish were collected for three consecutive days at each station. The gillnets were set between 16:00 and 18:00 hours and hauled between 6:00 and 7:00 hours the following day.

**2.3. Data collection**

Data for this research was collected from both the field and in the laboratory. Field techniques were used to collect length (mm) and weight (grammes) variables from each fish species while laboratory techniques were used to age (in years) each fish species. In the field, total length and standard length of a fish sample were measured to an accuracy of one millimetre using fish measuring boards. The Total length of each mouth brooding specimen was measured from the tip of the anterior part of the mouth to the posterior end of the caudal fin. Standard length was measured from the tip of the anterior part of the mouth to the mid-base of the caudal fin. A total of 687 mouth brooding tilapiine specimens were sampled using gillnets. Body weight of individual tilapiine fish species was determined to the nearest 1.0 gramme using a kitchen balance. Using strong forceps, six (06) scales were removed from each fish; all from just above the lateral line three from each side of the trunk. The extracted scales were put in paper envelopes. The envelopes were then labelled by a unique code (for example ON1), location and date of extraction. In the laboratory at the University of Zambia, the scales were cleaned by soaking them in warm distilled water (at 25 °c) for about ten minutes to soften them. The scales were then soaked in 10% hydrochloric acid in order to remove flesh attached to them. The scales were then made razor thin by rubbing them with a fine sand paper before embedding them between two glass slides and sealed with sellotape to avoid curling. The scales were then examined under a light microscope at low power (x10 magnification) to determine the age (in years) of each fish species by counting the number of annuli. The annuli were determined from the face of the centrum. The number of annual rings in each scale indicated the age of the fish in years. Fish growth was estimated using the formula by [6] which is:  $L_t = L_{\infty} (1 - e^{-k(t-t_0)})$ ; where  $L_t$  is the predicted length at different ages,  $L_{\infty}$  is asymptotic length,  $t-t_0$  is the change in time and  $k$  is the growth coefficient. Total mortality coefficients of mouth brooding tilapiines were determined using linearised catch curves, and using the formula by [7]. The linear regression curves were obtained using the ages of fish against natural logarithm of the number of fish at each age, using Statistix 9 software [8]. The gradients of regression analysis denoted total mortality ( $Z$ ) coefficients of the mouth brooding tilapiines [9]. The equation from [7]:  $Z = \frac{k(L_{\infty} - L_m)}{L_m - L_c}$  where:  $L_m$  is the mean length of the catch samples and  $L_c$  is the length for which all fish of that age and longer are under full exploitation. Asymptotic length ( $L_{\infty}$ ) was determined using the equation by [10] which is:  $L_{\infty} = \frac{L_{max}}{0.95}$   $L_{max}$  is the largest length among the measured total lengths of the fish species. The natural mortality coefficient,  $M$  was estimated using the equation by [11] equation expressed as  $M = 0.8 \exp(-0.0152 - 0.279 \ln$

$L_{\infty} + 0.6543 \ln K + 0.4634 \ln T$ ). T is the mean temperature of the water body where fish is found. Using the estimated values of total mortality [7] and natural mortality [11] above, the exploitation ratio (E) was then determined from the formula of [12]:  $E = \frac{Z-M}{Z}$ . Values of exploitation ratios were used to determine whether or not mouth brooding tilapiines of the Kafue Floodplain fishery was over-exploited. An exploitation value of 0.5 denotes optimal exploitation; an exploitation value above 0.5 denotes over-exploitation while an exploitation value below 0.5 signifies under-exploitation.

### 3. Results

#### 3.1. Growth coefficients of fish

The growth coefficients of *Oreochromis* fish species of the Kafue Floodplain fishery are given in table 2.

**Table 2:** Growth coefficients of mouth brooding tilapiines of the Kafue Floodplain fishery

Species	Growth variable	
	Asymptotic length ( $L_{\infty}$ )	Growth coefficient (k)
<i>Oreochromis andersonii</i>	357	0.11
<i>Oreochromis macrochir</i>	344	0.10
<i>Oreochromis niloticus</i>	447	0.22

There was no significant difference between the growth coefficient (k) of *Oreochromis andersonii* (k=0.11) and *Oreochromis macrochir* (k=0.10), the growth coefficient of the exotic *Oreochromis niloticus* (k=0.22) was different from the growth coefficients of *Oreochromis andersonii* and *Oreochromis macrochir*.

#### 3.2. Growth rates of fish in the Kafue Floodplain fishery

The growth rates of accumulated fishcatches in the Kafue Floodplain fishery that were obtained using [6] are given in Table 3.

**Table 3:** Growth rates of mouth brooding tilapiines of the Kafue Floodplain fishery

<i>Oreochromis andersonii</i>		<i>Oreochromis macrochir</i>		<i>Oreochromis niloticus</i>	
Age (years)	Total length (mm)	Age (years)	Total length (mm)	Age (years)	Total length (mm)
1	37	1	33	1	88
2	71	2	62	2	159
3	100	3	89	3	216
4	127	4	113	4	262
5	151	5	135	5	298

The total lengths of mouth brooding tilapiines at different ages show that *Oreochromis niloticus* was the fastest growing mouth brooding tilapiine in the Kafue Floodplain fishery. Between age one and two (in years), *Oreochromis niloticus* grew by 71 millimetres (from 88mm at age one to 159mm at age two) while *Oreochromis andersonii* and *Oreochromis macrochir* grew by 34 millimetres and 29 millimetres between age one and two. Overall growth in *Oreochromis niloticus* was 210 millimetres (from 88mm at age one to 298mm at age five) but overall growth in *Oreochromis andersonii* was 114 millimetres (from 37mm at age one to 151mm at age five). *Oreochromis macrochir* had the least overall growth of 102 millimetres (from 33mm at age one to 135mm at age five). There was a significant difference ( $p=0.0153$ ) in the growth rates of the mouth brooding tilapiines of the Kafue Floodplain fishery. The Least Significant Difference comparisons show that the mean growth rate of *Oreochromis niloticus* was significantly different ( $P=0.0153$ ) from the mean growth rates of *Oreochromis andersonii* and *Oreochromis macrochir*. The mean growth rates of *Oreochromis andersonii* and *Oreochromis macrochir* were statistically similar. Linear regression of ages and total lengths of the mouth brooding tilapiines in Table 3 showed that the relationship between age and total length of *Oreochromis andersonii* and *Oreochromis macrochir* were similar. The linear equation that represents the relationship between age and total length in *Oreochromis niloticus* is:  $\text{total length} = 48 + 52\text{age}$ . The linear equation for *Oreochromis andersonii* is:  $\text{total length} = 12 + 28\text{age}$ . The relationship between age (years) and total length (mm) in *Oreochromis macrochir* has a linear equation of  $\text{total length} = 80 + 26\text{age}$ .

### 3.3. Fish mortality variables of the Kafue Floodplain fishery

Mortality variables that were obtained using [7] were very similar to total mortality values that were obtained using linearised catch curves (Table 4).

**Table 4:** Mortality variables of mouth brooding tilapiines of the Kafue Floodplain fishery

Species	Natural mortality	Fishing mortality	Total mortality	
			Beverton-Holt	Linearised Catch curve
<i>Oreochromis andersonii</i>	0.49	0.21	0.7	0.64
<i>Oreochromis macrochir</i>	0.53	1.24	1.77	1.52
<i>Oreochromis niloticus</i>	0.68	0.45	1.13	0.82

Similar natural mortality variables were observed among the mouth brooding tilapiines. The least natural mortality coefficient was for *Oreochromis andersonii* (0.49). *Oreochromis niloticus* had the largest natural mortality coefficient (0.68), while *Oreochromis macrochir* had a natural mortality coefficient of 0.53. Fishing mortality values ranged from 0.21 for *Oreochromis andersonii* to 1.24 for *Oreochromis macrochir*. Total mortality variables ranged from 0.7 in *Oreochromis andersonii* to 1.77 in *Oreochromis macrochir*.

### 3.4. Exploitation levels

Exploitation ratios of the three mouth brooding tilapiines in the Kafue Floodplain fishery are given in Table 5.

**Table 5:** Exploitation ratios of mouth brooding tilapiines of the Kafue Floodplain fishery

Species	Exploitation ratio (E)
<i>Oreochromis andersonii</i>	0.3
<i>Oreochromis macrochir</i>	0.7
<i>Oreochromis niloticus</i>	0.4

The exploitation ratios ranged from 0.3 to 0.7. Both *Oreochromis andersonii* (Exploitation ratio=0.3) and *Oreochromis niloticus* (Exploitation ratio=0.4) were known to be under-exploited but *Oreochromis macrochir* (Exploitation ratio=0.7) was over-exploited.

#### 4. Conclusion

##### 4.1. Growth

This study found that *Oreochromis niloticus* is the fastest grower among the mouth brooding tilapiines of the Kafue Floodplain fishery. These results are in conformity with the studies of [13,1,14] which revealed that *Oreochromis niloticus* grows very fast and attains adulthood quickly. The results of this study on the fast growth of *Oreochromis niloticus* relative to local tilapiines is also consistent with international studies carried out by [15] in major African lakes of East Africa and West Africa. The fast growth of *Oreochromis niloticus* relative to other mouth brooding tilapiines of the Kafue Floodplain fishery is attributed to the fact that *Oreochromis niloticus* is very adaptive, hardy and it is able to colonise a wide range of habitats [16]. The adaptation was seen in the large growth coefficient of *Oreochromis niloticus* compared to the indigenous mouth brooding tilapiines of the Kafue Floodplain fishery. *Oreochromis niloticus* had a higher growth coefficient than the indigenous mouth brooding tilapiines due to its adaptive nature.

##### 4.2. Mortality

Natural mortality variables that were found in this research were slightly higher than those obtained by [16]. This could be attributed to the general increase in surface temperature which is making the habitat loosely unbearable for mouth brooding tilapiines of the Kafue Floodplain fishery. The mean surface temperature of the Kafue Floodplain fishery has increased from a mean of 24°C [17] to a mean of 27°C [18]. Studies by [9] also showed a correlation between increase in surface temperature and increase in natural mortality. Natural mortality coefficients obtained were generally larger than fishing mortalities. The larger contribution of natural mortality can be attributed to the changed habitat in the Kafue Floodplain fishery because dam construction promotes growth of weeds such as *Eichhorniacrassipes* and *Salvinia molesta* at the lower end which is permanently denudated while the upper end of the Kafue Floodplain fishery that is dry has less nesting grounds for fish [19]. The high natural mortality results relative to fishing mortality results confirm the pre-dam prediction by [20] which stated that dam construction along the course of the Kafue River would cause a natural mortality of 92% compared to a fishing mortality of about 8%. Reference [20] predicted reduced flooding after

dam construction which could make the Kafue Floodplain fishery less favourable for fish especially mouth brooding tilapiines that require a well-sheltered littoral zone. Reference [21] also found higher natural mortality coefficients relative to fishing mortality coefficients and concluded that the reduction in surface area of the Kafue Floodplain fishery due to drying up of about 1, 500km<sup>2</sup> is the main contributing factor to the larger natural mortality relative to fishing mortality. Reference [21] observed that during the artificial flooding in the Kafue Floodplain which occurs around April when the Itezhi-tezhi dam is opened; fish is concentrated in pools making them vulnerable to predatory fish and birds hence the large natural mortality relative to fishing mortality. Other environmental factors such as chemical modification of the water in the Kafue Floodplain fishery could also explain the high natural mortality relative to fishing mortality. Reference [18] observed that industrial activities and agricultural activities in the Kafue Floodplain catchment area is responsible for a water concentration of 68mg/l to 220mg/l of dissolved solids in the Kafue Floodplain fishery which increase natural mortality of fishes in the Kafue Floodplain fishery. The fishing mortality variables of mouth brooding tilapiines were however, larger than those obtained by [16] because the number of fishers has increased over the years. The fishing mortality coefficients obtained in this study are smaller than those determined by [22] because of strict regulations at present. Legislation was not so rigid at the time of [22] study so fishers were using many types of fishing gear throughout the year leading to high fishing mortality. Total mortality variables obtained in this study agree with those obtained by [4]. Both studies have shown that total mortality variables of mouth brooding tilapiines of the Kafue Floodplain fishery are generally above 0.5. The results of these two studies however, differ in that [4] established that the main contribution to total mortality was fishing while this study has found that natural mortality contributes more than fishing mortality. This difference in results could be attributed to differences in techniques used in the study. Reference [4] used the catch-per-unit effort method while this study used length-based fish stock assessment methods.

### **4.3. Exploitation**

The research established that *Oreochromis macrochir* is over-exploited in the Kafue Floodplain fishery. Over-exploitation is consistent with studies done by [23,24,4]. Reference [1] on the Kafue Floodplain fishery, and [15] on thirteen medium-sized fisheries in Africa, Kafue Floodplain fishery inclusive, showed that most fishes of the Kafue Floodplain fishery are being over-exploited. The under-exploitation of *Oreochromis niloticus* in the Kafue Floodplain fishery can be attributed to the fast growth of this mouth brooding tilapiine which makes it less vulnerable to the legally-recommended fishing gear. Reference [15] also established that invasive species are normally under-exploited in most African countries. Exploitation ratios of *Oreochromis macrochir* at all study sites were all above the optimum value (0.5). Over-exploitation of *Oreochromis macrochir* is consistent with the results of [25] who correlated increase in exploitation to change in the ecology of the Kafue Floodplain fishery.

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## **5. Copyright declaration**

I, Mauris Chinyama Makeche, hereby declare that this Journal article represents my own work and that it has not previously been submitted for publication to this or another Journal.

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