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MORTALITY AND EXPLOITATION OF THREE *OREOCHROMIS* FISH SPECIES OF THE KAFUE FLOODPLAIN FISHERY, ZAMBIA

Makeche Chinyama Mauris[1]*, Katongo Cyprian[2] and Mudenda Hangoma Gordon[2]

[1]Department of Biological Sciences, University of Zambia, Zambia
[2]University of Zambia, Zambia

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Corresponding author: Makeche Chinyama Mauris,

ABSTRACT

Mortality and exploitation 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 mortality and exploitation 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. 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.

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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 (Zambia Department of Fisheries, 2008). 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^2 (FAO, 2017). There are several environmental concerns affecting the development and management of the Kafue Floodplain fishery. The waters of the Kafue Floodplain are exposed to pollution from industrial and agricultural activities taking place in the catchment areas. The introduction of exotic fish species such as *Oreochromis niloticus* and Cray fish is also another concern to local biodiversity in the Kafue Floodplain fishery (Schelle and Pittock, 2005). 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 (Zambia Department of Fisheries, 2008). Cichlids (Breams) are an important family in the Kafue River and have two lineages, haplochromine and tilapiines. The tilapiines are the most abundant fish species in this habitat,they are preferred by the local markets and they are also used in aquaculture.The mouth brooding tilapiines of the Kafue Floodplain fishery which were studied included: *Oreochromis andersonii*, *Oreochromis macrochir* and *Oreochromis niloticus*. These are the only mouth brooding tilapiines of the Kafue Floodplain fishery (Mbewe, 2006). 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 (FAO- Fisheries report, 2010).Reasons for the decline in fish harvests have not been properly understood and investigated. The possible explanation to the decrease in 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 (Mung'omba, 1992).

The other explanation to the decrease in fish yields from the Kafue Floodplain fishery can be attributed to the increase in fishing pressure (Mbewe, 2006). The general objective of the stuy was to investigate the growth and exploitation of mouth brooding tilapiines of the Kafue Floodplain fishery. This study tested the hypotheses that: (i) there are no significant differences in growth rates of mouth brooding tilapiines of the Kafue Floodplain fishery and, (iii) there are no significant differences in the exploitation ratios 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 mouth brooding tilapiines in the Kafue Floodplain fishery.

MATERIALS AND METHODS

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 Iis 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. (Cowardin *et al*., 1979).

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 (Zambia Department of Fisheries, 2008). Gillnets of different mesh sizes were intended to catch fish specimens of different sizes. Fish were collected for three consecutive days at each station. The nets were set between 16:00 and 18:00 h and hauled between 6:00 and 7:00 h the following day.

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 tilapiine fish species 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 fish species 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 each fish species unique code, 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 species in years (Skelton, 2001). The age of each fish species wasused to determine total mortality of sampled fish species using linearised catch curves.

Total mortality coefficients of the *Oreochromis* fish species that were studied were determined using linearised catch curves and Beverton and Holt equation (1957). The linear regression curves were obtained using the ages of fish against natural logarithm of the number of fish at each age, using Microsoft Excel (Analytical software, 2007. The gradients of regression analysis denoted total mortality (Z) coefficients of the *Oreochromis* fish species (Pauly, 1980). The Beverton and Holt equation (1957): $Z=\frac{k(L\infty-Lm)}{Lm-Lc}$ 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_∞) was determined using the equation by Pauly (1979) which is: $L_\infty=\frac{Lmax}{0.95}$Lmax is the largest length among the measured total lengths of the fish species. The natural mortality coefficient, M was estimated using Pauly (1983) equation expressed as M = 0.8 exp (– 0.0152−0.279 In L_∞ + 0.6543 In K +0.4634 In T). T is the mean temperature of the water body where fish is found. Using the estimated values of total mortality (from Beverton and Holt equation of 1957) and natural mortality (from Pauly equation of 1983) above, the exploitation ratio (E) was then determined from the formula of Gulland (1982): $E = \frac{Z-M}{Z}$. Values of exploitation ratios were used to determine whether or not the fish stocks in the Kafue Floodplain fishery are 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.

Data analysis

***Oreochromis* fish ages:** The ages of sampled fish species were analysed using One-way Analysis of Variance (p=0.05), in Statistix 9 software (Analytical Software, 2009). This analysis was done for accumulated results of each mouth brooding tilapiine fish species that was studied in the Kafue Floodplain fishery.

Mortality variables: Mortality variables of the mouth brooding tilapiines of the Kafue Floodplain fishery were compared to determine significant differences, if any.

Levels of exploitation: Exploitation ratios of the mouth brooding tilapiine fish species of the Kafue Floodplain fishery were compared to determine significant differences, if any.

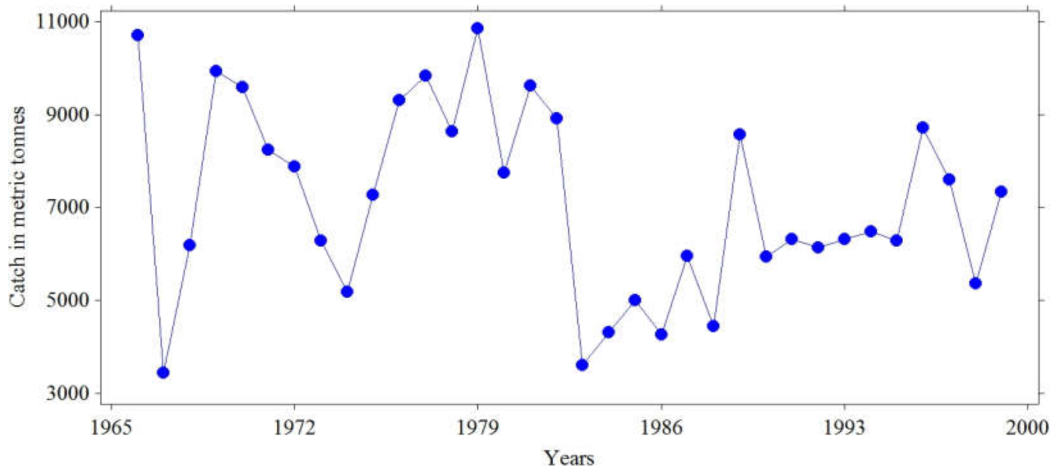

Figure 1. Fish catches from the Kafue Floodplain fishery from 1965 to 2000 (source: FAO Fisheries report, 2010)

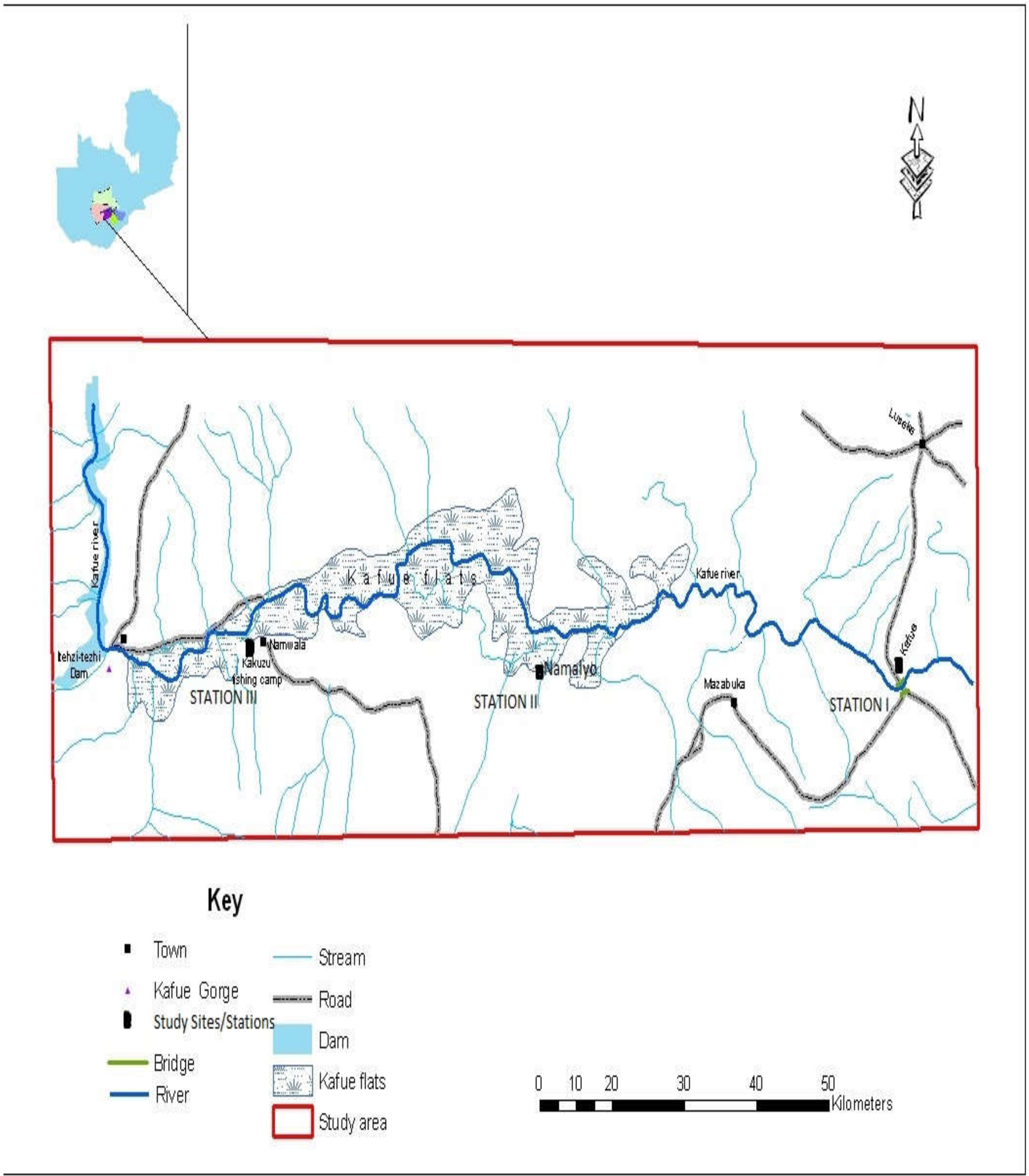

Figure 2. Location of the study sites (Kafue Road Bridge, Namalyo and Kakuzu) within the Kafue Floodplain fishery

RESULTS

Fish mortality variables of the Kafue Floodplain fishery: Mortality variables that were obtained using the Beverton-Holt method were very similar to total mortality values that were obtained using linearised catch curves (Table 2).

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

Table 2. Mortality variables of mouth brooding tilapiines of the Kafue Floodplain fishery

Species	Natural Mortality (M)	Fishing Mortality (F)	Total mortality (Z)	
			Beverton-Holt	Linearised Catch curve
Oreochromis andersonii	0.49	0.21	0.7	0.64
Oreochromis macrochir	0.53	1.24	1.77	1.52
Oreochromis niloticus	0.68	0.45	1.13	0.82

Table 3. Exploitation ratios of three *Oreochromis* fish species of the Kafue Floodplain fishery

Species	Exploitation ratio (E)
Oreochromis andersonii	0.3
Oreochromis macrochir	0.7
Oreochromis niloticus	0.4

Exploitation levels: Exploitation ratios of the three *Oreochromis* fish species in the Kafue Floodplain fishery are given in Table 3. 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.

DISCUSSION

Mortality: Natural mortality variables that were found in this research were slightly higher than those obtained by Schwanck (1994). 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 (Carey, 1971) to a mean of 27˚C (Smardon, 2009). Studies by Pauly (1980) 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 *Eichhornia crassipes* 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 Ellenbroek (1987). The high natural mortality results relative to fishing mortality results confirm the pre-dam prediction by Carey and Bell-Cross (1967) 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%. Carey and Bell-Cross (1967) 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. Nyimbili (2006) 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^2 is the main contributing factor to the larger natural mortality relative to fishing mortality. Nyimbili (2006) 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. Smardon (2009) 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 Schwank (1994) because the number of fishers has increased over the years. The fishing mortality coefficients obtained in this study are larger than those determined by Mortimer (1965) because of strict regulations at present. Legislation was not so rigid at the time of Mortimer's 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 Mbewe (2006). 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 Mbewe (2006) 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. Mbewe (2006) used the catch-per-unit effort method while this study used length-based fish stock assessment methods.

Exploitation: The research established that *Oreochromis macrochir* is over-exploited in the Kafue Floodplain fishery. Over-exploitation is consistent with studies done by William (1960), Muncy (1976) and Mbewe (2006). The Zambia Department of fisheries report (2008) on the Kafue Floodplain fishery, and Food and Agriculture Organisation Fisheries report (2010) 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. The Food and Agriculture Organisation -Fisheries report (2010) 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 Haller and Marten (2008) who correlated increase in exploitation to change in the ecology of the Kafue Floodplain fishery.

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