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# Size at Maturity and Fecundity of *Oreochromis niloticus* and Mouth Brooding Tilapiines Indigenous to Kafue Flood Plain Fishery, Zambia

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**Abstract**

The present investigation was conducted to ascertain whether or not Size at maturity, Fecundity, and Total Length-Fecundity variation could explain the population dominance of *Oreochromis niloticus* (Linnaeus 1758) over three spot breams *Oreochromis andersonii* (Castelnau 1861) and Green-Headed Bream *Oreochromis macrochir* (Boulenger 1912) in the Kafue Flood Plain during the spawning season (October 2020 to March 2021).

Fish samples caught using a full standard multifilament net with mesh sizes ranging from 25 to 150 mm increments of 12.5 mm were purchased from Local Fishermen at Chanyanya and Kasaka fishing camps. The Total length of each fish was recorded to the nearest 0.1 cm using the fish measuring board. Reproductive stages of the three Tilapiine fish species were determined using standard keys. Whole ovaries from sexually mature females (ripe) were weighed and preserved in 10% formalin solution; logistic regression lines were used to determine size at maturity ($L_{50}$). Fecundity was determined using gravimetric procedures. The *O. andersonii* matured at a Total length of 210.98 mm, *O. macrochir* at 199.48 mm, while *O. niloticus* matured at 189.82 mm. The *O andersonii* had mean Fecundity of 1843.92 ± 68.805; *O. macrochir* had 1640.82 ± 92.164 while *O. niloticus* had 1422.24 ± 91.103. The relationship between Fecundity and Total length was found to be strongest in *O. macrochir* (y=12.845x-1175; r=0.8770), followed by *O. niloticus* (y = 12.912x – 1614.3; r=0.8104) and finally *O. andersonii* (y=10.715x-591.91; r=0.7606).

The studied characteristics among the Tilapiines indicated that *O. niloticus* was superior in reproductive biology. There should be proper guidelines in the laws and regulations regarding the introduction of *O. niloticus* into other water bodies. The *O. niloticus* must be promoted in aquaculture because of its reproductive advantages compared to the local Tilapiines.

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## 1. Introduction

Size at first maturity is the size at which 50% of individuals attain gonadal maturity [1]. The size (length, *L*) of an organism is a crucial criterion for key ecological processes, and many factors as well as the environment, genetic variability in life-history characteristics, predator-prey relationships, and competitive interactions [2], affect changes in size distributions. Information on size at maturity is a basic requirement for an ecological management approach to exploited fisheries and additionally helps in deciding on the mean size of fish stocks once it is associated with different life-history information [3]. In order for the stock biomass to be maintained, fish should be allowed to spawn at least once over their lifetime before being caught [4], which demands that their size at capture should exceed their size at maturity [5]. Thus, size at maturity is the basis in setting the minimum legal size under which fish should not be caught.

Fish fecundity is an indicator of the reproductive strength of any fish species [6]. Assessment of Fecundity is of great importance in fisheries management as it provides knowledge about the number of offspring produced in a season and the reproductive capacity of the species [7].

The Fecundity and its reference to the size of a fish make it possible to estimate the quantity of eggs probably to be liberated [8].

Tilapia (*Oreochromis species*) also commonly known as breams, constitute a group of fish native to the African continent that has been introduced into various other countries. The Nile Tilapia, *O. niloticus* is one of the most widespread and important fishes in tropical freshwater aquaculture. The main advantage of Tilapia is its comparatively low cost of production, especially for fry and feed, and the quality of its flesh [9].

**Figure 1:** *Oreochromis niloticus* species of the Kafue Flood Plain.

Zambia has an estimated 145,194 square kilometres of water in form of rivers, lakes, and swamps, delineating 11 major fishery areas, which belong to either the Congo or the Zambezi basins [10]. There are 55 known fish species in the Kafue Flood Plain Fishery, of which 23 are of commercial importance. Cichlids account for 80% of all economically significant fishes in the Kafue Flood Plain Fishery [11]. The *Oreochromis andersonii* (Castelnau 1861), and the *Oreochromis macrochir* (Boulenger 1912) are mouth brooding Tilapiines naturally found in the Kafue Flood Plain.

**Figure 2:** Oreochromis niloticus also known as Green-headed bream of the Kafue Flood Plain.

**Figure 3:** *Oreochromis andersonii* also known as Kafue bream.

Fishery areas and their fish resources remain susceptible to the emerging threat of exotic species. Once introduced species are established in an ecosystem, they are known to have immense, insidious, and usually irreversible impacts, and may be damaging to the native species and ecosystems [12]. These phenomena put both beneficiary human and associated flora and fauna communities at risk.

Kafue River, and in particular Kafue Flood Plain has been known as the 'Home of the Kafue bream', *O. andersonii*, and ‘green-headed bream’, *O. macrochir*. However, catch-trends indicate that the introduced ‘Nile Tilapia’, *O. niloticus* [13], has surpassed *O. andersonii* and *O. macrochir* in dominance. The introduction of *O.*

*niloticus* is of concern to biodiversity of mouth brooding Tilapiines in the Kafue Flood Plain Fishery [14], and whilst this study may not explicitly isolate several other factors such as (growth, mortality, sex ratio, egg size, gonadosomatic index, behavior etc.) which may give *O. niloticus* a competitive advantage over indigenous Tilapiines, it attempts to indicate whether or not size at maturity and fecundity of *O. niloticus* contributes to the observed population dynamics among mouth brooding Tilapiines in the Kafue Flood Plains.

## 2. Materials and Methods

### *2.1 Study Area*

This research was conducted in the Kafue Flood Plain Fishery (fig.1) which is located about 50 km south of Lusaka, the capital city of Zambia. Kafue Flood Plain stretches from longitude 26˚E to 28˚E and latitude 15˚S to 16˚S and is 250 km long and 60 km wide covering an area of 6500 km$^2$ [15].

The Kafue Flood Plain contains grasslands, lagoons, oxbow lakes, and reed beds and supports a diverse range of wildlife and fisheries [16]. The area has an annual rainfall of between 600 mm and 780 mm received between November and April. Temperatures range from 25°C to 35°C. With the onset of floods during the rainy season (November-April), the aquatic grasses and other vegetation begin a period of rapid growth and most of the fish species reproduce around this period [17].

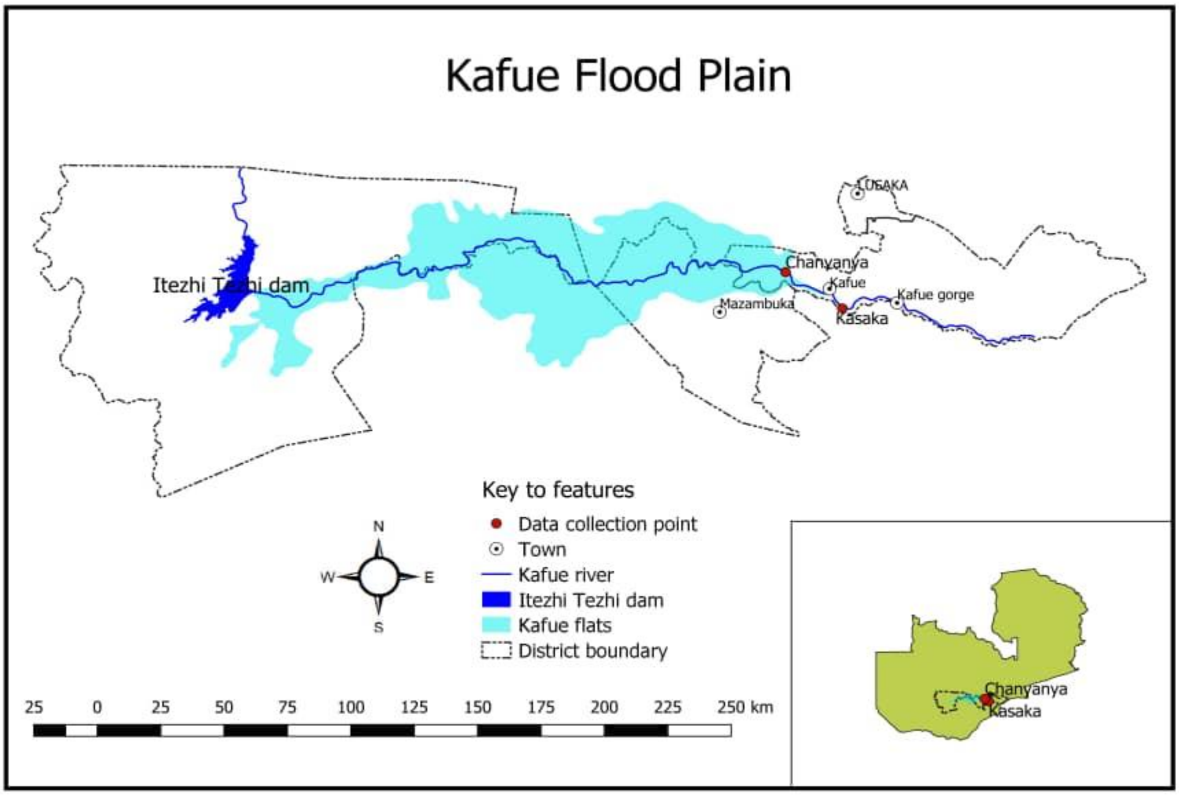



**Figure 4:** Location of the study sites within the Kafue Flood Plain Fishery.

### *2.2 Sampling Design*

Two stations were selected on the Kafue Flood Plain for the target fish species. Fish samples were collected from the Kasaka Fish Camp, representing the river channel habitat and at Chanyanya Fish Camp representing the lagoon habitat. All the specimens were purchased from local Fishermen. Actual sampling was done on five occasions at each site targeting fish caught using nets of mesh sizes as shown (Table 1) below, during the period October 2020-March 2021. Fishermen at Kafue Flood Plain tend to ply their fishing over wide and overlapping areas. Freshly collected samples of *O. andersonii*, *O. macrochir*, and *O. niloticus* from Kafue District local Fishermen were stored in the cooler box in ice and brought to the Biological Sciences Laboratory of the University of Zambia on the same day of capture. The fish were washed, and the excess water from the fish removed with the help of blotting paper.

**Table 1:** Mesh Sizes of the nets used to catch the targeted fish.

| 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 |

### *2.3 Sample Collection*

Data on the following variables were broadly presented under the general headings: Size at maturity and fecundity. Proxy variables were inferred from these headings.

#### *2.3.1 Size at Maturity*

**Table 2:** Description of Maturity Stages [19].

| Maturity state of gonads | Code | Description |
|---|---|---|
| Immature | I (I) | Young individuals not yet engaged in sexual activity; gonads are small and may present with difficulty in distinguishing the sexes |
| Inactive | Q (II) | Sexual products still undeveloped; gonads still small-sized; Oocytes not distinct |
| Active | A (III) | Oocytes distinguishable; gonads rapidly attain greater weight and size; testes assume a pale rose colour from transparent appearance |
| Ripe | R (IV) | Sexual products ripe; gonads have attained maximum weight |
| Ripe-running | K (V) | Oocytes and milt are released easily from genital aperture by application of gentle pressure over the belly |
| Spent | S (VI) | Sexual products have been discharged: genitalia appear inflamed, flaccid with residual oocytes, and sperm |

The fish specimens were dissected using a mounted scalpel by making a longitudinal slit from the cloaca to the region below the pelvic fins; respective sexes were then determined on the basis of the morphological appearance of the gonads. Target fish species were analysed for sexual maturity as outlined in [18], taking note of specimens that were in the active, ripe, ripe-running, or spent stages (Table 2.) The target Tilapiines were individually placed on the measuring board (metre rule) and the Total length (TL) was determined. The Total length (TL) of the targeted fish was measured from the tip of the anterior part of the mouth to the edge of the caudal fin. The Total length of each fish was recorded to the nearest 0.1 cm.

***2.3.2 Fecundity***

To estimate Absolute Fecundity, the gravimetric method was applied in the present study.

Three sub-samples were taken from the front, mid and rear sections of each ovary and sub-samples weighed using an electronic balance. The weight of each ovary and sub-sample was recorded to the nearest 0.01g.

The numbers of eggs in each of the sub-samples were counted under a field microscope after 24 hours and the mean value of the eggs was computed. Fecundity was calculated by the following formula: $F = n \times G/g$, where "F" is fecundity, "n" is the average number of eggs counted, "G" is the weight of the gonads and "g" is the weight of the subsample.

***2.2.3 The Relationship between Fish Length and Fecundity***

The observations recorded for Total length for the Size at first ovary maturity were associated with the Fecundity data for respective individual species.

**3. Data Analysis**

***3.1 Length at Maturity***

Length data was resolved into intervals, determined by the smallest observed size of sexually active fish, for the entire target Tilapiines species.

The cumulative frequencies were calculated as percentages and plotted against Total length (mid-points from ascertained length classes) as shown in figure 6. The Classical method used to estimate size-at-first-maturity was based on fitting a logistic function and calculating the size class where randomly chosen individuals had 50% chance of being mature [18].

***3.2 Fecundity***

To determine mean fecundity among mouth brooding Tilapiines of the Kafue Flood Plain Excel was used. One-way ANOVA was used in ascertaining statistical significance in observed fecundities ($\bar{x} \pm 95\%$ CI).

***3.3 Relationship between Fish Size and Fecundity***

Regression lines were plotted to demonstrate the relationships between fecundity and the total length of *O. andersonii*, *O. macrochir*, and *O. niloticus*. To find the comparative relationship of fecundity with total length, regression analysis was conducted and observed. Analysis of covariance was employed to test if the regressions were significantly different for these fish species.

## 4. Results

### *4.1 Size at maturity*

The relation between Total Length and Maturity was studied in 630 fish samples from randomly selected catches. There were 251 specimens belonging to *O. andersonii*, 201 specimen *O. macrochir*, and 178 *O. niloticus* (Fig. 2). The smallest mature specimen was observed in *O. andersonii* at 151 mm, *O. macrochir* at 122 mm, and *O. niloticus* at 141 mm (Fig. 3). The estimated L50 of *O. andersonii* was 210.98 mm, *O. macrochir* 199.48 mm, and *O. niloticus* 189.82 mm Total TL. So, at 210.98 mm, 199.48 mm, and 189.82 (Fig. 4) and above of total length for *O. andersonii*, *O. macrochir*, and *O. niloticus* most of the females are identified as reproductive (maturing, spawning, and post-spawning).

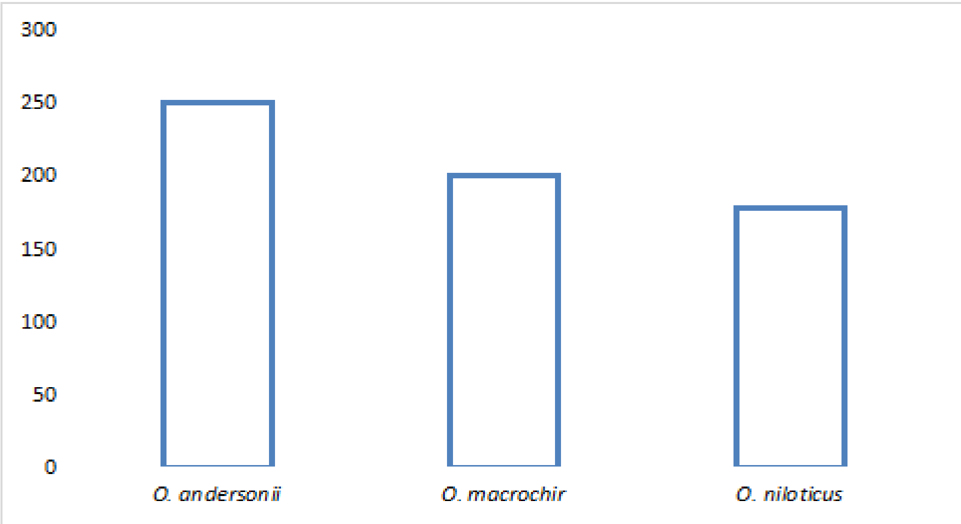



**Figure 5:** Number of Specimen in the sample for the studied Species.

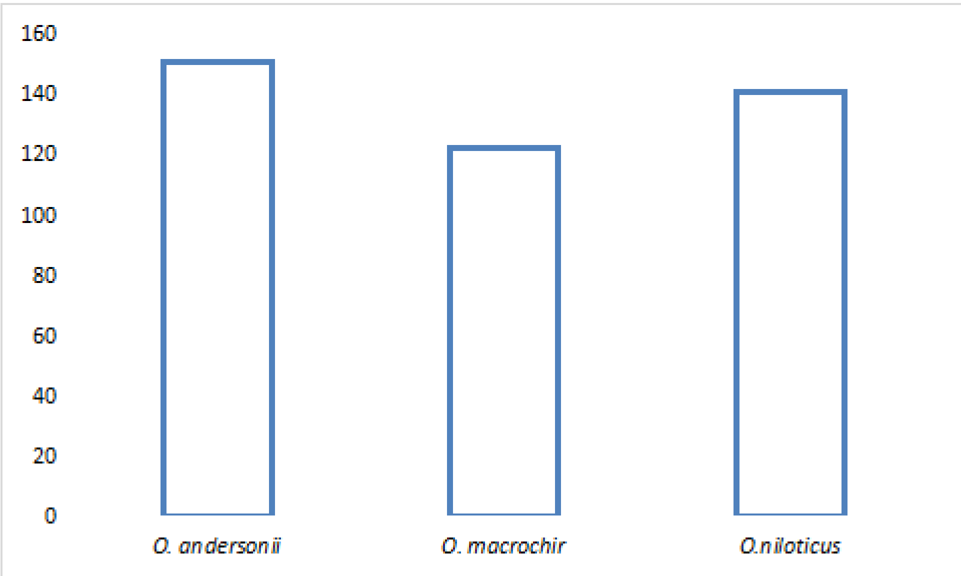



**Figure 6:** Smallest Observed Length at Maturity of the Studied Species.

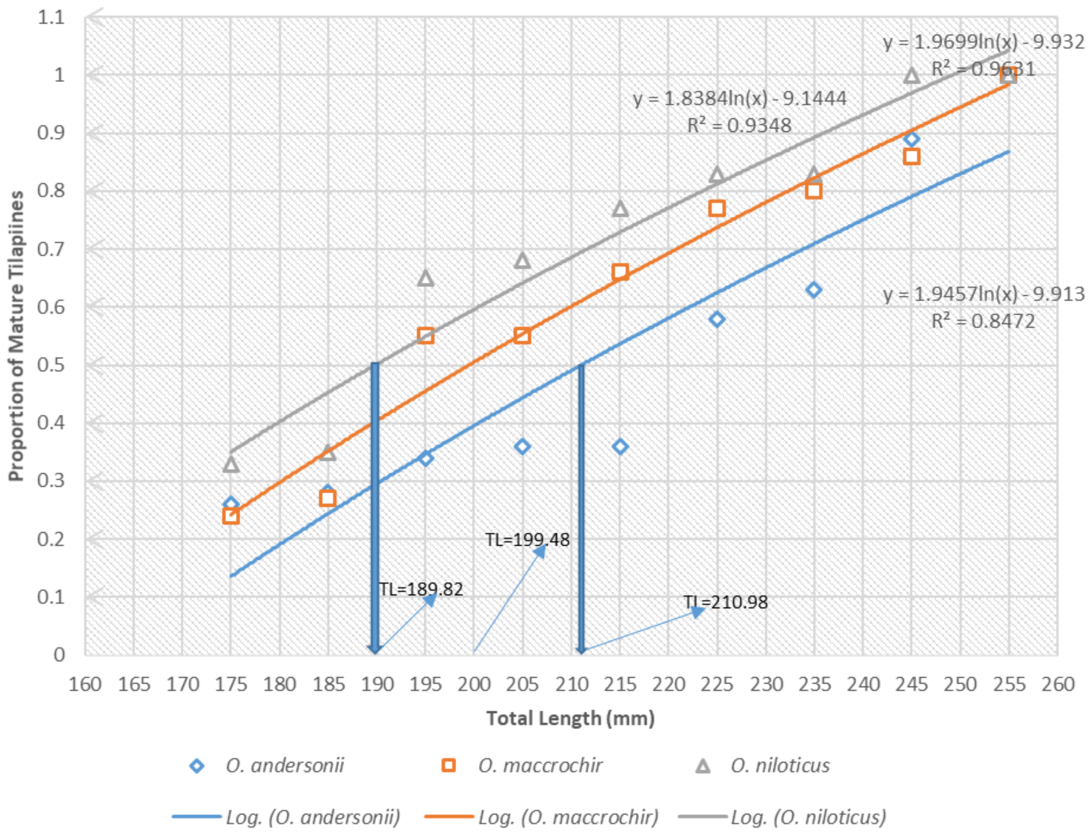



**Figure 7:** Size of the Studied Species at First Maturity.

### *4.2 Fecundity*

Mean Fecundity for the Tilapiines in the present study was found to be (1843.92 ± 68.805, n=49 *O. andersonii*, (1640.82 ± 92.164, n=57) *O. macrochir* and (1422.24 ± 91.103, n =47 *O. niloticus*.

There were wide variations observed in the number of oocytes borne by the sexually ripe females. The number of oocytes in *O. andersonii* ranged from 520 - 2905, while *O. macrochir* 661 - 2990 and *O. niloticus* had (420 - 2782). Statistical analyses revealed significant differences (0.04) in the average fecundities of the various Tilapiines at (p - 0.05) as shown in Table 3.

Further analysis revealed significant differences (0.003) between *O. andersonii* and *O. niloticus*. There were no significant differences between *O. andersonii* and *O. macrochir* (0.207) and between *O. macrochir* and *O. niloticus* (0.169) as shown in Table 4.

**Table 3:** Fecundity of the Studied Species.

| species | Fecundity |
|---|---|
| *Oreochromis andersonii* | 1843.92 ± 68.805 |
| *Oreochromis macrochir* | 1640.82 ± 92.164 |
| *Oreochromis niloticus* | 1422.24 ± 91.103 |

**Table 4:** ANOVA for Comparison of Fecundity among the Studied Species.

| SPECIES | P-value |
|---|---|
| *Oreochromis andersonii* and *Oreochromis macrochir* | **0.207** |
| *Oreochromis andersonii* and *Oreochromis niloticus* | 0.003 |
| *Oreochromis macrochir* and *Oreochromis niloticus* | 0.169 |

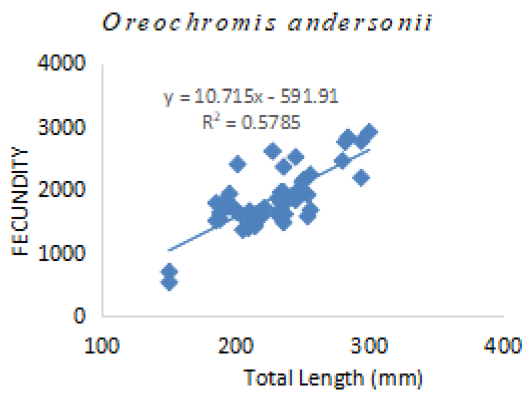
***4.3 Relationship between Fish Size and Fecundity***

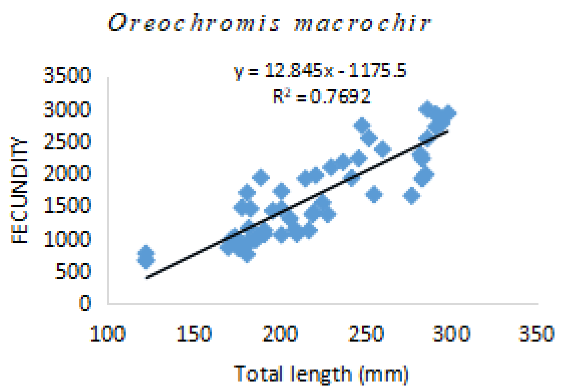
A positive correlation (table 5) was found to exist between the Total-length and Fecundity in all three species in the current study. The co-relationship of fecundity with Total-length was found to be linear and the correlation coefficient (r) values were 0.7605, 0.8770, and 0.8104, for *O. andersonii*, *O. macrochir*, and *O. niloticus* respectively. The relationship between fecundity and Total-length was found to be strongest in O. macrochir (y=12.845x - 1175; r=0.8770), followed by *O. niloticus* (y = 12.912x – 1614.3; r=0.8104) and finally *O. andersonii* (y=10.715x-591.91; r=0.7606) as shown in Table 5.

**Table 5:** Relationship between Fecundity and Total Length and among Species.

| | Species | $R^2$ | Equation | Sig |
|---|---|---|---|---|
| Fecundity Vs TL | *Oreochromis andersonii* | 0.7605 | y=10.715x-591 | 0.00 |
| | *Oreochromis macrochir* | 0.8770 | y=12.845x-1175.5 | 0.00 |
| | *Oreochromis niloticus* | 0.8104 | y=12.912x - 1614.3 | 0.00 |
| Among species | *Oreochromis andersonii*<br>*Oreochromis macrochir*<br>*Oreochromis niloticus* | | | 0.079 |

The Fecundity for *O. niloticus* was consistently lower (fig 5) than *O. andersonii* and *O. macrochir* for any given Total-length while Fecundity for *O. andersonii* was higher than Fecundity for *O. macrochir*. This vertical shift is statistically not significant 0.079 for the three species under the current study at p-0.05.



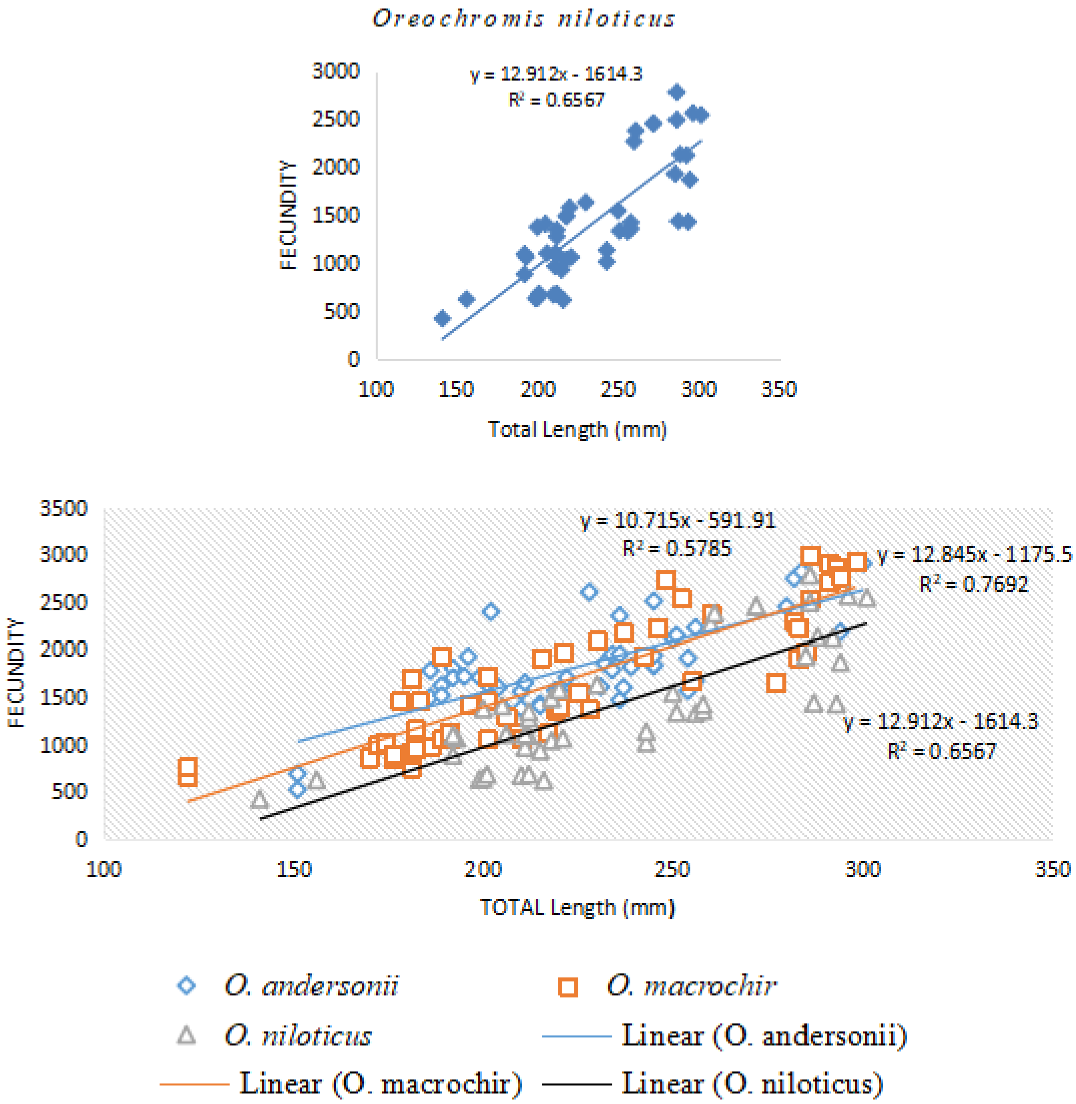



**Figure 8:** Fecundity-Total length Relationship for *O. andersonii, O. macrochir and O. niloticus*.

## 5. Discussion

### *5.1 Size at Maturity*

Size at maturity has been shown to be affected by demographic structure, resource availability, and size-selective predation [20]. Length at maturity of *O. niloticus* in the current study (189.82 millimetres) was observed to be lower than the length of the same species observed by the author [21] on lake Kariba (240.91 millimetres) but higher than 116-35 millimetres in Lake Ayame at lengths 116 ±0.13 millimetres and 113 ±0.72 millimetres during 1995 and 1996 respectively [22]. The author [23] also observed a higher length at maturity of *O. niloticus* at 280-300 millimetres, in the Nyanza Gulf of Lake Victoria. Studies by the authors [24] indicated that *O. niloticus* matured at the Total length of 105 millimetres, maturing much earlier than the Kafue Flood Plain stock.

The author [25] noted that male and female *O. niloticus* on Lakes Nabugabo and Wamala attained maturity at total lengths of approximately 200-250 millimetres. Studies conducted by the author [26] on a man – made lake showed that female *O. niloticus* attained maturity at 110 millimetres Total length. The author [27] reviewed several observations of Size at maturity for *O. niloticus* noting 280 millimetres Total length in Lakes George and Albert, 390 millimetres Total length in Lake Turkana, and 250 millimetres Total length in Lake Edward. Meanwhile, the author [28], observed the size at maturity for the Nile tilapia in the Nile (Khartoum) to be 143 millimetres. Length at maturity in Emiliano Zapata Dam, Mexico observed by the author [29] was 151 millimetres. Studies conducted by the author [30] in the Tereze reservoir showed that Nile Tilapia attain maturity at 140 millimetres.

Generally, the population of Nile Tilapia from Kafue Flood Plain attained sexual maturity at lower sizes than in most of the populations from the East African Lakes. Many studies on size at maturity have been done in the lacustrine ecosystems (lake ecosystem) and very little has been done on the riverine ecosystem (lotic ecosystem). None of these findings compare favorably with those of the current study.

However, size at maturity in Tilapiines has shown to be a very plastic trait; [22] for instance observed a variation of 20 mm within two consecutive years of studying *O. niloticus* on Lake Ayame. It has been noted that Tilapia mature early in systems with unpredictable conditions of draughts, drawdowns, and food - resource shortages [31]. Among the factors (demographic structure, resource availability, and size-selective predation) described by the author [20], resource shortages arising from unstable environmental conditions and, size-dependent predation may be factors strongly explaining the observed pattern in the maturity lengths of Tilapiines in the Kafue Flood Plain; predation in this context refers to fishing by humans, and non-human predation.

Growth and reproduction are in principle parallel processes competing for the same limited amount of body resources. The onset of maturation reflects that certain requirement, with respect to either size or accumulations of energy stores, or both, have been fulfilled at a specific time in life. If juvenile fish growth is reduced, size at maturation is expected to happen at an older age. If maturation occurs when certain body size is achieved, accelerated growth should imply a reduction in age at maturation, but not necessarily in size at maturation [5].

However, optimum size at maturation is not the same under different ecological or physiological conditions. In a heavily exploited population, characterized among other aspects by excessive removal of larger individuals, fish genotypically programmed to late maturation (at large size) are inevitably much less likely to reproduce before being fished out. Contrarily, those individuals programmed to mature early, and at a smaller size, may reproduce at least once [5].

Although delaying maturity may increase fecundity, it also reduces survival. Nile Tilapia have early sexual maturation and are multiple spawners, meaning that they can reproduce throughout the year, with short vitellogenic periods [32]. Fisheries based on slow-growing, late-maturing, long-lived species should be more susceptible to overfishing and stock depletion and may show more gradual recovery than those based on species with rapid growth and development, and shorter life spans [33].

### *5.2 Fecundity*

Although Fecundity does not always equate to reproductive success (fertility), it can provide an objective measure of reproductive effort [34]. The author in [35] showed that a given Tilapiines species would have either small oocytes in larger numbers or larger oocytes in fewer numbers. A study conducted by [13] reviewed that *O. niloticus* had a larger oocyte size compared to *O. andersonii* and *O. macrochir.*

Because predation and competition are most intense in nursery and breeding grounds, the hatchlings from smaller oocytes have lower chances of surviving to maturity. In explaining the Tilapiines abundances, the authors in [36] further postulated that maternal *O. niloticus* may spend a relatively shorter time offering parental care because their offspring grow faster, thus allowing the females to resume their breeding cycle.

The number of oocytes for *O. andersonii* and *O. niloticus* in the Kafue Flood Plain was lower than observed by the author in [21] on lake Kariba in Sinazongwe area where average fecundity was 1650 and 2923 and ranged from 934-3062 and 1306-3455 respectively. However, the number of oocytes in the Kafue Flood Plain were equally higher than the number of oocytes observed by the author [22] on Lake Ayame where absolute fecundity ranged between 160 and 717 oocytes in O. niloticus. These differences may be due to differences in the fish size in the samples used in the studies. Several factors may contribute to the observed differences in Fecundity of Tilapiines. The author in [37] observed that within a given species, Fecundity might vary because of different adaptations to environmental habitats. Even within a stock, Fecundity varies annually and undergoes long-term changes, and has been observed to be proportional to fish size and condition [38]. In addition, the variation in Fecundity may be attributed to the differential abundance of food within the members of the population. The rather low Fecundity observed at Lake Ayame was attributed to pollution [22]. It may be difficult to confidently attribute the higher Fecundity observed in the Kafue Flood Plain to lack of pollution, bearing in mind that the area has come under increasing anthropogenic influence. Effluent from farming and irrigation schemes, cage-aquaculture, crocodile farms, oil and carbon discharge from manufacturing industries are some of the processes that may be affecting the reproductive biology of Tilapiines. There have not been any studies determining the relationship between aspects of fish biology and changes in water pollution.

### *5.3 Relationship between Fecundity and Total Length*

The author in [34] stated that in mouth brooding cichlids, the fecundity is considerably low because the parents assure the survival of the offspring, and in consequence less mortality. In addition, the variation in fecundity may be attributed to differential abundance of food within the members of the population. When expressed in terms of body length, *O. niloticus* fecundity is much lower than that of most economically exploited species, as mentioned by the authors in [28] for *T. nilotica*, the authors [9] for *O. mossambicus*, and the authors [39] for S. galilaeus. This is probably a result of the restrictions imposed by the mouth-brooding habit of this species and the limited space available for rearing of the spawn in the mouth cavity [28].

From the present observations, it is clear that Fecundity is directly proportional to the Total length. In this respect, *O. niloticus* is similar to other commercially exploited Tilapiines species of the Kafue Flood Plain.

However, current observations suggest that Fecundity was considerably lower in *O. niloticus* than in other Tilapiines of similar body size.

The correlation between Fecundity and Total length of *O. niloticus* in the Kafue Flood Plain is stronger than that obtained at Tekeze reservoir by authors in [40], where Fecundity was found to be positively correlated with Total length r=0.77 and results obtained by the authors [41] at Lake Coatetelco, Mexico where the correlation between Fecundity and Total length expressed relationship was 0.7930. the author [6] in his study conducted in lake EDKU, Egypt, concluded that the absolute fecundity of parental species and hybrid specimen was positively correlated to fish length. The Fecundity and its relation to female size make it possible to estimate the potential of egg output [8] and the potential number of offspring in a season and the reproductive capacity of fish stocks [7]. Changes in egg number based on fish length could affect recruitment in fish stocks, especially in exploited fisheries where larger fish tend to be harvested, leaving smaller fish as the main component of reproductive potential [42].

There is lack of research information on size at maturity and fecundity especially of *O. andersonii* and *O. macrochir* in the environments similar to that of Kafue Flood Plain. It is therefore difficult to make meaningful comparisons among the studied species. In order to protect the genetics of the indigenous species, there should be proper guidelines in the laws and regulations regarding the introduction of *O. niloticus*.

**5. Conclusion**

This study provides some basic information on the body Size at sexual maturity and Fecundity for *O. andersonii, O. macrochir,* and *O. niloticus* that will be helpful in the evaluation of the reproductive potential of individual fish species in similar studies. The *O. niloticus* matures early at a smaller size than other species, which makes it less susceptible to overfishing and stock depletion and recovers quickly. The study has further shown that *O. niloticus* has low fecundity. Fewer oocytes are usually larger than many oocytes. Hatchings from larger oocytes have higher chances of surviving to maturity. The *O. niloticus* spend a relatively shorter time offering parental care because their offspring grow faster, thus allowing the females to resume their breeding cycle.

The analysis of the relationship between total length and fecundity further reviewed that *O. niloticus* had a considerably lower fecundity than other Tilapiines of similar body size, which helps it, maintain a larger oocyte size and shorter time for parental care throughout its reproductive period. The *O. niloticus* has a competitive reproductive advantage over *O. andersonii* and *O. macrochir*. The *O. niloticus* has the potential to replace *O. andersonii* and *O. macrochir* in the Kafue Flood Plain. The replacement of the local Tilapiines in the Kafue Flood Plain Fishery threatens the biodiversity in the area.

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