



REPRODUCTIVE DYNAMICS AND VIRTUAL POPULATION ANALYSIS (VPA) OF *Tilapia zilli* (PERCIFORMES: CICHLIDAE) IN A TROPICAL FLOOD RIVER BASIN

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ABSTRACT

A total number of 4044 specimens, comprising 2342 females and 1702 males of *Tilapia zilli* were caught from mid Cross river basin. There were significantly more females than males with the sex ratio of 1:1.4 for *T. zilli* ($\chi^2 = 101.29$, $df = 1$, $P < 0.05$). Statistical analysis revealed that there were significant differences in the M: F sex ratio of *T. zilli* in all the four gonad maturation stages, immature stage, mature stage, ripe stage and spent stage. Gonadosomatic index ranged between 0.3 and 19.5 with a mean of 3.16 ± 0.46 for males and 7.44 ± 1.85 for females. Fecundity of *T. zilli* ranged from 628 to 3631 with a mean of 1583 ± 898 eggs. The fertility co-efficient for the fish was 0.30 ± 0.08 . The smallest sexually mature female of *T. zilli* was 11.0cm TL. VPA results for *T. zilli* indicated one peak of fishing mortality (F) (0.99yr^{-1}). The peak of F occurred in the length class 13.0 to 14.0cm TL. Catch in number was 1210881 and population of survivors was 13019479.59. Recruitment to fishery was 77075319.18. Reproduction of *T. zilli* population is successful and the population structure indicates a species that is well adapted.

Keywords: Cichlidae, *T. zilli*, sex ratio, gonad maturation, GSI, fecundity

INTRODUCTION

Tilapias of the family Cichlidae (Perciformes) originated from African (Gómez-Márquez *et al.*, 2003). Tilapias are known to be one of the important economically viable fishes in tropical inland waters of Africa and they play significant roles in the ecology of African freshwater systems (Ikomi and Jessa 2003, Jiménez- Badillo 2006). Fish is a source of food rich in protein for poor people which can play a significant role in improving Africa's food security and nutritional status. More than 200 million Africans eat fish regularly. Fresh, smoked, dried fish, or even as powder, is an essential source of dietary protein and micronutrients for many isolated communities in rural areas. Fish obtained through subsistence fishing efforts is essential and can make the difference between good and bad nutrition or between food security and starvation for many who cannot afford to buy meat (World Fish Centre, 2005). Fishes of the family Cichlidae have moderate sizes; inhabit shallow and vegetative areas (Eccles 1992). *Tilapia* is the common name for *Sarotherodon*; *Oreochromis* and *Tilapia* of the family Cichlidae of about 70 species (Meyer 2002). *Tilapia zilli* inhabits the fresh and brackish water rivers and are widely distributed within these waters (Meyer 2002). El-Sayed (2006) mentioned that *T. zilli* is known to be one of the most salinity-tolerant tilapia species and

can grow, survive, and reproduce at 10 to 30%, depending on the species, size and sex. Therefore, adequate management of the species will enhance fish production. Knowledge of reproductive capability is important in stock assessment, stock discrimination and rational utilization of stock, also studies on reproductive biology are needed to protect new recruits and predict recruitment variability (Offem *et al.*, 2008). Fish fecundity is important for evaluating the commercial potentialities of its stock, life history, practical culture and actual management of the fishery (Musa and Bhuiyan, 2007). Several authors have studied the biology of *Tilapia* (Faunce *et al.*, 2002; Ikomi and Jessa 2003; Negassa and Getahun 2003; Anene 2005; El-Sawy 2006; Akel and Moharram 2007; Negassa and Padanillay 2008; Mahomoud *et al.*, 2010). The goal of this study is to determine the sex ratio, gonad maturation, gonadosomatic index, fecundity and Virtual Population Analysis (VPA) of *T. zilli* which is aimed at providing basic information for the development of an appropriate fishery management of this specie.

Study area

The role of the Cross River is essential to the fishery of the inland waters of South Eastern Nigeria (Okoh *et al.*, 2007). Cross River originates from Cameroon and flows through Ebonyi State and Cross

River State into the Atlantic Ocean. The river (Fig. 1) (Okoh *et al.*, 2007) lies in the area between $5^{\circ}57''$ latitude $5^{\circ}30'20''$ North and $7^{\circ}58''$ longitude $5^{\circ}30'20''$ East. The approximate surface area of the Cross River is 3,900,000 ha (Ita *et al.*, 1985). The two main

seasons of the area are the rainy season and the dry season. The latter occurs between October and November - March, while the former is from April - September and October (Okogwu 2008).

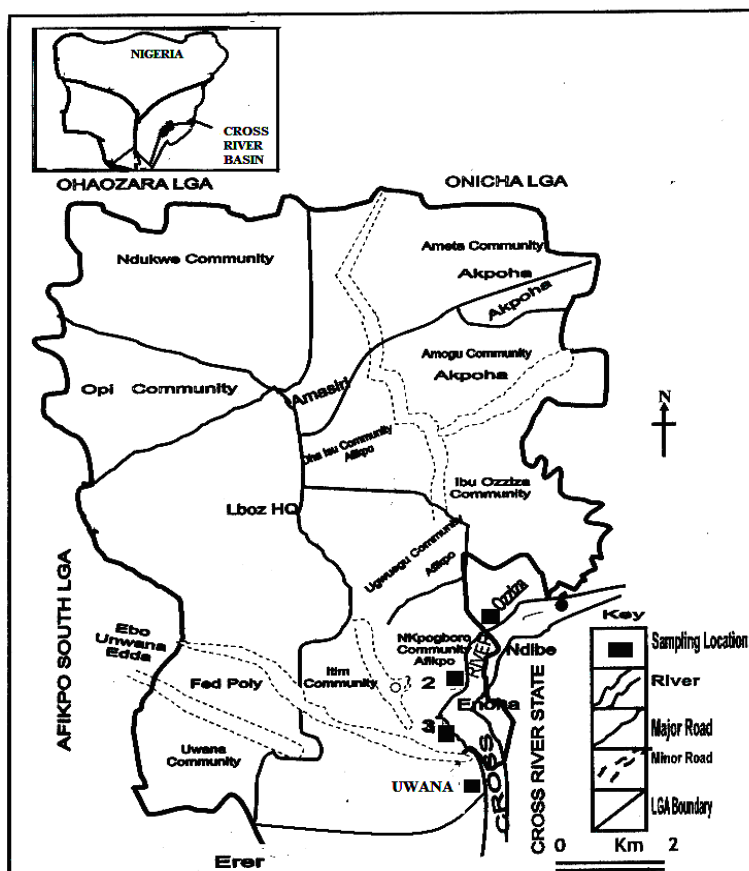


Fig. 1: Map of Afikpo North Local Government Area showing the sampling locations in the Cross River basin (Okoh *et al.*, 2007)

MATERIALS AND METHODS

Sample collection

The study was carried out on *Tilapia zilli* ($n = 4044$) population from Cross River basin South-eastern Nigeria. The study area is shown in Fig. 1. Monthly samplings were made by random samples of the catch of the commercial artisanal fishers using gillnets with various mesh sizes (18-55 mm), cast nets, lift nets, fishing baskets and traps between January 2010 and July 2011.

Morphometric measurements

The samples were sorted and identified to species level using the guides of Olaosebikan and Raji (1998). Sex determination, gonad maturation stage and fecundity were done through examination of the internal sex organs. The sex and the stages of

development of the gonad were determined by visual inspection and graded. The surrounding ovarian tissues were removed and the number of eggs in each pair of ovaries was determined by direct enumeration. Total length (TL) and Standard length (SL) were measured to the nearest 0.1cm with a meter rule measuring board. Weight measurements were made with a FEJ-1500A electronic compact weighing balance to the nearest 0.1g. Fish samples were preserved in 10% formalin as voucher specimens.

Reproductive biology

Sex ratio

Length-frequency distribution table was constructed the species population to determine the dominant size group(s) and their percentage

composition. Mean values of length and weight measurements were determined. Overall sex ratio and heterogeneity significance with the use of Chi square statistical analysis were determined.

Gonad maturation

Gonad maturation were evaluated macroscopically and categorized into four maturation stages (Ezenwaji and Offiah 2003) as follows: Immature stage (stage I), Mature stage (stage II), Ripe stage (stage III), Spent stage (stage IV). Chi square statistical analysis would be used to determine the significance difference in the sex ratio in all the stages.

Gonadosomatic index (GSI)

Gonadosomatic index (GSI) was estimated according to De Vlaming *et al.*, (1982) as:
 $GSI = \text{Gonad weight} / \text{Body weight} \times 100$

Fertility co-efficient (FC)

Fertility co-efficient (FC) was estimated according to the equation of Riedel (1969):
 $FC = E / TL^3$
 where E = number of eggs produced and TL = total length of female fish (cm).

Fecundity

Fecundity was also studied by gravimetric method (Hunter *et al.*, 1989). The procedure is as follows; the subsamples of 1 or 2 g according to the size of the eggs were taken from the front, middle and back parts of the ovaries. The number of the subsamples was multiplied up to the weight of the ovary. Nikolsky (1969) and King (1991) described the relationship between fecundity and total length and weight as:

$$F = aTL^b, F = aSL^b, F = aGW^b \text{ and } F = aWT^b$$

where F = Fecundity
 TL = Total length in cm
 SL = Total length in cm
 GW = Gonad Weight

WT = Body Weight

b = Slope of the regression line (regression constant).

a = Intercept of the regression with the y - axis (regression coefficient).

Regression analysis was used in the estimation of the a and b values and the level of significance of the value of co-efficient of correlation (r).

Virtual population analysis

Virtual population analysis (length structured VPA) is methods which allow the reconstruction of the population from total catch data by age or size. The initial step is to estimate the terminal population (N_t) given the inputs, from $N_t = C_t \cdot (M + F_t) / F_t$ where C_t is the terminal catch (i.e., the catch taken from the largest length class).

Then, starting from N_t , successive values of F are estimated, by iteratively solving,

$$C_i = N_{i+\Delta t} \cdot (F_i / Z_i) \cdot (\exp(Z_i \cdot \Delta t_i) - 1)$$

where

$$\Delta t_i = (t_{i+1} - t_i), \text{ and}$$

$$t_i = t_0 - (1/K) \cdot \ln(1 - (L_i / L_\infty))$$

and where population sizes (N_i) are computed from

$$N_i = N_{i+\Delta t} \cdot \exp(Z_i)$$

The last two equations are used alternatively, until the population sizes and fishing mortality for all length groups have been computed. An F-array representing the fishing mortality for each length group, the reconstructed population (in numbers), and the mean stock biomass by length class were made using FISAT II.

RESULT

Size composition

The length-frequency distribution (Fig. 2) of *T. zilli* (Plate 1) (n=4044) showed that the smallest and largest specimens were 6.5cm TL and 26.8cm TL, respectively (mean 16.6cm ± 0.86). The 11 to 15cm TL size groups were numerically dominant and constituted 67.2% of the population. There was only one mode at 13-14cm TL (Fig. 2). The weight ranged between 8.3 and 511.7g (mean 198g ± 25).

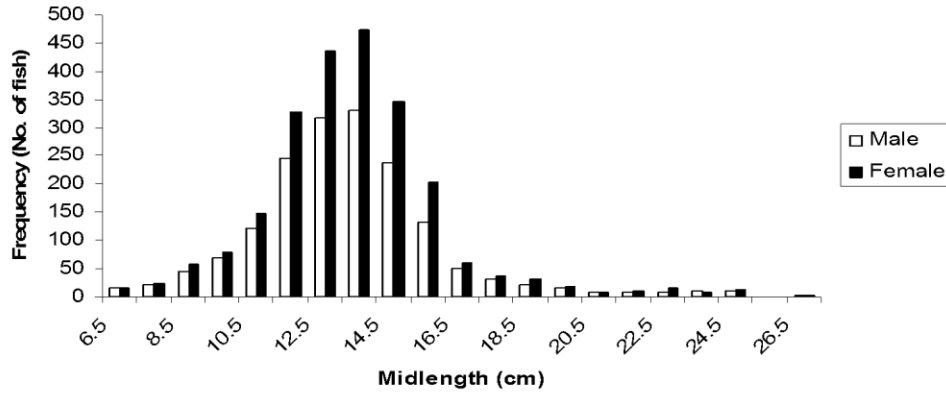


Fig. 2: Length-frequency distribution of male and female of *T. zilli*

Sex ratio

Variation in sex ratio with length class showed that females dominated markedly at 15-16cmTL (m: f = 1:1.6) and 22-23cm TL (m: f = 1:1.7) (Fig. 3) while males dominated in the 23-24 cm TL. Variation in sex ratio with the months showed that females dominated markedly in October 2010 (m: f = 1:1.6), November 2010 (m: f = 1:1.7) and December 2010 (m: f = 1:1.7) (Table 1). The overall sex ratio of 1:1.4 showed that females (n = 2342) were significantly more than the males (n = 1702) ($\chi^2 = 101.29$, df = 1, $P < 0.05$) (Table 1). Within the months, females dominated in all the months of the sampling period

(January 2010 - June 2011). Statistical analysis showed that there was significantly heterogeneity ($\chi^2 = 108.54$, df = 17, $P < 0.05$). In the dry season (January 2010 - March 2010 and November 2010 - March 2011), the males (n = 666, 41%) and females (n = 958, 59%) were significantly different in the number sampled, ($\chi^2 = 52.50$, df = 1, $P < 0.05$). During the rainy season (April 2010 - October 2010 and April 2011 - June 2011), males (n = 1036, 42.8%) differed significantly from females (n = 1384, 57.2%) ($\chi^2 = 50.04$, df = 1, $P < 0.05$). There were more females than males in both the dry and rainy seasons with sex ratio of 1:1.3 and 1:1.4 respectively.

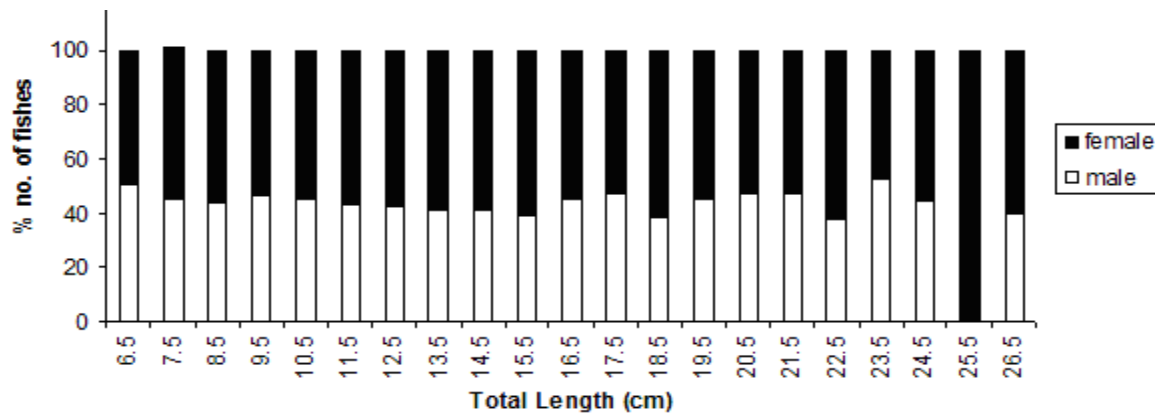


Fig. 3: Variation in sex ratio with (length class) size of *T. zilli*

Table 1: The monthly sex ratio (M:F) of *T. zilli*

Month	Number sampled			Sex ratio	
	Male	Female	Total	M:F	Calculated χ^2
JAN. 2010	71	87	158	1:1.2	1.62
FEB. 2010	75	101	176	1:1.3	3.84
MAR. 2010	71	101	172	1:1.4	5.23
APR. 2010	103	137	240	1:1.3	4.82
MAY. 2010	117	138	255	1:1.2	1.73
JUN. 2010	138	181	319	1:1.3	5.80
JUL. 2010	86	118	204	1:1.4	5.02
AUG. 2010	101	135	236	1:1.3	4.90
SEP. 2010	104	138	242	1:1.3	4.78
OCT. 2010	99	159	258	1:1.6	13.95
NOV. 2010	92	153	245	1:1.7	15.19
DEC. 2010	88	147	235	1:1.7	14.81
JAN. 2011	96	126	222	1:1.3	4.05
FEB. 2011	103	145	248	1:1.4	7.11
MAR. 2011	70	98	168	1:1.4	4.67
APR. 2011	80	110	190	1:1.4	4.74
MAY. 2011	99	120	219	1:1.2	2.01
JUN. 2011	109	148	257	1:1.4	5.92
TOTAL	1702	2342	4044	1:1.4	101.29
RAINY SEASON	666	958	1624	1:1.4	52.50
DRY SEASON	1036	1384	2420	1:1.3	50.04

Gonad maturation

Macroscopic examination of the gonad of *T. zilli*, revealed four maturation stages, immature, mature, ripe and spent stages. Percentage of male and female in each stage were as follows: In males 29.6% of the total fish were in immature stage (I); 41.1% were in mature stage (II); 25.9% were in ripe stage (III) and 3.4% in spent stage (IV). Therefore, 67% of total male fish were in the reproductive process. In females 26.8% of the total fish were in immature stage (I); 38.7% were in mature stage (II); 31.3% were in ripe stage (III) and 3.2% in spent stage (IV). In all, 70% of the total female fish were in reproductive process. Statistical analysis revealed that there were significant differences in the M: F sex

ratio in all the stages, immature stage ($\chi^2 = 13.58$, $df = 1$, $P < 0.05$), mature stage ($\chi^2 = 26.42$, $df = 1$, $P < 0.05$), ripe stage ($\chi^2 = 73.19$, $df = 1$, $P < 0.05$) and spent stage ($\chi^2 = 2.17$, $df = 1$, $P < 0.05$) (Table 2). Highest percentage of females was in the ripe stage (1:1.7) while the lowest percentage of females was in the immature stage (1:1.2). The smallest mature male and female were 9.8 and 11.0 cm TL respectively, while the median length at maturity (i.e. length at which 50% of the catch was mature) was 14.16 cm TL for both sexes. Thus, the species matured when it attained 51% of its asymptotic length. Estimated length (l_m) and age (t_m) at sexual maturity were 15.24 cm TL and 1.76 yrs respectively.

Table 2: Maturation stages dynamics of male and female *T. zilli*

Maturation stage	No (%) of	No (%) of	Sex ratio M:F	Calculated χ^2	p
	Male	Female			
Immature	504 (29.6)	628 (26.8)	1:1.2	13.58	0.05
Mature	700 (41.1)	906 (38.7)	1:1.3	26.42	0.05
Ripe	440 (25.9)	733 (31.3)	1:1.7	73.19	0.05
Spent	58 (3.4)	75 (3.2)	1:1.3	2.17	0.05
Total	1702	2342	1:1.4	101.29	0.05

Gonadosomatic index (GSI)

The gonadosomatic index (GSI) of *T. zilli* was 3.16 ± 0.46 (males) and 7.44 ± 1.85 (females) ranging between 0.3 and 19.5. Monthly variations in GSI revealed that both sexes followed nearly the

same pattern. GSI showed higher values during the period from May to September with a peak in June while the lower ones occurred during the period from October to February (Fig. 4). From Fig. 4, it is clear that females acquired higher GSI over males.

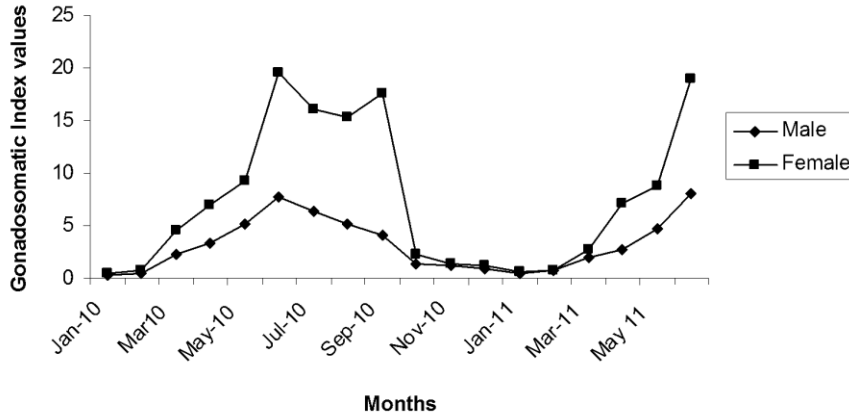


Fig. 4: Monthly gonadosomatic index of *T. zilli*

Fecundity

The number of eggs per clutch of *T. zilli* ranged from 628 (12.1cm TL, 38.3g) to 3631 (25.6 cm TL, 241.3g) with a mean of 1583 ± 898 eggs. The fertility co-efficient for the fish was 0.30 ± 0.08 with highest and lowest values in females with 18.0cm TL, 2950 eggs (0.51) and 17.4cm TL, 906 eggs

(0.17) respectively. Fertility co-efficient did not have any correlation with the length. Fecundity was positively correlated with total length (TL), standard length (SL), total weight (TW), and ovarian weight (OW) (Table 3). It is worthy to note that fecundity varied with total length by a factor of 2.52 and standard length of 2.56 (Table 3).

Table 3: Functional equation showing the relationship between fecundity (F) and other variables of *T. zilli*

Functional equation ($F = a X^b$)	Correlation coefficient (r)	r ²	p
$F = 1.109 (TL)^{2.52}$	0.988	0.977	0.05
$F = 1.621 (SL)^{2.56}$	0.981	0.963	0.05
$F = 2.106 (TW)^{1.48}$	0.968	0.936	0.05
$F = 166.341 (OW)^{1.08}$	0.668	0.446	0.05

Key: TL = Total length, SL = Standard length, TW = Total weight, OW = Ovarian weight

Virtual Population Analysis (VPA)

VPA results for *T. zilli* indicated one peak (Fig. 5) of fishing mortality (F). The peak of F occurred in the length class 13.0 to 14.0cm TL with

midlength of 13.5cm, F mortality of $0.99yr^{-1}$ with catch in number as 1210881 and population of survivors as 13019479.59. Recruitment to fishery was 77075319.18.

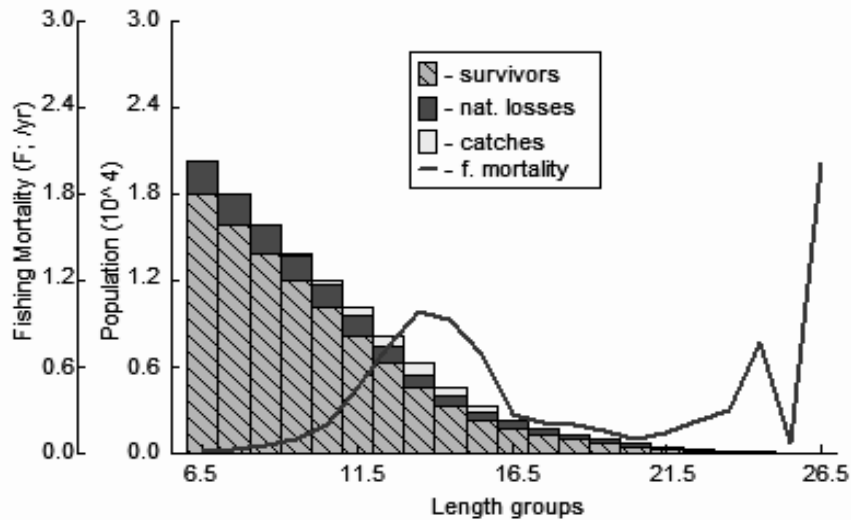


Fig. 5: Length structured Virtual Population Analysis of *T. zilli* in the mid Cross River basin, Nigeria

DISCUSSION

Population structure

In this study, 4044 samples of *T. zilli* were analysed with the length range of 6.5-26.8cm TL. The 11 to 15cm TL size groups were numerically dominant and constituted 67.2% of the population with only one mode at 13-14cm TL. This is in line with the Virtual Population Analysis (VPA) results which revealed the peak of fishing mortality (F) in the length class 13.0 to 14.0cm TL which might be associated with the use gillnets with various mesh sizes (18-55 mm), cast nets and lift nets used by the artisanal fishers in the river system.

Sex ratio

The overall sex ratio of *T. zilli* of this study with sex ratio of 1:1.4 favouring the females over the males is in agreement with the findings of Akel and Moharram (2007), with the overall sex-ratio (M/F) of *T. zilli* from Abu Qir Bay, Egypt as 1:1.05. However, occurrence of males was relatively higher than females in autumn (52.7%) and winter (56.7%),

while for females, sex ratio was found to occur in higher percentage in summer (54.5%). Chi square test showed insignificant seasonal differences between the sexes ($P < 0.05$); this was in contrast with the findings of this study in which females had higher occurrence throughout the sampling period and showed significant difference between both sexes. Overall sex ratio (M/F) of *T. zilli* from Lake Timsah Egypt, 1:0.9 (Mahomoud *et al.*, 2011) and 1:0.97 from Lake Edku (El-Sawy 2006), were not in agreement with this study. Similarities in findings may be related to the fact that the species are the same while differences may not be unconnected to dissimilarities in population and environment. Mahomoud *et al.*, (2011) pointed out that in the African lakes; it is common in the cichlid populations that males dominated because they generally exhibited more growth than females (Table 4). The sex ratio favouring females obtained in this study of *T. zilli* may be related to the genetic factor set up to ensure constant and continuous procreation for the regeneration of the stock.

Table 4: Comparative results of the sex ratio of other cichlid fishes in different localities

Species	Sex ratio(M/F)	Authors	Calculated χ^2
<i>Oreochromis aureus</i>	1:0.76	Messina <i>et al.</i> , (2010) Aguamilpa Reservoir, Mexico.	33.36*
<i>Tilapia mariae</i>	1:0.9	Olurin and Odeyemi (2010) Owa Stream, South - West Nigeria	0.007 n.s
<i>T. mariae</i>	1:0.66	Soyinka and Ayo-Olalusi (2009) Badagry Lagoon, Nigeria.	NA
	1:070	Ologe Lagoon, Nigeria.	
<i>T. mariae</i>	1:1.56	Anene and Okorie (2008) Umuoseriche man-made lake, Nigeria.	3.976*
<i>Sarotherodon galilaeus</i>	1:1	Offem <i>et al.</i> (2009) Cross River inlands	NA
<i>Hemichromis fasciatus</i>	0.5:1	wetlands, Nigeria	
<i>Hemichromis bimaculatus</i>	1:0.3		

* Significantly different, n.s no significant difference, NA not available

Gonad maturation

Data on gonad maturation of *T. zilli* in this study showed that 41.1% of males were in mature stage (II) and 25.9% were in ripe stage (III). Therefore, 67% of total male fish were in the reproductive process. 38.7% of females were in mature stage (II) and 31.3% were in ripe stage (III). So, 70% of the total female fish were in reproductive process. This was in agreement with the findings of Akel and Moharram (2007) who reported that percentage of gonadal maturity stages of *T. zilli* from Abu Qir Bay, Egypt were as follows: In females 37% of the total fish were in mature stage (III) and 31% were in ripe stage (IV), therefore, 68% of total fish were in the reproductive process. In males 41% of the total fish were in mature stage (III) and 24% were in ripe stage (IV). So, 65% of the total fish were in reproductive process. The smallest mature male and female *T. zilli* of 9.8 and 11.0 cm TL respectively of this study were in contrast to the findings of *T. zilli* in Lake Timsah, Egypt in which the smallest mature male observed was 8.4 cm total length and the smallest mature female was 7.5 cm total length (Mahomoud *et al.*, 2011). The present study also disagreed with Akel and Moharram (2007) in Abu Qir Bay in that females (8.7 cm) reach their first sexual maturity before males (9.7 cm) and also in disagreement with Lake Manzalah 8.6 cm (females) and 10.1 cm (males) (El-Shalloof 1991). In Lake Borollus, both sexes reached first sexual maturity at the same length 7 cm (El-Haweet 1991). The findings of this study showed that males reach their sexual maturity first before the females. However in

agreement, the smallest mature male was 8 cm TL while the female was 9 cm TL, indicating that males reached first sexual maturity at smaller lengths than females in Lake Edku, Egypt (Phillips 1994). The differences in length at first sexual maturity may be attributed to differences in genetical and environmental conditions such as food supply, population density and changes in temperature and salinity (Mahomoud *et al.*, 2011).

Gonadosomatic index

As stated by Mahomoud *et al.*, (2011), monthly variations in gonadosomatic index (GSI) showed that both sexes of *T. zilli* in Lake Timsah Egypt followed nearly the same trend. In females, several peaks of GSI values were observed during January, April, June and August meaning that females could breed more than once in the season and the period from January to August represented the spawning (breeding) period of the stock in the region. It was also clear that females acquired higher values of GSI than males. However, in this present study, higher GSI values were from May to September with a peak in June indicated the breeding period and females also had higher GSI values than males. The present study was in agreement with Maclaren (1981) who reported that cichlids exhibited prolonged spawning season in Lake Manzalah extending from April to September. Negassa and Getahun (2003) reported that breeding in *T. zilli* in Lake Zwai (Ethiopia) is all year round with peak breeding between April and September. The observations in this study were similar to those in other localities: In

Lake Borollus (El-Haweet 1991); Lake Mariut (El-Shazly 1993) and Lake Edku (Phillips, 1994). Also, Negassa and Padanilly (2008) stated that indeed, fish with well-developed gonads were noted almost throughout the year.

According to Offem *et al.* (2012), analysis of the average monthly values of GSI and the frequency distribution of the maturation stages, showing the presence of ripe stages in the ovary throughout the year, indicate a polycyclic breeding habit for *T. zilli* in Agbokum waterfalls. This is also in agreement with the findings of this study, indicating that *T. zilli* in the mid Cross river basin exhibits a polycyclic breeding habit.

Fecundity

The absolute fecundity (628 - 3631, mean 1583 ± 898 eggs) of *T. zilli*, in this study, attained lower values than in other areas. Akel and Moharram (2007) stated that the variation of fecundity within wide limits of fishes of the same length may be due to ecological conditions, genetic factors or total amount of energy given to the ovary during gonad maturation. Functional equations showing the relationship between fecundity (F) and other variables (X) of *T. zilli* as obtained in this study ($F = 1.109 (TL)^{2.52}$, $F = 1.621 (SL)^{2.56}$ and $F = 2.106 (TW)^{1.48}$ (where TL, SL and TW are total length, standard length and total weight respectively) agreed with the equations of *T. mariae* of Umuoseriche Lake, Nigeria ($F = 0.006 (TL)^{2.49}$, $F = 0.071 (SL)^{2.11}$ and $F = 18.499 (BW)^{1.02}$) (Anene and Okorie 2008). However the relationship between fecundity (F) and ovarian weight (OW) ($F = 166.341 (OW)^{1.08}$) was in contrast ($F = 448.81 (OW)^{0.629}$). This may be related to the varying number of eggs among fishes with the same ovarian weight. It is worthy to note that in this study, fecundity varied with total length by a factor of 2.52 and standard length of 2.56, indicating that fecundity approximate the square of the body length. Calculations with total length instead of standard length may cause slight differences in the values while the use of fish weight to determine the fecundity should be treated with caution since somatic weight changes near the spawning period and thus introduces errors.

Virtual Population Analysis (VPA)

The length-structured VPA is an important tool for stock assessment by which the size of each cohort is estimated alongwith the annual mortality caused by fishing. The highest peak of F was 0.99 yr^{-1} and evident in the 13-14cm TL length group which might be associated with the use gillnets with various mesh sizes (18-55 mm), cast nets and lift nets used by the artisanal fishers in the river system. Catch in

number was 9.3% (1210881) of the survivors indicating a stable and viable population.

CONCLUSION

Findings from this study indicate that *T. zilli* in the mid Cross River has female preponderance. *T. zilli* exhibit a polycyclic breeding habit. Virtual Population Analysis (VPA) indicates that dominance in number contributes to fishing pressure but not directly related to it. Smaller fish dominated in this population therefore should be used for the species conservation. Reproduction of *T. zilli* population of the mid Cross River basin is successful and the species, well adapted, therefore can provide excellent broodstock.

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