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Reproductive potential of Nile tilapia (*Oreochromis niloticus* Linnaeus, 1757) in the Golinga reservoir in Ghana

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Abstract
The study investigated the reproductive potential of *Oreochromis niloticus* by assessing the developmental stages of gonads, the fecundity and the environmental conditions (water quality) in which the fish lives. It was conducted for six months (November 2006-April 2007) with fortnight sampling of fish. Of a total of 115 fishes sampled, males were 42 and females 73. Of the 73 females 14 were gravid. For the stages of gonad development, immature (white coloured gonads) were 7.14%, maturing (yellow coloured gonads) represented 7.14%, ripe (deep green coloured gonads) was 50% and those spent (red, flaccid coloured gonads) were 35.7%. Fecundity of the fish ranged from 137-250 oocytes/eggs. Gonado-somatic index (4.49) and condition factor (4.07) were highest in April. The pattern of gonad development indicated that spawning in the species was not synchronized, however, spawning peaked in April. The water quality parameters measured were within the tolerable limits for growth of the fish.

Keywords: Gonads, Gonado-somatic index, fecundity, condition factor, *Oreochromis niloticus*

1. Introduction

Fish production processing and trade generates income to over 10 million Africans. Ghana is the leading consumer of fish in West Africa and about 69% of the dietary animal protein of Ghanaians comes from fish (Ahmed *et al*, 2005; Bene and Heck, 2005) [1, 2]. About 80 species of fish are referred to by the common name Tilapia which belongs to the tribe; Tilapiini an exclusive African group of fish within the family Cichlidae. The three main genera are: *Oreochromis* (maternal mouth-brooders), *Sarotherodon* (paternal or biparental mouth-brooders) and *Tilapia* (substrate spawners). The grouping is based largely on differences in their reproduction, feeding habits and biogeography (Brainage and Roberts, 1995) [3].

In Northern Ghana fishing is done mainly in rivers, dug-outs, dams and in reservoirs. Fish is used as food and some sold in the local markets for income. The two most prominent species that are of economic importance in the capture fisheries are *Oreochromis niloticus* and *Sarotherodon galilaeus*. The Ministry of Food and Agriculture (now Ministry of Fisheries and Aquaculture Development) has been promoting the farming of *O. niloticus* for nearly two and half decades ago, however, the choice of *O. niloticus* is based widely on the recognized attractive cultural attributes and its importance in world aquaculture rather than the local experience conditions (Owusu-Frimpong *et al.*, 2005) [12]. According to Brainage and Roberts (1995) [3] diversity of replication in aquaculture coupled with a high growth rate and wide consumer acceptability have made *O. niloticus* virtually unique as a potential global food-fish and justifies its popular accolade as an “aquatic chicken”. The attributes which make Nile tilapia *O. niloticus* suitable for fish farming are its general hardness, ease of breeding, rapid growth rate, ability to efficiently convert organic and domestic wastes into highly quality protein and high consumer acceptability. This has attracted many studies on the species in the water bodies in and around Northern Ghana. Over the years consumer’s perception about fish has increased favourably because the mind set of consumers encompasses attributes such as healthiness, naturalness and convenience of the use of fish. A number of preliminary studies have been carried out in many water bodies in Northern Ghana of which Golinga is not exclusive. The species composition, sex ratios, length-weight relationship and gonad assessment have been researched into and documented on *O. niloticus* in the Golinga reservoir.

This study examined the reproductive potential of *O. niloticus* by looking at the stages of gonad development, fecundity and their related features (i.e. total and standard lengths, total weight and the condition factor). Some physico-chemical parameters such as temperature, pH, conductivity, and transparency which affect the reproduction of all fishes were monitored within the study period.

2. Materials and Methods

2.1 Study Area

Golinga is the study area and it is about 12km north-west of Tamale. It is located on latitudes 9^0 and 10^0 N and on longitudes1^0 and 2^0 W. The total surface area of the reservoir is 80 ha. Golinga is located within the Guinea savannah zone of the country and it is boarded by three communities namely Gbulaligu, Golinga and Galinkpegu.

2.2 Species Identification;

The study was conducted in six (6) months (i.e. from November 2006 to April 2007) with fortnightly visits in each month. The species were identified by closely examining the shape and position of the mouth parts and mouth respectively, the body colour, and by counting the number of rays and fins (Holden and Reed, 1972) [8].

2.3 Sexing

The identified species which were above 20g (fish with weights > 20g have visible reproductive organs for easy sorting) were sorted into males and females by observing the shape of the genital papillae with the aid of a hand magnifying glass

2.4 Body Measurements

The standard length {SL} (i.e. from the tip of the snout to base of the caudal fin and the total length{TL} (i.e. from the tip of the snout to the end of the caudal fin) were measured to the nearest 0.1cm for each fish using a measuring board. They were then weighed to the nearest 0.1g using a kitchen scale.

2.5 Gonad Study

Fish that were above 20g were dissected and inspected for the presence of gonads and milt. The colours of the gonads (eggs) present were recorded for determination of the stage of maturity of the eggs. They were then placed into plastic containers with tight fitting lids and then taking to the laboratory. In the laboratory, they were weighed to the nearest 0.1g using an electronic scale. Matured (deep green) gonads were dissociated into single (individual) eggs for easy counting using five (5%) formalin solution to determine the fecundity.

2.6 Physico-chemical data

Temperature, Conductivity and pH were measured using a wagtech meter and Dissolved Oxygen (DO) using an oxymeter (model: OXI 45). Three (3) sampling sites were established across the reservoir thus at the southern end, the middle and the northern end. The probeof each instrument was immersed 20-30cm deep at various locations into the water and the readings taken after 2-3minites when the values on the screens of the instruments had stabilized on each visit. Water samples were also collected in 5ml bottles and tested for turbidity using a turbidimeter (model: 2020).

2.7 Data Analysis

Gonado-somatic Index (GSI) was calculated using the formula:

$$Gonado-somatic\ index = \frac{Gonad\ weight}{Total\ body\ weight}\ x\ 100$$

The mean monthly Condition Factor (K) was computed using the formula:

$$K = \left(\frac{W}{SL^3}\right) x\ 100$$

Where: K = condition factor, W = weight of fish in grammes and SL = the standard

Fecundity verses body length was computed, using the relationship**:**

$$Fecundity = a\ Total\ lenght^b$$

Where a and b are constants

Mean monthly records and ranges of temperature, pH, conductivity, turbidity and dissolved oxygen (DO) were computed using Microsoft excel and presented in a table. A graph was used to show the relationship between the mean monthly temperatures, turbidity and dissolved oxygen as these were closely related.

3. Results

3.1 Sex Ratio

A total of 115 fishes were obtained during the study period. Males were 42 (36.52%) and females 73 (63.58%) in Table 1 below. Females (39 fish) were more in January 2007 and April 2007 and males (24 fish) in November 2006 and December 2006.

Table 1: Sex ratio of monthly samples *Oreochromis niloticus*

Months	Total №	Males	Females	Sex Ratio M:F	$\chi^2(P<0.05)$ $\chi^2=11.070$	$\chi^2(P<0.05)$ $\chi^2=3.841$
November 2006	13	10	3	3:1	9.143	S
December 2006	10	4	6	1:5	0.052	NS
January 2007	39	14	25	1:8	0.006	NS
February 2007	16	8	8	1:1	1.258	NS
March 2007	13	1	13	1:1	5.206	S
April 2007	24	8	42	1:2	2.254	NS
Total	155	42	73	1:1.7	17.920	S

S=significant and NS not significant at $p<0.05$, $\chi2=11.070$ at a degree of freedom (df) = 5 for the whole study period and $\chi^2=3.814$ at a degree of freedom (df) = 1 for each month.

3.2 Body Measurements
The 115 fishes that were studied ranged from 10cm as the minimum in December 2006, an average of 13.05cm and a maximum of 18.1 cm in April' 07 for the total length (TL) and 6.0cm as the minimum in December 2006, an average of 10.5cm and a maximum of 15cm in April 2007 for the standard length (SL) of the fish. The body weights of the fish were 20g, 40g and 120g for the minimum, average and maximum respectively. In figure 1, the relationship between body length and weight was positive (R^2= 0.03).

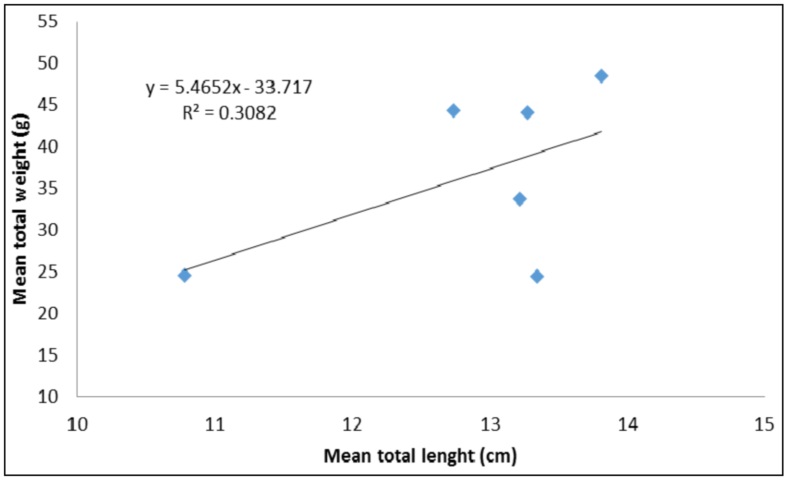

Fig 1: Relationship between total length-total weight of *Oreochromisniloticus*

3.3 Stages of gonad development
Out of the 73 females, gravid were 14 and the remaining 59 were non-gravid. Of the 14 that were found to be gravid the following stages were identified.

- Immature(white) = 7.14% occurred in January 2007
- Maturing(yellow) =7.14% in March 2007
- Ripe(deep green) = 50% in April 2007
- Spent (red, flaccid)= 35.7% in March 2007.

3.4 Condition factor and gonadosomatic index
The condition factor (K) was highest in April 2007 and lowest in November 2006. The highest gonado-somatic index (GSI) was recorded in April 2001 and the lowest record was in November 2006.

3.5 Fecundity (F)
There were zero (0) records of fecundity from November 2006–February 2007, however, in March, 162 matured (deep green) oocytes/eggs were counted from a single female. Most of the remaining females had their gonads still forming (white coloured). About 874 matured (deep green) oocytes were counted from five (5) females with lengths ranging from 13-15.00cm for the total lengths and 10.0-12.5cm for the standard lengths in the month of April. Analyses of the relationship of fecundity with fish total length (TL) for all the examined fish (i.e. those with matured eggs(deep green) revealed that, the correlation between fecundity and body length expressed by the relationship ($F = 0.10TL^{2.86}$) was higher (r=0.873, *p*<0.001) than the correlation of fecundity versus body weight (r= -0.310, *p*<0.001) which was expressed as Log F = 363.08 + (-0.34)Log TW where F= fecundity (oocytes/fish) and TW= Total weight (g). The mean fecundity obtained for tilapia through the direct summation procedure was 173 oocytes. Oocytes number increased with ovarian weight in fishes that had eggs which could be counted.

3.6 Physico-chemical Parameters
Maximum temperature of 29.15ºC was recorded in the months of November 2006 and April 2007, a minimum of 24.0ºC occurred in January'07. Conductivity kept rising from 0.14 to 0.29µS/cm and that of pH remained relatively constant throughout the study period (November 2007- April 2007). Dissolved oxygen (DO) kept fluctuating with high values in windy days and low values in non- windy days. Turbidity also increased from 9.68NTU-24.00NTU from November 2006 to April 2007.
The relationship between the mean monthly temperature, dissolved oxygen and turbidity as these parameters are directly related (data not shown).

4. Discussion
The reproductive potential of *O. niloticus* in the Golinga reservoir was studied from samples collected every month for a period of six (6) months from November 2006 to April 2007. The critical χ^2 value from the chi-square (χ^2) distribution table is 11.070 tested at 5 degrees of freedom. Since the χ^2 calculated (17.920) is greater than the critical χ^2 value then we conclude that there is significant differences between the sex ratio of *O. niloticus*. Hence the sex ratio of 1:1.7, significantly is 1:2 (χ^2=17.920, *P*<0.05). This indicates that, males and females are different in numbers and the deviation from the expected 1:1 (male: female) was significant. Onimisi and Ogbe (2015) [11] also reported differences in males and females numbers of the same species in Nigeria in a resent study. However, our results are not in line with the findings of other studies (Gomez-Marquez *et al.*, 2003 Pena-Mendoza *et al.*, 2005; Gómez-Márquez et al 2008) [6, 13, 7] on the same species in different places in which the sex ratio was significantly 1:1. We believe that reason for female dominance is because between January 2007 to April 2007 which makes the spawning season, females were always more than males, as they were trapped by the seine nets of fishermen whiles spawning in vegetation at the edges of the reservoir. Moreso, increase in turbidity from February 2007 to April 2007 possibly gave these seine nets a concealing colour, so were not easily seen by the fishes, thereby making visibility and differentiation of the nets from the water very difficult. Also spatial segregation could be the possible course of different sex ratios (García-Lizárraga *et al.*, 2011) [5]

Correlation (r = 0.561) between the mean total length and mean total weight is positive. This means that increase in fish length results in a corresponding increase in fish weight, hence agrees with Salifu (2006) [14]. However as to whether the fishes were growing isometrically or allometrically, that was not looked in this study.

The monthly gonado-somatic index (GSI) of females ranged from 0.24 to 4.49. Higher GSI values were recorded in April. This pattern of gonad development for females indicated that the spawning of *O. niloticus* was not synchronized since females had different reproductive cycles (i.e. from November 2006 – April 2007). Our results seems to be slightly higher than reported by Onimisi and Ogbe (2015) [11] with GSI for females ranging from 0.12 to 3.92. In spite of the percentage variation in the gonadal stages of females, the periodicity of spawning for *O. niloticus* at Golinga indicates that the breeding season and the reproductive cycle begins around January and reaches its peak in April-May where there is increase in food abundance from run-off during the onset of the rains. This corroborates the highest condition factor recorded in the month of April. This revelation agrees with Turner and Robibson (2000) [11, 6]. In contrast, Onimisi and Ogbe (2015) [11] reported the spawning season to span from May – October. We are of the opinion that water quality parameters such as temperature fluctuations and the availability and abundance of food could be determinants of spawning and gonad maturation. In this study, temperatures kept increasing from January to April. There was also an observed increase in GSI from immature to ripe gonads during this same period with an increase in spawning intensity especially in the months of March and April. The increase in GSI is as a result of increased food availability and increased metabolism as temperature increases. The above observations are in line with other work (Mark *et al.,* 2004; García-Lizárraga *et al*., 2011) [10, 5]. Duponchelle and Legendre (2000) [4] mentioned that most of the breeding activity of *O. niloticus* was spread over a period from January to September, with a peak between April-May and July. This confirms the high proportion of resting females between July and December as found in our study with zero (0) or no records in gravid females between the months of October-November. This however is not in line with the results of a very recent study (Onimisi and Ogbe, 2015) [14]. The reason could be attributed to the abundance of food linked to differences in seasonality.

The study of fecundity helps in ascertaining the total number of eggs produced by a matured female. In other words, how prolific a female can be. This may be useful in designing breeding programs. Fecundity of fish seems to vary from study to study. For instance Gomez-Marquez *et al*. (2003) [6] had a fecundity range of 104 to 373. In this study, the fecundity ranged from 137 to 250. This falls almost within the same range. It however differs from Pena-Mendoza *et al* (2005) [13] who had a wider range (243 to 847) and Onimisi and Ogbe (2015) [14] reporting a range of 219 - 1321. Fecundity positively correlated (r=0.873, p<0.001) with fish total length (TL).This agrees with the results obtained by Gomez-Marquez *et al* (2003) [6] and Shoko *et al*., (2015) [15]. However, the regression analysis of fecundity with body weight tends to disagree with their results since fecundity was found to be negatively correlated (r = - 0.310, p<0.001) with body weight. Bigger/heavier females do not necessarily have more eggs. The variation in fecundity may be attributed to differential abundance of food within the members of the population, and fish species exhibit wide fluctuations in fecundity among fish of the same species, size and age. In addition, fecundity is largely dependent on environmental factors such as temperature, altitude and latitude and these factors vary from one location to the other.

Sexual maturity is a function of size and may be influenced by the abundance and seasonal availability of food, temperature and by other environmental factors (Gomez-Marquez *et al*, 2003) [6]. The physico-chemical parameters (temperature, pH, conductivity and Dissolved Oxygen) were relatively good comparing it to findings of John *et al* (1993) [9]. However, turbidity, which measured up-to a mean of 23.45 NTU, exceeded the ideal standard (< 20 NTU)) for the good health of the fish. This might have posed problems with breeding and feeding activities, therefore accounting for the low numbers (total sample size) and smaller sizes of *O. niloticus* in the reservoir. The increase in turbidity was as a result of the increase in the concentration of suspended particles from fine soil deposit from the hamattan winds (i.e. in the months of December 2006 - January 2007) coupled with a decrease in water volume (i.e. fetching of water for domestic use and for the irrigational of crops). Continues stirring of the water by fishermen during their fishing activities made the water turbid at all times. In terms of management of natural stocks or even in aquaculture, turbidity should be a potential factor to consider as this could influence the success of natural or artificial propagation.

Increase in temperature corresponded with a decrease in dissolved oxygen because warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic life. Increase in temperature exerts a major influence on the biological activity and growth of aquatic organisms. The higher the water temperature, the greater the biological activity in cold-blooded aquatic organism. Growth rates in aquatic animals doubles if temperature increases by 10°C. This is because the rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity (feeding and breeding) hence more demand for oxygen. This explains the reason why increase in temperature corresponds with a decrease in dissolved oxygen. Increase in turbidity reduces sunlight penetration in the water due to the presence of the suspended particles. This limits the photosynthetic activity of aquatic micro and macrophytes, so reduces the amount of oxygen been released into the water. This also gave the reason why oxygen decreased with an increased in turbidity. Taking all the above interplay of physico-chemical factors we can reasonably assumed that growth of fish in the reservoir could have been better than found. There calls our attention for further research in the future.

5. Conclusion

The sex ratio (1:2) of *O. niloticus* is a good indication that the population will increase with time since females are more. Breeding of *O. niloticus* begins around January and reaches a peak in April-May. The mean fecundity of *O. niloticus* is 173 oocytes. The physico-chemical parameters generally are optimal for the survival, growth and reproduction of *O. niloticus* and other aquatic species. However, some sort of attention could be given to help reduce the turbidity levels. The off season of fishing (Apr-Oct) should be observed since that is the period of reproductive activities for most tilapia species as indicated in figure 1 on the spawning period of *O. niloticus*.

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