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Original Article

Sex Ratio, Fecundity, Gonado-Somatic Index, Length-Weight Relationship and Growth Condition of *Sarotherodon melanotheron* (Rüppell, 1852) inhabiting Lagos Lagoon, Nigeria

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ABSTRACT

This study estimated the sex ratio, fecundity, gonado-somatic index, condition factor and length-weight relationship of *Sarotherodon melanotheron* inhabiting Lagos Lagoon, Nigeria. A total of 80 fish samples were collected fortnightly with castnets in August 2020, and the sex ratio (3.21:1) was male biased (X^2 = 22.05) and revealed a significant deviation from the expected 1:1. The minimum and maximum number of eggs counted in the fish were 251 and 370, respectively, while the mean was 331.37±55.64. The female fish had the highest gonado-somatic index, GSI (3.11%), followed by combined sexes (1.44%) and males (0.82%). The regression equation of the length-weight relationship indicated hypoallometric growth for males (W = 1.58L-0.07) and combined sexes (W = 1.74L-0.50), and hyperallometric growth for females (W = 3.15L-4.42). The condition factor ranged from 1.86 (female) to 2.20 (male), while the K of both sexes was 2.11. The result also revealed that TL (r = 0.975), SL (r = 0.931) and WT (1.000) of the fish were positively and significantly correlated with the fecundity of the fish at $p < 0.05$. This study therefore established that the study area was conducive for the fish and that their fecundity was directly proportional to their sizes. For conservation and management of *S. melanotheron*, it is recommended that monitoring of fishing be ensured.

1. Introduction

Fisheries stock assessments quantify a fish population's biomass and age structure, as well as providing detailed information on average egg production, sex ratio, and feeding habits. This data assists fisheries manager in detecting changes in fish condition over time [1; 2]. Sex ratio variation is a longstanding theme in evolutionary biology. The sex ratio provides basic information to assess the reproductive potential and estimates the stock size of fish populations. The knowledge of the sex proportion of naturally existing fish is crucial because it allows for the estimation of differential fishing in various seasons and size groups [2]. It can also provide data on the sex ratio's abundance at various times of the year, such as during breeding season. It also gives data that is useful in determining a population's reproductive capacity [3].

According to Fryxell *et al.* [4], natural selection should maintain 1:1 sex ratio by consistently favouring the rare sex, thereby always returning skewed sex ratios to equality. Differential death rates for males and females, endocrine-disrupting environmental contaminants, inbreeding and local competition for mates, and adaptive maternal effects that allow differential investment in male or female offspring are all explanations for skewed sex ratios in nature [4, 5 and 6]. Despite the focus on the causes of sex ratio variation in nature, its implications for population growth, and, in some cases, its consequences on communities and ecosystems [6], data on the sex ratio of *S. melanotheron* in Lagos lagoon is scarce and this may be attributed in part to the assumption that the sexes of most species are ecologically comparable in their impacts on communities and ecosystems.

Meanwhile, many species exhibit considerable sexual dimorphism in body size and other ecologically important features. Sexual size dimorphism can possibly impact resource use since prey capture is size-dependent and body size influences overall feeding rates [4]. Rates of nutrient excretion are also influenced by body size and physiology, which has substantial implications for ecological processes [7]. Males and females can have dimorphic physical or behavioural features, which might affect resource usage. Fisheries researchers and management utilise the length-weight relationship to build a mathematical relationship in which the value of one variable is estimated if the other is known using an established equation, and to determine the

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fish's growth pattern. The length-weight relationship reflects the health of the fish and allows for comparisons of the relationship's characteristics among species from different regions [8]. The condition factor is a method for determining a fish's physical condition and seasonal variation in well-being [2]. The purpose of determining the condition factor of a particular fish population is to know if it weighs more or less than would be expected based on its length [9].

Tilapias (Cichlidae) are a family of African native fish that have been introduced to a few other countries. *Sarotherodon melanotheron* is typical estuarine species that is native to coastal regions of West Africa. The species is significant in the fisheries of brackish water systems since it makes up a significant share (50–95%) of the overall catch in brackish environments [10]. *S. melanotheron* is capable of surviving and reproducing in a variety of salinities by limiting its growth, reducing the size-at-maturity, and altering its fecundity. It is a paternal mouthbrooder that displays minimal sexual dimorphism. The heads of adult males are often slightly larger than the heads of females [10]. *S. melanotheron* is of tremendous economic significance because it not only provides protein for human use but also significantly influences the coastal economy [8].

Tilapias start spawning while they are just a few months old, and their weight is usually below market value. Early sexual maturity may have a detrimental impact on growth rate as well. The large number of fishermen engaged with fishing utilizing different fishing gears can adversely affect the natural stock and may prompt overfishing [1]. Many works had been done on several aspects of the biology of *S. melanotheron* [11, 12, 13, 14, 15, 16 and 17]. Amazingly, there is dearth of information on the reproductive biology of *S. melanotheron* in Nigeria. In fact, there is already sign of decrease in stock being experienced by the fishermen in the Lagos lagoon [18, 19].

Unfortunately, the impacts of fishing activity on the natural stocks of fish in the Lagos lagoon are hard to evaluate because of scarcity of studies on the status of natural stocks of the fish in the area [8]. Such circumstance makes it hard for the relevant agencies to implement sustainable management of the fishes in the environment. Hence, this study was conducted to address the information and knowledge gap in the length-weight relationship, sex ratio, gonado-somatic index and growth condition of *Sarotherodon melanotheron* in the Lagos lagoon in order to help in the management of the species for fishery development, food security, conservation and sustainable socio-economic development.

2. Materials and Methods

2.1. Study Area

The Lagos lagoon (which is found within the heart of the Lagos Mega City) has a surface area of 208 km^2, lies between Longitude 003º 24.473'E and Latitude 06º31.048'N (Figure 1). It is an open, shallow, and tidal lagoon that is characterized by fresh and slightly brackish conditions in the wet and dry seasons, respectively [8]. It forms part of an intricate system of waterways made up of lagoons and creeks that are found along the coast of Nigeria from the Republic of Benin border to the Niger Delta [12]. The proliferation of urban settlements and slum in the city of Lagos has also meant increased human pressure and the generation of domestic effluents, which eventually find their way into the lagoon. The lagoon receives a complex mixture of domestic and industrial waste and has served as the ultimate sink for the disposal of domestic sewage since the latter part of the 19th century. However, the lagoon has received an excellent attention due to its environmental and economic importance for being a big source of fish production in Lagos, Nigeria [8].

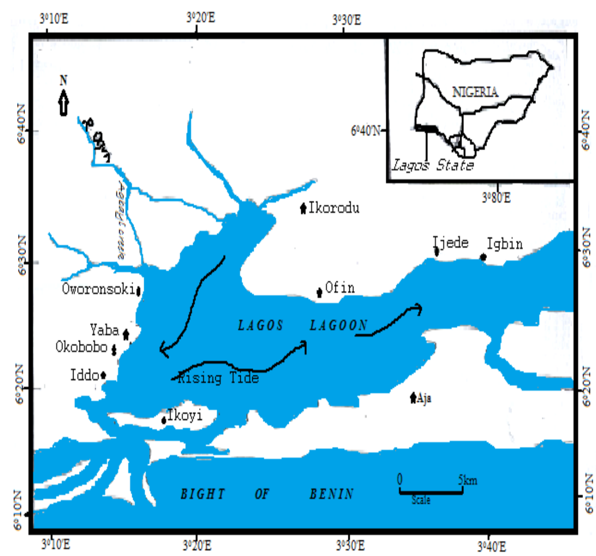

Figure 1: Map of Lagos Lagoon, Nigeria

2.2. Collection and Identification of Samples

Eighty (80) samples of *Sarotherodon melanotheron* were collected fortnightly in August 2020 from fishermen operating on the lagoon using cast nets. Samples were identified according to Olaosebikan and Raji [20] and transported in an ice chest to the Fisheries and Aquaculture Laboratory of the Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria.

2.3. Sex determination

Visual inspection was used to distinguish between male and female fish. The presence of genital papillae just before the anal fin served as a distinguishing feature between males and females [3, 6].

2.4. Sex ratio

The sex ratio was computed according to Arendt *et al.* [6] and Indarjo *et al.* [2] as the total number of males/ total number of females. The sex ratio was computed and tested for statistical significance by the chi-square method based on the null hypothesis of a 1:1 ratio of male to female at a 95 % confidence interval (CI) using the formula:

$$X^2 = \sum \frac{(O-E)^2}{E} \quad [2]$$

Where, X^2 = Chi-square test,

O = observed values and

E = expected values.

The null hypothesis (H_o) states that there is no difference in the proportion of females and males.

2.5. Sample measurement

The total length (from the tip of the snout to the edge of the caudal fin) and standard length (from the tip of the snout to the outer end of the caudal peduncle) were measured according to Loto *et al*. [8] to the nearest 0.1cm using a measuring board, while the weight was measured to the nearest 0.01g using a sensitive weighing balance (Model 1100).

2.6. Gonad Examination and Determination of Gonado-somatic index (GSI)

Individual fish gonads were meticulously removed from dissected fish specimens by cutting into the abdominal part. Forceps were used to carefully remove the gonads [4]. The gonad-somatic index (GSI) for each fish was computed as the weight of the gonads as a proportion of the total body weight [3]. For fecundity estimations, mature female fish (n = 16) were used. The total number of oocytes present in the ovary of the fish was used to calculate fecundity. A "direct summing" approach was used to obtain the mean fecundity of all samples [21, 22].

2.7. Determination of Length- weight Relationship

The length- weight relationship of the fish population was estimated as:

$W = aL^b$ [9]

which was then logarithmically transformed into:

$logW = loga + blogL$

Where 'W' is the weight of fish in grams, 'L' is the total length of fish in centimetres, 'a' is the constant of proportionality and 'b' is the regression coefficient.

2.8. Determination of Condition Factor (K)

Condition factor (K) was calculated using the formula:

$K = \frac{100W}{L^3}$ [8]

where, 'W' represents the mean weight of the fish (g) and 'L' represents the mean total length of the fish (cm).

Condition factor of the fish was categorised by Indarjo *et al*. [2] and Loto *et al*. [8] into five categories i.e. very thin (K=0.01-0.50), thin (K = 0.51-0.99), ideal (K = 1.0), fat (K = 1.01-1.50), and very fat (K>1.50).

2.9. Statistical analyses

SPSS (20.0) was used to conduct all statistical analyses. Analysis was done in respect of total length, standard length, male, female, and combined sexes, where combined sexes include male and female specimens put together. The regression analysis was employed to analyse the length-weight relationship, whereas the sex ratio was determined using the Chi-square test. The relationship between fecundity and fish size was determined using correlation. All relationships were considered significant at P<0.05.

3. Results and Discussion

The sizes (standard lengths, total lengths, and weight), length-weight relationship, and condition factor of *Sarotherodon melanotheron* in Lagos lagoon were presented in Table 1 which showed that the average standard length was 14.18±0.63cm, 15.83±0.83cm and 14.57±0.97cm in male, female, and combined sexes, respectively. The total length was 11.66±0.32 cm, 12.47±0.53 cm and 11.85±0.51 cm while the weight was 62.58±8.00 g, 73.92±11.40 g and 65.28±10.10 g in male, female, and combined sexes, respectively. The table also revealed that the lowest condition factor (K) was recorded in the female (1.86) while the highest K was recorded for the male (2.20). The regression coefficient '*b*' recorded for the length-weight relationship was 1.58 (a = -0.07; R^2 = 0.30), 3.15 (a = -4.42; R^2 = 0.95) and 1.74 (a = -0.50; R^2 = 0.56) for male, female, and combined sexes, respectively.

The sex ratio as presented in Table 2 was 3.21:1 (χ^2 = 22.05) departing from the expected sex ratio of 1:1, where males were significantly (P < 0.05) more numerous than females during the study period, showing a predominance of males in the population. According to the female gonadic maturation stages (as presented in Table 3), none of the examined fish was at the immature stage (Stage I), 10.53% of the fish were maturing (Stage II), 47.37% were mature (Stage III), 36.84% were ripe (Stage IV), and 5.26% were spent (Stage V). Therefore, 94.74% of the female fishe were in the reproductive process. In the male gonadic maturation stages, 1.64% and 11.48% of the fishe were immature (Stage I) and maturing (Stage II), respectively while 55.74% were mature (Stage III), 22.95% were ripe (Stage IV), and 8.20% were spent (Stage V). Therefore, 90.17% of the male fishe were in the reproductive process (Table 3).

The gonado-somatic index (GSI) of *Sarotherodon melanotheron* in Lagos lagoon as presented in Figure 2 shows that the female fish had the highest GSI (3.11%), followed by combined sexes (1.44%), and males (0.82%). The fecundity of *Sarotherodon melanotheron* in Lagos lagoon is presented in Table 4 which shows that the minimum and maximum number of eggs counted in the fish were 251 and 370, while the mean was 331.37±55.64. The table also showed that the female gonad (2.30±0.70g) was weightier than the male gonad (0.54±0.32g).

The relationship between the fecundity (number of eggs) and size (TL, SL, and WT) of *Sarotherodon melanotheron* in Lagos lagoon is presented in Table 5. The table shows that the sizes, viz: TL (r = 0.975), SL (r = 0.931) and WT (1.000) of the fish, were positively and significantly correlated with the fecundity (number of eggs in the ovary) of the fish at P < 0.05.

Table 1: Sizes, Length-weight relationship, and condition factor of *Sarotherodon melanotheron* in Lagos lagoon

n	SL (cm)	TL (cm)	WT (g)	K	*a*	*b*	R^2
61	14.18±0.63	11.66±0.32	62.58±8.00	2.20	-0.07	1.58	0.30
19	15.83±0.83	12.47±0.53	73.92±11.40	1.86	-4.42	3.15	0.95
80	14.57±0.97	11.85±0.51	65.28±10.10	2.11	-0.50	1.74	0.56

n: number of fish; SL: Standard Length; TL: Total Length; WT: Weight; K: Condition Factor

Table 2: Sex ratio of *Sarotherodon melanotheron* in Lagos lagoon

Males	Females	Total	Ratio	χ^2 Calc.	χ^2 Critical	
61	19	80	3.21:1.00	22.05	10.83	0.0

Table 3: Gonad Maturity of *Sarotherodon melanotheron* in Lagos lagoon

Gonad Maturity	Interpretation	Female		Male		Total	
		n	%	n	%	n	%
Stage I	Immature	0	0.00	1	1.64	1	1.25
Stage II	Maturing	2	10.53	7	11.48	9	11.25
Stage III	Mature	9	47.37	34	55.74	43	53.75
Stage IV	Ripe	7	36.84	14	22.95	21	26.25
Stage V	Spent	1	5.26	5	8.20	6	7.50
Total		19	100.00	61	100.00	80	100.00

Plate 1: Picture of Male *Sarotherodon melanotheron*

Plate 2: Picture of Female *Sarotherodon melanotheron*

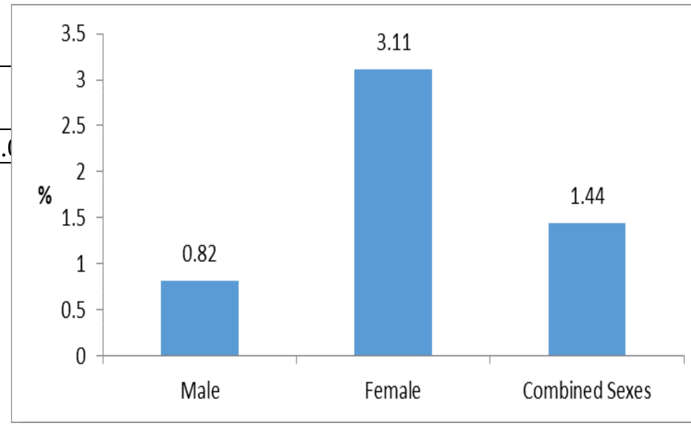

Figure 2: Gonado-Somatic Index (GSI) of *Sarotherodon melanotheron* in Lagos lagoon

Table 4: Fecundity of *Sarotherodon melanotheron* in Lagos lagoon

	No of Eggs	Weight of Gonad (g)	
		Female	Male
Minimum	251	1.23	0.04
Maximum	370	2.98	0.96
Mean + SD	331.37 ± 55.64	2.30 ± 0.70	0.54 ± 0.32

Table 5: Relationship between the fecundity (number of eggs) and size (TL, SL and WT) of *Sarotherodon melanotheron* in Lagos lagoon

	TL	SL	WT	No of Eggs	Ovary WT
TL	1.000				
SL	0.884*	1.000			
WT	0.974*	0.933*	1.000		
No of Eggs	0.975*	0.931*	1.000*	1.000	
Ovary WT	0.973*	0.925*	0.995*	0.996*	1.000

* Correlation is significant at $P < 0.05$

The morphometric traits of the studied species were found to be consistent with the taxonomic features of *S. melanotheron* reported by Olaosebikan and Raji [20]. Olawusi-Peters *et al.*, [23] reported that the morphometric and meristic methods remain the simplest and most direct methods for fish species identification. According to Olaosebikan and Raji [20], the sizes obtained in this study were considered small fish. However, 94.74% and 90.17% of the female and male samples, respectively, were sexually mature. It can therefore be said that *S. melanotheron* in this study attained early maturity. Sexual maturity is not a component of size and can be impacted by the amount and seasonal availability of food, temperature, photoperiod, and other ecological factors in various locations [24]. Similarly, Gómez-Márquez *et al.*, [22] reported that tilapias reach sexual maturity at three months of age with an average total length of 8 to 16 cm, while Fawole and Arawomo [25] reported that male *S. galilaeus* in Opa reservoir grows and matures at almost the same size as the female (12.5 and 11.7 cm, respectively).

The gonadal stages of males and females indicated that the study period coincided with or was very close to the breeding period, even though they breed more than once per year [24]. According to Loto *et al*. [18], the frequency of tilapia spawning varies greatly depending on environmental conditions, with tilapia spawning occurring up to ten (10) times in a year. Similarly, Oso *et al*. [26] found that when tilapias attain sexual maturity, they can reproduce for three to six weeks when the water is warm, but reproductive activity is suspended when environmental conditions are unfavorable. The ability of an animal to separate its growth and reproductive stages is dependent on the environment's consistency and predictability [27]. Despite the regularity of oviposition and spawning, the creation and development of gonads appeared to continue unabated, as evidenced by the high frequency of occurrences of all stages of gonadal maturation. According to Olawusi-Peters *et al*. [1], oogenesis may occur continuously or cyclically throughout the reproductive lives of most teleosts. Thus, the high frequency of fish with mature gonads indicated the suitability of the lagoon as a habitat for the fish.

In this study, the calculated exponents of the length-weight relationship of both male and female fish showed a negative (b = 1.58) and positive (b = 3.15) allometric growth, pattern respectively. Overall and regardless of sex, the fish stocks showed a negative allometric (b = 1.74) growth pattern, which may indicate that the increase in weight of the fish was relatively slower than the increase in length [2]. This means that female *S. melanotheron* gain weight quicker than their length increases, whereas male *S. melanotheron* gain weight slower than their length increases. According to Ajibare *et al.* [9] and [27], factors responsible for variation in the length-weight relationship of fish include (but are not limited to) sex, growth phase, season, stages of gonad maturity, stomach fullness, health state, physical/environmental conditions, population, and variances within species. It has also been linked to food abundance and availability, analytical methods, water conditions, as well as size and development of females [2].

In this study, analysis of the condition index of the fish revealed slight variations in body shape between males and females. Since different values of the condition factor imply different body shapes of the fish. Thus, according to Indarjo *et al.* [2], the fish were classified as very fat since the observed K was higher than 1.5 (K > 1.5) even though the male fish specimens appeared to have a wide distribution of body shape compared with the females. Summarily, the growth constant values for both sexes in this study fall within the range of 1.5 and 3.5 reported for most fish [27], and within the range of 1.0 and 4.8 indicated as ideal for adult freshwater tropical fish [9, 28].

Understanding the interaction between individuals, the environment, and the state of the population requires knowledge of the sex ratio [24]. The sex ratio recorded for *Sarotherodon melanotheron* in this study was 3.21 males to 1 female, which was significantly different from the expected 1:1 ratio in males and females ($P < 0.05$). This variation may occur because, once the eggs have been fertilized, the males may migrate from the spawning areas to feeding areas, while the females may migrate to submerged vegetation and rocky regions to stay away from fishermen and complete the incubation and protection of the offspring [4]. When Jega *et al.* [3] observed a slight female dominance over males in the *Hemibagrus menoda* population in the Kangsha River, they attributed it to partial segregation of mature forms due to habitat preferences and migration, or behavioural differences between sexes that made one sex more effortlessly caught than the other.

The divergence from the expected sex ratio of 1:1 in this study may be beneficial to the fisheries since it can act as a sex ratio regulatory mechanism. This observation could be related to the type of fishing gear used or because the fish were not caught close to the brooding grounds. Fawole and Arawomo [25] reported that the sex ratio varies a lot from species to species, although it is usually near one, and it can change from year to year in the same population. According to Ramos-Cruz [29], the sex ratio for *O. aureus* was 2.6 males: 1 female, which is considered normal. Also, Quarcoopome [24] noted that in African lakes, males often dominate cichlid populations because they grow faster than females, without posing a concern to the fisheries. However, Indarjo *et al*. [2] argued that when the number of male specimens was higher than females (as observed in this study), it showed that the natural stocks of the species are over-exploited and there is an indication of fishing preference for one specific sex, which could be a worry for sustainable fishery management. Therefore, more studies are needed to examine what variables could eliminate more females in the study area before management strategies can be planned and carried out.

The GSI for the males was lower than that of the females. This is linked to female gonads that are larger than male gonads. This shows that mature ovaries were available all year, indicating that the fish bred all year. On criteria of fecundity (number of eggs), it was observed that smaller females produced fewer eggs. The occurrence of eggs of various sizes also indicated multiple spawnings by the species. It was also observed that fecundity was directly and significantly correlated with total length (r = 0.975), standard length (r = 0.931) and weight (r = 1.000). In this study, the fecundity range (251-370 eggs) was lower than the observations of Gómez-Márquez *et al.*, [22] who stated that fish show great fluctuations in fecundity among fish of the same age, size, and species. Similarly, Jega *et al*., [3] stated that fecundity is typically significantly higher in mouthbrooding cichlids because the parents ensure the offspring's survival, resulting in lower mortality. This fluctuation could be explained by differences in food abundance among members of the population.

4. Conclusion

This study revealed that male *S. melanotheron* slightly dominates in the Lagos lagoon, Nigeria. Differences in sex ratio were significant at the 95 % confidence interval, indicating a divergence from the expected sex ratio of one male to one female. Even though female fish exhibited a positive allometric growth pattern, the male population was in better physical condition. The information on the sex ratio and length-weight relationship of *S. melanotheron* presented in this study could contribute to the management of natural stocks of these fish species, which are ecologically and economically important and may have suffered threats from overfishing, pollution, and climate change. The findings of this study will therefore be used to identify and predict the sex ratio and length-weight relationship of *S. melanotheron* in the Lagos lagoon. Further research and studies should be carried out to obtain more information about the fishes in the study. Moreover, fishing restrictions on both female and male fish are recommended for sustainable management of this fishery, particularly during the breeding season. To ensure food security, fishery development, and sustainable management interventions, frequent assessments of the ecological, biological, and environmental aspects of the lagoon are also required.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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