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Reproductive Biology of *Sarotherodon melanotheron* in the Dominli Lagoon, Ghana

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ABSTRACT

Condition indices, sex ratio, length at sexual maturity, fecundity and gonadosomatic indices of *Sarotherodon melanotheron* in the Dominli lagoon were investigated with the aim of providing basic information on the reproductive biology of the species for fisheries management and considerable aquaculture development in the study area. Condition indices which varied from 3.42 to 4.53 indicated that the fish were in good conditions. Sex ratio of 1:1.5 in favour of the females and length at first sexual maturity (L_m) of 13.4 cm SL were determined for the fish. The fecundity ranged from 97 to 379 eggs with a mean of 206 eggs suggesting the less-fecund nature of the fish in the lagoon. The presence of mature gonads encountered throughout the study is a suggestive continuous recruitment into the population. *S. melanotheron* which sexually matures at a larger size necessitates an upward review of the current minimum mesh size (5.1 cm) of fishing nets used in the lagoon so as to allow the fish to spawn at least once in its lifetime prior to exploitation.

Key Words: Condition index; Sex ratio; Gonadosomatic index; Black-chinned tilapia; Fecundity; Recruitment

INTRODUCTION

The Black-chinned tilapia, *Sarotherodon melanotheron*, which notably provides cheap protein to many coastal dwellers, belongs to the family Cichlidae in the order Perciformes. The species is widely distributed in the lagoons along the Ghanaian coast (Blay 1998). Its rapid growth and well-being are more pronounced in the West African closed lagoon systems (Boughey 1957). In relation to feeding habits, *S. melanotheron* is reportedly omnivorous subsisting on a variety of food items of both animal and plant origins. Hence, it evidently occupies an important trophic level of the aquatic food web. It is well known for its natural ability to provide a high degree of parental care for the young ones (Trewavas 1983).

Contributing to the knowledge of the reproductive biology of *S. melanotheron*, Faunce (2000) reported on overall sex ratio of 1:1 for the species in a seasonally impounded mangrove ecosystem in east-central Florida. Similarly, a sex ratio of 1:1 was determined for *S. melanotheron* population in the Buguma Creek, Nigeria (Oribhabor and Adisa-Bolanta 2009). Lengths at first sexual maturity (L_m) of 5.5 cm SL and 4.6 cm SL were respectively reported for *S. melanotheron* populations in the Benya lagoon and the Kakum river estuary of Ghana (Blay 1998). The males and females were observed to undergo first sexual maturity at lengths 12.8 cm SL and 14.5 SL, respectively in the impounded mangrove ecosystem, Florida (Faunce 2000). According to Faunce (2000), although *S. melanotheron* had a prolonged spawning season, the breeding activities were highly intense in April and May. The population inhabiting Ayamé Lake in Côte d' Ivoire had overlapping breeding patterns which suggested that the species bred throughout the year (Koné and Teugels 2003). In Ghana, only few reports have been documented on the biology of *S. melanotheron* with much emphasis on their feeding and reproductive processes (Eyeson 1979, 1983, 1992) as well as population characteristics (Blay and Asabere-Ameyaw 1993, Blay 1998).

Of these scanty studies, none of them focused on the biology of *S. melanotheron* in the Dominli lagoon. An effective management of fisheries resources requires a comprehensive insight into the reproductive biology of species targeted for exploitation. Also, studies of the reproductive biology of fish species play a noteworthy role in their culture. In this light, this study aimed at providing requisite information on the reproductive biology of *S. melanotheron* to provide possible ways of sustaining the fishery and also facilitate aquaculture operation in the area. The study therefore dwelt on length-weight measurements, condition index, sex ratio, length at sexual maturity, fecundity and gonadosomatic index of *S. melanotheron* in the Dominli lagoon.

MATERIALS AND METHODS

Dominli lagoon is located at Bonyere between latitudes 5° 1´ and 5º 2´ N and longitudes 2° 44´ and 2º 47´ W in the Jomoro District of Ghana as shown in Figure 1. It has a catchment area of 465,724.14 m^2. It is a classical closed lagoon (Yankson and Obodai 1999) indicating that it normally gets separated from the sea by sand bar for greater part of the year. However, lagoon-sea contact is routinely established during the rainy season through either artificial or natural means to avoid inundation of neighbouring farms and villages. The lagoon is naturally fringed with mangroves and coconut trees. It serves as a reliable source of water and fisheries resources for the neighbouring communities. Fishing-day ban is unobserved in the lagoon. Cast nets and funnel-shaped-entrance fish traps made of wire mesh were the fishing gears for fishing activities in the lagoon.

Monthly samples were regularly collected in the lagoon for 12 months (October, 2011- September, 2012). Fish samples obtained from the fishermen were kept in an ice chest with ice cubes and transported to the laboratory for analysis. Each fish specimen was counted and measured for its standard length (SL) and total length (TL) to the nearest 0.1 cm by using a measuring board. In addition, each specimen was weighed to the nearest 0.01g using an electronic weighing balance (model FEL-500S). The well-being of each fish specimen was determined using the formula below (Pauly 1993):

$$CI = 100W/SL^3 \quad (1)$$

where CI = condition index, SL = standard length of fish and W = wet weight of fish specimen.

Fish specimens were dissected and the sexes determined by inspection of the gonads. The monthly sex ratio (male: female) as well as the overall monthly sex ratio of the specimens was determined. The mean length of the

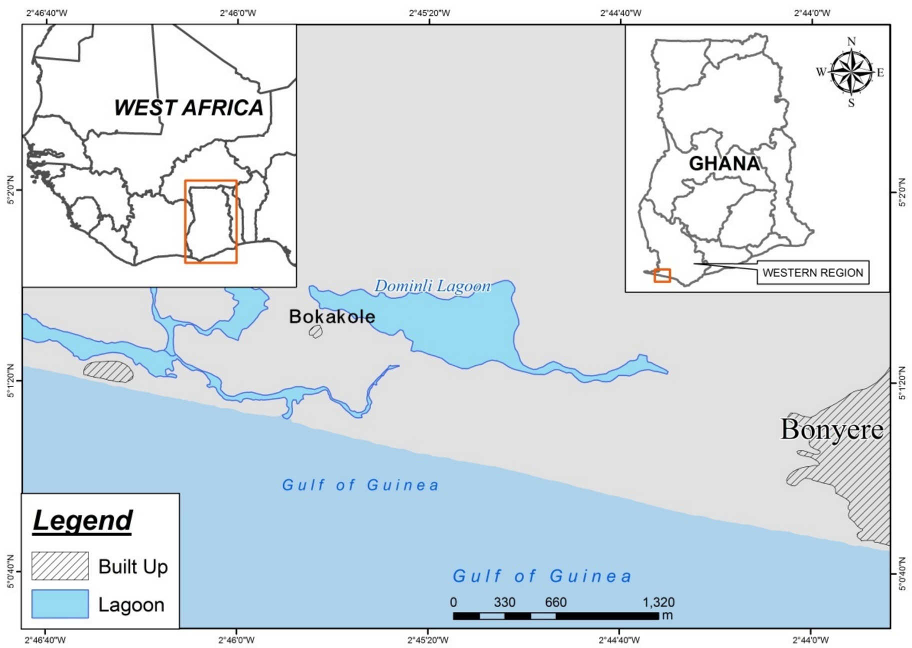

Figure 1. Location of Dominli lagoon in the Western Region of Ghana

fish at sexual maturity (L_m) described as the length at which 50 % of all individuals were sexually matured (Pitt, 1970) was estimated for the females only because their gonad maturation stages were more perceptible than that of the males. Four stages of gonad maturation were determined for the female specimens using histological procedures described by Witte and Van Densen (1995).

The ovaries of the females were staged as:

Stage I – Immature: ovaries translucent; small eggs can be seen with magnifying glass;

Stage II – Developing: Ovaries pinkish; eggs visible to eye;

Stage III – Developed: Ovaries with eggs clearly discernible; ovaries occupy about two-thirds of central cavity;

Stage IV – Gravid / Ripe or ready to spawn, eggs completely round and released from ovary with slight pressure on abdomen.

Based on these gonadal maturity stages, individuals with gonads staged as III and IV were considered sexually mature. Hence, the length at which 50% of the individuals were mature was estimated using cumulative length-frequency plot fitted with logistic regression curve (Sendecor 1956, Sparre and Venema 1992). Fecundity, defined as the number of ripe eggs present in the ovary of a fish, was determined using the whole count method (Ezenwaji and Offiah 2003). The ripe gonads of the females were gently and carefully removed after dissection and stored in 10 % formalin for two weeks to free the individual eggs. The eggs were washed and counted for further analysis. The gonadosomatic index (GSI) of each specimen was determined using the formula:

$$GSI = \frac{\text{Weight of gonad}}{\text{Total body weight}} \times 100\% \qquad (2)$$

RESULTS

The monthly mean condition indices of both male and female *S. melanotheron* in the Dominli lagoon (Figure 2) indicated that values for the males slightly fluctuated from October, 2011 to March, 2012, after which it rose sharply to a peak of 4.2 ± 0.13 in April, 2012. This was followed by a sudden fall in May, 2012 with subsequent minor fluctuations occurring until September, 2012.

However, the condition indices for the males ranged from 3.5 ± 0.12 in October, 2012 to 4.48 ± 0.13 in April, 2012. On the other hand, from 3.42 ± 0.12 to 4.53 ± 0.15 was the range of mean condition indices for the female *S. melanotheron* in the lagoon. The lowest and highest condition indices for the females were obtained in December, 2011 and April, 2012, respectively. In general, the condition indices for both sexes of *S. melanotheron* in the lagoon followed the same pattern. In addition, both sexes had high condition indices in the month of April, 2012. There was no significant difference ($p > 0.05$) between the condition factors of both male and female *S. melanotheron* in the lagoon.

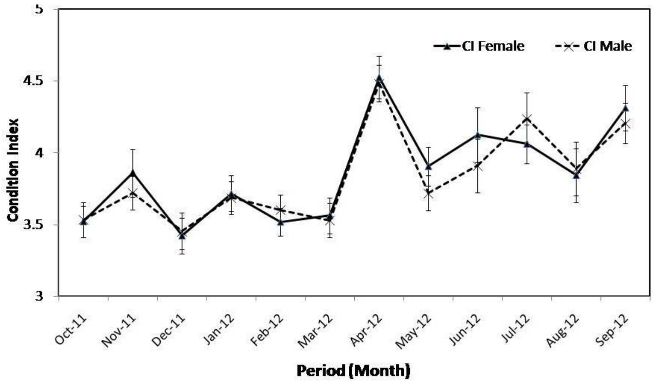

Figure 2. Monthly mean condition indices of male and female *Sarotherodon melanotheron* in Dominli lagoon (vertical bars represent standard errors)

The monthly sex ratios of *S. melanotheron* (Table 1) indicated that apart from the months of May, June, August and September, 2012 where more males of *S. melanotheron* were caught from the lagoon, the females of *S. melanotheron* dominated the black-chinned tilapia fishery for the rest of the months. However, the overall sex ratio (M: F) of *S. melanotheron* was 1: 1.15 which was significantly different ($P < 0.05$) from the normal expected sex ratio (1:1) of fish populations.

From Figure 3, the mean size at sexual maturity was determined as 13.4 cm SL. However, the sexually mature female *S. melanotheron* with the smallest size had a standard length of 9.2 cm.

The fecundity of *S. melanotheron* (Figure 4) was presented as a scatter plot relating total number of eggs to the standard length of individual fish with ripe ovaries. The number of ripe eggs of *S. melanotheron* in the lagoon ranged from 97 to 379 eggs with a mean of 206 eggs. The relationship between fecundity (F) and standard lengths (SL) of *S. melanotheron* was represented as $F = 3.754SL + 154.12$. The relationship between fecundity and body

Table 1. Sex ratios of *Sarotherodon melanotheron* in Dominli lagoon (October 2011– September 2012)

Month	Male (M)	Female (F)	Sex ratio (M:F)	χ^2	Significance
Oct 2011	62	64	1.00 : 1.03	0.031	NS
Nov 2011	51	64	1.00 : 1.25	1.476	NS
Dec 2011	51	66	1.00 : 1.29	1.923	NS
Jan 2012	43	67	1.00 : 1.59	5.236	S
Feb 2012	45	54	1.00 : 1.20	0.818	NS
Mar 2012	19	37	1.00 : 1.95	5.786	S
Apr 2012	44	63	1.00 : 1.43	3.374	NS
May 2012	49	46	1.07 : 1.00	0.095	NS
Jun 2012	27	26	1.04 : 1.00	0.019	NS
Jul 2012	23	27	1.00 : 1.17	0.32	NS
Aug 2012	40	18	2.20 : 1.00	8.345	S
Sep 2012	33	27	1.20 : 1.00	0.6	NS
Total	487	559	1.00 :1.15*	4.956	S

*indicates overall monthly sex ratio, S = significant and NS = not significant

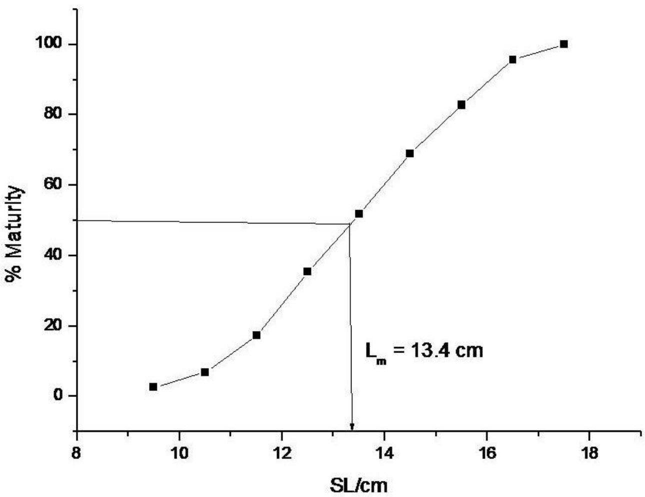

Figure 3. Length at sexual maturity of female *S. melanotheron* in the Dominli lagoon

weights of *S. melanotheron* in the lagoon was also established (Figure 5). Fecundity-body weight relationship of *S. melanotheron* in the lagoon yielded a regression equation as F = 176.44 + 0.2821BW (r = 0.19).

The monthly variations of the GSI for both male and female *S. melanotheron* in the Dominli lagoon (Figure 6) indicate that the mean GSI of the male *S. melanotheron* varied from 0.025 ± 0.79 to 0.075 ± 3.31. The GSI of the males sharply fluctuated from October, 2011 to February, 2012, after which it reduced gradually until May, 2012. This was followed by a gentle rise which extended to a value of 0.063 ± 2.7 in August, 2012. However, the mean GSI for the female *S. melanotheron* in the Dominli lagoon ranged from 0.24 ± 0.86 to 1.74 ± 6.57. The pattern of GSI for the females was almost similar to that of the males. Comparatively, the GSI of the females in general were significantly higher than those of the males (P < 0.05). Four peaks were shown in the trend of GSI for female *S. melanotheron*. Of the four peaks identified, the major ones occurred in December, 2011 and February, 2012 with the minor ones in April, 2012 and July, 2012.

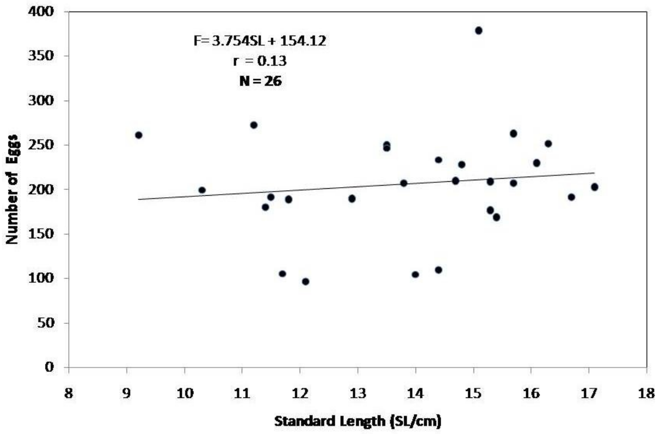

Figure 4. Relationship between fecundity and standard length for *Sarotherodon melanotheron* in Dominli lagoon from October, 2011 to September, 2012

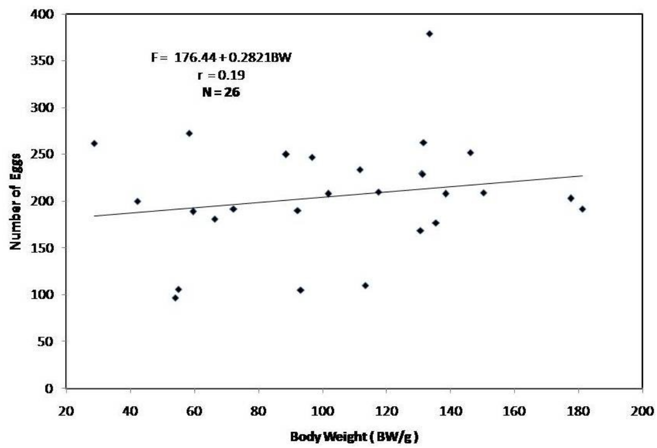

Figure 5. Relationship between fecundity and body weight for *Sarotherodon melanotheron* in Dominli lagoon from October, 2011 to September, 2012

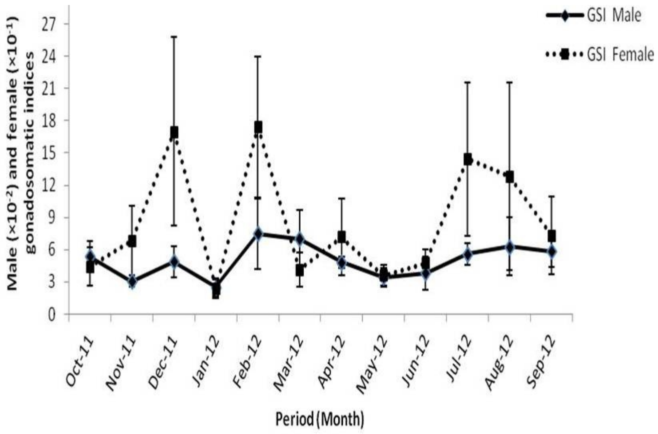

Figure 6. Monthly mean gonadosomatic indices (GSI) of male and female *Sarotherodon melanotheron* in Dominli lagoon (bars represent standard errors)

DISCUSSION

Condition factor is notably employed in fisheries studies in order to assess the condition, fatness or well-being of fish. It is based on the hypothesis that heavier fish of a certain length are in a better physiological condition (Bagenal 1978). Ndimele et al. (2010) confirmed *S. melanotheron* with condition factor range of 2.38 - 2.39 to be in better conditions in the Ologe lagoon (Nigeria). It could therefore be inferred that the same species in the Dominli lagoon are also in better conditions (3.42 - 4.53) and this finding is further complemented by Fagade (1979). The present study which portrayed that there were no significant differences ($p > 0.05$) between the condition indices of both sexes is in agreement with the findings by Koné and Teugels (2003). Likewise, Anene (2005) did not find any significant variations between condition factors of *S. melanotheron* with respect to sex.

Seasonal variations were observed in condition factors of *S. melanotheron*. This complements the finding by Oni et al. (1983) who noted that condition factor was not constant for a species or population over time due to influence by both biotic and abiotic factors such as state of gonadal development and feeding regime, respectively. Panfili et al. (2004) and Niyonkuru and Laleye (2012) found high condition factor in the dry season for *S. melanotheron*. However, high condition factor was observed in the wet season for the same species in the present study. Probably, the lagoon was sufficiently resourced with food materials principally generated from land runoffs during the rainy season and this might have contributed to the high condition indices observed for *S. melanotheron* population in that season.

Reproductive success of a fish population partly depends on sex ratio in an aquatic system. Sex ratio is a biological indicator which provides basic information on proportions of males and females in a population. Consequently, it provides more clues on the dominating sex in a population of fish. It is also noted as a tool for assessing the reproductive potentials of a fish population. The dominance of a particular sex has its own specific implications (Vicentini and Araujo 2003; Morgan 2008). Oribhabor and Adisa-Bolanta (2009) reported an overall sex ratio of 1:1 for *S. melanotheron* in the Buguma creek (Nigeria) confirming the normal sex ratio expected in fish populations. A sex ratio of 1.00:1.15 was however observed for *S. melanotheron* in the Dominli lagoon in favour of the females. According to Yankson (1996), the preponderance of females in a population prior to onset of adverse conditions happens to be a strategy to improve breeding success as a few males could contribute to fertilization of numerous eggs. Hence, the dominance of the female *S. melanotheron* in the lagoon during the dry season when the water level was extremely low with its attendant disconnection from the sea could be due to a strategic approach by *S. melanotheron* populations to enhance breeding success so as to stabilise the ichthyomass of the fish stock.

According to Trewavas (1983), the males of the species generally brood the young ones in their mouths, a situation which makes them inactive thereby limiting their movements. It could therefore be inferred that the abundance of the females in the traps could also be due to their activeness to swim into the fishing gears. Temperature reportedly bears an influence on sex ratios in fish populations (Patino et al. 1996; Baroiller et al. 1999) especially cichlids, as the sexes are labile at the infant stages. On this basis, Baroiller and D'Cotta (2001) specifically revealed that high water temperatures promote female-biased sex ratios while low temperatures produce male-biased sex ratios. Relatively high number of female *S. melanotheron* observed during sunny periods (March – April, 2012) in the Dominli lagoon is in agreement with the findings by Patino et al. (1996) and Baroiller et al. (1999).

First sexual maturity (L_m) of 5.5 cm SL and 4.6 cm SL were documented for *S. melanotheron* populations in the Benya lagoon and the Kakum river estuary, respectively (Blay 1998). L_m (13.4 cm SL) observed for the same population in the lagoon for the present study is certainly higher than those reported by Blay (1998). It could be inferred that *S. melanotheron* in both Benya lagoon and Kakum river estuary relatively mature sexually at a smaller size as compared to the Dominli lagoon. It is therefore conceivable that *S. melanotheron* from different localities mature sexually at different bodily sizes. The sexual maturity phase which occurs at later stage of development in the *S. melanotheron* population of the Dominli lagoon possibly suggests that the averaged mesh size (5.1 cm) of fishing gears used in the lagoon could be increased so as to allow the females to spawn at least once in their lifetime prior to exploitation.

Gonadosomatic index is an important aspect of fish reproductive biology which gives information necessary for successful fisheries management and recruitment of fish populations in aquatic systems (Njiru et al. 2006; Adebisi 2012). Good understanding of gonadosomatic index of fish populations enhances interpretation of their breeding patterns (Wootton 1998; Mahboob and Sheri 2002) as well as determination of breeding seasons for fish species (Weng et al. 2005). Highest peak of GSI recorded in February, 2012 for *S. melanotheron* in the Dominli lagoon shows a build-up of mature sexual products in the fish. According to Faunce and Lorenz (2000), accumulation of sexual products which is a characteristic of enhanced reproduction in cichlids is normally accelerated at high temperatures. A similar observation was made in the *S. melanotheron* population for the current study as high values of GSI were recorded at high temperatures in the lagoon.

Decline in GSI of both female and male fish which occurred from February to June, 2012 indicated shedding of their mature sexual products (Ghanbahadur and Ghanbahadur 2012). Hence, it could be inferred that the major breeding activity entered the rainy season. This agrees with Faunce (2000). It could be deduced that much fingerlings considered for stocking aquaculture holding facilities could be obtained in the rainy season. The major breeding which occurred just before the heavy downpour could be ascribed to a strategy for ensuring maximum survival of offspring as the wet season is characterized by high volume of water (more spaces) and availability of food. According to Wootton (1998), the GSI of total spawners is more often than not high just prior to spawning but reduces drastically after spawning. On the basis of this, *S. melanotheron* in the Dominli lagoon could be described as total spawners.

Welcomme (1967) reported that the ovary of a ripe female cichlid, *Oreochromis leucostictus,* represents only 3 % of the body weight. Wootton (1979) indicated that, in some species, the ovaries form 20 – 30 % of the body weight. The ovaries in other species constitute less than 5 % of the body weight (Wootton 1998). In the present study, the ripe ovary percentage was less than 5 % of the body weight but on the average greater than 3 % reported for *O. leucostictus* by Wootton (1998). The differences could partly be attributed to variations in the temporal pattern of egg development and spawning.

According to Koné and Teugels (2003), *S. melanotheron* in Ayamé Lake (Côte d' Ivoire) reproduced almost throughout a year with their breeding activities overlapping. The presence of mature gonads observed throughout the sampling events in the present work suggests that *S. melanotheron* bred throughout the year in the lagoon. This agrees with Fagade (1973) and Legendre and Ecoutin (1989). The continuous reproduction and protection for eggs through oral brooding exhibited by *S. melanotheron* in the Dominli lagoon might have contributed to their population abundance and resilience. Babiker and Ibrahim (1979) reported that several peaks observed in GSI trends of fish populations suggest that the fish breed more than once a year. Hence, the breeding pattern (GSI) of female *S. melanotheron* which exhibited several peaks indicated that the fish spawned in multiplicity within a year.

Assessment of fecundity is one of the fundamental requirements for the study of the biology and population dynamics of fish (Kingdom and Allison 2011). The number of eggs produced by fish at a particular time is a critical biological trait that attracts much attention when considering fish populations for aquaculture operation. Proliferation of young ones with consequent competition for life-sustaining resources may occur in holding facilities if brood stocks frequently lay a great number of eggs with associate high rate of hatching success and negligible predation.

The range of fecundity observed for *S. melanotheron* in the Dominli lagoon points to the fact that the species is relatively less fecund. According to Baylis (1981), parental care is more prevalent in freshwater families. The care is mostly shown by many African cichlids with the eggs and larvae normally brooded in the buccal cavity of either the male or female (Fryer and Iles 1972). In some instances, the free-swimming fry retreat to the parent's mouth whenever danger arises. Such species are ordinarily characterised by relatively low fecundities but large eggs (Welcomme 1967, Moyle and Cech 2000).

According to Trewavas (1983), members of the genus *Sarotherodon* practice mouthbrooding. Hence, the low fecundity noted for *S. melanotheron* in the present work could be attributed to the practice of oral brooding by *S. melanotheron* as a great number of eggs cannot be orally brooded at a time. Yanagisawa (1986) reported that one of the key benefits derived from subjecting male fish to oral brooding is to allow the female fish to be liberated from parental duties which consequently accelerates spawning activity. This phenomenon could contribute to year-round recruitment (Wootton 1998) as observed for *S. melanotheron* in the Dominli lagoon. Gerking (1980) suggested that abrupt changes in water levels may also cause reduced fecundity. Dominli lagoon which is a classical closed lagoon (Yankson and Obodai 1999) had varied water levels during the study. Hence, the low fecundity for *S. melanotheron* in the lagoon may also be ascribed to drastic changes in water levels caused by rapid inflow of freshwater from nearby forest and outflow into the adjacent sea, especially during the rainy season.

The current study on fecundity for *S. melanotheron* revealed that number of ripe eggs for the female individuals within the population were at variance with one another. According to Siddiqui et al. (1997), variation in fecundity may be attributed to differential abundance of food within members of population. It could therefore be inferred that the individuals of *S. melanotheron* popula-tion might have fed at different intensities, hence that might have contributed to the differences in fecundity among the females in the lagoon. However, marked dis-similarities in fecundity recognised among species often reflect different reproductive strategies (Murua and Saborido-Rey 2003). In addition, fecundity may vary within different species as a result of different adaptations to environmental habitats (Witthames et al. 1995).

The regression coefficients (r) of 0.13 and 0.19 generated for the respective fecundity-standard length and fecundity-weight relationships indicated poor correlations. Wootton (1984) postulated that large fishes normally lay a great number of eggs at a time with strong positive correlation between length and fecundity. On this basis, Kjesbu et al. (1989) asserted that fecundity is said to vary yearly within a stock and has been shown to be directly proportional to fish size and condition. Bone et al. (1995) also reported that fecundity of fish increases with age and size. The situation, however, is different for *S. melano-theron* in the Dominli lagoon as there was no clear evidence to suggest that larger fishes laid more eggs or smaller ones laid low number of eggs.

CONCLUSIONS

Generally, both the male and female *S. melanotheron* in the lagoon were in good conditions. The female *S. melanotheron* noted to be less fecund were preponderant over the males in the Dominli lagoon. The breeding activities of *S. melanotheron* occurred throughout the year with the major breeding activity occurring in the wet season and the minor one in the dry season. The reproductive attributes of the species seemed to be promising for aquaculture development in the area. The minimum mesh size (5.1 cm) of fishing gears utilised by the local fishermen in the lagoon could be upwardly reviewed allowing the females to carry out their natal roles at least once in their lifetime before they are eventually exploited.

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