GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 12, NO. 3, 2006: 287 - 293

FECUNDITY, GONADOSOMATIC INDEX AND SIZE AT MATURITY OF BONGA, *ETHMALOSA FIMBRIATA* IN THE COASTAL WATERS OFF THE CROSS RIVER ESTUARY, NIGERIA

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(Received 6 June, 2005; Revision Accepted 26 September, 2005)

ABSTRACT

Studies were conducted to determine the fecundity, gonadosomatic index and length at maturity of bonga, *Ethmalosa fimbriata*, in the coastal waters off the Cross River Estuary. Fecundity of bonga ranged from 20, 120 to 190, 374 eggs per female with a high degree of variability. The fecundity was directly correlated with body weight ($r^2 = 0.53$, $p \leq 0.01$, n = 116). The GSI ranged from 2.70 to 16.9%, with the peaks between November and January, indicating the spawning period. Male bonga matured at the size of 22.5 cm while female bonga matured at the size of 23cm. This information is useful in the stock assessment of the species.

KEYWORDS: Life history, *Ethmalosa fimbriata* Cross River Estuary, Nigeria

INTRODUCTION

Bonga fishery is receiving greater attention in the Cross River Estuary and the adjacent coastal waters because of its position in the economy of the people of the lower Cross River Basin (Ama-Abasi 2002; Moses 1988; 2001). Recent studies have revealed that the fishery is under excessive fishing pressure from the purse seine fishery leading to drastic decline in the bonga stock over the last 20 years (Ama-Abasi, 2002). A regular stock assessment of the fisheries requires a body of knowledge concerning the dynamics of the fish population, which include the reproduction of the species.

Various reproductive characteristics of fish species include the fecundity, the spawning period, sex ratio, condition factor and maturity stages and the gonadosomatic index (GSI). Fecundity estimate is a staple for fisheries science (Hunter et al. 1992). It is germane because when fecundity estimates are combined with the estimate of abundance of eggs, they can be used to estimate the biomass of fish stock in the sea. Cuellar et al (1996) states that fecundity data are needed to determine the spawning stock ratio in annual stock assessment to be able to formulate management regulations.

Fishery scientists find fecundity study as critical parameters of stock assessment based on egg production method (Saville, 1964). This is a basic aspect of fish biology and population dynamics. Egg population technique as a means of stock size determination is particularly useful in estimating the stock sizes of fish which form dense spawning aggregations on which catch-per unit effort is highly variable, and therefore a poor indicator of stock size (King, 1995).

There is no report on the fecundity study or reproductive characteristics of bonga in the coastal waters off Cross River even though the fish species is a very important commercially exploited species in the inshore waters of eastern Nigeria. This study was conducted on the reproductive characteristics of bonga to determine its fecundity, gonadosomatic index, and age at maturity in the coastal waters off the Cross River Estuary.

MATERIALS AND METHODS.

The sampling site is Ibaka in Akwa Ibom State of Nigeria (Figure 1). This is where the purse seine fishers land their bonga catches all year round. Bonga specimens were sampled from purse seine catches from November 1999 to February 2001 comprising two spawning seasons. The purse seine boats exploit adult bonga in the coastal waters of the Gulf of Guinea and the juveniles in the Cross River Estuary (Ama-Abasi, 2002). About 20 adult specimens of bonga ranging in size from 20 cm total length to 33 cm were sampled during each trip. The fish were transported in ice-cold boxes back to the laboratory for studies. The fish were placed in the refrigerator until the following day for processing. Fish specimens were measured to the nearest 0.1 cm total length and weighed in grams using an electronic balance. Measurement was to the nearest 0.1g. Each weighed fish was cut open to remove the gonad.

Gonads that were at the final stage of ovarian development, i.e. stage 5 of Fagade & Olaniyan (1972) were used for the fecundity study. Total fecundity was used for this study. Total fecundity is defined as the standing stock of advanced yolked oocytes (Hunter et al., 1992). The gonad was weighed also to the nearest 0.1g. Ovary-free weight was obtained by subtracting the weight of the gonad from the total weight of the fish. The ovary-free weight was used for the correlation and regression analysis and size-fecundity analysis.

Each ovary was cut into sub-samples weighting 1g. The sub-samples were derived from the three longitudinal sections of the ovary viz: anterior, middle and posterior portions. They were placed for three weeks in the modified Gilson fluid inside small glass bottles, after the method of Simpson (1959). This accelerated the disintegration of the ovarian tissue and the liberation of the ova. At the end of three weeks eggs were rinsed and dewatered using a 333μm square mesh screen and low vacuum suction to remove the resulting disintegrated ovarian tissues. Eggs were then dispersed into Petri dishes and any large clumps were gently separated. Agarose gel was then poured into the Petri dishes and were carefully mixed to disperse the eggs for even distribution. After the Agarose hardened, the eggs were counted under a stereomicroscope. This provided the number of eggs per each gram weigh. of the sub-sample.

Analysis of variance was employed to test for any significant difference amongst the three positions of the ovary from ten fishes. Since there was no significant difference amongst the three positions, two sub-samples from each fish were employed for the fecundity estimations according to Hunter et al (1992). The average number of eggs per gram was then

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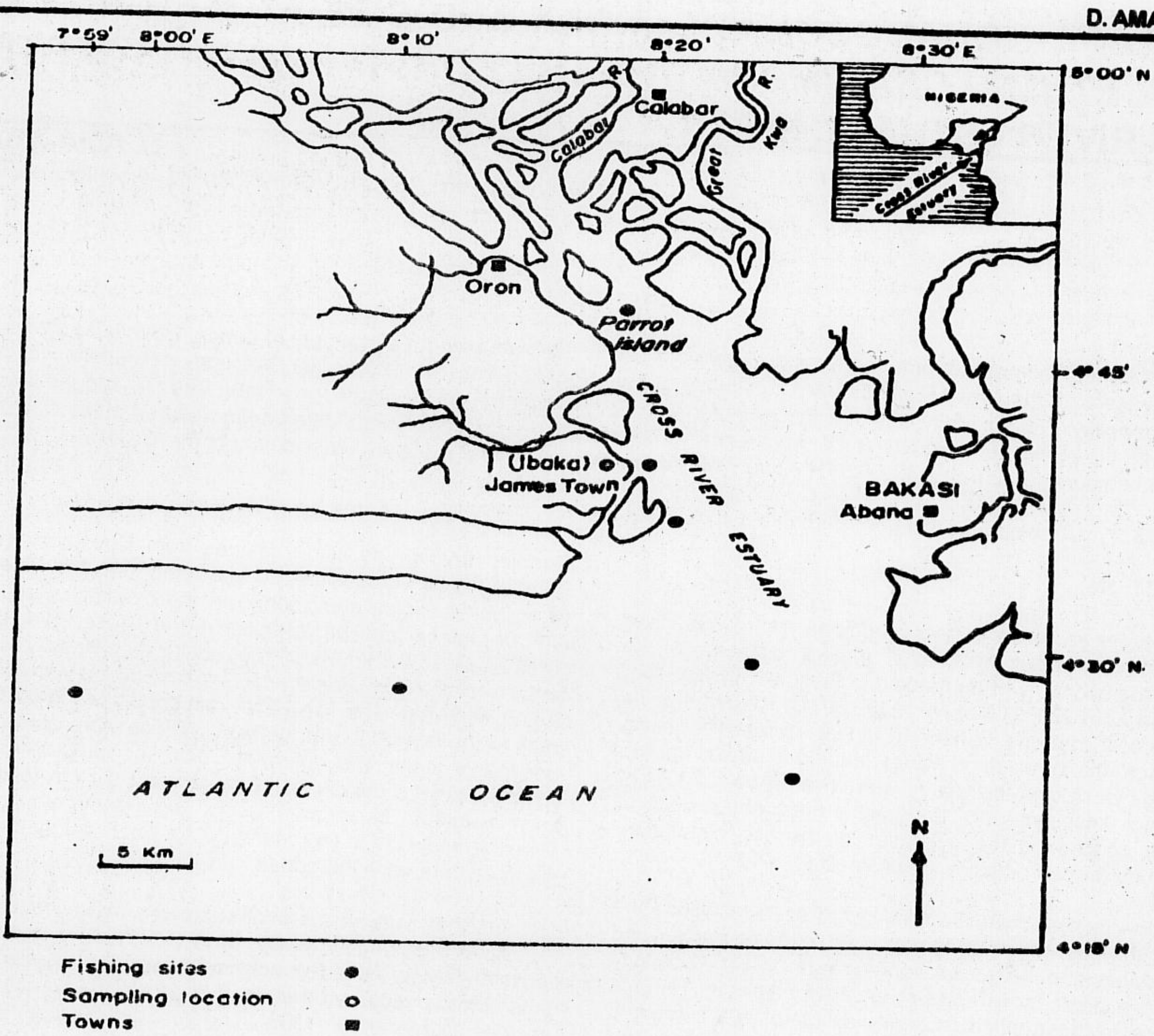

Figure 1: Map of Cross River Estuary showing the study area. (Parrot Island is indicated by the arrow).

multiplied by the ovary weight to get the total number of eggs per individual fish. The gonadosomatic index (GSI) was determined by the formula.

$$GSI = \frac{\text{ovary weight} \times 100}{\text{Fish weight-ovary weight}} \qquad \ldots\ldots\ldots\ldots\ldots 1$$

Fish without observable oocytes were also recorded and this was used to trace the period of no reproductive activities. The data for the two spawning seasons were pooled together to calculate the correlation and regression analysis. The correlation and regression analyses for weight and fecundity relationship and for the gonadosomatic index and fecundity relationship were performed using SPSS (1997) student version. For length at maturity the proportion of fish with ripe gonads was plotted against their length from where the length at maturity was estimated after the method of King (1995).

A logistic curve was fitted to the proportion (p) of sexually mature individuals by length (L) using the expression

$$P = 1/(1+\exp[-r(L-L_M)]) \qquad \ldots\ldots\ldots\ldots\ldots 2$$

were r is the slope of the curve and Lm is the mean length at sexual maturity or the length which corresponds to a proportion of 0.5 or 50 per cent in reproductive condition.

Gonadal development was used to identify the sexes. Males of 22 cm were readily identifiable whereas females were readily identified at the size of 23cm. Any specimens above 22cm without any observable gonad were included as females since males at this size were distinct.

RESULTS

Fecundity of *Ethmalosa fimbriata*

The fecundity of bonga, *E.fimbriata* in this study ranged from 20, 120 to 190,374 eggs per female. Mean fecundity was estimated at 63,108.8 with a standard deviation of ± 32,338. There was a very high variation in the fecundity of bonga. The coefficient of variation (CV) was estimated at 51% for the pooled data of the two spawning seasons. For the 1999/2000 spawning season, fecundity estimate was from a range of 22,462 to 190,374 with a mean of 70,328 ± 33,471 eggs per female. Coefficient of variation (CV) was 47.6%. For the 2000/2001 spawning season, the fecundity ranged from

21,120 to 151,145 eggs with a mean of 50,853.3 ± 26,417 eggs per female. The coefficient of variation was 52%.

Fecundity and size relationship

Fecundity was positively correlated with size. Larger individuals tended to have higher fecundities than smaller individuals. Both weight and length of bonga were significantly correlated with fecundity. The relationship between weight and fecundity is given in Figure 2. In the 1999/2000 spawning season, the heaviest female was 240.1g, ovary free weight with a fecundity of 75,528 eggs while the smallest female was 127.8 g ovary free weight with a fecundity of 24,977 eggs. Pearson correlation coefficient revealed a significant correlation between weight and fecundity (($p \leq 0.01$, $r^2 = 0.63$, n= 116). The pooled data for the two seasons shows that the fecundity-weight relationship was significant with linear regression model.

$F = 834.7W - 73133.3$ (Figure 2).

Fecundity and gonadosomatic index (GSI)

The GSI of the fecund females ranged from 2.95 to 9.30% in the 1999/2000 spawning season with a mean of 5.65 ± 1.41%. In the 2000/2001 spawning season the GSI ranged from 2.70 to 16.9% with a mean of 7.1 ± 4.7. When data for the two seasons were pooled together, the GSI ranged from 2.70 to

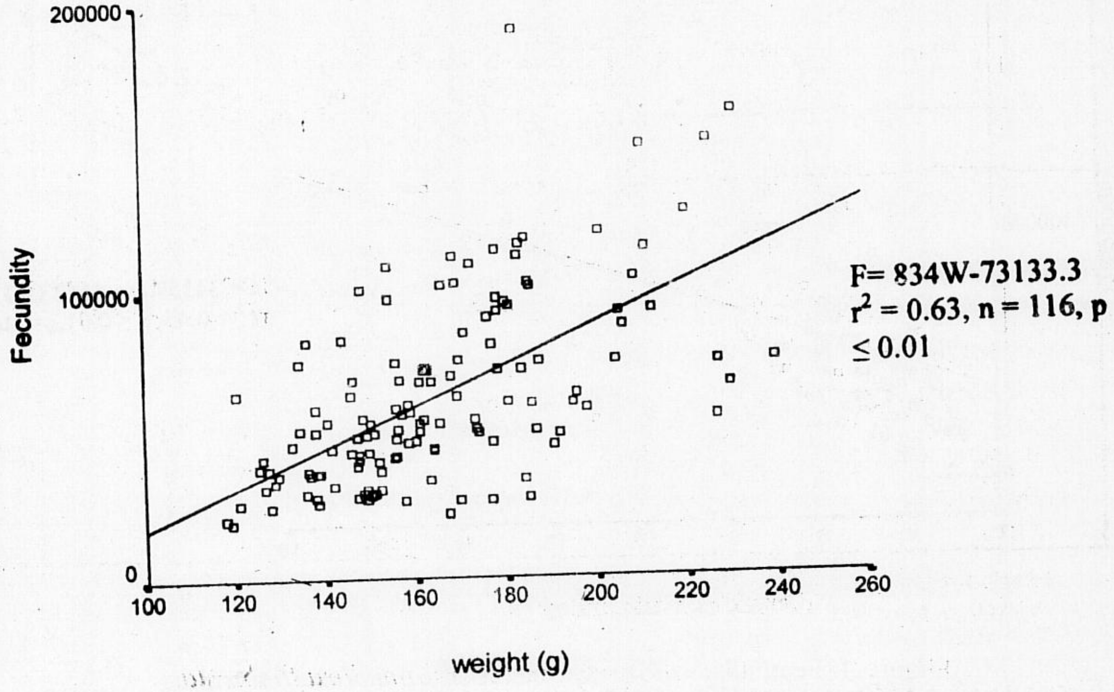

Figure 2: Fecundity- weight relationship in *Ethmalosa fimbriata*

16.9% with a mean of 6.19 ± 3.11%. The variation was high as seen by the high coefficient of variation, which was 25% in the 1999/2000 spawning season but 65% in the 2000/2001 spawning season. Figure 3 shows the seasonal trend in the GSI of bonga during the study period. In 1999/2000 spawning period, peak GSI was in January 2000 while in 2000/2001 spawning period peak GSI was in November 2000. From April to September, GSI was near zero.

Even though there was a correlation between fecundity and GSI, the highest fecundity was not from the fish with the highest GSI. Also the lowest fecundity was not from the fish with the least GSI. The highest GSI of 16.9 was from a fish of fecundity 151,145 eggs while the lowest GSI was from a fish of fecundity of 29,653 eggs. In the 1999/2000 spawning season, the correlation between fecundity and GSI was significant. A pooled data for the two spawning seasons also showed a

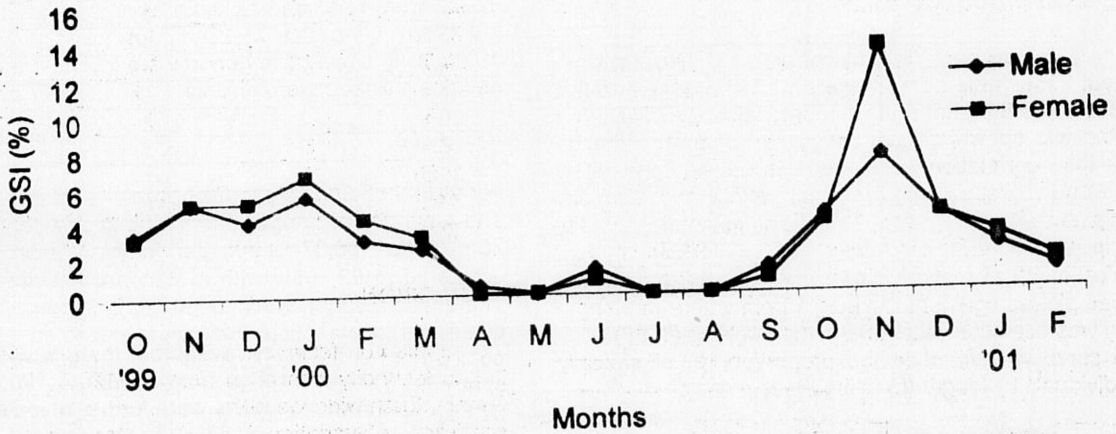

Fig.3 : Seasonal trend in GSI of bonga from October 1999 to February 2001.

significant correlation between GSI and fecundity (r^2 = 0.45, $p \leq 0.01$, n = 116). The linear regression model is given by the equation F=34357.8 ± 4642GSI. (Figure 4)

Length at maturity

Tables 1 and 2 show the number of female and male bonga with ripe gonads in the samples in a range of size classes. The proportion of sexually matured individuals is given in column 4 of tables 1 and 2. Figure 5 is a logistic curve fitted into the proportions in Tables 1 and 2 using equation (2). From the figure it is clear that male bonga are sexually matured at the size of 22.5 cm while the female are sexually matured at the size of 23cm. Analysis of variance between the size of males and females revealed significant difference between the two ($P \leq 0.05$; df = 1, 443; F = 6.63). Majority of the females were identified from the size of 23cm. the mean size for the males was 24.3cm while that of the females was 25.5cm. The smallest identifiable female was 22.8cm with a weight of 127.3g. Males of length 22cm were very distinct and readily identifiable. Few males could be identified from the gonad structures at the size of 21cm. the smallest identifiable male was 21.1cm with weight 89.6g. All males that were 23cm were very distinct. At the size of 22.5cm where there was no proper development of gonad, such an individual was concluded to be a female since males of 22cm were matured with distinct gonads.

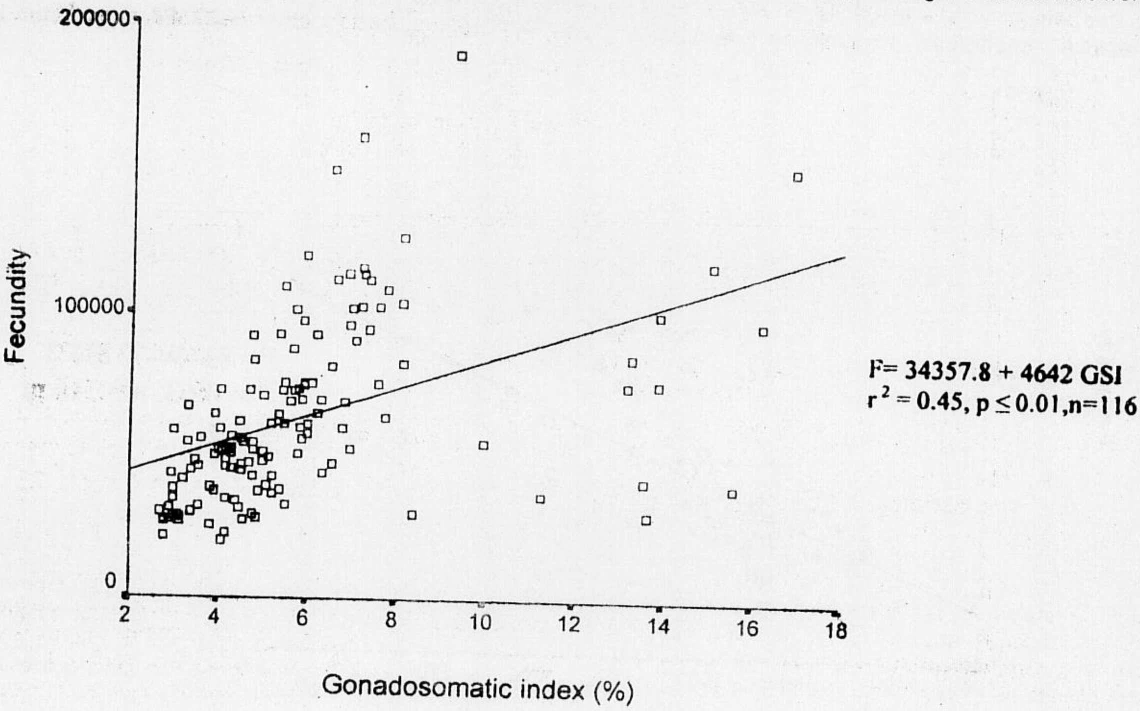

Figure 4: Fecundity –GSI relationship in *Ethmalosa fimbriata.*

Table 1: Proportion of sexually matured female *E. fimbriata* in spawning population.

Length class (cm)	Number in sample	Number ripe	Proportion ripe
20.5	-	-	-
21.5	-	-	-
22.5	11	1	0.06
23.5	26	21	0.81
24.5	55	54	0.98
25.5	47	47	1
26.5	38	38	1
27.5	15	15	1
28.5	6	6	1
29.5	1	1	1
30.5	1	1	1

Table 2: Proportion of sexually matured male *E. fimbriata* in spawning population

Length class (cm)	Number in sample	Number ripe	Proportion ripe
20.5	-	-	-
21.5	7	1	0.14
22.5	10	5	0.5
23.5	23	19	0.85
24.5	20	19	0.95
25.5	14	14	1
26.5	2	2	1
27.5	3	3	1
28.5	1	1	1
29.5	1	1	1
30.5	-	-	-

DISCUSSION

The studies on fecundity reveal that there is wide variation in bonga fecundity with range from 20,120 to 190,374 eggs per female. Such wide variations were further revealed by the high coefficient of variation of 51%. There exists a considerable variation in fecundity of bonga of same size and same GSI.

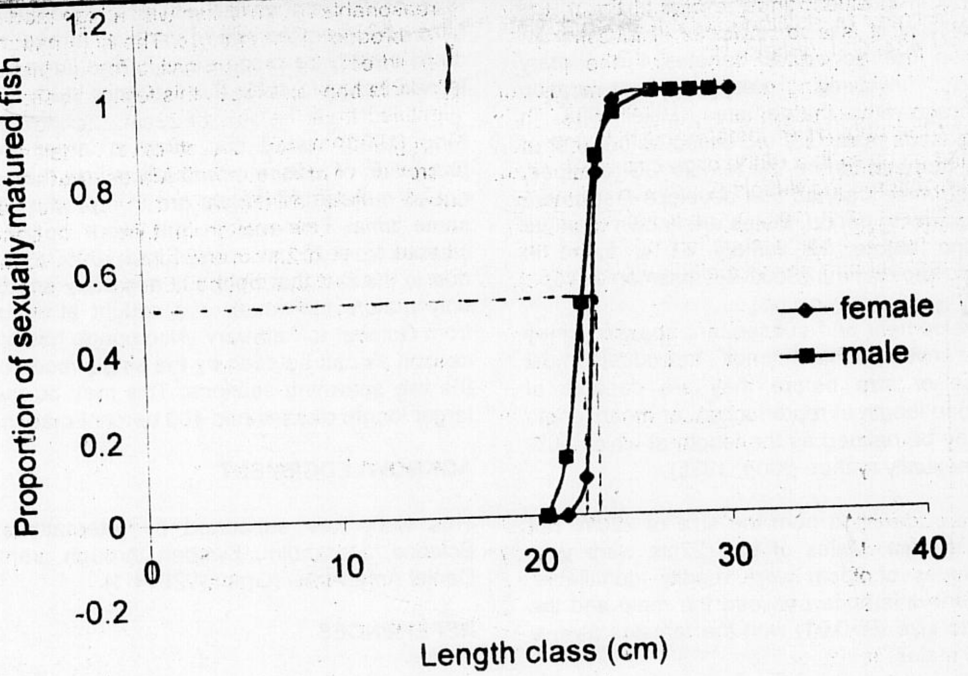

Fig. 5: A logistic relationship between the number of reproductive individuals (expressed as a proportion of the reproductive population) and length of bonga in the Cross River Estuary. The dotted lines show size at maturity. Male 22.5 cm; female 23 cm

Such variations resulted in a wide confident limit on the estimated mean fecundity and, weight and GSI. Although weight is generally correlated with GSI, sufficient variation in GSI at any particular size was observed in this study. The variation may be contributed by variation in age among the fish of same size or vice versa. The gonadosomatic index for males is seen to be generally much smaller than for females. This is a general characteristic in fish (Helfman et al, 1997). This reflects the lower effort directly expended in reproduction in males of bonga.

The fecundity of bonga to a great extent is correlated with both gonadosomatic index and size of the individual. Instantaneous fecundity typically increases with body size of female, although the direction of change in relative fecundity will depend on the ratio between the ovary weight and the body size, i.e gonadosomatic index. In the present study fecundity has been compared with weight. Differences within species in body proportions may lead to considerable dispersion in length at similar weights. But this is not the case in the present study.

Even though there was a positive correlation between fecundity and size, the highest fecundity did not come from the largest fish nor did the lowest fecundity come from the smallest fish. The highest fecundity was recorded from a fish of 27cm total length and ovary-free weight of 183.5g. The smallest fish however had fecundity of 48,768 eggs whereas the lowest fecundity was 20,120 eggs. This phenomenon is normal, as there exist individual differences between organisms of same age or size. In Lagos Lagoon, Fagade & Olaniyan (1972) recorded lowest fecundity of 23,800 eggs found in bonga specimen of 17.5cm and highest fecundity of 187,000 eggs for fish of 30.5cm. Their results fall within the lower fecundity limits for this study.

The linear plot between weight and fecundity obtained in this study is always the case in all fishes (Fagade & Olaniyan 1972; Elliot 1995). In the majority of goboids reported by Miller (1983), fecundity increased with body length, with correlation coefficient of over 0.9. Regression equations obtained for 35 species were mostly power functions of length, as is normal for teleosts. Although in some cases the functions are linear, a few species, such as *Chaenogobine scrobiculatus* show little correlation between body length and fecundity.

There are clear seasonal patterns with distinct peaks in the monthly variation of mean GSI of *Ethmalosa fimbriata*. These are indicators of maximum breeding activities. Spawning period theoretically is between the time of maximum GSI and the time when GSI attains a near minimum value (Mayer et al, 1987). Thus breeding period of this species in the coastal waters off Cross River Estuary occurs from November to March. Ama-Abasi et al. (2004) reported that growth of bonga slows down in February, a phenomenon they attributed to energy expenditure due to reproductive activities of the species within this period. Spawning of bonga from November to March is a reproductive strategy with such a timing that ensures that the larvae are hatched at a time when the salinity of the estuary is high enough for the survival of the juveniles as they enter the estuary, which they use as their nursery (Ama-Abasi 2002; Ama-Abasi & Holzloehner 2002). This work therefore confirms the earlier study.

From April to May the GSI neared zero and actually reached zero between July and September. The low level of GSI between the months of April and September therefore is an indication that no spawning activities take place in these months. Ama-Abasi (2002) & Ama-Abasi et al (2004) reported that the highest recruitment in bonga off the Cross River Estuary and adjacent coastal waters occurs between May and July. This period falls within the period of no reproductive activities as revealed by this study. Thus an approximate life cycle of bonga is provided by these findings.

GSI is useful not only in elucidating the annual timing of the fish's spawning activity; it is also an index of investment for material resources in the gonad. It denotes the primary reproductive effort (involving · prezygotic maturation biosynthesis and storage within the gametes, (Miller 1983). In the two spawning seasons male GSI increased before that of the female and also dropped before the female GSI dropped. In most cases it is the male's gonad that develops first before the female's in the spawning period. Males are known to arrive the spawning ground before the female as is found in American Shad, *Alosa sapidissima* (Scott & Crossman 1973).

Although gonad development and subsequent spawning may depend on various environmental stimuli, individuals must reach a certain age or size before they are capable of reproduction. The mean length at reproduction, or mean length at sexual maturity may be defined as the length at which 50% of all individuals are sexually mature (King, 1995).

Very few females were identified from the size of 22cm. But they were not very distinct. Males of size 22cm were very distinct. But the females of 23cm were readily identifiable. There was a significant difference between the male and the female with respect to size (P>0.01) with the females always being bigger than the males.

This work has shown that 22.5cm is the size at maturity for male bonga and 23cm for female bonga. This is quite different from the result of Fagade & Olaniyan (1972) who reported a female of 17.5cm with fully ripe gonads and fecundity of 23,800 eggs. The same authors report sexual maturity for male bonga to begin at a size of 17cm total length. Salzen (1958) gave the total length of mature females from Sierra Leone River system to be 28cm while mature males were 27cm total length and above. There is agreement between this work and those of Fagade & Olaniyan (1972) and Salzen (1958) with regards to the differences in maturing size between males and females bonga. The three studies have indicated that the males attain sexual maturity at a smaller size than the females.

However there is deviation in the maturation size of bonga in Cross River Estuary from the onces in Lagos Lagoon by Fagade and Olaniyan (1972). Fecund females ranged from size of 23cm to 34.5cm total length. It could be the Lagoon stock is different from the stock off Cross River Estuary.
On the other hand Salzen (1958) reported a higher size of maturing fish than the ones in this present study. Gras (1958), reported for Lake Nokoue, part of Benin coastal Lagoon system, the existence of stock of relatively very small individuals maturing and breeding at less than 10cm or about half the size of first maturity recorded for the estuarine stocks as shown by Salzen 1958. Longhurst (1965) opined that this relatively landlocked and stunted stock might be typical of the Lagoon systems, for similar stocks appear to occur in Lagos Lagoon. Therefore it is very probable that the Lagoon stocks are quite different in their biology from that of the coastal waters off Cross River Estuary.

Rikter & Efanov (1976) demonstrated that fish with higher natural mortality mature as early in life compensating for this high mortality (m) by starting to reproduce earlier. Ama-Abasi et al (2004) reported that natural mortality for bonga of the present area of study is 1.61 per year. This may be one reason female bonga reproduces from the size of 23cm while male reproduce from the size of 22cm.

There exist a relationship between natural mortality (m) and the ratio of gonad weight to somatic weight (GSI). This is reasonable because fish with a high mortality may compensate by producing more eggs. The high natural mortality for bonga could equally be responsible for the large amount of eggs per female bonga found in this fecundity study.

King (1995) stated that even in larger length classes, the proportion of mature individuals is less than one, meaning that not all mature individuals are in reproductive condition at the same time. However in this work bonga of larger length classes from 25 cm upward had 100% maturity. This may be due to the fact that bonga is migratory and that in most cases only mature individuals are caught at the spawning periods from October to February. Also bonga has a defined spawning season as can be seen by the single mode of the GSI cycle in the two spawning seasons. This may be the reason why the larger length classes had 100 percent maturity.

ACKNOWLEDGEMENT

This work was supported by International Foundation for Science, Stockholm, Sweden through grant provided to Dr. Daniel Ama-Abasi (Grant A/2914-1).

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