Breeding season and population dynamics of Bonga-Ethmalosa fimbriata (BOWDICH 1825) (CLUPEIDAE) in the Qua Iboe River Estuary, South Eastern Nigeria

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Abstract: The breeding season and population dynamics (growth, mortality, yield per recruit to the fishery) of the shad (also called bonga) Ethmalosa fimbriata in the Qua Iboe River estuary was studied. A total of 2,693 specimens of E. fimbriata were sampled over a period of 12 consecutive months (October 2003 to September 2004). The mean monthly values of condition index, gonadosomatic index, and % occurrence of gravid females showed maximum values from October to December. After, there was a decline from December till minimum values were obtained in July. Therefore, the breeding season is between December to July. The median size at which 50% of the fish were sexually mature were 22 cm total length for males and 22.8 cm for females. Fecundity showed a positive correlation with length and weight of fish. The smallest fecund fish of 21.0 cm (weight = 100.667 g) contained 11,272 eggs while a long specimen of 27.1 cm (weight = 203.924 g) had 175,280 eggs. The length frequency data of the 2,693 specimens were analysed using FISAT software. The estimated growth parameters for the seasonalized von Bertalanffy growth function (VBGF) were L∞ = 36.50 cm, K = 0.50 per year, C = 0.70 and WP = 0.10 of the year. Using the seasonalized catch curve procedure, the instantaneous total mortality coefficient Z was 2.72 per year, the instantaneous natural mortality coefficient M was 1.09 per year, and the instantaneous fishing mortality coefficient F was 1.63 per year. The analysis of probability of capture of each length class showed that the length at first capture was 22.93 cm. The exploitation rate (F/Z) was 0.60 per year. Relative yield per recruit and relative biomass per recruit were computed using Knife edge (Emax = 1.00, Eo.1 = 1.00 and Eo.5 = 0.41) and selection ogive (Emax = 0.63, Eo.1 = 0.61 and Eo.5 = 0.36) procedure. The species is over exploited.

Introduction
The West African shad or bonga fish Ethmalosa fimbriata is a shoaling pelagic fish, which is found throughout the West African region where it supports large artisanal and semi industrial fisheries. It occurs in inshore waters, lagoons and in estuaries of rivers where they move down during flood season, but up again during seawater intrusions in the dry season.

Because of its economic importance, it has been intensively exploited by local fishers and extensively investigated by many scientists. Fagade and Olaniyan (1972) investigated the biology of E. fimbriata in the Lagos lagoon while Blay and Eyeson (1981) studied the reproductive biology of the species in the coastal waters of Ghana. Moses (1988) elucidated the growth, mortality and potential yield of bonga E. fimbriata off the Nigerian inshore waters around the mouth of the Cross River estuary. Ama-Abasi et al (2003) worked on the dynamics of exploited population of E. fimbriata in the Cross River estuary and the adjacent Gulf of Guinea.

The population dynamics of the bonga in the Qua Iboe River estuary has not been studied before. This research will bridge this gap in knowledge. The aim of this work is to assess the population dynamics of E. fimbriata in the Qua Iboe River estuary. This knowledge is central to the understanding of its fisheries ecology and the proper management of the stock.

Data Collection and analyses
Monthly samples of E. fimbriata were collected from artisanal fishers who fished with gill nets along the Qua Iboe River estuary (Latitude 4° 30’ and 4° 45’ N and longitudes 7° 30’ and 8° 15’ E) and landed their catches at Ibene beach. At the beach, the total length of each specimen was taken. About 50 specimens were purposely selected to cover all the available size ranges and then preserved in 10% formalin.

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In the laboratory, the total length and total weight of each of the 50 specimens were taken. They were dissected and each gonad was weighed and preserved in gilson fluid. The total number of eggs in each ovary (fecundity) was determined using the gravimetric method of Bagenal and Braun (1978). Condition index was determined for each specimen as the body weight expressed as a percentage of the cube of its length, while gonadosomatic index was computed as the gonad weight expressed as a percentage of its body weight.

FiSAT (Gayanilo et al 1996) software was used in analysing the length-frequency data. First, the Powell-Wetherall algorithm (Powell 1979, Wetherall 1986) as modified by Pauly (1986) was used to obtain a preliminary estimate of $L_\infty$; through a rearrangement of the Beverton and Holt (1956) length-based Z-equation into a linear regression thus:

$$\bar{L} - L' = a + bL' \quad \text{………………………………………… (1)}$$

where $L'$ is the smallest length of fully recruited fish or cut-off length and $\bar{L} = \frac{L_\infty + L'}{1 + (Z/K)} = \text{the mean length of all fishes } \geq L' \text{ cm.}$ From Equation (1) $L_\infty$ was calculated as $a/b$ while $Z/K$ was computed as $- \frac{1 + b}{b}$. This preliminary value of $L_\infty$ was seeded into ELEFAN routine in FiSAT (Gayanilo et al 1996) to obtain optimised values of the seasonalized von Bertalanffy growth coefficients.

The seasonalized VBGF (von Bertalanffy growth function) proposed by Pauly and Gaschutz (1979) and later modified by Somers (1988) takes the form

$$L_t = L_\infty \left(1 - \exp\left(-\frac{K(t-t_0) - (CK/2\pi) \sin 2\pi(t-t_0) + (CK/2\pi) \sin 2\pi(t_0 - t_0)}{2}\right) \right) \quad \text{…………(2)}$$

Table 1: Monthly length frequency date of E. fimbriata (October 2003-September 2004; N = 2,693).

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where $L_\infty$ is the asymptotic length, $K$ is the von Bertalanffy growth constant, $L_t$ is the length at age (t), $C$ is the amplitude of growth oscillations, $t_0$ is the time between birth and onset of first growth oscillations, $t_0$ was replaced with $WP$ (Winter point) = $t_0 + 0.5$. $WP$ is the time when growth was slowest. If $C = 0$, then seasonality is not considered and equation (2) reverts to the original VBGF. Equation (2) was fitted to the sequentially arranged and restructured length–frequency data to obtain optimised VBG coefficients.

Total mortality coefficient $Z$ was estimated from the single negative exponential mortality model (Equation 3) using the seasonalized length-converted catch curve (Pauly 1990, Pauly et al 1995).

$$N_t = N_0 e^{-Zt} \quad \text{……………………………………………………………………………………………………………………… (3)}$$

Here, $N_0$ is the initial number, $N_t$ is the number after time $t$. Seasonalized $Z$ was then computed from the equation.
ln (N) = a + bt' ................................................................. (4)

where N is the number of bonga in pseudo cohorts sliced by the growth curves, t' is the relative age of bonga in pseudo cohort, b with sign changed gave the value of Z. Non-seasonalized Z was computed from

ln (Ni/Δt) = a +bt ................................................................. (5)

where Ni is the number of bonga in length class i, Δt = (1/K ln [(L∞-L1)/(L∞-L2)] = time needed for the fish to grow through length class I, L1 and L2 being the lower and upper limits of length class i, t_i = (1/K) ln (1-(L/L∞)) = relative age corresponding to the class mid-point of length class i, and b with sign changed gives Z without seasonality.

Log M = 0.0066 – 0.279 log L∞ + 0.6543 log K + 0.4634 log T ...............................(6)

Equation (6) is the empirical model of Pauly (1980), which was used in estimating the instantaneous natural mortality coefficient M. For Equation (6), T = the mean annual surface water temperature of the estuary (here = 29°C). To assess the overall growth performance φ', the model of Pauly and Munro (1984) was used (Equation 7).

φ' = 2 log L∞ + log K .................................................................(7)

The ascending left arm of the non-seasonalized length converted catch curve was used in computing the probability of capture (P) of each size class i. This involved dividing the number of fishes actually sampled by the expected numbers (obtained by backward extrapolation of the straight portion i.e. the descending part of the catch curve) in each length class of the ascending part of the catch curve. By plotting the cumulative probability of capture against class mid-length, a resultant curve was obtained from where the length at first capture Lc was taken as corresponding to the cumulative probability at 50%.

The seasonal recruitment pattern of the fish was reconstructed using the entire restructured-length frequency data set. This involved projecting backward (along trajectory described by the computed VBGF) all restructured length-frequency data onto a one-year time scale (Pauly 1987). Then, employing the maximum likelihood method, the distribution was resolved into its Gaussian components using the NORMSEP (normal separation) procedure of Hasselblad (1966).

The model of Beverton and Holt (1966), (Equation 8) as modified by Pauly and Soriano (1986) was used in predicting the relative yield per recruit (Y'/R) of the bonga to the fisheries.

Y'/R) = EU^M[K[1-(3U)/(1 + m) + (3U^2)/(1+ 2 m) – (U^3)/(1+ 3m)] ...........................................(8)

Where, E = F/Z = current exploitation rate i.e. the fraction of death caused by fishing activity, F = the instantaneous fishing mortality coefficient, U = 1- (L_c/L∞) = the proportion of growth to be completed by the fish after entry into the exploitation phase, M = (1 – E)/(M/K) = K/Z. The relative biomass per recruit (B'/R) was estimated as

B'/R = (Y'/R)/F .................................................................(9)

By solving for the first derivative of this function, E_max, E_0.1 and E_0.5 were estimated. Here, E_max = exploitation rate which produces maximum yield, E_0.1 = exploitation rate at which the marginal increase of the relative yield-per-recruit is 0.1 of its value at E=0, and E_0.5 = the value of E under which the stock has been reduced to 50% of its virgin biomass. Yield contour (or yield-isopleth) diagrams were plotted for use in assessing the impact on yields of changes of E and c the critical size ration ( = L_50 / L∞), a proxy to a change in mesh size.

Result and Discussion

The monthly variation in gonadosomatic index (for both males and females), testis weight, and percentage occurrence of gravid females showed their maximum values from October to December (Fig 1). The decline in the values of these indices from December till about July when the minimum values were obtained implied that the species spawns during the dry season months i.e. from December to June. The smallest fish with any visible gonad was 20.9 cm, consequently any fish with length < 20 cm was regarded as juvenile. In this work, it was observed that
juveniles were more abundant from April to July (Fig. 2). The timing of the spawning event was such that the fry stood to profit from the productivity of the water body during the ensuing rainy season months.

From Fig. 3, the size when 50% of the species were mature (i.e. size at first maturity or median size at maturity) were estimated as 22 cm for males and 22.8 cm for females. Males were smaller than females at maturity. These findings are similar to that of Blay and Eyeson (1981) who estimated the size at maturity as 22 cm.

A 21 cm fish of weight 100.667 g was found to contain 11,272 eggs while a 27.1 cm fish weighing 203.924 g had 175,280 eggs. In Cape Coast, Ghana, Blay and Eyeson had reported that a 21.2 cm fish (weighing 88 g had 16,000 eggs while a 30.4 cm fish (weighing 242.7 g) contained 51,750 eggs.

![Fig. 1: Monthly variation in different indices for E. fimbriata](image1)

![Fig. 2: Percentage occurrence of juveniles plotted against months](image2)
A total of 2,693 specimens of *E. fimbriata* were sampled over a period of 12 consecutive months i.e. from October 2003 to December 2004. Fig. 4 shows the seasonalized von Bertalanffy growth curves ($L_\infty = 36.50$ cm, $k = 0.5$ per year, $C = 0.77$ per year, $WP = 0.10$) which have been superimposed on both the normal (Fig. 4A) and the restructured (Fig. 4B) length frequently histograms. The parameters here are comparable with those of Moses (1988) where $L_\infty = 36.60$ cm and $K = 0.36$ per year and that of Ama-Abasi et al (2003) where $L_\infty = 35.95$ cm and $K = 0.90$ per year. The Winter Point $WP$ of 0.1 implied that the period of slowest growth was January. Ama-Aasi et al (2003) got a value of 0.1, which implied that the winter point is in January.
Fig. 5: Length-converted catch curves for *E. fimbriata* (A) seasonalized catch curves from where the slope of the descending right arm (black dots) of the line with sign changed gives an estimate of the seasonalized Z. Parameters of the regression line: \(a = 32\) (standard deviation = 1.77, confidence interval = 6.77 to 15.87), \(b = 2.72\) (standard deviation = 6.96, confidence interval = -5.17 to -0.260, \(r = 0.78, r^2 = 0.617, n = 7\). Estimated seasonalized Z = 2.72 per year. (B) Non-seasonalized length-converted catch curve. Parameters of the regression line: \(a = 20.428\), (standard deviation = 1.57, confidence interval = 16.08 to 24.78), \(b = -5.12\) (standard deviation = 0.6680, confidence interval = -6.97 to -3.26), \(n = 6, r = 0.97, r^2 = 0.94\). Other computed statistics: cut-off length \(L^* = 21.95\) mean length (from \(L^*\) = 23.64. Estimated Z = 5.12. Points on the ascending left arm of the curve (open dots) were used in calculating the probability of capture of each size class (open dots = numbers actually sampled, open squares = expected numbers). Dividing N by \(\Delta t\), serves to correct for the non-linearity in the growth of the bonga.

The Z value was 2.72 per year from the seasonalized catch curve (Fig. 5 A) and 5.12 per year from the non-seasonalized catch curve (Fig. 5B). Moses (1988) obtained a Z value of 1.2 per year and Ama-Abasi et al (2003) got a value of 6.91 per year. In this work M = 1.09 per year, giving an F (instantaneous fishing mortality coefficient) of 1.63 per year and exploitation rate \(E (=F/Z)\) of 0.60. Ama-Abasi et al (2003) had a value of E = 0.77. The Qua Iboe estuary stock of bonga fish is almost as heavily exploited as the Cross River estuary stock. In this study, the computed E (=0.60) was the same as the predicted value of 0.63 from the relative yield per recruit analysis using the selection ogive (Fig. 6). The analysis of recruitment pattern through the backward projection of the restructured length-frequency data on to a one year time scale shows that there was one peak of recruitment into the fishery. This agrees with the analysis of monthly variation in GST, which showed one peak also. The monthly changes in preponderance of juveniles showed one peak in a year, lending credence to our findings from recruitment pattern, which was reconstructed from length frequency data.
Breeding season and population dynamics of Ethmalosa fimbriata from the Qua Iboe River

Fig. 6: (A) Relative yield-per-recruit and (B) relative biomass per recruit for *E. fimbriata* using the knife edge selection procedure. Summary statistics: $E_{\text{max}} = 1.00$, $E_{0.1} = 1.00$, $E_{0.5} = 0.41$ (C) Relative yield-per-recruit (D) Relative biomass per recruit using selection ogive procedure. Summary statistics: $E_{\text{max}} = 0.63$, $E_{0.1} = 0.61$, $E_{0.5} = 0.36$.

Fig. 7: Yield isopleths for *E. fimbriata*. The yield contours predict the response of the relative yield-per-recruit of the fish to changes in $L_c$ (length at first capture) and $E$ (exploitation rate). $L_c/L_\infty$ values represent varying scenarios equivalent to a change in mesh size and $E$ corresponds to changing levels of $F/Z$. The dotted line is the actual computed value of the critical ratio $L_c/L_\infty = 0.63$.
The yield isopleths are presented in Fig. 7. Since this stock is over exploited ($E = 0.06$ and $E_{\text{max}} = 0.63$), we recommend that the collapse of the fishery could be averted by reducing pressure on the stock. Theoretically, many options are open – increase the mesh size, reduce effort, regulate number of boats in the fishery, set total allowable catch, issue licence.

References


