

AGE AND GROWTH OF MUGIL CEPHALUS (LINNAEUS, 1758) (PERCIFORMES: MUGILIDAE) IN BONNY ESTUARY

BY

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ABSTRACT

The age and growth of Mugil cephalus was investigated in the Bonny estuary from January, 1995 to December, 1996. Length weight relationships were isometric with length exponents of 2.84 (males), 2.90 (females) and 2.88 (Overall). Modal length at age were 12.0cm, 20.9, 25.0cm, 28.4cm and 30.2cm TL for ages 0+, 1+, 2+, 3+ and 4+ respectively. Corresponding total weights were 20.01g, 78.93g, 173.12g, 217.61g and 247.50g respectively. Asymptotic length (L_{∞}) was estimated as 33.2cm TL, asymptotic weight (W_{∞}) was 484g, growth coefficient $K=0.55847\text{yr}^{-1}$ and hypothetical age at zero length $T_0 = 0.152\text{yr}$. Longevity T_{max} was 5.0yr, length and weight growth performance indices were $Q^1=2.79$ and $Q^2=1.44$ respectively. Total mortality, natural mortality and fishing mortality were $z = 1.02\text{yr}^{-1}$, $M=0.607\text{yr}^{-1}$ and $F=0.3129\text{yr}^{-1}$ respectively. The exploitation ratio E was 0.4048 and exploitation rate $U = 0.2302\text{yr}^{-1}$.

INTRODUCTION

Age and growth studies are particularly important for describing the status of a fish population and for predicting the potential yield of fishery. Unfortunately, age and growth determination in fishes of tropical waters are not easily back calculated from annual. This is because water temperatures vary only slightly throughout the year, making formation of growth marks on scales and other hard parts uncertain (Arowomo, 1982).

The length-weight relationship is used for converting weight data to length and vice-versa. The length-weight relationship for fish is curvilinear with the length exponent (regression coefficient) ranging between 2.5 and 4.0 (Lagler *et al.*, 1977). Bagenal and Tesch (1978) reported that growth is isometric (i.e. a constant specific gravity) when the length exponent is 3 and allometric (growth with changing specific gravity) when the length exponent is greater or less than 3. Length could have been caused by changes in habitat and gonadal maturation. (Welcome, 1969). influenced in part by the genetic composition of the species and by prevailing conditions.

Mature mugilids migrate to the sea from coastal systems for spawning and return to the coastal lakes, estuarine waters and sometimes freshwaters after spawning these migration include large variations in the growth rate as this can change from year due to environmental factors especially if all the migrations from one biotype do not return there as is always the case (Quignard and Farrugio, in Owen, 1981). The growth rates of Mugil cephalus have been studied (Marquez, 1975; Farrugio, 1975; Brulhet, 1974, 1975; Grant and Spain, 1975 and Alessio, 1976).

Study Area

The study site is located between latitudes $4^{\circ}25'$ and $4^{\circ}50'N$ and longitudes $7^{\circ}00'$ and $7^{\circ}15'E$. The basin has a total area of about 66,000 hectares, made up of elevated beach ridges, mangrove swamps, rivers and creeks. The mean tidal range at Bonny town is 1.35m (Wokoma & Ezenwa, 1982), and the river is tidal over the whole length.

The climate is characterised by two seasons -- dry (November -- March) and wet (April -- October). Annual rainfall in Bonny is between 355.6cm to 469.8cm (Udo, 1978). The vegetation include *Rhizophora spp.*, *Avecenia sp.*, *laguncularia sp.* growing on water-logged deposits of soft mud and clay-silt sediment.

Material and Methods

Sampling

Samples of *Mugil cephalus* were collected between January 1996 and December 1996. Several sampling methods employed which included use of beach seines, gill nets and collection from landing. The size of the nets used were between 30mm and 60mm mesh size specimens were collected twice a month and conveyed to the laboratory in thermos -- cool boxes. The samples caught were counted and other morphometric measurements taken.

Standard and Total Lengths

These information were obtained by measuring the standard and total lengths of the fish to the nearest 0.1cm. The standard length (SL) was measured from the most anterior extremity to the hidden base of the median tail fin rays. The total lengths (TL) was measured from the most anterior extremity to the end of the bi-furcated fin tips.

Weight

The weights (Wt) of the fish were obtained by weighing samples on digital meter balance to the nearest 0.01g. Weights were obtained after draining water from the buccal cavity and blot-drying samples.

Length-Weight Relationships

Length-weight relationships of *Mugil cephalus* was represented by the exponential equation:

$$Wt = a(TL)^b \quad (1)$$

Where Wt = total weight, TL - total length; a = a constant and b = an exponent, both of which were estimated by the least squares linear regression method after logarithmic transformation of equation 1 into the form,

$$\text{Log } Wt = \text{Log } a + b \log TL \quad (2)$$

Scales

Scales of *Mugil cephalus* were removed from under to first dorsal fin at the middle part of the body which corresponds to the extremity of the pectoral fins (Oven, 1981). These were cleaned, dried, mounted between two glass slides and examined under high power (x 100) compound microscope. There were no clear annuli that would have facilitated ageing from scalimetry. An indirect length - based ageing method involving length-frequency distribution was therefore used on the assumption that discrete modes in length frequency distribution could be interpreted as indicating age-groups.

Age

To estimate the ages of *Mugil cephalus*, a total of two hundred and forty-six (246) specimens were used. Age was estimated by the analysis of a polymodal length-frequency distribution plot (based on samples grouped into 1cm length classes) using Pauly's (1983) integrated method. The length data were pooled into one length-frequency plot which was assumed to roughly represent a steady state population. The cumulative length-frequency diagram was repeated six times along the time-axis and a single continuous growth curve was fitted by eye. Modes were present for the presumed age groups and they showed progression overtime; the

relative age (yr) and corresponding modal lengths were determined from the plot. This method is based on the premise that year to year growth is similar and that in young, growth is initially rapid before decreasing smoothly with increase in age and is best approximated by a long continuous curve which passes through most peaks in a sequential series of length frequencies, a single growth curve inter-connecting most peaks of sequentially arranged length frequency samples is very likely to depict the mean growth of a given stock (Pauly, 1983).

Growth

The annual growth pattern of *Mugil cephalus* was depicted by the exponential function (Roff, 1988).

$$LT = a(T)^b \quad (3)$$

Where LT = length at age T; a = a constant and b an exponent of which were estimated by regressing length on age after logarithmically transforming the data and linearizing equation 3 into the form

$$\log LT = \log a + b \log T \quad (4)$$

The annual accretion in length was also modelled by the asymptotic von Bertalanffy's growth function (VBGF) (Pauly, 1983).

$$LT = L (1 - \exp(-k(T - T_0))) \quad (5)$$

Where LT = length at age T, L = asymptotic length (i.e. length of very old fishes), K = growth coefficient, expressing the rate (1/T) (Per year) at which growth approaches the asymptote and T₀ (yr) = hypothetical age at which length is zero L and K were estimated from Ford-Walford Plot (Pauly, 1983) or LT + 1 (length separated by one year interval) against LT and fitting the line by least squares linear regression of the form, (Culland, 1969), {PRIVATE }

$$\ln(L - LT) = a + bT \quad (7)$$

Where a = $\ln(L - LT)/L$ - axis intercept and b = slope of the regression line.

The 3/4 intercept of the resulting straight line on the T - axis gave T₀
Estimation of total weight at age mugil cephalus was made from the Von Bertalanffy growth function (VBGF) for growth in weight (Pauly, 1983),

$$WT = W (1 - \exp(-K(T - T_0)))^b \quad (8)$$

Where WT = Total weight at - age T, K and T₀ are as defined in equation 5; W = asymptotic weight corresponding to the asymptotic length and was estimated as (Sparre *et al*, 1989).

$$W = a L^b \quad (9)$$

Where a and b are as defined in equation 1

Pauly and Munro's (1984) length performance index (O) was estimated from the equation

$$O = \log K + 2 \log L \quad (10)$$

Where K and L are parameters of VBGF (egn 5) Munro and Paul's (1983) weight growth performance index (O) was estimated from the formula.

$$O = \log K + 0.67 \log W \quad (11)$$

Where K and W are parameters of the VBGF (egns 5 and 8)

The longevity (ie, maximum age attainable by individual specimens in the Population) of mugil cephalus was estimated according to Pauly (1983),

$$T_{max} = 3/K \quad (12)$$

Where T_{max} = longevity and K is defined in egn 5

To evaluate the growth in morphometric parameters relative to total length (allometric growth), the standard length and body depth were measured with measuring meter rule. The growth pa of each morphometric parameter (Mi) relative to total length (TL) was determined from the general function

$$Mi = a(TL)^j \quad (13)$$

Where a = initial growth constant (millimeters increases per millimeter total length) and j growth

rate exponent, both coefficients were determined by least squares regression analysis after logarithmically transforming all data and linearizing eqn 13 into the form,

$$\log M_i = \log a + \log TL \quad (14).$$

In eqns 13 and 14, if $j = 1.0$ then M_i growth rate is constant and equal to the initial growth constant (isometric growth) otherwise there is a negative ($j < 1.0$) or positive ($j > 1.0$) allometric growth.

Mortality

The total mortality co-efficient (Z) of mugil cephalus was estimated from the formula (Scenteng and Harkin, 1973)

$$Z = \frac{1}{(n+1) \ln(L - l/L - 1)} \quad (15)$$

Where n - number of fish used in computing the mean length (l) l = smallest size of fish that is fully represented in the catch; K and L are parameters of the VBGF (eqn 5) An independent estimate of Z was obtained from the Hoening's (in Kunzel and Lowenberg, 1990) empirical model.

$$\ln(z) = 1.45 - 1.01 \ln(T \max) \quad (16)$$

Where T max = longevity (yr)

Natural mortality co-efficient (m) was estimated from Taylor's (Ehrhard *ete al.*, 1983) formula,

$$M = 2.9957/T_0 + (2.9975/k) \quad (17)$$

Where T_0 and K are parameters of (VBGF) (eqn 6). Fishing mortality co-efficient (F) was estimated as $Z - M$.

The exploitation ratio (E) was given as F/Z (Pauly, 1983). The rate of exploitation (U) was calculated from the equation (Landau, 1979),

$$U = F/Z (1 - e^{-z}) \quad (18)$$

Where F and Z are coefficients of fishing and total mortality respectively; $e = 2.7182$ (base of natural logarithms).

Results

Size Composition

The largest specimen (L max) of mugil cephalus recorded in the Bonny river was a 30.1cm TL (maximum weight $W_{max} = 247.50g$) female caught in June. Specimens comprised of 12.5 - 27.9cm total length (23.91 - 205.5g total weight) males and 12.2 - 30.1cm total length (20.01 - 247.50g total weight) female.

Monthly size frequency distribution of mugil cephalus (fig. 5) shows that juveniles of less than 12.0cm were not represented in the sample, Juveniles were caught more in January, August and December. The largest specimens of 26.0 - 30.9cm TL were caught in May, June, July and September. The month size distribution (fig. 5) showed that the specimens between 14.0 - 24.0cm TL were evenly distributed throughout the year with their modes around September, October and November. The size frequency distribution showed a polymodal pattern. Specimens between 12.0 - 22.9cm TL showed the highest Peaks and represented 86.59% of the length distribution.

Total length is used as a measure of fish size in this research, the linear relationship between the total length and standard length indices are described by the equations.

$$SL = 0.3260 + 0.7614 TL$$

$$TL = (SL/0.7614) - 0.4282.$$

For females fish samples of 12.2cm TL - 30.1cm TL. The correlation co-efficient were highly significant ($r = 0.998$, $df = 120$, $P < 0.001$).

The male fish were described by the equations (For fish of 12.2 - 27.9cm TL).

$$SL = 0.1977 + 0.7782 TL$$

$$TL = (SL/0.7782) - 0.2540$$

The correlation coefficient for the relationships was highly significant ($r = 0.957$, $df = 122$, $P < 0.001$).

About 99.60% and 91.58% of the variance in one of the parameters for female and male fish respectively were explained by the variance in the other.

Length - Weight Relationships

Length - weight relationship of mugil cephalus from Bonny river are shown in figs. 7 and 8, and the exponential equations presented in table 2. The correlations were highly significant with coefficients of determination (r^2) of 99.40% for males and 98.01% for females. The length exponent (b) was 2.84 for males (12.2 - 27.9cm TL) and 2.90 for females (12.2 - 30.1cm TL). The overall pattern had a high significance of correlation with coefficients of determination (r^2) of 97.61% and length exponent (b) of 2.88. This signified that growth was isometric and the value of b can be approximated to 3.0.

Age Composition

Five age groups were determined from Paul's (1983) integrated method (fig. 9) of the 246 specimens, age 1 + dominated the catch 65.45%, followed by age 2 + (21.95%), age 3+ (15.00%), age 0+ (4.47) and age 4 + (2.03) respectively as shown in table 3.

Growth in Length

The age-groups, their corresponding modal lengths, ranges and annual length increments for *M. Cephalus* are shown in fig. 9 and table 3. While the modal length increased with age, the annual length increment showed an inverse relationship to age. The annual length increment was highest in age 0+ and decreased progressively thereafter reaching its minimum in age 4+. The growth from age 1+ to 4+ confirmed to the exponential equation of the form ($r = 0.9999$, $df = 2$, $P 0.005$) $LT = 20.895 T^{0.270}$.

Which accounted for 99.75% of the variance in length. The growth rate exponent ($b = 0.2702$) which was less than one (1) depicted a decreasing growth increment per year, characteristic of asymptotic growth patterns.

Fig. 10 shows that the fit between the observed and predicted (from above exponential model) lengths of mugil cephalus was highly significant ($r = 0.998$, $df = 2$, $P 0.005$) with 99.60% of the variance in predicted lengths being accounted for by changes in the observed lengths. The slope and intercept ($1p = 0.081 + 0.99710$) did not deviate significantly from the expected 1 and 0 respectively.

Fig. 11a depicts the exponential length curve of mugil cephalus which conformed to the asymptotic Von Bertalanffy's growth functions (fig. 11b).

Estimates of $L = 33.2$ cm TL and $K = 0.5547$ yr⁻¹ (fig. 12a) while $T_0 = - 0.466$ yr (fig. 12b). From these parameters, the year to year length growth patterns of mugil cephalus can be represented by $LT = 33.2 (1 - \exp (-5547 CT + 0.466))$. The correlation between length at age of *M. cephalus* predicted from the above VBGF and the observed (fig. 13) was highly significant ($r = 0.996$, $df = 3$, $P 0.005$), with 99.40% of the variation in predicted lengths accounted for by the variance in the observed lengths. However, the slope and intercept ($1p = 1.2712$ $10 - 7.7184$) of the regression deviated markedly from the expected values of 1 and 0 respectively, the results showed a slight tendency for the predicted lengths to be less than the observed especially in ages 0+ and 1+ but in ages 2+ to 4+ the differences became considerably minimal.

Comparison of the length growth parameters (observed and predicted) using ANOVA showed that there is no significant differences in the parameters ($F = 0.37$, $df = 11$, $P = 0.05$) as shown in table 5.

The length growth performance index of mugil cephalus was estimated at $O = 2.786$.

Growth in Weight

The weight-at-age and annual weight increments of *M. cephalus* are given in table 4. Total weight increased from 20.01 in age 0+ to 247.50g in age 4+. Annual weight increment reached its peak age 2+ (94.19g, Yr⁻¹) and declined thereafter. The sigmoid weight - growth curve of the asymptotic asymmetry is illustrated in fig. 15. The weight converted VBGF showing the year - to - year weight growth pattern of *M. cephalus* (determined from fig. 14) can be represented by the equation.

$$WT = 484 (1 - \exp(-0.235 (T + 0.04)))^{0.7906}$$

The correlation between weight - at - age of *M. cephalus* predicted from the above VBGF and the observed was highly significant ($r = 0.992$, $df = 3$, $P = 0.001$), with 98.44% of the variation in predicted lengths accounted for by the variance in the observed lengths.

The growth in weight from age 1+ to 4+ conformed to the exponential equation of the form ($r = 0.973$, $df = 2$, $P = 0.05$)

$$WT = 89.07 T^{0.778}$$

Which accounted for 94.77% of the variance in weight.

Comparism of the weight growth parameters (observed and predicted) using ANOVA showed homogeneity in the parameters ($F = 0.26$, $df = 11$, $P = 0.05$) as shown in table 6.

The weight growth performance index of *M. cephalus* was $O = 1.44$.

Longevity

The maximum age attained by individual specimens of *M. cephalus* in Bonny river was $T_{max} = 4.99$ yr (appx. 5.0 yr).

Mortality

Estimated total mortality coefficient for *M. cephalus* using Ssentengo and Larkins (1973) formula gave $Z = 1.196$ yr⁻¹, while hoeing's (in Kunzel and Lowenberg, 1990) enperical model gave $Z = 0.841$ yr⁻¹. The discrepancy between both estimates was only 0.335 in favour of the former. The average of the estimates is $Z = 1.02$ yr⁻¹.

Naturally mortality coefficient $M = 0.6071$ yr⁻¹. The exploitation ratio ($E = 0.4048$) showed that 40.48% of the total mortality of available stock of *M. cephalus* was caused by exploitation. The rate of exploitation ($U = 0.2302$ yr⁻¹) showed that only 23.02% of available stock was fished annually.

Discussion

The maximum size (L_{max}) attained by *Mugil cephalus* in Bonny river is lower than in other aquatic systems (Table 15). This can be attributed to the high fishing pressure in the Bonny river. L_{max} is generally location specific and the Bonny river is highly polluted with noise from outboard engines and petrogenic effluents which may affect the growth rate of the fishes.

The maximum size attained by an animal occurs when it grows to 95% of its asymptotic length according to the relationship (Moses, 1990)

$$L'_{max} = 0.95L_0$$

Where L'_{max} = estimated maximum size (distinguished from L_{max} which is the maximum size encountered). This relationship for *M. cephalus* with $L = 33.2$ cm TL would give $L'_{max} = 31.5$ cm TL. The values of the length exponent in the length-weight relationships of *Mugil cephalus* in Bonny river indicates that increase in weight related to length is isometric. This implies that fish did not increase in weight faster than the cube of its total length. The result conforms with the observations of Hora and Pillay, (1962) and EI Maghraby *et al* (1973) who recorded isometric length-weight relationships ($b = 2.88$) and ($b = 2.81$) in *M. cephalus* populations in India and (Borullus) Egypt respectively.

The modal regression pattern showing fig. 9 indicates that the (Pauly, 1983) model estimates for length - at - age are reliable as these agreed with estimates from the exponential model (fig. 10) and the von Bertalanffy growth function model (fig. 13). Though the age length estimates may not be completely error - free due to the selectivity of the gear which resulted in no catch of specimens less than 12.0cm, it does not invalidate the estimates as it is comparable to those for other populations (Table 16).

The estimate for growth coefficient (K) in this study is similar to observations for other populations (Brulhet, 1975; Cech and Wohlschlag, 1975; Farrugio, 1975 and Alessio, 1976) (Table 17).

The weight growth pattern of *M. cephalus* (Table 4) shows that growth in weight peaked in age 2+ and was least in age 0+. A similar pattern was observed for *Tilapia mariae* in Ibaoku stream, Nigeria (King, 1991). But the result is discordant with the data on *Oreochromis niloticus* in Opa reservoir, Nigeria where growth peaked in age 3+ and was least in age 1+ (Arawomo, 1982). Growth in length is a more reliable index over growth in weight as a long-term monitoring index because it depends on skeletal structures and once gained cannot be lost (Arawomo, 1982).

Growth performance index for length (O) (Pauly and Munro, 1984) and weight (O) (Munro and Pauly, 1983) are used in comparing the growth efficiency of different populations of the same species. The length growth performance index, $O = 2.79$ recorded in this study is higher than $O = 2.69$ recorded in the sea near Texas, U.S.A. (estimated from Cech and Wohlschlag, 1975). In Australia, O of 3.10 (estimated from Grant and Spain, 1975) is slightly higher than the O value recorded in this study.

The mortality of *M. cephalus* in Bonny was observed to be affected more by natural mortality than exploitation of stock by man. Only 23.02% of the available stock was harvested annually. The high natural mortality can be attributed to environmental stress contributed by oil exploration and exploitation activities.

Fish predation is another factor that may have contributed to the observed high mortality. King (1984) reported that the species occurred in the diets of *Caranx spp.*, *Shyrcana sp.*, *Lutjanus sp.* and *Callinectes spp.*. However this study disagrees with the suggestion by King (1984) that the major cause of mortality of this species in Bonny river is due to man's fishing activity. However, the models employed in this study may be biased since they did not consider the emigration and immigration components of an open system such as Bonny river.

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Table 2: Length-weight relationships of *M. cephalus* in Bonny river

{PRIVATE }Category of fish	N	Length-weight eqn.	r
Males	126	Wt = 0.0157 TL 2.84	0.997*
Females	120	Wt = 0.0132 TL 2.90	0.990*
Males+Females	246	Wt = 0.0141 TL 2.88	0.988*

N = Number in sample
r = Correlation coefficient; *P<0.001

Table 3: Age composition, length-at-age and annual length increment of *m. cephalus* in Bonny River

{PRIVAT E }Age(Yr)	N	%N	Modal total length (cm)	Annual length increment (cm.yr-1)	L _{T+1}
0+	11	4.47	12.0	12.0	20.9
1+	161	65.45	20.9	8.9	25.0
2+	54	21.95	25.0	4.1	28.4
3+	15	6.10	28.4	3.1	30.2
4+	5	2.03	30.2	1.8	
	246				

N = Number in Sample
L_{T+1} = Length separated by 1-year interval

Table 15: The maximum size attained by different populations of *M. cephalus*.

{PRIVATE }Locality	Max. size attained (Total length, cm)	Reference
Bosphorus and Marmara sea	67.0 cm	Erman, 1959
Berre salt lake, France	49.0 cm	Ezzat, 1965
Coastal waters, Mauritania	61.1 cm, 92.4cm	Brulhet, 1974, 1975
North Queensland, Australia	62.0 cm	Grant and Spain, 1975
Texas (Coastal waters), U.S.A.	30.9 cm	Cech and Wohlschlag, 1975
Orbetello lake, Italy	54.0 cm	Alessio, 1976
Bonny river, Nigeria	30.1 cm	This study

Table 16: Summary of the age-length data for some populations of *M. cephalus*.

{PRIVATE } Locality	Length - at - age (yr)					Reference
	0+	1+	2+	3+	4+	
Bosphorus and Marmara sea	-	7.0	17.4	26.0	35.5	Erman, 1959
Salt lake (Berre), France	-	14.0	22.8	28.4	33.4	Ezzat, 1965
Coastal water, Mauritania	-	-	38.4	50.9	59.1	Brulhet, 1974
North Queensland, Australia	-	11.4	28.9	36.9	40.4	Grant and Spain, 1975
Texas (Coastal waters), U.S.A	-	16.6	22.8	27.4	31.3	Cech and Wohlschlag, 1975
Orbetello lake, Italy	-	21.6	35.1	43.2	49.1	Alessio, 1976
Bonny river, Nigeria	120	20.9	25.0	28.4	30.2	This study

Table 17: Comparism of growth coefficient (K) of different population of *M. cephalus*.

{PRIVATE } Location	Growth coefficient (K. yr ⁻¹)	Reference
Mexican sea	0.340	Marquez, 1974
Coastal waters, (Texas), U.S.A	0.240	Cech and Wohlschlag, 1975
North Queensland, Australia	0.344	Grant and Spain, 1975
Salt lake (Tunis), Tunisia	0.190(F)	Farrugio, 1975
Orbetello lake, Italy	0.400	Alessio, 1976
Bonny river, Nigeria	0.555	This study