

**BREEDING, GROWTH, MORTALITY AND YIELD OF THE
GUINEA SPRAT *Pellonula leonensis*, (Teleostei: Clupeidae)
IN IMO RIVER ESTUARY, NIGERIA**



ISSN: 2141 – 3290
www.wojast.com

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ABSTRACT

We studied the reproductive biology, growth, mortality and yield – per – recruit to the fishery of the Guinea sprat *Pellonula leonensis* in Imo River estuary in the eastern Niger delta of Nigeria. Monthly variation in gonadosomatic index reveals that males and females spawn twice in a year June and November. We collected and analysed 12 consecutive months length frequency data using FiSAT software. Fitting the Seasonalised Von Bertalanffy growth function to these data gave the following results: $L_{\infty} = 11.9$ cm, $K = 1.2$ yr⁻¹, $C = 0.85$, $WP = 0.3$ of the year. Using the seasonalised catch curve procedure, the estimated instantaneous total mortality Coefficient $Z = 6.32$ yr⁻¹. The instantaneous fishing mortality Coefficient, $F = 3.68$ yr⁻¹, and the instantaneous natural mortality coefficient, $M = 2.60$ yr⁻¹. Our computed exploitation rate $E = 0.58$ showed that fishing pressure on the stock is high. This is supported by the results of the relative yield – per – recruit analysis which showed that the predicted maximum exploitation level $E_{max} = 0.42$ which was lower than the current exploitation rate ($E = 0.58$).

INTRODUCTION

The clupeid *Pellonula leonensis* has a very high commercial value among the riparian communities of West Africa. It is found in Lagoons, Lakes and in both lower and upper reaches of rivers from Senegal to Cameroon, and also in the coastal river basins from Cameroon to Democratic Republic of the Congo, upper Niger and lower Benue, (Ikomi, 1993). It is also reported in Cross River System (Kunzel *et. al.* 1985; Kunzel and Lowenberg, 1990). They are predominantly marine but some species have colonised fresh water successfully using numerous adaptations to maintain the pelagic habitat of their ancestors in the sea.

An important fishery for *Pellonula leonensis* exists at the study area. It constitutes an important affordable source of protein to the riparian human community. Although they are naturally small size fish and often less attractive particularly to the ‘wealthy class’, however, they are highly cherished by under privileged people who constitutes the majority in tropical countries. Apart from serving as food, the species is exploited for use as fish bait and also processed as fish meal component for livestock feed manufacturing. Literature search reveals scanty data on the species in West Africa including works of Kunzel *et. al.*, (1990); Ikomi (1993); Ita (1983), and Akpan *et. al.* (2005).

The Imo River estuary, is located in the tropical rainforest belt with an equatorial climate regime. There are two seasons – the rainy season (May to October) characterised by moist winds and heavy precipitation and the dry season (November to April) with hot humid winds and scanty precipitation. In Imo River estuary, *Pellonula leonensis* is exploited for use as fish bait, raw material for livestock feed and human food. We studied aspects of the breeding biology and spawning season of the species. We also quantified the growth parameters and mortality rates and elucidate the yield of the species to the fishery.

MATERIAL AND METHODS

We obtained monthly (January – December, 2010) samples of *Pellonula leonensis* from the fishermen at ATC beach in Ikot Abasi in eastern Niger Delta, Nigeria. Fishing was done at the estuary (Fig. 1) by the artisanal fishers using lift net, measuring 2.9 x 2.9 m, which lies between latitude 4°31'1" and 4°40'1" N and longitude 7°35' to 7°40' E mesh size 1 mm (Kunzel, *et. al.*, 1985). The identification of the species followed Whitehead (1985).

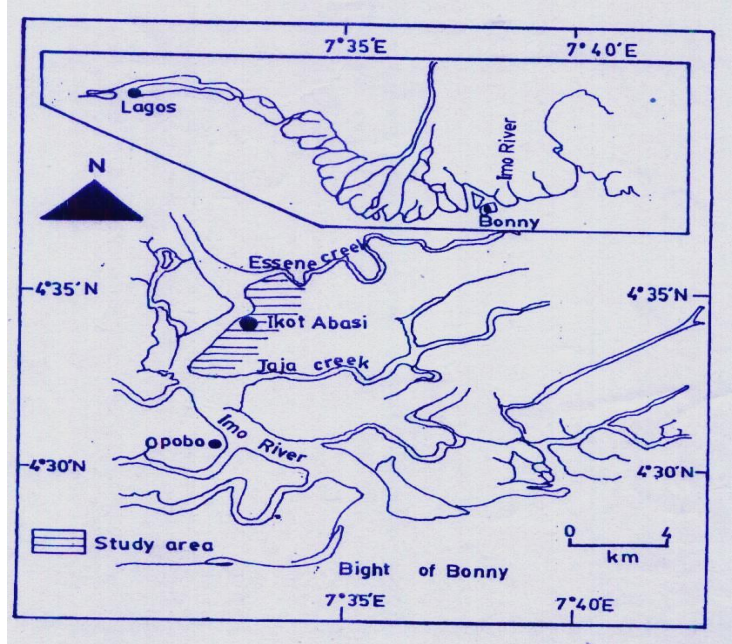


Figure 1: Map of Imo River estuary showing the sample collection station

We sexed each specimen based on differences in morphology of the gonads using the guidelines in Bruton (1976). The total length and total weight of each specimen were measured before dissecting it to weigh its gonad. We computed the gonadosomatic index (GSI) (weight of gonad expressed as a percentage of body weight less gonad weight), the condition index (CI) (weight of the specimen expressed as a percentage of its length cube). The monthly mean of each of these indices was plotted against time of sample collection to obtain the seasonal variation. Total absolute fecundity was estimated according to the method of Bagenal and Braum (1978).

We used FiSAT (Gayanilo *et. al.* (1990) to analyse the length-frequency data, and ELEFAN procedure contained in FiSAT software, to sequentially arrange and restructure the length-frequency data. We then fitted the Seasonalised Von Bertalanffy Growth Function (VBGF) Eq. (1) proposed by Pauly and Gaschutz (1979) and later modified by Somers (1988) to our length frequency data.

$$L_t = L_\infty \left(1 - \exp(-K(t - t_0)) + \left[\frac{CK}{2\Pi} \right] \right) \times \sin 2\Pi(t - t_s) - \left[\frac{CK}{2\Pi} \sin 2\Pi \right] (t_0 - t_s) \quad 1$$

Where L_t is the length at age t , L_∞ the asymptotic length, K the Von Bertalanffy growth coefficient, C the amplitude of growth oscillations, to the age of the Guinea sprat at zero length t_s the time between birth and onset of the first growth oscillations. WP is the time when growth

is slowest and is substituted for t_s since $WP = t_s + 0.5$. Eq (1) reverts to the original VBGF if $C = 0$, i.e. if the effect of changing season on growth is not considered. We used the Powell-Wetherall Procedure (Powell, 1979; Wetherall, 1986) as modified by Pauly (1986) to obtain initial estimate of L_∞ . In this method, the Beverton and Holt (1956) length-based Z-equation was rearranged to a linear regression model of the form.

$$L - L^1 = a + bL^1 \tag{2}$$

Here, $L = (L_\infty + L^1) / (1 + (Z/K))$ is the mean length of all *Pellonula leonensis* sp. $\geq L^1$ and L^1 the smallest length of fully recruited *Pellonula leonensis* sp. From Eq. (2) we computed L_∞ as a/b , and z/k as $-1/(1+b)$. We then seeded this initial value L_∞ into ELEFAN to obtain optimised values of the seasonalised VBG coefficients.

The seasonalised length – converted catch curve (Pauly, 1990; Pauly *et. al.* 1995) was used to estimate the instantaneous total mortality coefficient Z of the single negative exponential mortality model.

$$N_t = N_0 e^{-Zt} \tag{3}$$

Here N_0 is the initial number and N_t the number at time t . Seasonalised Z was then computed from the regression equation.

$$\ln(N) = a + bt^1 \tag{4}$$

Where N is the number of *Pellonula* sp in pseudo-cohorts sliced by the growth curves, t^1 the relative age of *Pellonula* in that pseudo-cohort, b with sign changed gives Z with seasonality.

The method of Pauly (1987) was used to analyse the probability of capture P of each size class i using the ascending left arm of the length – converted catch curve. This entails dividing the number of *Pellonula* 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. Plotting the cumulative probability of capture against mid-length, gives a resultant curve from which the length at first capture L_c was taken as corresponding to cumulative pattern of the *Pellonula* using our entire restructured length-frequency data set. This involves projecting backward, along a trajectory defined by our computed VBGF, all the restructured length-frequency data onto arbitrary 1-year time scale (Pauly, 1987). Then using the maximum likelihood approach, we separated the recruitment pattern into its Gaussian component using the NORMSEP (normal separation) method of Hasselblad (1966). The model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) was used to predict the relative yield – per – recruit.

$$\frac{Y^1}{R} = EU^{M/K} \left[1 - \left[\frac{3U}{1+m} \right] - \left[\frac{3U^2}{1+2m} \right] - \left[\frac{U^3}{1+3m} \right] \right] \tag{5}$$

Where $E = \frac{F}{Z}$ is the exploitation rate, i.e. the fraction of mortality caused by fishing activity, F the instantaneous fishing mortality coefficient,

$$U = 1 - \left[\frac{L_c}{L_\infty} \right]$$

The fraction of growth to be completed by *Pellonula* after entry into the exploitation phase,

$M = (1 - E)/M/K = K/Z$. The relative biomass per recruit was estimated as

$$\frac{B}{R} = \left\{ \frac{Y^1/R}{F} \right\} \tag{6}$$

Then, we estimated E_{MAX} (exploitation rate which produces maximum yield), $E_{0.25}$ (the value of E under which the stock is reduced to 75% of its unexploited biomass); $E_{0.5}$ (the value of E

under which the stock is reduced to 50% of its unexploited biomass and $E_{0.75}$ (the value of E under which the stock is reduced to 25% of its unexploited biomass) through the first derivatives of the Beverton and Holt (1966) function.

RESULTS AND DISCUSSION

In 3,817 specimens of *Pellonula leonensis*, there were more females (64.17%) than males (35.83%) $\chi^2 = 61.95$, $df = 1$; $P < 0.010$). The pooled dry season (December to February) sample ($n = 429$) showed a sex ratio of 1.00 male to 1.51 females ($\chi^2 = 9.084$, $df = 1$, $P < 0.010$), and the rainy season (March to November) sample ($n = 400$) showed a sex ratio of 1.00: 2.00 in favour of females ($\chi^2 = 8.341$, $df = 1$, $P < 0.010$). For both sexes, the length – weight relationship took the form; $weight = 0.095$ (total length)^{3.01} and fecundity – length relationship was $fecundity = 4.12$ (total length)^{2.02}

The monthly variation in gonadosomatic, condition indices for both sexes are shown in Fig. 2. For females, Peak values of GSI occurred from June to November, a similar trend was observed for males. The temporal location of peak GSI values between June and November for both males and females means that the species breed during these periods. Thus, it spawns twice in a year, in the rainy and dry seasons. So the fry stand to profit from the attendant abundance of detritus, benthic algae, fish larvae and other allochthonous materials during the rainy season months and the much algae production in ensuing dry season.

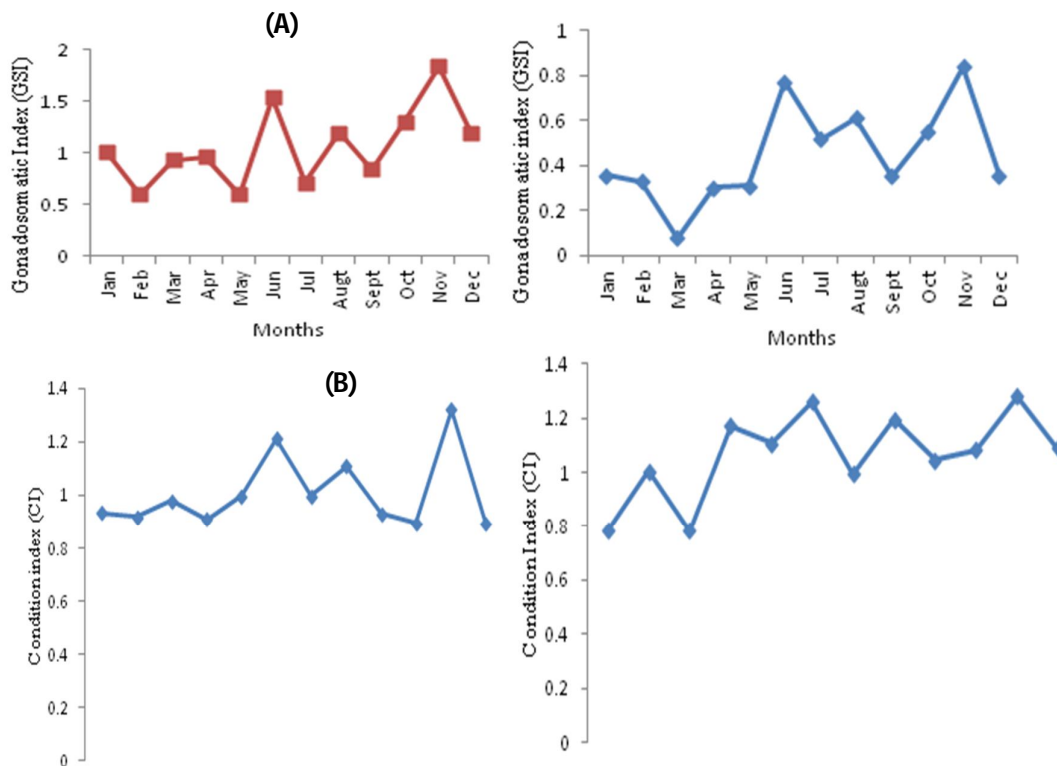


Figure 2: Monthly variation in Mean gonadosomatic and condition indices for both (A- Male and B-Female) *P. leonensis*.

The Guinea sprat, *Pellonula leonensis* in Cross River State estuary (latitude...) also spawns twice in a year between June and November (Okon, 2015). While Kunzel *et. al.* (1992) considers the species as being all year spawners with a dominant peak in dry season and a

smaller peak early in the rainy season. The difference between the mean maximum and mean minimum GSI for female (1.0) is greater than that for males (0.5). Thus, the reproductive build-up and subsequent drain on the females is greater than that on the males. There was a regular trend in increase in both GSI and CI for both sexes. This shows that the energy build-up was tailored principally for reproductive purpose.

Growth of fish could be investigated using annuli on hard parts like otoliths, marked recaptured experiment or by adopting analysis of length-frequency data. In this study, we used length-frequency analysis because it is the widely used method in recent time. Many workers Kunzel, *et. al.*, 1990; Etim, *et. al.*, 1996; King, 1996; Pauly and Morgan, 1987; Moses, 2001 and Pauly, 1990 have successfully used length-frequency data to study the growth and mortality of fish populations and the results are comparable to annuli studies. Table 1 presents the monthly length-frequency data of 3,817 specimens of the *Pellonula leonensis* collected during the 12 months study. The following optimised seasonalised growth, curves ($L_{\infty} = 11.9$ cm, $K = 1.2$ yr⁻¹, $C = 0.7$, $WP = 0.3$) were obtained using ELEFAN I procedure available in FiSAT, and were superimposed on the restructured length-frequency histograms (Fig. 3). Asymptotic length that a species could attain (granted it grows throughout life) in its habits given the ecological peculiarities of that environment, and the K parameter indicates the speed at which the species grows towards this final size, our computed values $L_{\infty} = 11.9$ cm, $K = 1.2$ yr⁻¹ are within the range for those computed by Kunzel, *et. al.*, 1990. ($L_{\infty} = 15.6$ mm, $K = 0.81 - 0.96$ yr⁻¹ for the same species in the Cross River estuary and $L_{\infty} = 13.5$ cm, $K = 1.15$ yr⁻¹ as reported by Okon (2015) in lower Cross River estuary.

Table 1: Length (T L cm) Frequency Data of *Pellonula Leonensis* in Qua Iboe River Estuary (Nigeria) from January to December, 2010. ML = Midlength of Class Interval (cm), N = 1,780

ML/Date	Jan	Feb	Mar.	Apr.	May	June	Jul.	Aug.	Spe.	Oct.	Nov.	Dec.
2.0												
2.5												
3.0	17	4				1			4	1	5	41
3.5	12	34		2		1		3	31	19	17	63
4.0	31	11	9	3	8	3		5	61	49	13	24
4.5	5		15	25	51	11	11	23	42	29	41	16
5.0	10	2	8	31	21	7	4	11	13	19	23	7
5.5	1	17	2	25	11	4	19	18	11	10	15	15
6.0	3	14	40	30	30	16	26	41	7	17	9	3
6.5	14	59	25	17	4	43	42	14	6	4	7	7
7.0	52	5	12	2	27	18	4	5	2	3	12	2
7.5		2	4	10	9	9	2	4	4	2	3	1
8.0	9		6	1	4	10	1		1		2	
8.5	3		10		1	3	3					
9.0	1		1			5	1		1			
9.5						1						
10.0												
10.5												
SUM	258	148	132	143	166	131	113	127	183	153	147	179

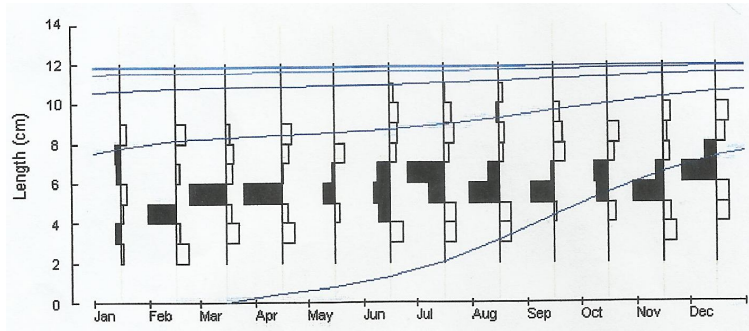


Figure 3: Seasonalised Von Bertalaffy growth curves for *P. leonensis* ($L_{\infty} = 11.9\text{cm}$ $K = 12\text{yr}^{-1}$ $C = 0.85$, $WP = 0.3$) Superimposed on the restructured Length Frequency historian.

However, it is worth indicating that growth of fish is not linear, so direct comparison of these coefficient does not make much biological sense as one species or stock can grow faster than the other when young and slower when old. Thus growth comparison must be taken as a multivariate problem in which both the asymptotic length and growth rate are simultaneously considered.

In this study, the amplitude of growth oscillation C , is 0.7 and the Winter Point (WP), (Period when growth is slowest) is 0.30, i.e. between March and April. Growth seasonality in aquatic animals is a well-known phenomenon especially in temperate zones where growth could be quite slow or completely retarded during winter. In tropical West Africa, the environmental water temperature is high all year. For instance, in the Imo River estuary, the difference between the mean and maximum temperature ($\approx 30^{\circ}\text{C}$) and the mean minimum temperature ($\approx 24^{\circ}\text{C}$). (Enplan Group, 1974) and could be less than 5°C . Therefore, temperature variations may not have a major impact on growth retardation in this environment. Also seasonal growth oscillations of the guinea sprat in the Imo River estuary could be attributed to trade-off between growth and breeding especially as June/November period is the time for intense breeding activity.

The seasonalised length-converted catch curve gave a Z value of 6.32 yr^{-1} (Fig. 4). A Z of $0.9^{-1} - 1\text{ yr}^{-1}$ was determined for the Cross River population by Kunzel, *et. al.*, (1990). In this study $M = 2.69\text{ yr}^{-1}$, giving an F (instantaneous fishing mortality coefficient) of 3.68 yr^{-1} and an exploitation rate $E (= F/Z)$ of 0.58. The fishing pressure on this stock is greater than the value obtained in the Cross River by Kunzel, *et. al.*, (1990). It is also observed that the species is not cherished by the people of the Cross River area as food fish rater mostly only exploited for use as bait. Whereas the Imo River population is exploited both by human as food and as bait. Based on that, there is greater fishing pressure on the stock in the study area which add credence to the high total mortality (Z). Our analysis of capture of each size class shows that the length at first capture L_c is 4.86 cm (Fig. 5) which is below the estimate for the Cross River population by Kunzel, *et. al.*, 1990.

The selection ogive method for the analysis of relative yield per recruit gave an $E_{\text{MAX}} = 0.42$. The selection ogive procedure assumes that the probability of capturing any specimen is a function of is length and is considered to be more realistic. Our computed current exploitation rate $E (= 0.58)$ exceeds the predicted values of $E_{\text{MAX}} (= 0.42)$ and suggests that the stock is overexploited. This is supported by our Z/K value from the Powell- Wetherall plot. As a rule of thumb, where $Z/K > 1$, then the population is mortality-dominated, the ratio: if less than 1, then

it is growth-dominated. In a mortality-dominated population, a value of $Z/K = 2$ indicates a light level of exploitation. Here the Z/K value of 5.3 indicates a heavy level of exploitation.

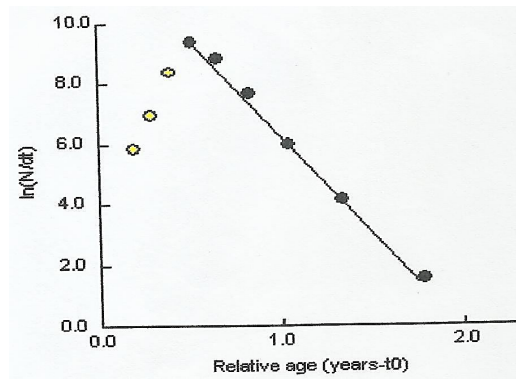


Figure 4: Seasonalised Length Converted Catch Curve for *P. leonensis* from where the slope of the descending right arm (black dots) of the line with sign changed gives an estimate of the seasonalised z .

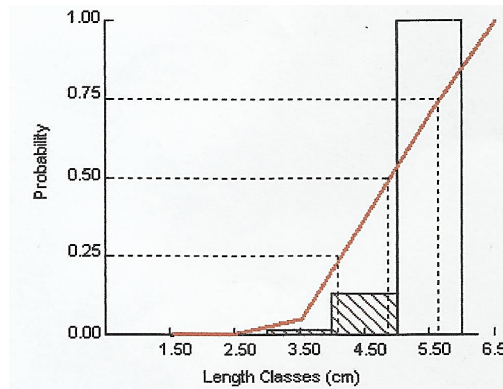


Figure 5: Probability of capture of each class of *P. leonensis*. The estimated length at first capture L_{∞} or $L_c = 4.86\text{cm}$, $L_{25} = 4.10\text{cm}$, $L_{75} = 5.63\text{cm}$. L is one inputs in computing the relative yield-per-recruit and relative biomass per recruit (Eqs (5) and (6))

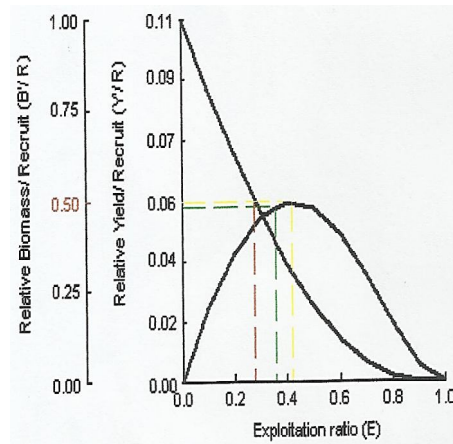


Figure 6: Relative yield-per-recruit and relative biomass per recruit using the selective O_{give} procedure. Summary statistics. $E_{max} = 0.42$, $E_{10} = 0.36$, $E_{50} = 0.28$.

The instantaneous natural mortality coefficient M , apart from indicating the source of death caused by all possible sources of death except fishing, is a critical input in the computation of many models in fish population dynamics study such as the Beverton and Holt's relative yield-per-recruit and relative biomass per recruit. Our estimated $M = 2.60 \text{ yr}^{-1}$ is very high compared to that of Kunzel *et. al.*, (1990) ($0.8 - 0.9 \text{ yr}^{-1}$) for the same species in the Cross River estuary that of Marshall (1987) for *Limnothrissa moidon* in Lake Kariba (Zimbabwe) (0.70 to 1.15 years^{-1}).

CONCLUSION

Based on the results obtained, it is obvious that the fishing pressure on the stock is high. This is supported by the results of our relative yield-per-recruit analysis which showed the predicted maximum exploitation level $E_{\text{MAX}} = 0.42$ which was lower than the current exploitation rate ($E_{\text{MAX}} 0.58$).

ACKNOWLEDGEMENT

This is part of the study that was sponsored by the University of Uyo, Uyo, Akwa Ibom State, Nigeria under the Staff Development Programme. Aniefiokmkpong Okon is grateful to the University Management for the support.

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