Original Research Article

Some Aspects of the Life-History Strategy of *Pellonula Leonensis* (Boulenger, 1916) (Teleostei: Clupeidae) in Qua Iboe Estuary, Nigeria

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Abstract: Some aspects of the life-history strategy of the clupeid, *Pellonula leonensis* in Qua Iboe estuary, Nigeria were investigated. Results obtained showed that length-weight relationship was approximately isometric (exponent, b = 3.010), estimated asymptotic total length, L_∞ = 11.5 cm and growth coefficient, K = 1.5 yr^{-1}; these parameters were used to derive the Von Bertalanffy's length models; L_T = 11.5 (I – e.$^{1.5T}$), the coefficient total mortality, Z = 8.22 yr^{-1}, natural mortality, M = 3.12 yr^{-1} and fishing mortality, F = 5.10 yr^{-1}. The exploitation ratio (E = 0.62) indicated that this stock of *P. leonensis* was being overexploited at 12% above its optimum yield level. A protraction of the ongoing exploitation rate could endanger and lead to the collapse of the fishery. Breeding was year-round with minimum and maximum intensities in May and December respectively. Absolute fecundity was 2,286 – 4,509 eggs (Mean eggs = 3,133). The fish was recruited into the artisanal fishery at size 3.0 cm before attaining sexual maturity. This is an undesirable situation since there is a high risk of depleting the stock of potential spawners. The main life-history traits of *P. leonensis* (rapid growth, early sexual maturity, high fecundity, year-round breeding, small maximum body size, and high natural mortality) were typical of an γ-selected species. However, *P. leonensis* exhibited iteroparity rather than semelparity.

Keywords: growth parameters, reproductive attributes, r-selection, *Pellonula leonensis*, Qua Iboe estuary, Nigeria.

INTRODUCTION

The Atlantic coastal waters of the Gulf of Guinea, from Senegal to Zaire, support a considerable stock of the shoaling pelagic-clupeid, *P. leonensis*. This species and other clupeids are of high commercial importance in the Nigeria inshore waters (Otobo [1]; Ikomi [2]; Kunzel *et al.* [3]; Ita [4]; Akpan *et al.* [5] where they constitute important catch component of artisanal fisher folks in Qua Iboe estuary, East of the Niger Delta. The artisanal fishery is sustained by *P. leonensis* among other clupeids. Considering the economic importance of this fishery in terms of providing employment and rich protein source for several Nigerians living in the hinterland and riparian communities, particularly the less privileged people who constitute the majority in the tropical countries and also affordable source of bait and ingredient for livestock feed manufacturing, it is surprising that only few workers have studied aspects of the biology of *P. leonensis*.

Most of these investigations have concentrated on the populations of *P. leonensis* in Epe Lagoon in Lagos (Balogun, [6], in Lake Kainji [Otobor, [1]; Otobo & Imevbore, [7]] in upper Niger and lower Benue [Ikomi, 2]. Comparatively, little is known about the biology of this species elsewhere. A notable exception is the works of Moses [8] and Kunzel & Lowenberg [9] who reported the ecology and fisheries in Cross River, Nigeria and population dynamics of *Pellonula leonensis* in Cross River respectively. No attempt has hitherto been made to assess the life-history strategy of *P. leonensis*, the knowledge of which is of prime value in the formulation of rational stock management and conservation policies for this species.

The present study contributes to the biology of *P. leonensis* by providing data on the life-history characteristics of the population in the Qua Iboe estuary, Nigeria which has in last three decades been subjected to heavy anthropogenic environmental stresses arising from crude oil pollution [Umoren & Onianwan, [10]; Andem *et al*. [11]] and other petroleum exploitation-related perturbations. The life-history strategy of an organisms involves a combination of a number of traits including size and age at first capture, longevity (maximum age attainable), maximum body size attained, mortality, and/or survival rates, reproductive effort and responses to environmental variability (Bone & Marshall, [12]). The interplay of these attributes determines the fitness of the organism to growth, reproductive success, survival and the maintenance of several forms of interactions with its biotic and abiotic environments. In this paper, particular attention is given to growth, mortality and reproductive attribute of *P. leonensis* using an integrative approach. The results are elucidated by being discussed in the context of the evolution of K- and r-selection strategies (MacArthur & Wilson, [13]).

MATERIALS AND METHODS

Qua Iboe estuary (Fig. 1) is in Akwa Ibom State, Nigeria lies in the area East of the Niger Delta between Cross River and Imo River estuaries, (longitude $7^{o}30 – 8^{o}20$ E; latitude $4^{o}30 – 5^{o}30$ N). Besides the wide opening into the Gulf of Guinea at the Bight of Bonny, this estuarine ecosystem includes mixohaline water, tidal, creeks, small lagoons and fringing mangrove swamps. The macrophytes of the mangrove swamps are dominated by *Rhizophora harrizonii, Leechman, Rhizophora mangle I., Rhizophora racemosa Mey* (red mangroves: Rhizophoraceae), *Avicennia africana* Beauv (white mangrove: Avicenniaeae) and *Laguncularia racemosa* Gaetm (black mangrove: Combretaceae) (Ekpo *et al*. [14]). Others include the pteridophytes, *Acrosteichum aureum L.* (Adiantaceae) and the palms, *Nypa fruticans* Wurmb and *Phoenix reclimate* Jacq (Palmae). The bottom of the estuary consists mainly of silt, mud and considerable accumulation of organic detritus transported downstream by the river. The depth of the main estuary is $0.5 – 9.0$ m while the tidal amplitude is $1–3$ m.

Qua Iboe estuary is located in the equatorial rainforest climatic belt of southern Nigeria typified by year-round precipitation. Inspite of this, two major seasons are discerned in the area; the dry season extends from November to March with peak in January while the rainy season ranges between April and October with peak in July. Further details regarding the Qua Iboe River basin ($7^{o}30 – 8^{o}20$; $4^{o}30 – 5^{o}30$N) are contained in Tahal Consultants Ltd [15].
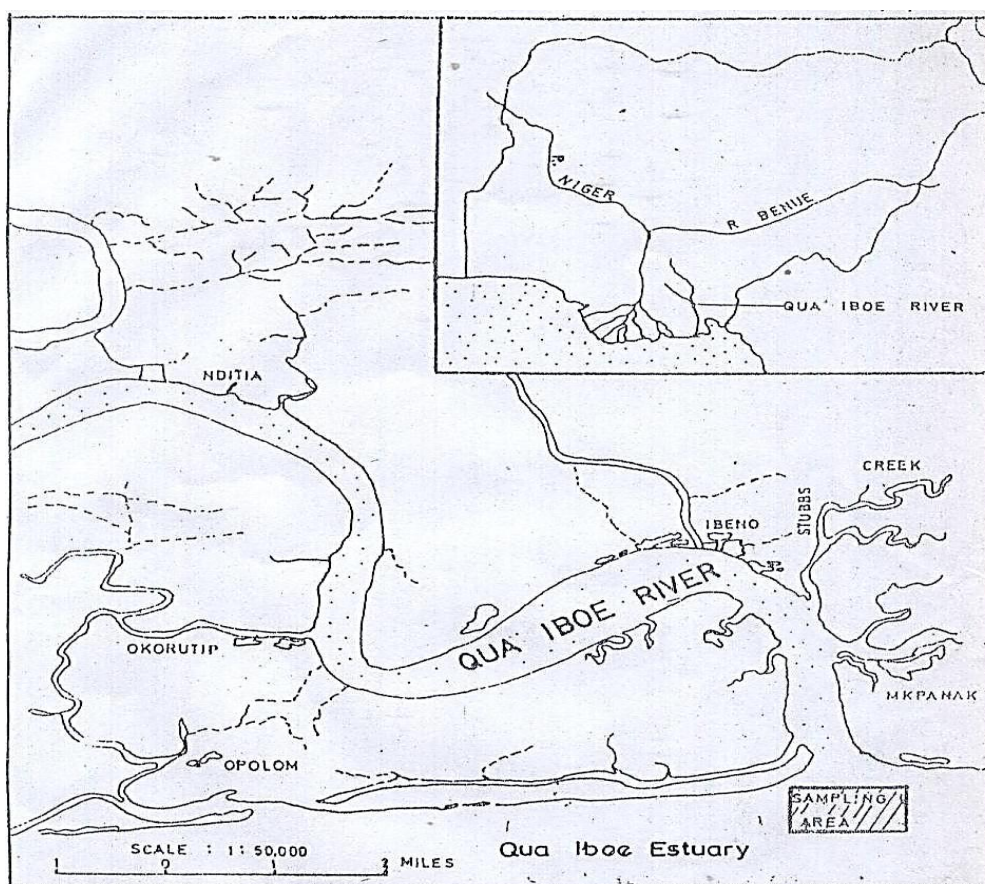

Fig-1: Map of Qua Iboe River estuary showing the sampling station. (Insert: Map of Nigeria showing the location of Qua Iboe River)

From January – December 2010, a total of 1,747 random specimens of *P. leonensis* were obtained from artisanal fishers at Ibeno fishing harbour. Fishing was by the use of lift nets called traditionally as "atalla" measuring 2.9 x 2.9 m, mesh size 1 mm. Specimens were measured to the nearest 0.1 cm total length and weighed to the nearest 0.1 g total weight after draining water from the buccal cavity. The fish were divided into 1.0 cm length categories and the FAO/ICLARM Stock Assessment Tools (FiSAT) software was used to determine the growth and mortality parameters of the fish (Pauly, [16], [17]). The length growth performance index ($Ø^1$) was estimated from the parameters of the Von Bertallanffy's Growth Model (VBGM) (Pauly and Munro, [18]).
Thus,

$$Ø^1 = \text{Log } K + 2\text{Log } L_\infty$$

A total of 664 specimens of *P. leonensis* were obtained for studies of other reproductive attributes over a 1-year period. They were measured and weighed and sexed by visual inspection of the gonads after dissection. The ovaries of each specimen were weighed to the nearest 0.01 g and gonadosomatic index (GSI) calculated thus:

$$\text{GSI} = \frac{\text{Ovary Weight}}{\text{Somatic weight}} \text{ x } 100$$

The somatic weight (g) of each fish specimen was calculated as the difference between fish total weighted gonad weights (ovary weight). Ovarian stages of maturity were categorised as immature, mature, ripe and spent stages following criteria given by Lagler *et al.* [19]. To estimate absolute fecundity (AF), ripe ovaries from each of 60 selected females were preserves in labeled vials containing 4% formaldehyde solution until the eggs hardened (over 2 – 4 weeks). The vials were periodically agitated to ensure the separation of eggs from ovarian tissue. The eggs were later air-dried on absorbent paper for 24 hours at 27 – 30 ^{o}C ambient temperature. Absolute fecundity was then estimated gravimetrically following the methodology outlined in Wilkinson & Jones [20].

The relationship between fecundity and each of the independent variables (X_i) (e.g. total length (L), total weight (W), gonadosomatic index (GSI) and condition index (CI).

$$\text{CI} = \frac{\text{Somatic Weight}}{\text{TL}^3} \text{ x } 100$$

Was represented by the exponential functions:
$$\text{Fecundity} = aX_i^b$$

Where,
a = a constant and b = regression coefficient; both of which are estimated by least squares linear regression analysis using Log/log transformed data.

RESULTS
Size Composition
Total length and weight of *P. leonensis* were significantly correlated (r = 0.9; 421; df = P<0.05) for combined sexes of fish measuring 3.0 – 10.0 cm and weighing 0.52 – 9.0 g. An exponential expression of the form, TW = 0.6013 $\text{TL}^{3.010}$ accounted for 96.4% of the variation in fish total weight (Fig. 2).
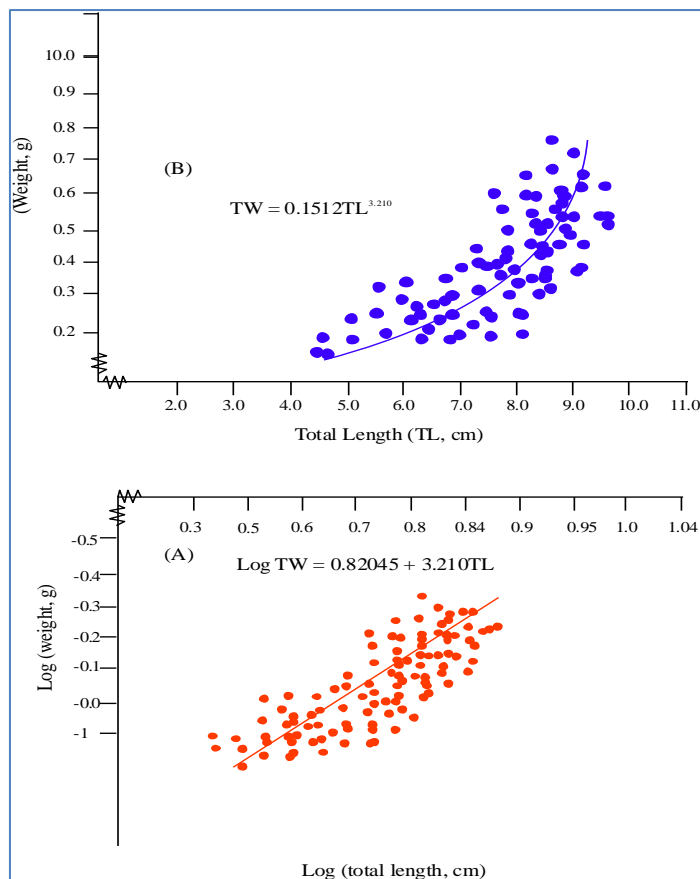
Fig-2: Length – weight relationship of *P. leonensis* from Qua Iboe estuary, Nigeria (A = Log transformation; B = Linear transformation)

Growth Pattern

The monthly length frequency data of the specimens collected during this investigation are given in Table 1. The growth parameters obtained were: L_∞ = 11.5 cm and $^Z/_K$ = 5.48. The growth coefficient, K was 1.5 yr^{-1}. The Von Bertallanffy's growth resulting from the above growth parameters is represented as:

$$LT = 11.5 (I - e^{-1.5T})$$

The length growth performance index, $\emptyset^1$ = 2.32.

Table-1: Length frequency data of *Pellonula leonensis* sampled in Qua Iboe Estuary (Nigeria) from January to December, 2004. (ML = Mid-length of class interval (cm), N = 3,817)

| ML/DATE	$^{01}/_{10}$	$^{02}/_{10}$	$^{03}/_{10}$	$^{04}/_{10}$	$^{05}/_{10}$	$^{06}/_{10}$	$^{07}/_{10}$	$^{08}/_{10}$	$^{09}/_{10}$	$^{10}/_{10}$	$^{11}/_{10}$	$^{12}/_{10}$
2.0							1					
2.5	13	1					0					
3.0	60	17		1		1	1	1			2	
3.5	12	8	1	0		1	0	0			0	
4.0	44	45	4	8	5	91	5	2	39	15	8	1
4.5	4	81	37	24	51	6	0	2	11	4	10	0
5.0	17	22	192	122	150	102	62	112	146	65	134	1
5.5	0	23	104	124	26	22	23	38	18	20	29	2
6.0	47	11	25	39	124	103	150	86	70	93	78	130
6.5	45	17	14	19	2	8	1	2	2	2	5	23
7.0	54	15	22	14	12	22	22	33	10	19	24	77
7.5	51	4	10	11		1	1	0	0	1	3	2
8.0	14	2	9	3		8	6	13	6	4	14	13
8.5	3		3			1	0	1	0		1	0
9.0						2	2	9	2		3	1
9.5						1	0	4				
10.0						0	1	0				
10.5						1		1				
	364	246	421	376	370	369	277	304	308	223	309	250
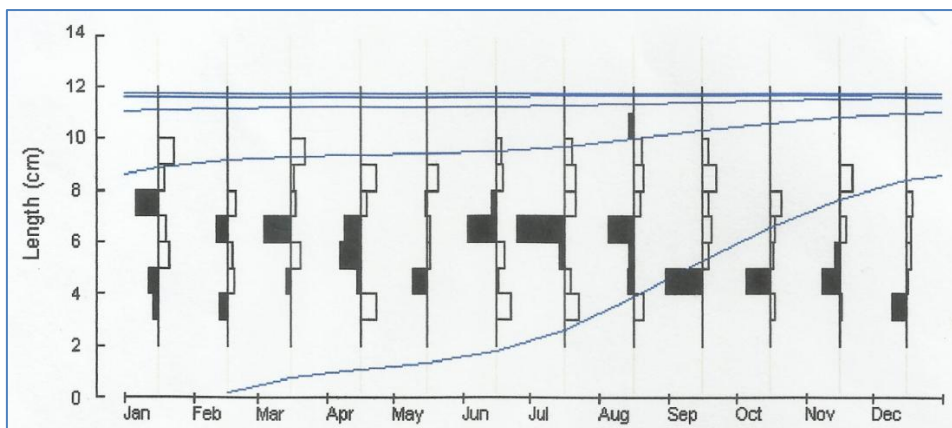
Fig-3: Plot of seasonalised Von Bertalanffy growth curves for *P. leonensis* (L_∞ = 11.5 cm, K = 1.5 yr^{-1} C = 0.85, WP = 0.3) superimposed on the restructure length-frequency histograms in Qua Iboe estuary, Nigeria

Mortality

The seasonalised catch curve (Fig. 4) gave the estimated coefficient of total mortality, Z = 8.22 yr^{-1} and natural mortality M = 3.12 yr^{-1}. Fishing mortality, F (F = Z-M) was 5.10 yr^{-1}. The computed exploitation rate, E (= F/Z) gave 0.62. The smallest size of *P. leonensis* under exploitation measured 3.0 cm. The ratio of natural mortality to growth M/K = 2.08 and that of fishing mortality to natural mortality, F/M = 1.63. From the analysis of probability of capture of each length class (Fig-5), Lc was 5.55 cm. The Selective O_{give} procedure was used to compute the relative yield-per-recruit (Fig. 6). The following results were obtained: E_{max}= 0.42, E_{10} = 0.36 and E_{50} = 0.28.

The pooled 664 adult specimens sexed comprised 270 males and 394 females, which gave an overall male: Female ratio of 1.0: 1.5; portraying a strong female bias goodness of fit. (X^2 = 0.65; df = 1; P<0.010).
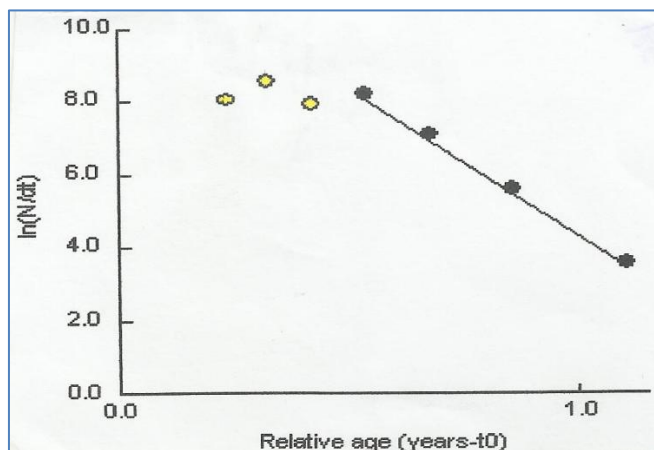

Fig-4: Seasonalized length-converted catch curve for *P. leonensis* from Qua Iboe estuary, Nigeria
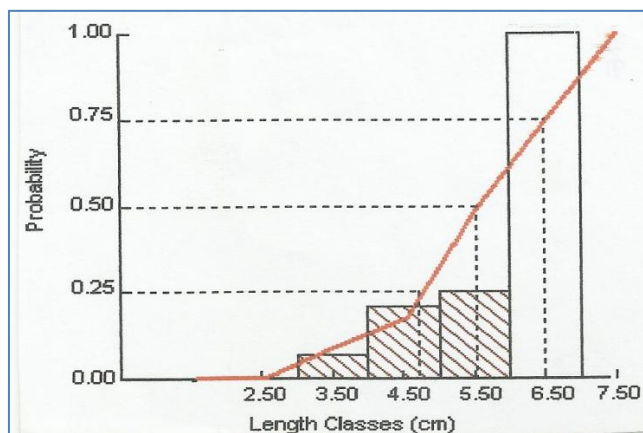

Fig. 5: Probability of capture of each size class of *P. leonensis* (The estimated length at first capture L_{50} or L_c = 5.55 cm; L_{25} =4.73 cm and L_{75} = 6.49 cm) in Qua Iboe estuary, Nigeria
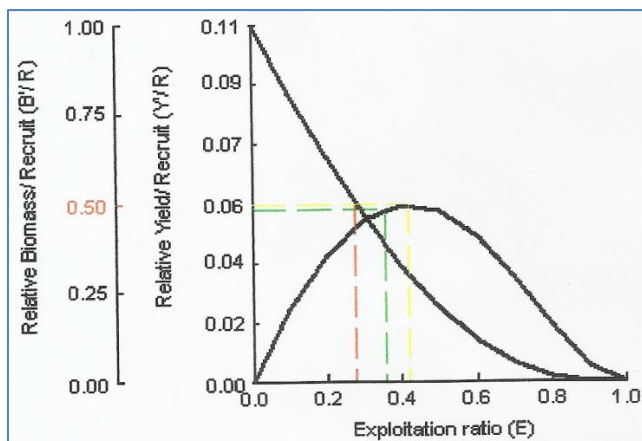
Fig-6: Relative yield per-recruit and relative biomass per-recruit using the selective O$_{give}$ procedure (E$_{max}$ = 0.42; E$_{10}$ = 0.36; E$_{50}$ = 0.28) in Qua Iboe estuary, Nigeria

Reproductive Investment

The changing pattern of reproductive investment (the fraction of body weight devoted to reproductive tissue i.e. GSI of *P. leonensis* with ovarian morphogenesis. Reproductive investment increased with ovarian maturation, peaking at the ripe stage and declining in spent fish. The relationship between gonadosomatic index and fish size in showed a decline in reproductive effort with increasing fish size.

Breeding Seasonality

Temporal regimes in occurrence of the gonadosomatic index for both sexes were depicted in Fig. 7. Ripe females were encountered all year-round in proportions varying from 42% in March to 66.7% in October. The occurrence of mature and ripe females in all months indicates a year-round breeding activity albeit in a pattern suggesting some seasonality. Monthly regimes in gonadosomatic index designated high breeding activity in August – September, January, June – July. The major breeding peak occurred in August (peak rainy season) and minor ones in June (early rainy season) and November (early dry season).
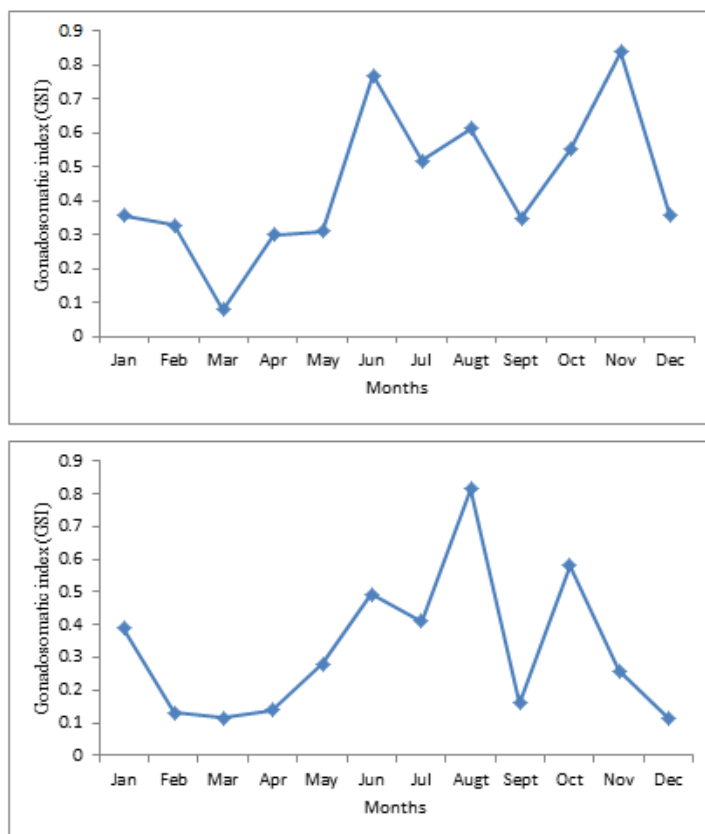

Fig. 7: Monthly trend in occurrence of the gonadosomatic indices for both sexes (A – Male and B – Female) of *P. leonensis* from Qua Iboe estuary, Nigeria

Fecundity

Mean absolute fecundity estimate was 3,133 eggs (range 2,286 – 4,509) for fish of 6.5 – 9.5 cm. It increased with fish size (r = 0.0232; df 58; P <0.001) according to the expression, AF = 2.448; $TL^{3.201}$ which accounted for 70 of the variance in egg number. Absolute fecundity also increased with fish total weight (4.5 – 9.0 g) according to the exponential equation of the form:

$$AF = 2.431, TW^{1.212}$$

About 35.5% of the variation in absolute fecundity was explained by changes in fish total weight. Mean gonadosomatic index was 0.37 (range 0.11 – 0.71), it increased with absolute fecundity (r = 0.613; P <0.05). Changes in gonadosomatic index accounted for 60.4% of the variation in Absolute fecundity. The exponential expression for this relationship was:

$$AF = 0.531 \, GSI^{2.312}$$

Condition index ranged between 0.05 and 1.66. Absolute fecundity and condition index were inversely correlated (r = -0.451; P < 0.05); this was represented by the exponential function;
$$AF = 0.713 CI^{3.101}$$

This accounted for 18.2% of the variation in total egg number. There was no significant relationship between absolute fecundity and condition index.

DISCUSSION

The length exponent in the length-weight relationship of pooled sexes of *P. leonensis* was 3, thus indicating that increase in weight is isometric. This is comparable with the findings of Akpan *et al*. [5]. For most fishes the length exponent lies between 2.5 and 4.0 (Lagler *et al*. [19]). The estimated asymptotic length seems reasonable in view of the maximum size encountered by the author in the estuary, L_{max} 11.5 cm TL; compared with by other authors such as Balogun [6] in Ekpe Lagoon (Nigeria) L_{max} = 12.2 cm TL; and Lowenberg & Kunzel [21] in Cross River (Nigeria) L_{max} = 15.6 cm.

The length growth performance index ($Ø^1$) obtained here (2.32) corresponds fairly well with estimates for the stocks of allied clupeids e.g. *Ethmalosa fimbriata* ($Ø^1$ = 2.59; Moses, [22]; *Sardinella maderensis* ($Ø^1$ 2.75; Djama *et al*. [23]); in inshore waters of West Africa. This corroborates the concept that values of the growth performance index of closely related taxa are very similar with minimum variance and can be used to characteristic members of the same family [Pauly & Munro, [18]; Sparre *et al*. [24].

The exploitation ratio provides a rough estimate of whether or not a fish stock is over exploited based on the assumption that optimal yield level is attained when E = 0.5 (i.e. fishing mortality is about equal to natural mortality) [Gulland, 25]. The present finding indicates that human exploitation is instrumental to 62% of the total mortality of the stock of *P. leonensis* in Qua Iboe estuary and this exceeds its optimum yield level by 12%. This will be deleterious to the persistence of the fishery since a protraction of the ongoing exploitation pressure could culminate in the collapse of the fish population and consequently, the fishery. The high $^F/_M$ ratio (1.63) for *P. leonensis* is an index typical of a heavily exploited fish stock and it confirms the author's earlier assertion that fishing mortality was the dominant element in total mortality.

The present finding which shows a strongly female – biased sex ratio of *P. leonensis* is similar to that of Ikomi [2] in River Warri; Ikusemiju *et al*. [26] in Lagos Lagoon, Nigeria; Marcus & Ikusemiju [27] among clupeids in Lagos coast and Stockholm & Isebor [28] in area of Benin Republic and off Lagos State, Nigeria. The above situation adds credence to the assertion by Roff [29] which holds that females continually replace themselves and fits the basic framework of life time; of average one female that herself survives to reproduce in order to maintain an equilibrium population. Moreso, the female dominance in number could be attributed to the fact that females are more active than males, thus are more vulnerable to capture - a behaviour that could be likened to the cichlids (Keansleyside, [30]).

This study revealed that *P. leonensis* bred on a year-round basis with high intensities in July – September, October – January. Breeding peaks occurred in January, August, September, October, November and December. Kunzel & Lowenberg [9] recorded a similar year-round breeding in this species with peaks in January, February and a minor spawning peak in the early rainy season in Cross River. Ita [4] also affirms the early flood season as the species breeding season in Cross River. Moses [8] report reveals that the main spawning pulse also occurs from November. However, Kapetzky [31] reports that the most species in Magdalena River in Columbia (tropical South America) bred during February – April low waters and in the first stages of the rising flood. He also observed another peak breeding activity

during the second stages of rising water in October while few species bred during falling water (December – January). The results from this work suggest a similar pattern.

Based on the afore findings of the present study, *P. leonensis* can be regarded as a multivoltine species, although further studies are needed to ascertain the number of generations of progeny that are produced annually by an individual fish. The species also appears to be a pelagic open-water spawner which merely broadcast eggs in the water and accords no parental care to the eggs or progeny.

The mean absolute fecundity of *P. leonensis* from Qua Iboe estuary is relatively lower compared to the value mean 2,859 eggs; range 140 – 4,9000 eggs) (Otobo & Imevbore, [7]) for the population in Kainji Lake, Nigeria. This disparity could be attributed to a number of factors including availability of food resources, sizes and age of specimens examined, season and specific environmental conditions [King, 32].

Weasel *et al*. [33] noted the disparity in fecundity among populations of a given fish species as adaption to different environmental conditions that produce higher or lower survival opportunities for the species. This undoubtedly explains the lower fecundity of the species in this study area which is under intense eco-succession, deforestation, siltation and other human perturbations (Umoren & Onianwan, [10]; Andem *et al*. [11]).

The life-histories of organisms can be expressed in terms of the theory of k- and γ-selection pressures operating in varying environments (MacArthor & Wilson, [13]). This stipulates that k-selected species inhabit stable, crowded environments while r-selected species are fitted for high population growth rate in uncrowded but highly variable environments. Notwithstanding the criticisms, that the dichotomy is not perfect, too rigid and simplistic; and that it only represents the extremes of a continuum of methods for maximizing reproductive success (McNaughton & Wolf, [34]). It is worth indicating that the notion of a continuum implies the existence of organisms that will exhibit both k- and γ-selected properties in their life-histories due to overlaps or their transitional positions along the continuum. This is expected, if the k- and γ-selected strategies are considered as non-rigid evolutionary trends toward the maximization of reproductive success. Thus, for a fish like *Gasterosteus aculeatus L.,* which incorporates both the k- and γ-selected properties in its life history (O'Hara & Penczak, [35]), it would be most appropriate to interpret it as occupying an intermediate position in the continuum of life-history strategies rather than inadequacy in the k- and γ-selection theory in describing the life-history adaption.

The k- and γ-selected theory has subsequently been expanded and made more flexible by incorporating other life-history attributes. Studies (Bone & Marshall, [12] and O'Hara & Penczak, [35]) have revealed γ-selection as favouring slow growth, low fecundity, large body size, delayed sexual maturity, and long life-span while γ-selection favours rapid growth, early sexual maturity, high fecundity, small body size and short life span.

CONCLUSION

Based on the aforementioned attributes, *Pellonula leonensis* of the Qua Iboe estuary, with a rapid exponential growth rate, high reproductive output (i.e. fecundity), small body size, high natural mortality and early sexual maturity can be classed as an γ-selected species. However, unlike a typical γ-selected species, *P. leonensis* exhibits iteroparity rather than semelparity. It is undoubtable that the latter life-history strategy could compensate for the rather high observed mortalities although the sustenance cannot be ascertained especially with the observed influences of stochastic environmental factors prevailing in the estuary.

ACKNOWLEDGMENTS

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