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Population dynamics of the West African croaker *Pseudotolithus elongatus* in the Cross River Estuary, Nigeria*

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SUMMARY: The population dynamics (growth, recruitment, mortality) of the West African Croaker *Pseudotolithus elongatus* in the Cross River estuary (Nigeria) was studied using 13 consecutive monthly (May 1986 to May 1987) length frequency samples and the ELEFAN software. The seasonally oscillating von Bertalanffy growth parameters were $L_\infty = 60$ cm, $K = 0.38$ y^{-1}, $C = 0.4$, and $WP = 0.7$. Total mortality rate Z estimated by a length converted catch curve was estimated to be 1.42 y^{-1}, while natural mortality rate M was 0.79 y^{-1}, giving the fishing mortality F as 0.63 y^{-1}. Recruitment is year-round with two peaks in a year, one major and one minor apparently occurring during rainy and dry seasons, respectively.

Key words: Population dynamics, *Pseudotolithus*, Cross River, Nigeria.

RESUMEN: DINÁMICA DE POBLACIONES DEL RONCADOR DEL OESTE AFRICANO, *PSEUDOTOLITHUS ELONGATUS* , EN EL ESTUARIO DEL RÍO CROSS, NIGERIA.- Se ha estudiado la dinámica de poblaciones (crecimiento, reclutamiento y mortalidad) del roncador del oeste africano, *Pseudotolithus elongatus*, en el estuario del Río Cross (Nigeria) utilizando 13 frecuencias de tallas mensuales consecutivas (mayo de 1986 a mayo de 1987) y el programa ELEFAN. Los parámetros de crecimiento estacionalmente oscilantes de von Bertalanffy fueron $L_\infty = 60$ cm, $K = 0{,}38$ y^{-1}, $C = 0{,}4$ y $WP = 0{,}7$. La tasa de mortalidad total Z, estimada a partir de la distribución de tallas de las capturas, se estimó en 1,42y^{-1}, mientras que la tasa de mortalidad natural M fue de 0,79y^{-1}, dando una mortalidad por pesca F de 0,63y^{-1}. El reclutamiento ocurre durante todo el año con dos máximos anuales, uno mayor que otro, coincidiendo aparentemente con las estaciones lluviosa y seca respectivamente.

Palabras clave: Dinámica de poblaciones, *Pseudotolithus*, Río Cross, Nigeria.

INTRODUCTION

Pseudotolithus species are found throughout the Atlantic coast of West Africa and in estuaries from Senegal to Gabon (FISHER *et al.*, 1981) where they are exploited by both the industrial (LÖWENBERG and KÜNZEL, 1991) and artisanal (UWE-BASSEY, 1988) fisheries. The dominant species are *P. elongatus, P. typus* and *P. senegalensis*. The growth and other related aspects of the population dynamics of these species have been studied in different areas (Table 1), but never before in the Cross River estuary. The aim of this paper is to elucidate the

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TABLE 1.– Growth and other fisheries parameters for three *Pseudotolithus* species. L, K, C, WP: Parameters of the (oscillating) von Bertalanffy growth model, Lc: Mean length at first capture, Z: Mortality rate, f': Index of growth performance, M: Males, F: Females.

Species	L_∞	K	C	WP	L_c	Z	ϕ'	Reference
P. typus	61.0	0.37	–	–	–	1.25	3.14	LONGHURST 1964
P. typus	103.0	0.29	–	–	19.0	–	3.49	BAYAGBONA 1965
P. typus (M)	61.1	0.35	–	–	–	–	3.11	POINSARD 1973
P. typus (F)	77.4	0.26	–	–	–	–	3.18	POINSARD 1973
P. typus	61.3	0.42	–	–	–	–	3.20	PAULY 1978
P. typus	89.7	0.16	–	–	–	–	3.11	POINSARD 1973
P. typus	105.0	0.22	–	–	–	–	3.38	PAULY 1978
P. typus	82.7	0.25	–	–	–	2.10	3.23	DJAMA 1986
P. senegalensis	80.0	0.34	–	–	18.0	–	3.34	BAYAGBONA 1968
P. elongatus	56.0	0.30	–	–	18.0	–	3.05	BAYAGBONA 1968
P. elongatus	60.0	0.29	–	–	–	–	3.02	FAO 1986
P. elongatus	60.0	0.38	0.40	0.70	12.0	1.42	3.14	This study

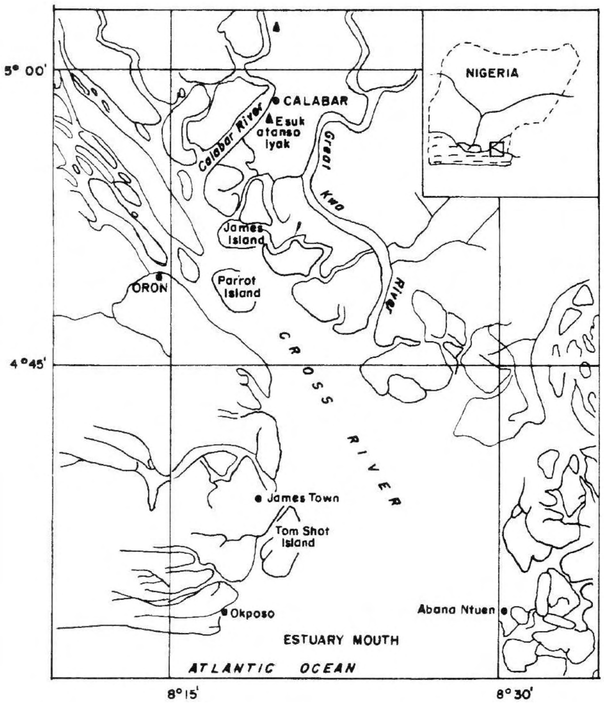

FIG. 1.– Map of the lower Cross River estuary showing the sampling point at Esuk Ata Nso Iyak, Calabar, Nigeria.

population dynamics of the species *P. elongatus* in the Cross River estuary with the results serving as input to fisheries managment decisions aimed at achieving optimal exploitation and conservation of the resource.

MATERIALS AND METHODS

From May 1986 to May 1987, monthly length frequency data of *P. elongatus* were obtained from boat landings of the gillnet fisheries of artisanal fishermen at Esuk Ata Nso Iyak, in Calabar, Nigeria (Fig. 1). In addition, data of the total catch by species landed were also collected. The ELEFAN (Electronic LEngth Frequency ANalysis) software developed by Pauly and co-workers (BREY *et al.*, 1988; GAYANILO *et al.*, 1989) was used for analysing the length frequency data.

The growth equation of the seasonally oscillating von Bertalanffy growth function (VBGF) as given by APPELDORN (1987), HOENIG and HANUMURA (1982) and SOMERS (1988) was used to describe individual growth. This takes the form:

$$L_t = L_\infty * (1 - e^{-K * [(t - to) + A - B]})$$

where

$$A = C * \sin(2\pi * (t - t_s)) / 2\pi$$
$$B = C * \sin(2\pi * (t_o - t_s)) / 2\pi$$

and where L_t is the length at age t, L_∞ is the asymptotic length, K is the growth constant, C is the factor that expresses the amplitude of growth oscillations, t_o is the "age" of the fish at zero length – assuming the fish had always grown according to the VBGF – and t_s is the beginning of the sinusoidal growth oscillation with respect to t = 0. In actual computation t_s is replaced by WP (winter point) which is the period of the year (expressed as a fraction of the year) when growth is slowest; WP = t_s + 0.5.

The growth parameters were estimated in two steps: (1) preliminary estimates of L_∞ and Z/K were obtained by the method of WETHERALL (1986) as modified by PAULY (1986), and (2) this estimated L_∞ was then used as a "seeded" value for fitting a growth curve to the length-frequency data.

TABLE 2.– Length-frequency data of *P. elongatus* sampled in the Cross River estuary between May 1986 and May 1987.

cm	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
6.5	0	0	0	0	0	0	0	0	4	0	0	0	0
8.5	6	4	2	3	0	0	0	4	11	2	3	1	14
10.5	26	21	2	2	6	1	0	12	17	6	8	3	17
12.5	39	18	12	5	1	0	0	12	28	6	14	9	36
14.5	103	18	13	12	3	6	2	15	41	22	24	54	41
16.5	119	49	22	20	14	27	8	42	48	11	33	103	64
18.5	45	27	18	11	19	31	13	77	46	18	28	109	72
20.5	13	22	8	8	10	12	44	85	31	44	28	68	58
22.5	10	7	9	5	9	6	46	51	21	41	39	52	30
24.5	6	5	4	4	7	1	17	27	9	30	27	39	31
26.5	7	14	5	8	10	5	11	18	5	19	22	21	14
28.5	8	15	6	10	9	4	14	11	3	3	7	5	10
30.5	2	3	4	6	2	3	18	8	3	4	4	2	4
32.5	3	5	3	3	8	3	23	18	4	0	4	2	0
34.5	2	4	0	1	2	6	29	11	4	3	4	5	1
36.5	1	2	1	2	2	2	11	7	1	1	2	2	2
38.5	0	1	0	0	0	1	8	10	4	4	5	6	10
40.5	0	4	0	1	1	1	5	9	5	1	1	0	1
42.5	0	1	4	0	0	0	8	6	1	2	3	4	2
44.5	1	0	1	1	0	0	1	4	0	1	0	1	1
46.5	0	3	0	1	0	1	0	0	0	2	2	1	4
48.5	1	1	1	0	2	2	0	0	0	0	0	4	0
50.5	2	0	1	0	0	0	2	1	0	0	0	0	0
52.5	0	0	0	1	0	0	0	0	0	1	0	2	0
54.5	0	0	2	0	2	0	1	0	0	0	0	1	1
56.5	0	0	0	0	2	0	1	0	0	2	0	0	0
58.5	0	0	1	0	0	0	0	0	0	0	0	0	1
Σ	394	224	119	104	109	112	262	428	286	223	258	494	414

The total mortality rate of the single negative exponential mortality model

$$N_t = N_o * e^{-Z \cdot t}$$

was estimated by a size-converted catch curve (PAULY 1984). This was calculated from the size frequency distribution of total catch of 3427 specimens (monthly samples converted from N/size class to %N/size class)

$$(N_i/\Delta t_i) = N_o' * e^{-Z \cdot t_i}$$

where N_i is the number of animals in sizes class i, Δt_i is the time required to grow through this size class and t_i is the relative age of the mid-size of class i as estimated from the inverse form of the von Bertalanffy equation. A plot of $\ln(N_i/\Delta t_i)$ against t_i should show a straight descending right arm, and total mortality Z is computed by the linear regression

$$\log_e(N_i/\Delta t_i) = a + b * t_i;\ Z = -b$$

The natural mortality rate M was estimated from PAULY`s (1980) empirical relationship

$$\log(M) = -0.0066 - 0.279 * \log(L_\infty) + 0.6543 * \log(K) + 0.4634 * \log(T)$$

where T is the mean annual water temperature in degrees centigrade (29 °C).

The fishing mortality rate F was calculated as the difference between total mortality rate Z and natural mortality rate M, while the exploitation rate was computed as the quotient of F and Z. The longevity was estimated from the relationship $t_{max} \approx 3/K$ (WAFFY, 1990).

Probabilities of capture were estimated from the length converted catch curve following the method of PAULY (1984). A graphical presentation of the recruitment pattern was obtained by backward projection of the length-frequency data onto a one-year time scale (PAULY, 1987).

Yield per recruit (Y/R) and biomass per recruit (B/R) were estimated from the model of BEVERTON and HOLT (1966).

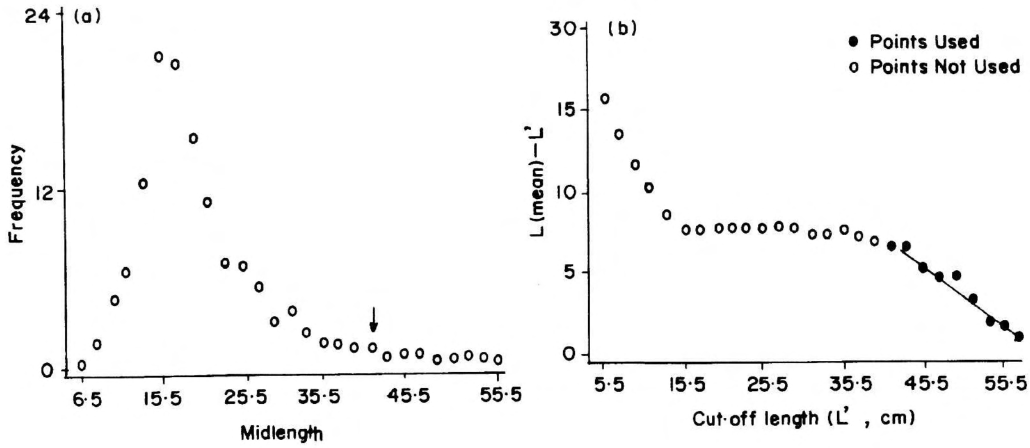

FIG. 2.– Modified Wetheral plot for *P. elongatus* caught in the Cross River estuary. Arrow in (a) indicates first "selected" point. Regression equation in (b): Y = 21.70 - 0.356 * X, N = 9, r = 0.975.

RESULTS

A total of 13 length frequency samples, consisting of a total of 3427 specimens, were taken (Table 2). Based on these the modified Wetheral plot gave a preliminary L_∞ of 61 cm (Fig. 2). The run of ELEFAN produced the seasonalised growth curve shown in Fig. 3, as superimposed on the percentage length frequency histograms; the curve has the following von Bertalanffy growth parameters:

L_∞ = 60.0 cm, K = 0.38 y^{-1}, C = 0.40, and WP = 0.70

The total mortality rate Z was estimated at 1.42 (Fig.4), the natural mortality was estimated at 0.79. The estimated fishing mortality of F = 0.63 gave a current exploitation rate of 0.44, while the yield per recruit analysis predicted an optimum exploitation rate of 0.43 (Fig. 5) for gradually increasing probabilities of capture (PAULY and SORIANO, 1986). Mean length at first capture was computed to L_c = 12.04 cm (Fig. 6).

The average life span or longevity of *P. elongatus* in the Cross River was estimated at approximately 8 years, whereas the recruitment pattern of *P. elongatus* suggests year-round recruitment with one major and one minor peak per year (Fig. 7).

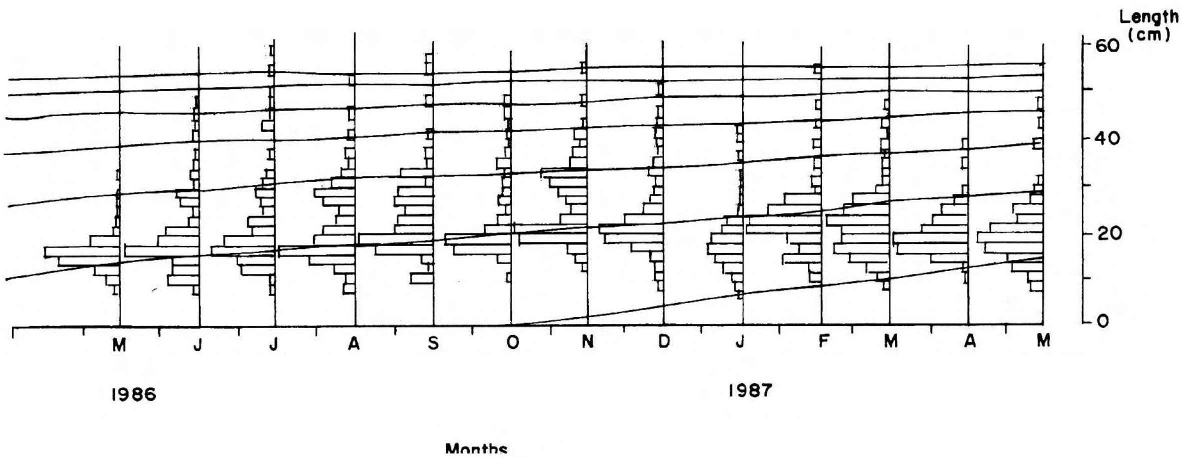

FIG. 3.– Percentage length-frequency histograms for *P. elongatus* with superimposed seasonalized von Bertalanffy growth curve. Parameter values are: L_∞ = 60.0 cm, K = 0.38, C = 0.4, WP = 0.3.

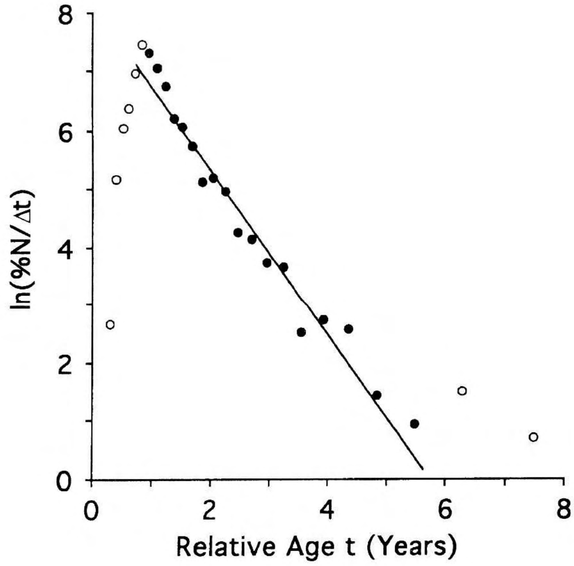

FIG. 4.– Length converted catch curve for P. elongatus in the Cross River estuary. Dots indicate points included in the regression Y = 8.16 - 1.42 * X, N = 18, r = 0.984.

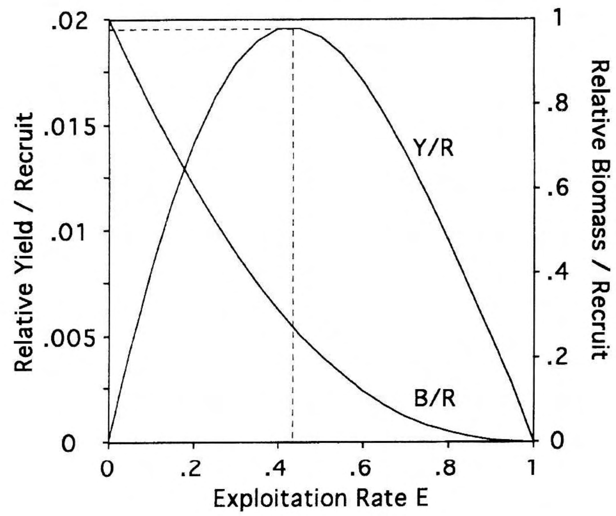

FIG. 5.– Yield per recruit (Y/R) and biomass per recruit (B/R) for *P. elongatus* in the Cross River estuary. Stippled line indicates E_{Max} = 0.43.

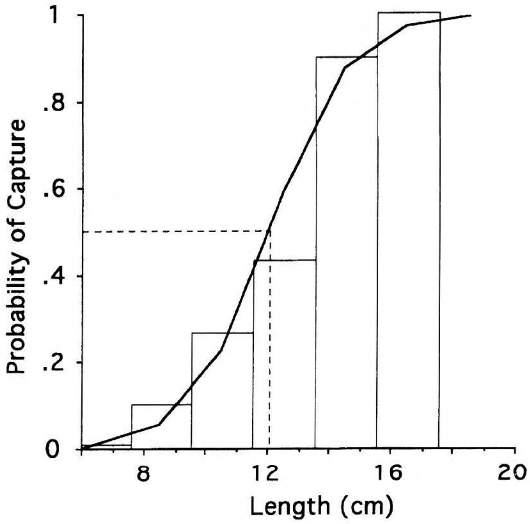

FIG. 6.– Probability of capture of *P. elongatus* in the Cross River estuary derived from catch curve in Fig. 5. Stippled line indicates mean length at first capture L_c = 12.04 cm. $L_{0.25}$ = 10.66 cm, $L_{0.75}$ = 13.42 cm.

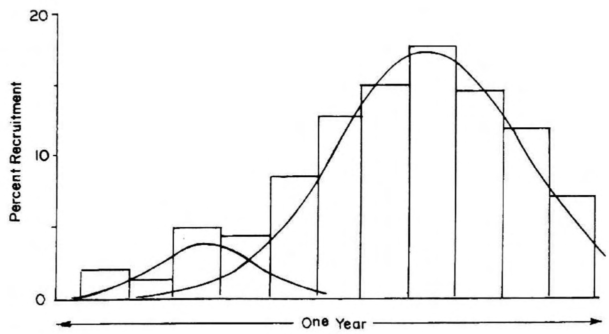

FIG. 7.– Recruitment pattern of *P. elongatus* in the Cross River estuary.

DISCUSSION

The analysis of the catch composition shows that 28 different species constituted the catch of the artisanal fishermen but only five species (*P. elongatus* 43.38%, *Chrysichthys nigrodigitatus* 23,39%, *Ethmalosa fimbriata* 13.37%, *Cynoglosus senegalensis* 4.20% and *Mugil cephalus* 4.15%) were important and together they contribute at least 80 to 90% of the total catch by weight in any particular month. However, only the data for *P. elongatus* were amenable to this kind of analysis because it was the only species that produced a consistently high occurrence throughout the sampling period (Table 2, Fig. 3).

The intraspecific comparison of non-linear growth functions by their parameters (here L_∞ and K) is not very useful. The concept of ϕ' (Phi prime) as a measure of growth performance was introduced (PAULY and MUNRO, 1984) to allow for intraspecific comparison of growth and is computed as

$$\phi' = \log(K) + 2 * \log(L_\infty)$$

PAULY and MUNRO (1984) showed fishes of the same family to have similar ϕ' values, and as demonstrated by VAKILY (1992) the ϕ' values are species specific parameters (i.e. they are narrowly distributed around a mean characteristic of that species). This is also true for *Pseudotolithus* as shown in Table 1. The calculated mean (± standard deviation) is 3.23 ± 0.14 for *P. typus* and 3.07 ± 0.06 for *P. elongatus*, while the mean for the genus is 3.2 ± 0.14. Thus, the ϕ' obtained for *P. elongatus* in this work compares well with those of other studies.

The algorithm for the complete catch curve analysis includes pooling all length-frequency samples of a data series to simulate steady state conditions, and it assumes a constant mortality rate Z over the whole lifespan. However, our results indicated a deviation of older fish (de-selected points in Fig. 4) from the common catch curve. Such difference may be attributed to some size or age specific biological phenomenon such as emigration (de-recruitment) or even differential mortality. However, the numerical contribution of these larger size classes to total catch was not very important (Fig. 3).

In a virgin stock, the natural mortality should equate the total mortality and optimum exploitation rate will be 0.5. If the exploitation rate E later exceeds 0.5, then the stock is overexploited (GULLAND, 1971). The estimated current exploitation rate of 0.44 slightly exceeds the predicted optimum rate of 0.43 (Fig. 5). The implication of this is that the stock is on the verge of suffering from overfishing. The probability of capture (Fig. 6) shows that the length at first capture L_c = 12.0 cm is quite low compared to other populations of *Pseudotolithus* whose values range from 18 to 19 cm (Table 1). This lower value may well be attributed to higher fishing pressure on the Cross River stock.

Precise estimates of absolute ages through determination of t_0 is needed for recruitment patterns to indicate the exact time of spawning. But t_0 can only be determined from age at length data. Nevertheless, from the general biology of other fishes in the estuary and the limnology of the river system itself (MOSES, 1979, 1987), it can be suggested that the major recruitment peak (Fig. 7) corresponds to cohorts spawned in the rainy season (March to September) while the smaller peak corresponds to cohorts spawned in the dry season (October to April). To test this hypothesis, a rough estimate of t_0 was computed for *P. elongatus* in the Cross River estuary using PAULY´s (1979) empirical relationship

$$\log(-t_0) = -0.3922 - 0.275 * \log(L_\infty) - 1.038 * \log(K)$$

where L_∞ is length in cm and K is put on an annual basis. This gave a value of t_0 = -0.36 which was then used together with the other von Bertalanffy growth parameters to obtain a rough idea of spawning and recruitment time. The estimated time of spawning was July (which is the peak of the rainy season) and of maximum recruitment of 17.6% month^{-1} was March. Since the probability density (height) of the major modal class of the recruitment pattern was about 80% greater than that of the minor model class (Fig. 7), it is thus inferred that the recruitment intensity is correspondingly larger. The same argument goes for the duration of recruitment of both cohorts as could be deduced from the spread of the curves along the abscissa. Additionally, the spread of the curves also indicated that there was an overlap in recruitment periods with the implication that recruitment takes place throughout the year with peak each in the rainy and dry season.

Our results indicated that the Cross River stock of *P. elongatus* is exploited intensely and may be close to overfishing. Hence, measures should be taken by the authorities in co-operation with the local fishermen to prevent this valuable resource from suffering extensive and permanent damage. Such measures could be (i) a limited catch season, (ii) a limited catch area or the establishment of protected areas, (iii) modifications of the gillnets used or (iv) definition and control of a minimum size at landing.

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