Studies on the Population Dynamics of *Pellonula leonensis* (Clupeidae) in the Cross River, Nigeria

T. KÜNZEL
Institute of Oceanography
University of Calabar
PMB 1115, Calabar
Nigeria

U. LÖWENBERG
Schlawer Weg 1
2000 Hamburg 73
Fed. Republic of Germany

Abstract

Based on length-frequency distributions and mean annual water temperature, growth and mortality parameter estimates, as well as spawning pattern of *Pellonula leonensis* (Clupeidae) occurring in the Cross River (Nigeria) have been obtained. The estimated von Bertalanffy growth parameters are $TL_\infty = 156$ mm, and K = 0.81 - 0.96 $year^{-1}$. Natural mortality ranges from M = 0.8 to 0.9 $year^{-1}$. Spawning occurs during the whole year with a dominant peak in the dry season and a smaller peak early in the rainy season. A tentative scheme describing the spawning migrations of *Pellonula leonensis* is proposed.

Introduction

Fishing for *Pellonula* and related clupeids in the larger rivers of Nigeria has an old tradition. The most successfully used gear appears to be the "Atalla" lift net. The fishermen usually fish at night when they can take advantage of the vertical upward movement of the clupeids. Echotraces show that the clupeids reach the surface shortly before sunset and remain there throughout the night. The processing of clupeids is done by smoking or sun-drying (Otobo and Imevbore 1979).

Pellonula and related clupeids are of high commercial importance in different parts of Africa, e.g., in Lake Kainji, Nigeria (Otobo 1979), in Lake Kivu, Rwanda (Spliethoff et al. 1983) and Lake Kariba, Zimbabwe (Marshall 1987).

Furthermore, small fishes, although often less attractive to "decision makers", have a high importance for the poor and underprivileged people who constitute the majority in tropical countries, more so than larger fish which are affordable mainly by more affluent groups. That should be reason enough for increasing interest in the population dynamics of these fishes, and specifically of *P. leonensis* in Nigeria.

Materials and Methods

Sampling

A lift net, measuring 2.9 x 2.9 m, meshsize 1 mm, and light attraction (300 W bulb, 50 cm above the surface of the river; lifting the net after 15 minutes light attraction) were used to catch *P. leonensis* at different stations (Fig. 1 and Table 1) along the Cross River (for methodological details, see Künzel et al. 1985). The identification of the species followed Whitehead (1985).

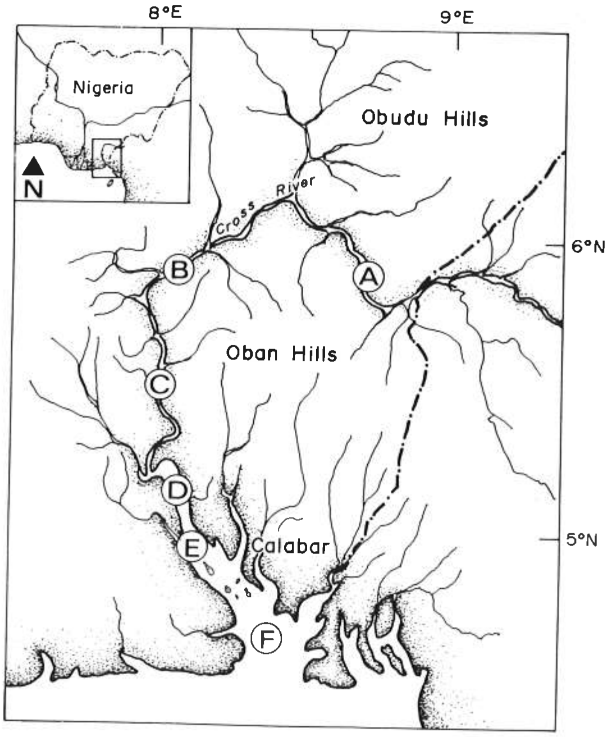

Fig. 1. Course of the Cross River in south eastern Nigeria.

Table 1. Details on fishing stations and catch per unit of effort (number caught per lift) of *Pellonula leonensis* sampled during the survey of Cross River, Nigeria from February to July 1988.

Date	Location	Station code[a]	Distance from river mouth (nm)	Fishing effort (no. of lifts)	Catch <35 mm	Lift ≥35 mm
21/02	Ikom	A	327	18	20	0-1
22/02	Itigiti	B	208	19	323	4
23/02	Ikot Okpora	C	133	16	816	7
25/02	Itu Bridge	D	100	22	102	8
27/02	Nwaniba	E	70	19	9	69
29/04	Ikot Okpora	C	133	18	16	12
02/05	Itigiti	B	208	12	19	9
06/05	Ikom	A	327	14	12	0-1
13/05	Itu Bridge	D	100	19	5	23
14/05	Nwaniba	E	70	12	22	10
13/06	Ikom	A	327	20	14	2
17/06	Itigiti	B	208	22	0-1	5
18/06	Ikot Okpora	C	133	25	0-1	3
10/07	Itu Bridge	D	100	18	0	1
11/07	Nwaniba	E	70	27	0-1	65
31/07	James Island	F	39	25	5	44

[a]See Fig. 1

All length data (total length in mm) collected from all lifts during one night and at one station have been pooled to a single sample. Based on 16 night fishing trips, 16 length-frequency distributions were constructed (Table 1).

Growth

Two methods were used to estimate the parameters of the von Bertalanffy growth function (VBGF). The first approach involved estimation of an approximate value of K, termed K', from an empirical relationship in Ursin (1984), i.e.,

$K' = 0.27 \exp (0.038\ T)$

where T is the annual average water temperature of the area inhabited by the population in question. The value of T = 29°C used for the present estimation, results from hydrographical investigations in the Cross River by Löwenberg and Künzel (unpubl. data).

K and its associated value of L_∞ were also estimated using the ELEFAN software package of Brey and Pauly (1986). The ELEFAN program is based on a VBGF modified for seasonal oscillations in growth (Pauly and Gaschütz 1979):

$$Lt = L_\infty (1-e^{-K((t-t_o) + \frac{CK}{2\pi} \sin (2\pi (t-t_s))}) \quad ...1)$$

Besides the usual VBGF parameters, equation (1) includes two additional parameters: C which is a constant expressing the amplitude of growth oscillation, and t_s which is the starting point, with regard to age t = 0, of a seasonal growth oscillation. The point of slowest growth within the year is called the winter point (WP) and is equal to $t_s + 0.5$[a].

The original 16 length-frequency distributions were poosed with regard to the sampling season and related to new "average" dates as detailed on Table 2.

To identify the best fitting growth curve, the following strategy was used:

i. Executing a group of runs in "narrow search" with the starting point fixed (sample no. 1/midlength = 27.5 and sample no. 2/midlength = 22.5) and with all other parameters variable (K = 0.5-1.5 year^{-1}; L_∞ = 145-160 mm; C = 0.1-1.0; WP = 0.1-0.9);

ii. Executing a group of runs in "narrow search" with the starting point variable and all other parameters fixed at values corresponding to some of the best ESP/ASP values resulting from (i);

iii. Executing a second group of runs in "narrow search" with the starting point fixed at values which correspond to some of the highest ESP/ASP values resulting from (ii), and with all other parameters variable around the values used as fixed in (ii);

iv. Executing a group of runs using the "response surface" option, with starting points and growth parameter values suggested by (i)-(iii).

Mortality

Natural mortality was estimated from the empirical equation in Pauly (1980), with T = 29°C,

[a] Editor's note: equation (1) generates biased estimate of t_o (see Somers 1988, Fishbyte 6(1): 8-11, but this can be ignored here, because t_o cannot be estimated from length-frequency data anyway.

Table 2. Pooled length-frequency samples of *Pellonula leonensis* caught during survey along the Cross River, Nigeria, 1988.

Total length (mm)	24 Feb.[a]	7 May[b]	15 June[c]	11 July[d]	31 July[e]
7.5	233	11	0	0	7
12.5	5,672	223	3	0	19
17.5	2,636	69	13	0	57
22.5	5,393	357	235	0	43
27.5	6,528	284	38	6	4
32.5	1,359	96	5	0	4
37.5	91	132	6	26	6
42.5	313	224	14	179	174
47.5	564	157	22	428	317
52.5	250	160	31	493	238
57.5	130	77	21	188	51
62.5	99	58	28	62	40
67.5	75	28	42	100	72
72.5	80	14	20	129	93
77.5	36	10	8	82	58
82.5	19	6	5	50	24
87.5	5	8	1	28	13
92.5	2	1	2	10	1
97.5	2	3	4	5	1
102.5	2	0	4	1	1
107.5	5	1	4	4	0
112.5	1	1	2	0	1
117.5	0	1	4	0	0
122.5	0	1	9	0	0
127.5	3	0	4	0	0
132.5	0	1	0	0	0
137.5	0	0	1	0	0
142.5	0	0	0	0	0
147.5	0	0	1	0	0
152.5	0	0	1	0	0

[a]"average sampling date" of samples from 21 Jan - 27 Feb.
[b]"average sampling date" of samples from 29 Apr. - 14 May
[c]"average sampling date" of samples from 13 June - 18 June
[d]"average sampling date" of samples from 10 July - 11 July
[e]sampling date

while Z was estimated from the empirical model of Hoenig (1982), i.e.,

$$\ln Z = 1.45 - 1.01 \ln t_{max}$$

where t_{max} was determined from L_{max} and the parameters of the VBGF.

Spawning pattern

Spawning patterns were derived from the original 16 length-frequency distributions (Table 1), the ELEFAN II program (Brey and Pauly 1986) and the estimated growth parameters. In a second approach, the whole range of total length of the measured specimen was divided into "juveniles (<35 m) and adults (≥35 mm). The resulting relative abundances of "juveniles" and "adults" were then plotted in a three-dimensional system of coordinates showing quantitatively the distribution of these two groups in time and space during the survey.

Results and Discussion

Growth

The estimated values of the exponential growth coefficient were derived from two independent methods. The estimates of the growth coefficient, K' = 0.81 (from Ursin's relationship) and K = 0.96 (ELEFAN I) are similar. However, for other clupeids living in warm waters such as e.g., *Sardinella aurita*, Pauly (1978) gave K values of 1.0 to 1.2 $year^{-1}$ (≈ 25°C) and 2.4 to 2.9 (≈ 29°C). The latter range appears high, and indeed, Ursin (1984) suggests for "clupeids in tropical waters" (≈ 26°C) a mean value of K ≈ 0.72.

The two parameters C and WP were estimated at 0.3 and 0.7, respectively. The amplitude of growth oscillation expressed by C = 0.3, corresponds to a small difference between "summer" and "winter" temperature in the area of investigation. J.C.D. Watts (cited in Longhurst 1957) found a seasonal variation of 3-4°C at a single station in mid-estuary of the Sierra Leone River (West Africa) over a two-year research period. The relationship between C and the summer-winter temperature difference in Pauly (1987) suggests that a value C = 0.3 should be linked to a temperature difference of about 3°C. The winter point WP = 0.7 refers to a season of lowest growth around September, i.e, during the high rainy season, when tropical rivers show the lowest growth of phytoplankton (Payne 1986) and low abundances of zooplankton. Thus, for example, zooplankton in the Sokoto River (West Africa) produce their nauplius larvae during the dry season and early rains. But none could be found at the high rainy season, nor as the flood receded (Hoenig and Green 1960).

From that point of view, it sounds reasonable to assume a reduced food supply for zooplankton feeders such as small clupeids (Marshall 1987) during the rainy season (which culminates at a "winter point" around September) resulting in growth depression.

The asymptotic length (L_∞) estimated using ELEFAN I was 156 mm. Balogun (1987) reports for *Pellonula leonensis* occurring in Epe Lagoon (Nigeria) L_{max} = 122 mm (total length). He found this L_{max} out of a total of 632 specimens measured during November 1979 to January 1980. The longest specimen we found, out of a total of 28,969 specimen measured, was 152 mm. Ita (1983) who collected samples from artisanal fishermen in the same area reports an L_{max} value of 150 mm (standard length) for *Pellonula leonensis*.

Fig. 3 shows how the parameters of the growth curve were estimated from the restructured length composition of *Pelonulla leonensis*.

Mortality

Pauly's empirical relationship of 1980 (Table 3) used here to estimate M is an upgraded version of an earlier relationship presented in 1978. With regard to the latter, Ursin (1984) suggested that the "mortalities of [tropical] clupeids are probably overestimated". Pauly himself regards M values of clupeids based on his formulae of 1978 and 1980 as too high, and suggested a reduction of estimated M by a factor of 0.8 to 0.6 in the case of clupeids.

Hoenig (1982) has developed a linear regression equation to predict total mortality (Z) from the maximum observed age (t_{max}) based on aging the few largest fish of the population. Maximum age was here estimated from the VBGF and L_{max}.

The values of natural mortality play a very important part in fisheries management, i.e., from the estimation of potential yields. Estimates of M that are too high can lead to an overestimation of potential yields. When there is no way to find out the correct value of M (and that is generally the case), it may therefore be prudent to accept an underestimation of M, since this will at worst lead to stock underexploitation, but not to overexploitation (when M is used to èstimate potential yields).

Our ranges of values of M (Pauly's relationship) and (Hoenig's formula) are 1.0 - 1.1 and 0.9 - 1.1 year^{-1}, respectively. We opted to use the factor 0.8 (instead of 0.6) to reduce the M values derived from Pauly's relationship, resulting in our final range of M ≈ 0.8 - 0.9 year (Table 3) (These estimates are too crude to make inferences on fishing mortality, i.e., on Z - M). Marshall (1987) lists catch-curve-based estimates of M for *Limnothrissa miodon* in Lake Kariba (Zimbabwe) ranging from 0.70 to 1.15 year^{-1}.

Spawning pattern

Fig. 4 shows the recruitment pattern reflecting the seasonality of recruitment to the stock in question. The graph suggests that there is spawning throughout the year with two seasonal pulses, one clearly dominating the other. Because t_0 is not available, the exact position of the recruitment pattern within the year is not known.

Table 3. Methods and results of the estimation of some parameters relevant to the population dynamics of *Pellonula leonensis* in the Cross River, Nigeria

Parameter	Method of estimation	Estimates
K'	$K' = 0.27 \exp(0.038\,T)$ Ursin (1984)	0.81 year^{-1}
K	ELEFAN I Brey and Pauly (1986)	0.96 year^{-1}
L_∞	ELEFAN I	156
t_{max}	$t_{max} = t_0 + \ln(-L_{max}/L_\infty + 1)/-K$	3.9 - 4.6 year^{-1}
M	Pauly (1980)	1.0 - 1.1 year^{-1}
	Reduced by a factor of 0.8	0.8 - 0.9 year^{-1}
Z	Hoenig (1982)	0.9 - 1.1 year^{-1}
C	ELEFAN I	0.3
WP	ELEFAN I	0.7

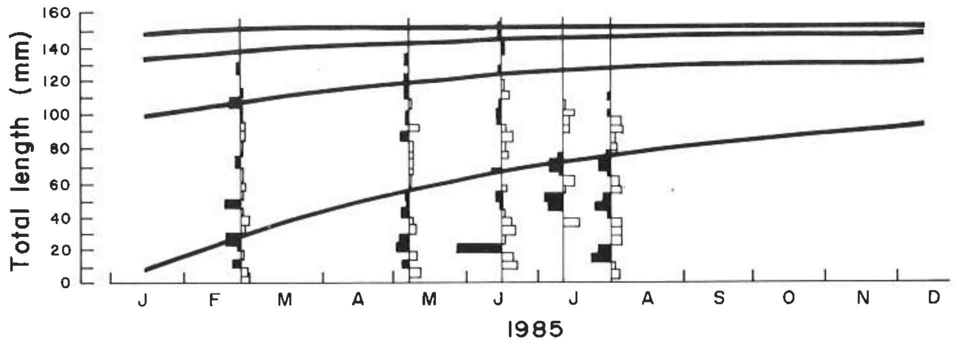

Fig. 2. Length-frequency data for *P. leonensis* (for Table 2) restructured using the ELEFAN I program, with superimposed growth curve.

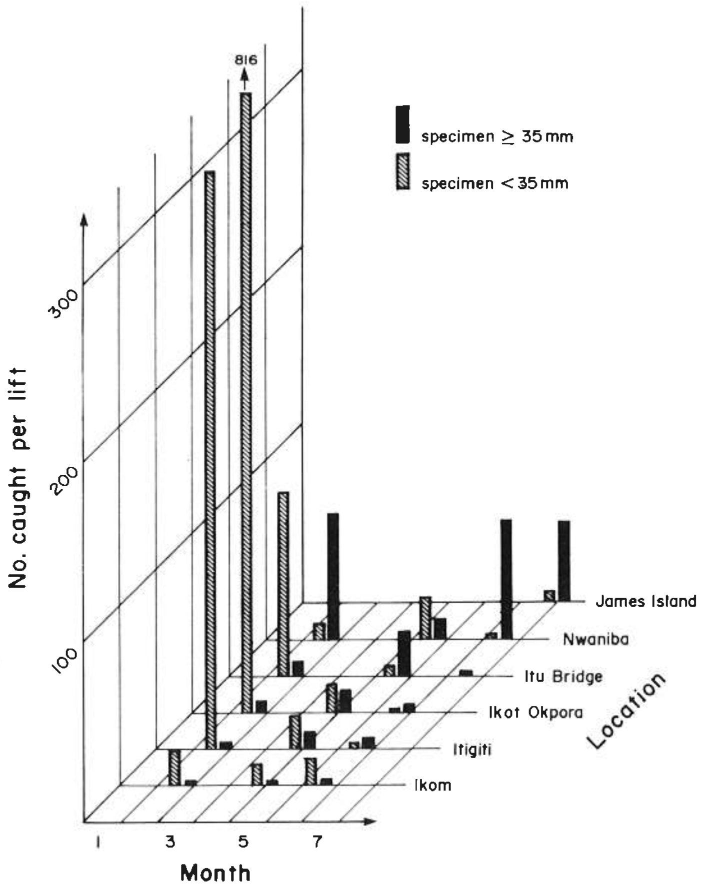

Fig. 3. Monthly occurrence of *Pellonula leonensis* juveniles and adults at six locations along the Cross River.

However, examination of the distribution of the "juveniles" in space and time shown in Fig. 3 give us the possibility to identify January/February tò be the time of highest spawning near Ikot Okpora, an upstream station with freshwater conditions during the whole year. We relate this point of highest abundance of "juveniles" to the dominant peak of Fig. 3. According to Moses (1977) who compiled the yearly rainfall at Ikot Okpora, the dry season extends from November (ca. 70 mm rainfall) to March (ca. 100 mm rainfall). This means that a main spawning pulse occurs during the dry season, and

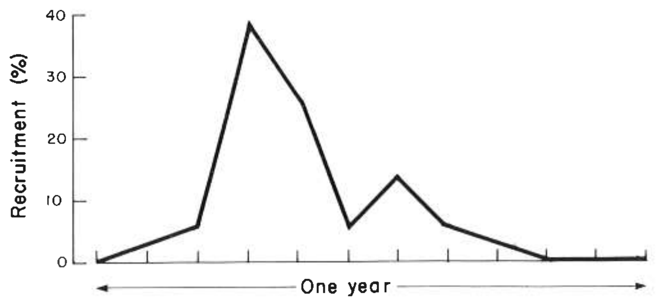

Fig. 4. Recruitment pattern of *Pellonula leonensis*.

that a second, minor spawning peak could occur in the early rainy season (Fig. 3 does not give strong evidence for the existence of a second spawning pulse but this may be due to insufficient sampling density).

Ita (1983) described Itu and Ikot Okpora as the early flood season breeding ground, probably with reference to the second (smaller) spawning peak in Fig. 4. Ita could not find the main breeding season because he carried out surveys in June, July and November only.

Figs. 3 and 4 allow to derive a hypothesis about the spawning migration of *Pellonula leonensis* in the Cross River area, as follows:

(i) *P. leonensis* hatch in upstream freshwater, grow and migrate downstream, down to brackishwater

(ii) upon reaching first maturity, *P. leonensis* migrates upstream, and have their main spawning activity during the dry season, in January/February. A second, but smaller spawning pulse may occur in more downstream areas, three months later, during the onset of the rainy season

(iii) after spawning the adults return to the estuary, whose salinity is much reduced by the rainy season.

The suggestion that the *P. leonensis* leave the estuary when salinity increases is supported by Balogun (1987) who found that this fish had disappeared from Lagos Harbor during the period of high salinity, from February to April. With regard to our sampling stations, only James Island (Station F in Fig. 1) has brackishwater conditions, at least during the dry season.

Kapetzky (1977) studied 18 species in the Magdalena River in Columbia, tropical South America. He found that "more than the half of the species studied bred during February-April low waters and in the first stages of the rising flood. There was another peak of breeding activity during the second stages of rising water (October), but few species bred during falling water (December-January)." Our results suggest a similar pattern for the West African *P. leonensis*.

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Maximo Rendimiento Sostenible de la Pesqueria Comercial en el Departamento de Loreto, Perú

V. MONTREUIL
S. TELLO
J. MACO
R. ISMIÑO
Instituto de Investigaciones
de la Amazonía Peruana (IIAP)
Apartado Postal 784
Iquitos, Peru

Abstract

Catch and effort data from the river fisheries of the Peruvian part of Amazonia are presented, and used to fit a Schaefer-type surplus production model. This suggests that present effort is in excess of what is required to generate Maximum Sustainable Yield, and that and increase in effort would actually reduce catches.

Introduccion

La pesquería que se desarrolla en los ríos de la amazonía peruana proporciona proteína animal a los habitantes del 45% de territorio nacional. Como el aporte de esta actividad no sólo es alimenticio, sino también económico a través de la creación de fuentes de trabajo o ingreso de divisas mediante la exportación de algunos de sus productos obliga a asegurar la protección y conservación de los recursos utilizados mediante la determinación de los niveles de explotación, los rendimientos potenciales y los métodos para maximizar estos rendimientos.

Considerando que el monitoreo de la captura y el esfuerzo de pesca en una población explotada es una técnica útil en la medición de la densidad de la población (Ricker 1971), debido a que la captura