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Length-weight relationship and population parameters of *Pellonula leonensis* Boulenger, 1916 (Clupeidae) in man-made Lake Taabo (Bandama basin; Côte d'Ivoire)

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Abstract

Length-Weight relationship and population parameters of *Pellonula leonensis* Boulenger, 1916 were studied in man-made Lake Taabo (Côte d'Ivoire). Samples were collected using beach seine with 6 and 8 mm mesh size from November 2008 to October 2009. Length frequency data collected were analyzed with FISAT software using the ELEFAN package to estimate the population parameters of *Pellonula leonensis*. The coefficient of allometry (b) was 3.24 and the correlation coefficient (r = 0.97) showed that there was a high and significant correlation between the standard length and the weight of *P. leonensis*. The asymptotic length (L∞) and growth rate constant (K) were estimated to be 6.56 cm and 0.86 year^{-1}. Based on these growth parameters, the estimated value for the fishing mortality coefficient (F) was 0.93 year^{-1} for *P. leonensis* in man-made Lake Taabo. Natural mortality coefficient (M) estimated was 2.55 year^{-1} and exploitation rate (E) was 0.27. The recruitment pattern of *P. leonensis* showed that there is a year round recruitment with the highest recruitment in April (24.84%) while the lowest recruitment were in November (0.42%) and December (0%).

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Introduction

The Pellonuline clupeids fishes are important ichtyofaunal component of freshwater and brackish ecosystems. There are important ecologically and commercially and are widely exploited (Uneke *et al.*, 2010). *Pellonula leonensis* Boulenger, 1916 is the most widely distributed freshwater Clupeidae in West Africa. It is found in lagoons, lakes and lower, as well as upper, courses of rivers, from Senegal to the cross (Paugy *et al.*, 2003). According to Yao (2008), the total production of *P. leonensis* in man-made Lake Taabo was estimated at 320 tons per year. Taabo Reservoir is one of the four hydroelectric lakes of Côte d'Ivoire and it is used for important fisheries. Studies on the fish community are useful for a durable management of fishing activities (Aliko *et al.*, 2010). Population parameters such as asymptotic length (L∞) and growth coefficient (k), mortality rates and exploitation level were studied with the major objective of rational management and resource conservation (Tah *et al.*, 2010; Nasser, 1999).

Growth information provides a lot of tools that are used in fishery management. The data on age of a fish can provide tools in fishery management such as the general background information needed for management decisions. It aids in diagnosis of management needs such as the recognition of overcrowding and stunting (Carlendar, 1955; Deekae and Abowei, 2010).

Mortality can be defined as the death of an organism. It is a very important aspect of population biology since it provides information about changes in the population. Mortality can be caused by fishing activity (fishing mortality) or by natural action (natural mortality) (Abowei and Hart, 2009; Abowei *et al.*, 2010). According to Marshall (1993), mortality rates are of prime importance to fishery scientists in expressing the dynamics of fish population.

Recruitment is the entrance of young fish into the exploited fishing area and became liable to contact w ith fishing gear (Gulland, 1983). Recruitment is the major source of variability in fish population. The mean age of fish at recruitment generally depends on the type of mesh size of the gear used in fishing (Bankole, 1990).

Population parameters can easily be estimated using models such as FAO ICLARM Stock Assessment Tool (FISAT) (Gayanilo and Pauly, 1997), analysis of the length - frequency data of the fish available (Sparre *et al.*, 1989) and by using the electronic frequency analysis (ELEFAN) (Abowei, 2010; Gayanilo *et al.*, 1988). Studies on the diet (Kouamé, 2006), production (Yao, 2008) and reproduction (Koné *et al.*, 2011) of the Clupeidae *Pellonula leonensis* were done in Côte d'Ivoire. However any of these studies considered the population parameters. The present work is the first attempt to investigate growth rates, mortality coefficients and the exploitation rate of this specie in Taabo reservoir using monthly length frequency analyses.

Material and methods

The study area

The Taabo hydroelectric dam was built on the Bandama River in south of Côte d'Ivoire between 6°20' to 6°40' N and 5° to 5°30'W (Fig. 1). The man-made Lake Taabo is established in the main-channel of Bandama River to approximately 120 km downstream from the dam of Kossou (Traoré, 1996). The artificial reservoir is 16 km long and 124 m wide (at the average operating level), with an area of 69 km². The climate of lake area is an equatorial transition zone with two rainy seasons separated by a short dry period in August and September and a more pronounced dry season from December to March (Iltis and Lévêque, 1982).

Fish sampling and data collection

Fish samples were collected monthly from commercial landings between November 2008 and October 2009. Specimens of *P. leonensis* were captured using beach seine with 6 and 8 mm mesh size. All specimens sampled were identified according to Gourène and Teugels (2003). Body weight was recorded to the nearest 0.001gram (g) and standard length (SL) was measured to the nearest millimeter (mm). Fish specimens were grouped into classes of

0.5 centimeter intervals. Data analyses were based on FISAT II (Gayanilo *et al.*, 2002).

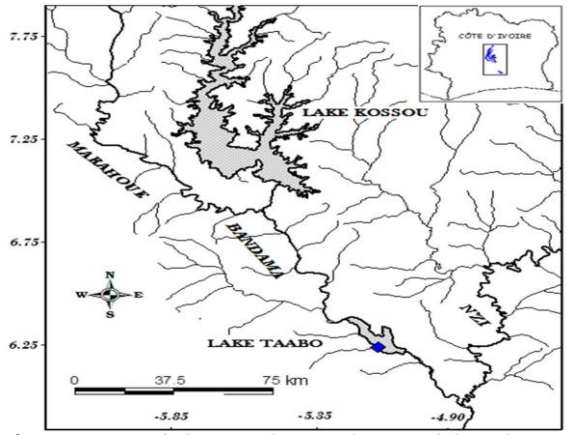

Fig. 1. Map of the Bandama River and location of man-made Lake Taabo (◆).

The length-weight relationship of fish was estimated using the equation: $W = a \times SL^b$

or in the linear form:

$$Log_{10} W = Log_{10}\ a + b\ Log_{10}\ SL$$

where W is the weight of fish in grams (g); SL is the standard length of fish (cm); a is a scaling constant and b is the allometric growth coefficient. The value of b gives information on the kind of growth of fish: the growth is isometric if b = 3 (Wootton, 1990; Naeem *et al.*, 2010) and the growth is allometric if b ≠ 3 (negative allometric if b < 3 and positive allometric if b > 3) (Ricker, 1975).

Assessment of growth parameters from length frequency data

The ELEFAN I program in FISAT II was applied to estimate the growth parameters (L∞) and (K), assuming that the body growth followed the von Bertalanffy growth equation (Gayanilo *et al.*, 2002). The growth model used is as follow:

$$L_t = L\infty \left(1 - e^{-K\,(t - t_0)}\right)$$

Where L_t is the length at age t; L∞ is the asymptotic length; K is the growth coefficient and t_o is the theoretical age at which the length is zero.

The t_o value estimated using the empirical equation Pauly (1979):

$Log_{10}(-t_o) = -0.392 - 0.275\ Log_{10}\ L\infty - 1.038\ Log_{10}\ K$

The fitting of the best growth curve was based on the ELEFAN I program (Pauly, 1984), which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. An index of goodness of fit, called Rn, was determined by automatic computer (Gayanilo *et al.*, 2002). The overall growth performance index (φ') was quantified using the model of Pauly and Munro (1984). The index is defined as: $\varphi' = \log_{10} K + 2 \log_{10} L\infty$.

The potential longevity of *P. leonensis* was estimated according to the following equation (Pauly, 1985):

$$T_{max} = \frac{2.9957}{K}$$

Total mortality Z was estimated by the length converted catch curve method as implemented in ELEFAN I. The linearized length-converted catch curve (Pauly, 1984) was constructed using the formula: $Ln\ (Ni/\Delta ti) = a + b\ t_i$

where: Ni is the number of individuals in length class i,

Δti is the time needed for the fish to grow through length class i,

t is the relative age corresponding to the mid-length of class i.

The slope (b) of the curve with its sign changed gives Z.

Natural mortality (M) was derived through the empirical equation of Pauly (1980):

$$Log_{10} M = -0.0066 - 0.279\ Log_{10} L\infty + 0.6543\ Log_{10} + 0.463\ Log_{10} T$$

where T is the annual mean of habitat temperature (in degrees Celsius). The indicated value is equal here to 29.9°C (Koné, 2012).

The estimate of fishing mortality (F) was taken by subtraction of M from Z and exploitation rate (E) was obtained from $E = \frac{F}{Z} = \frac{F}{F + M}$

The exploitation rate indicates whether the stock is lightly (E < 0.5) or strongly (E > 0.5) exploited, based on the assumption that the fish are optimally exploited when F = M or E = 0.5 (Gulland, 1971).

The estimates of length-at-first-capture (Lc or L_{50}) were derived from probabilities of capture generated from the catch curve analysis. The extrapolated points of the length-converted catch curve were used to approximate the probability of capture for each length group using the running average method to estimate the selection parameter L_{50} through linear interpolation.

Recruitment patterns were generated from the estimated growth parameters by backward projection of length frequency data, as done in ELEFAN I, onto the time axis (Moreau and Cuende, 1991). This type of back-calculation usually allows identification of the number of seasonal pulses of recruitment that have been generated by the population represented in the length frequency data (Gayanilo *et al*., 2002).

Results

Length-frequency distribution

The smallest specimen of *P. leonensis* (n = 5082) was 11 mm SL and the largest specimen was 64 mm SL (mean 32.59 ± 7.63 mm) as showed the length-frequency distribution (Fig. 2). Specimens with standard length between 21 – 40 mm were numerically dominant and constituted 80.61 % of the population. There is only one mode at 26 – 35 mm SL.

Table 1. Growth parameters of *Pellonula leonensis* in Lake Taabo (from November 2008 to October 2009).

Parameters	Values
Asymptotic length (L∞)	6.56 cm
Growth coefficient (K)	0.86 $year^{-1}$
Growth performance index (φ')	1.56
Goodness of fit index (Rn)	0.40
Hypothetical age (t_o)	-0.27 year
Longevity (t_{max})	3.48 years

Length-weight relationship

A strong positive relationship was observed between length and weight as indicated by the high regression coefficient (r) of 0.97 (Fig. 3). The values of *a* and *b* are respectively $1.23x10^{-2}$ and 3.24. The value of *b* was greater than 3 indicating that allometric growth is positive for *P. leonensis*.

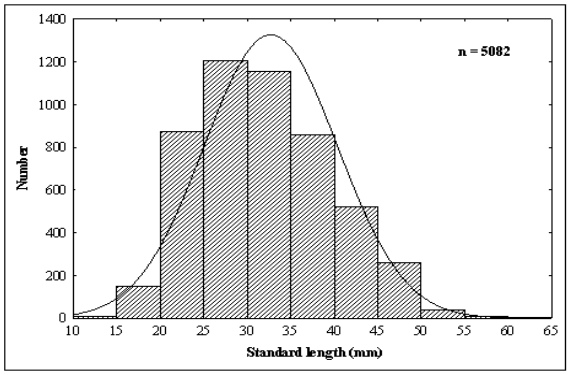

Fig. 2. Length-frequency distribution of *Pellonula leonensis* with one mode at 26- 35 mm.

Growth parameters

The estimated growth parameters for *P. leonensis* from man-made Lake Taabo are shown in Table 1. The Von Bertalanffy growth equation is as follow:

$$L_t = 6.56\left(1 - \exp\left[-0.86\left(t + 0.27\right)\right]\right)$$

The estimated values of asymptotic length (L∞) and growth coefficient (K) of the Von Bertalanffy growth formula were 6.56 (cm) and 0.86 ($year^{-1}$) respectively. The figures 4 and 5 show the growth curves generated from ELEFAN I for *P. leonensis* during the course of this study. It was assumed in the ELEFAN I analysis that the value of the third parameter of the von Bertalanffy growth function t_o was – 0.27. These curves were superimposed over the length-frequency histograms which show the normal length-frequency histograms (Fig. 4) and the restructured length-frequency histograms (Fig. 5).

Instantaneous mortality coefficients and exploitation Rates

The length converted catch curve (Fig. 6) showed that

the total mortality (Z) estimated for *P. leonensis* was 3.48 per year. The natural mortality (M) at 29.9°C was 2.55 per year while the fishing mortality (F) was 0.93 per year. Exploitation rate for *P. leonensis* in Taabo Lake was 0.27.

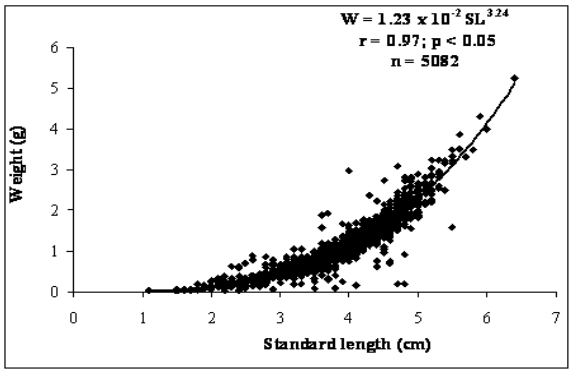

Fig. 3. The length-weight relationship curve of *Pellonula leonensis* in Lake Taabo.

Lengths at first capture and recruitment patterns

The estimated length-at-first capture L_{50} or Lc (length at which 50% of the fish entering the gear are retained) was 2.70 cm. The L_{25} (length at which 25% of the fish entering the gear are retained) was 2.32 cm and L_{75} (length at which 75% of the fish entering the gear are retained) was 3.14 cm (Fig. 7).

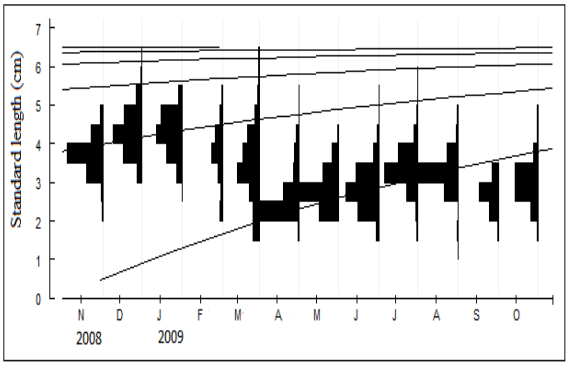

Fig. 4. Growth curve of *Pellonula leonensis* with normal length-frequency histograms (L∞ = 6.56 cm SL, K = 0.86 year^{-1}).

The recruitment pattern of *P. leonensis* (Fig. 8) showed that there is one peak per year. The model of recruitment of *Pellonula leonensis* in the man-made Lake Taabo is continual throughout the year. Recruitment is significant from March (12.32%) to June (14.86%) with high percentages in April (24.84%) and May (19.33%). The lowest recruitment were in November (0.24%) and December (0%).

Discussion

The length-weight relationship is an important factor for fisheries (Manoharan *et al.*, 2013). In the present study, specimens with standard length between 21 and 40 mm constitute the major part of the sample of Taabo. This result would indicate a strong pressure of fishing on the populations of *P. leonensis* in the Lake Taabo. Indeed, the structures of sizes of the fish populations are usually used in halieutics like indicators of the effects of fishing (Shin *et al.*, 2005). According to Nicholson and Jennings (2004), good correspondences exist between the indicators based on the sizes of fish and mortality by fishing. The parameters of the structures of sizes are thus modified under the effect of mortality by fishing. The average size decreases and the peak is moved towards the classes of smaller sizes.

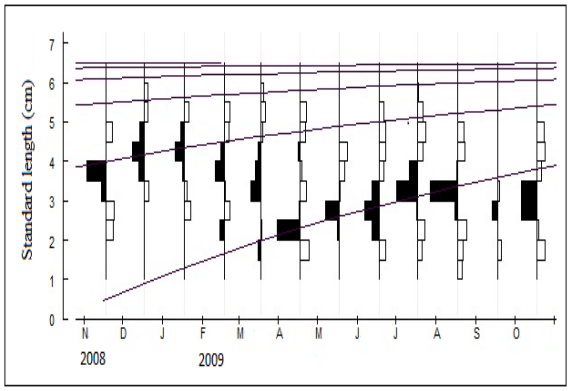

Fig. 5. Growth curve of *Pellonula leonensis* with restructured length-frequency histograms. The black bars are positive values of length-frequency and the white bars are negative values.

Our study revealed that the relationship was a positive allometry (b = 3.24). Ecoutin and Albaret (2003) reported a negative allometry (b = 2.856) for *P. leonensis* in Ebrie Lagoon. This change may be due to a number of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and locality (Frosta *et al.*, 2004; Wooton, 1990; Jhingran, 1968). Such differences in value 'b' can be assigned to a combination of factors such as differences in the number of specimens examined, area/season effects and the differences of length range analyzed of the specimens caught. According to Altinokand and Grizzle (2001) and Townsend *et al.* (2003) the slope

value 'b' indicates the rate of weight gain relative to growth in length and varies among different populations of the same species or within the same species.

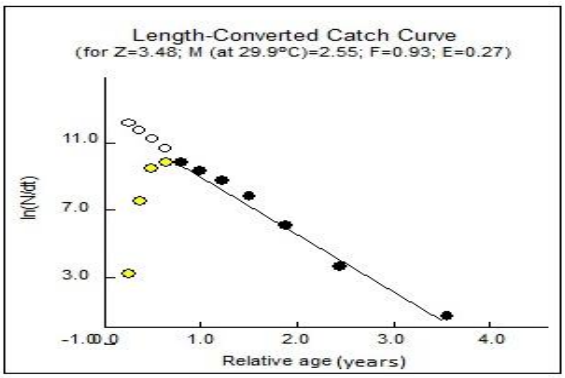

Fig. 6. Length-converted catch curve of *Pellonula leonensis*.

Dark circles in the figure represent the points used in calculating (Z) through least squares regression lines. The grey circles represent frequencies of fishes either not fully recruited or approaching (L∞), and hence discarded from the calculation. The expected frequencies of not fully recruited fishes are added as blank circles.

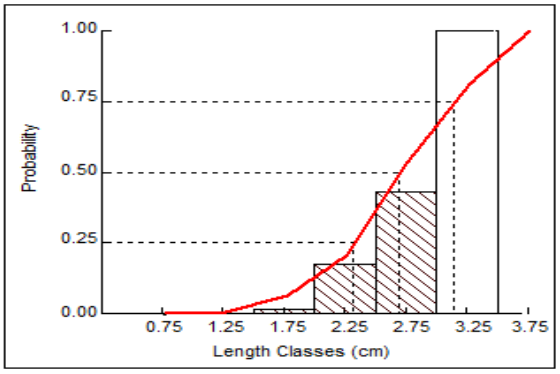

Fig. 7. Probability of capture analysis for *Pellonula leonensis* (L_{50} or Lc = 2.70 cm; L_{25} = 2.32 cm; L_{75} = 3.14 cm).

The parameters that describe growth in length (L∞ = 6.56 cm and K = 0.86 year^{-1}) of *P. leonensis* in this study are lower than those observed by other authors. Uneke *et al.* (2010) estimated infinity length and growth coefficient of *P. leonensis* at 9.98 cm and 1.3 year^{-1} in Anambra Flood River. Villanueva (2004) recorded L∞ of 11.90 cm FL and K of 1.48 year^{-1} in Gambia estuary, 10.49 cm FL (L∞) and 1.68 year^{-1} (K) in Sine Saloum estuary and 11 cm (L∞) and 2.00 year^{-1} (K) in Nokoué lagoon. Growth coefficient (K) estimated in lagoon (Nokoué) and estuaries (Gambia and Sine Saloum) are higher than those observed in freshwater (Lake Taabo). These differences could be explained by the fact that fish species in brackish and lagoon waters have a shorter life span and reach maximum size earlier than those in fresh waters (Longhurst and Pauly, 1987; Tah *et al.*, 2010).

The estimated total mortality (Z = 3.48 year^{-1}) and natural mortality (M = 2.55 year^{-1}) in this study are higher. This trend was also observed by Uneke *et al.* (2010) in Anambra Flood River for *P. leonensis*. According to Mubamba (1993), the mortality rates of other clupeids such as *Stolothrissa tanganicae*, *Limnothrissa miodon* in the north of the Lake Tanganyika are higher. These high mortalities rates are explained by the fact why the clupeids constitute the preys of some piscivorous fish species such as *Hydrocynus forskalii*, *Lates niloticus* and *Malapterurus electricus* (Lewis, 1974; Otobo, 1979). Natural mortality is the mortality caused by predation, diseases, stress, lack of food, old age and temperature of water (Sidibé, 2003).

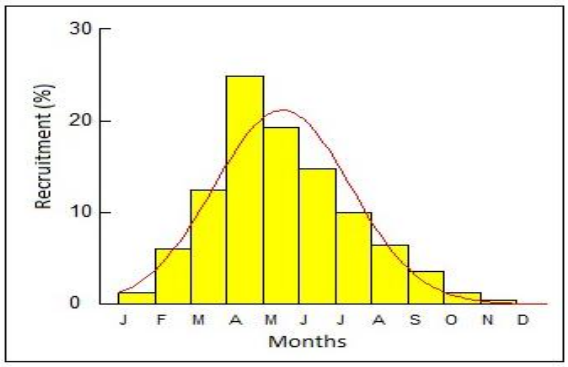

Fig. 8. Recruitment pattern of *Pellonula leonensis* in Lake Taabo.

From the probability of capture curve of *P. leonensis*, the length-at-first capture (Lc) was 2.70 cm. According to Koné (2012), the size of first maturity of *P. leonensis* in man-made Lake Taabo is 2.74 cm SL for females and 2.75 cm SL for males. This result shows that fishes were caught at smaller sizes before they had the chance to grow large enough and to breed to contribute substantially to stock biomass. Hence a fisheries regulation of minimum escape gaps

(mesh sizes) of artisanal traps should be enforced in the *P. leonensis* fishery of Taabo Lake to ensure that small size fishes can escape from the traps when caught.

Recruitment has been described as a year-round phenomenon for tropical fish and shrimp species (Tah *et al.*, 2010; Weber, 1976). This assertion was corroborated by our results which show that the recruitment of *P. leonensis* was continuous all year-round. Uneke *et al.* (2010) also reported a year round recruitment for *P. leonensis* in Anambra Flood River with two peaks in the months of April and September.

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