STOCK ASSESSMENT OF RED PANDORA *PAGELLUS BELLOTTII* (STEINDACHNER, 1882) IN THE IVORIAN CONTINENTAL SHELF (WEST AFRICA)

A. C. KOUAME[*1,2], S. SYLLA[2], S. S. YAO[1], C. B. TIA[1,2] & G. A. LOUKOU[2,3]

[1] Laboratoire des Milieux Naturels et Conservation de La Biodiversité, Université Félix Houphouët Boigny (Abidjan, Côte d'Ivoire), UFR Biosciences, 04 B.P. 322 Abidjan 04, Côte d'Ivoire,

[2] Centre de Recherches Océanologiques (CRO), B.P.V 18 Abidjan, Fax (225) 21 35 11 55, Côte d'Ivoire,

[3] Laboratoire de Biologie et de Cytologie Animale, Université Nangui Abrogoua, (Abidjan Côte d'Ivoire), UFR Sciences de la Nature, 02 B.P. 801 Abidjan 02, Côte d'Ivoire.

*Corresponding author : E-mail: kamoinceline@gmail.com Mobile No +225- 47 64 41 74 / 04 10 43 54.

ABSTRACT

Population parameters of Red Pandora *Pagellus bellottii* (Steindachner, 1882) were collected in the Ivorian continental shelf from March 2016 to February 2018. 799 specimens of *P. bellottii* used in this study. Their fork length ranging from 9.9 to 25 cm was measured. The length frequency data were analyzed using ELEFAN I in the software package FiSAT II. Estimated Von Bertalanffy parameters for the whole population were: L_∞ = 31.73 cm, k = 0.42 year^{-1} and t_0 = - 0.38 year^{-1}. The length-weight relationship all individuals of *P. bellottii* was described by the following parameters: a = 0.0186, b = 2.9796. Negative allometric was observed. The rates of total (Z) and natural mortalities (M) were 2.88 and 0.96 year^{-1}, respectively. The annual instantaneous fishing mortality rate (F) was 1.92 year^{-1}. The recruitment pattern was continuous with one recruitment pulse. The estimated length at first capture (Lc) was 14.39 cm.

The exploitation rate (E= 0.67) and the results from the yield-per-recruit analysis indicated that the resource has been heavily over exploited. Therefore, some measures of management should be imperatively implemented to protect the Red Pandora population in the Ivorian continental shelf.

Keywords: Population parameters, stock assessment, *Pagellus bellottii,* continental shelf, Côte d'Ivoire.

RESUME

Evaluation du stock du Pageot à tache rouge Pagellus bellottii (Steindachner, 1882) sur le plateau continental ivoirien (Afrique de l'Ouest)

Les paramètres de population du Pageot à tache rouge Pagellus bellottii *(Steindachner, 1882) ont été étudiés au niveau du plateau continental ivoirien de mars 2016 à février 2018. Au total, 799 spécimens de* P. bellottii *ont été utilisés dans cette étude. Leur longueur à la fourche varie de 9,9 à 25 cm. Les données de fréquence de taille ont été analysées à l'aide du programme ELEFAN I du logiciel FiSAT II. Les paramètres de croissance selon le modèle de Von Bertalanffy pour toute la population sont les suivants : L_∞ = 31,73 cm, k = 0,42 an^{-1} et t_0 = -0,38 an^{-1}. La relation longueur poids chez les deux sexes confondus de* P. bellottii *est décrite par les paramètres suivants : a = 0.0186, b = 2,9796. Ainsi, chez les sexes confondus,* P. bellottii *présente une allométrie négative. Les taux de mortalité totale (Z) et naturelle (M) ont été de 2,88 et 0,96 an^{-1}, respectivement. Le taux instantané annuel de mortalité par pêche (F) obtenu est de 1,92 an^{-1}. Le recrutement est continu est avec un seul pic. La taille de première capture (Lc) est de 14,39 cm. Le taux d'exploitation (E = 0,67) et les résultats de l'analyse du rendement par recrue indiquent que la ressource est fortement surexploitée. De ce fait, certaines mesures de gestion doivent être impérativement mises en œuvre pour protéger la population du Pageot à tache rouge sur le plateau continental ivoirien.*

Mots clés : *Paramètres de population, évaluation du stock,* Pagellus bellottii, *plateau continental, Côte d'Ivoire.*

INTRODUCTION

Family Sparidae is one of the most economically important marine fish families and it is well represented by the diversity of species and high commercial value (Tortonese, 1973; Fischer *et al.*, 1987 a).

The red Pandora, *Pagellus bellottii* is a demersal marine fish belonging to the Sparidae family. It is locally known as 'pageot' and exploited by the trawl fishery. It is widely distributed in the eastern Atlantic (Bauchot and Hureau, 1986). According to Russell and Carpenter (2014), *P. bellottii* is widespread and is one of the most abundant Sparidae species on the West African coast from Gibraltar to Angola. The species is also recorded in the southwestern Mediterranean, in the Alboran Sea, off the Algerian coasts and in the Gulf of Gabes (Oral, 2010). Some specimens have been recorded along the coast of Spain, and Morocco (Zenetos *et al.,* 2010). Bathymetric range of the species extends from may be something has been forgotten here to about 250 m, but it is most common at depths from 10-50 m. *Pagellus* genus is generally known as hermaphrodite and *P. bellottii* as protogynous (Fischer *et al.,* 1987 b). This species is an extremely valuable component of the Ivorian fishery; both in terms of abundance and quality. It contributed about 10.3% of the total trawl landings Ivorian marine catch **(**FAO, 2008). *P. bellottii* is one of the most commercially important fish in the Ivorian fishery.

Although there were studies on its reproductive biology and parameters population investigated in different geographic areas (Skorniakorv, 1963; Le Trong Phade and Komowski, 1972 ; Rujavec, 1973 ; Franqueville, 1983 ; Asabere-Araeyaw and Blay, 1999 ; Asabere-Araeyaw, 2000; Ould Yaba *et al*., 2004 ; Ndiaye, 2014 ; Amponsah *et al.,* 2016 ; Kouamé *et al*., 2018), informations regarding its population parameters in Côte d'Ivoire are scarce.

Management of commercially important fish species, as well as initiation of programs utilizing artificial propagation of captive fish has been frequently implemented in various countries (Rounsfell, 1975).

An effective management of these valuable demersal resources requires detailed biological information including the population dynamics on the species and the fisheries (Garratt, 1984). It's in this context that this study is conduct. The present work is the first to provide a preliminary assessment and management of *P. bellottii* in the Ivorian fishery. The study aims to estimate the population parameters required for proposing a future plan to sustain and manage this valuable fish resource. The specific objectives included the estimation of the growth parameters, mortalities coefficients, exploitation rates, recruitment, length at first capture (L_{50}), the evaluation of the yield and biomass-per-recruit and virtual population analysis (VPA).

MATERIALS AND METHODS

STUDY AREA

The study was conducted in Ivorian continental shelf (Figure 1). This area is bordered to the north by the Gulf of Guinea shoreline stretching from the Cape Palmas (7°W) and the Cape Three Point (2°W). The shoreline is 550 km long with a narrow continental shelf of 16000 km² and is characterized by a series of sandy beaches forming a wide arch opened to the Atlantic Ocean (Le Loeuf and Marchal, 1993).

SAMPLING

Pagellus bellottii's specimens were collected from the commercial catch of the trawl fishery in Abidjan fishing port every month from March 2016 to February 2018. A total of 799 individuals were obtained. All specimens were measured to the nearest 0.1 cm using an ichthyometer for total and fork length and weighted to the nearest gram using an electronic balance with 0.1 g precision for total weight. The specimens were dissected for macroscopic determination of sex. The length frequency data were pooled into groups of 1 cm length interval.

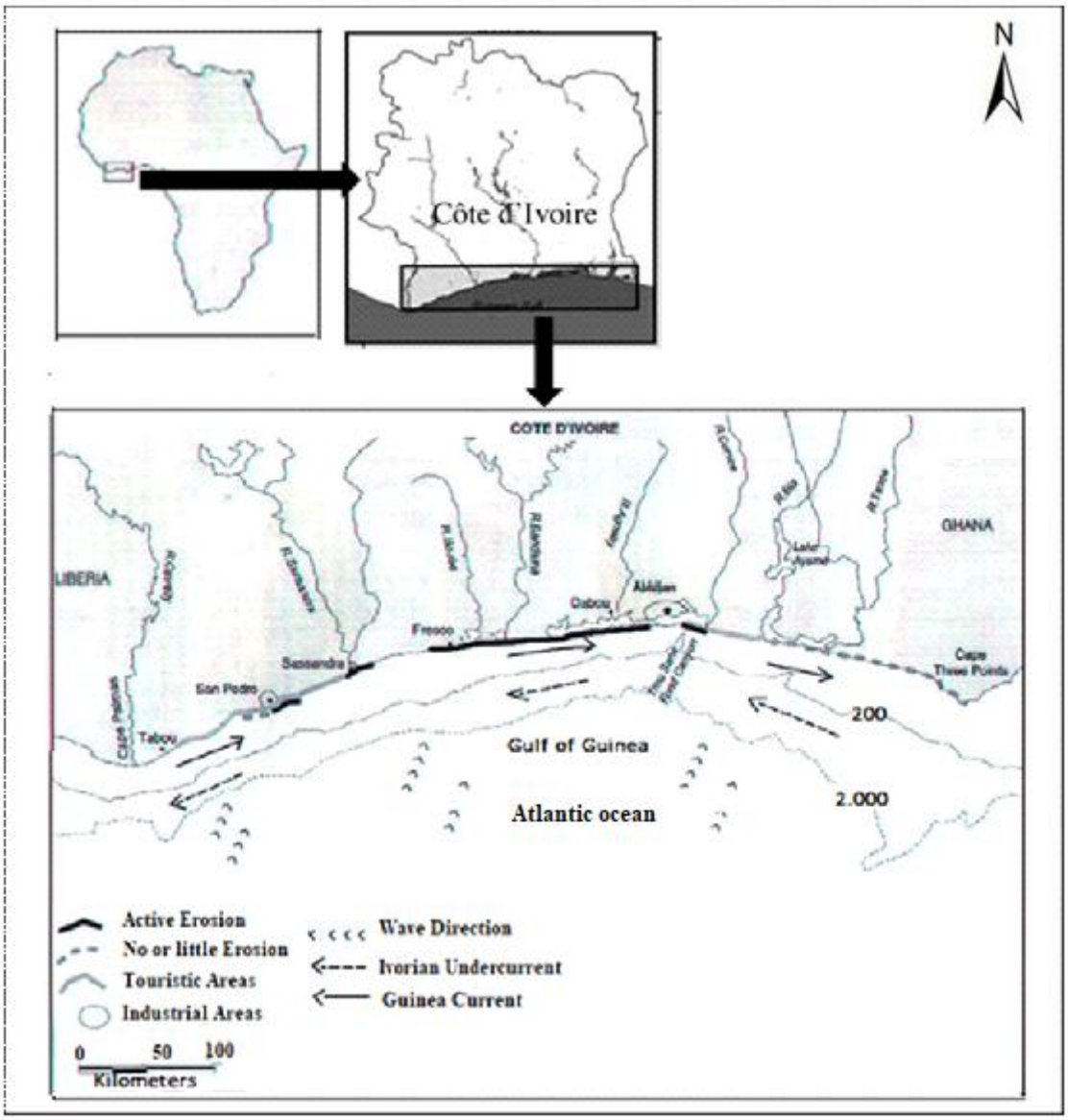

Figure 1: Fishing zone (Côte d'Ivoire, West African) and coastal towns.

Zone de pêche (Côte d'Ivoire, Afrique de l'ouest) et villes côtières.

GROWTH PARAMETERS

Growth was calculated by fitting the von Bertalanffy (von Bertalanffy, 1938) growth function to length frequency data. The von Bertalanffy growth equation is defined as follows (Sparre

and Venema, 1992): $L_t = L_\infty (1-e^{-k(t-t_0)})$; Where: L_t = length of the fish at age t; t_0 = hypothetical age of the fish when L is equal to zero L_∞ = asymptotic average maximum length K = instantaneous growth rate (rate at which the L_t approaches L_∞).

Length-frequency data were analyzed with the most recent version of FiSAT II (FAO ICLARM Stock Assessment Tools) version 1 software package (Gayanilo *et al*., 2003). The value for L_∞ was obtained by the Powell-Wetherall method (Sparre and Venema, 1992). The method used to estimate k was electronic length frequency analysis (ELEFAN I) (Pauly *et al*., 1984). Using the preliminary value of L_∞, values of k were scanned and the value that gave the highest Rn value (goodness of fit index value) was obtained (Gayanilo *et al*., 2003).

The t_0 value estimated using the empirical equation (Pauly, 1979).

$Log_{10}(-t_0) = -0.3922 - 0.2752\ Log_{10}L_\infty - 1.038\ Log_{10}K$.

The Powell- Wetherall Plot fitted in FiSAT II was applied in estimating the Z/K ratio for the treated fish species (Pauly, 1984 a).

Maximum age (t_{max}):

The maximum age was obtained from the equation: $t_{max} = 3/K$ (Pauly and Munro 1984); where: t_{max} is the longevity of fish species and K is the curvature parameter.

Growth performance index (φ')

In order to compare the growth of *P. bellottii* from the study area with those from other studies, the growth performance index was estimated .The growth performance index (φ') was computed according to the formula of (Pauly and Munro, 1984), as: $\varphi' = Log_{10}K + 2\ Log_{10}L_\infty$.

Length-Weight relationship

The length-weight relationship was determined by the equation: $W = aL^b$ (Le Cren, 1951; Kahraman *et al*., 2014), where : W= total weight (g), L= fork length (cm), a = constant, b= growth exponent. The parameters of this relationships were estimated by a linear regression model based on the least-square method (Zar, 1999), using log_{10}-transformed total weight (TW) and for length (FL) (for linearized relations; log (TW) = log (a) + b log (FL) for length–weight relationships). The degree of adjustment of the model was determined by the coefficient of determination (r^2). The hypothesis of isometric growth (Ricker, 1975) was tested by Student's *t*-test. Allometric growth was assessed based on the value of exponent b which denotes the relative change in proportion of body mass compared to the length during the growth of the organism. When b=3, increase in weight is isometric. When the b value is other than 3, weight increase is allometric: positive allometric if b>3 (the fish grows faster in weight than in length) and conversely, negative allometric if b< 3 (the fish grows faster in length than in weight (Karachle and Stergiou, 2012).

MORTALITY ESTIMATION AND EXPLOITATION RATES

The total mortality (Z) was estimated using the length-converted catch curve method (Sparre and Venema, 1998) from FiSAT II. Natural mortality (M) was estimated using the empirical relationship of Pauly (Pauly, 1980 a):

$Log_{10}M = -0.0066 - 0.279\ Log_{10}L\infty + 0.6543\ Log_{10}K + 0.4634\ Log_{10}T$. Where M is the natural mortality, $L\infty$ the asymptotic length, K the growth coefficient of the VBGF and T the mean annual habitat water temperature (°C). A mean environmental temperature (T) 26°C was taken in this study. Annual instantaneous rate of fishing mortality coefficient (F) was obtained by subtracting the natural mortality rate (M) from the total mortality rate (Z): F = Z – M (Beverton and Holt, 1957). The maximum fishing effort (F_{max}) was estimated using the expression: $F_{max} = 0.67K/0.67–Lc$ (Hoggarth *et al.,* 2006), where $Lc=Lc_{50}/L_\infty$. The exploitation rate (E) was then computed from the equation: E = F/Z (King, 1995).

RELATIVE YIELD PER RECRUIT (Y/R)' AND RELATIVE BIOMASS PER RECRUIT (B/R)

Relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' values as a function of E were determined from the estimated growth parameters and probability of capture by length (Pauly and Soriano, 1986). Evaluations of resource status were made using estimates of exploitation rates associated with a marginal increase of relative yield per recruit which is 0.1 of its value at E = 0. ($E_{0.1}$), a reduction in the stock to 50% of its unexploited size ($E_{0.5}$), maximum sustainable yield (E_{max}).The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated by using the Selection Ogive method of Beverton and Holt (1966), as modified by (Pauly and Soriano, 1986).

RECRUITMENT

The recruitment pattern was obtained following the procedure described in the FiSAT routine (Gayanilo *et al*., 2005). The length at first recruitment (Lr_{50}) was estimated as the midlength of the smallest length interval (Gheshlaghi *et al*., 2012); $Lr = L^- - K(L_\infty - L')/Z$.

Where: L' is the length for which all fish of that length and longer are under full exploitation.

L^- is the mean length and Z is the instantaneous total mortality coefficient.

LENGTH AT FIRST CAPTURE OR PROBABILITY OF CAPTURE (LC).

The mean length at first capture (L_c or $L_{50\%}$)

defined as the mean length at which 50% of the fish entering the gill nets were caught. This length was determined using the procedures by Pauly (1984 b). It was estimated by backwards extrapolation of the descending limb of the length converted catch curve. A selectivity curve was generated using linear regression fitted to the ascending data points from a plot of the probability of capture against length, which was used to derive values of the lengths at capture at probabilities of 0.25 (L_{25}), 0.5 (L_{50}), 0.75 (L_{75}) and 1 (L_{100}).

VIRTUAL POPULATION ANALYSIS (VPA)

For Virtual Population Analysis (VPA), the annual catch obtained from a single cohort during the exploited phase was used to calculate the abundance and fishing mortality rates of the cohort in each year (Gulland, 1965).

DATA ANALYSIS

All the statistical analyses were considered at significant level of 5%. Statistical analysis was performed using Statistica package (version 7.1), FiSAT II (FAO-ICLARM Stock Assessment Tools) (Gayanilo, 2005) and Microsoft Office Excel software (version 2007). The significance level of r^2 was estimated by ANOVA test. The student's t-test (ts) was used to determine whether the parameter b is significantly different from the expected or theoretical value of 3.

RESULTS

LENGTH FREQUENCY DISTRIBUTION

A total of 799 specimens were collected during the study period. The smallest specimen of *P. bellottii* obtained in the catches was 9.9 cm (FL), while largest specimen was 25 cm (FL). The majority of fish were located in 16.0 to 18.0 cm (FL); accounting for 42% of all samples (Figure 2).

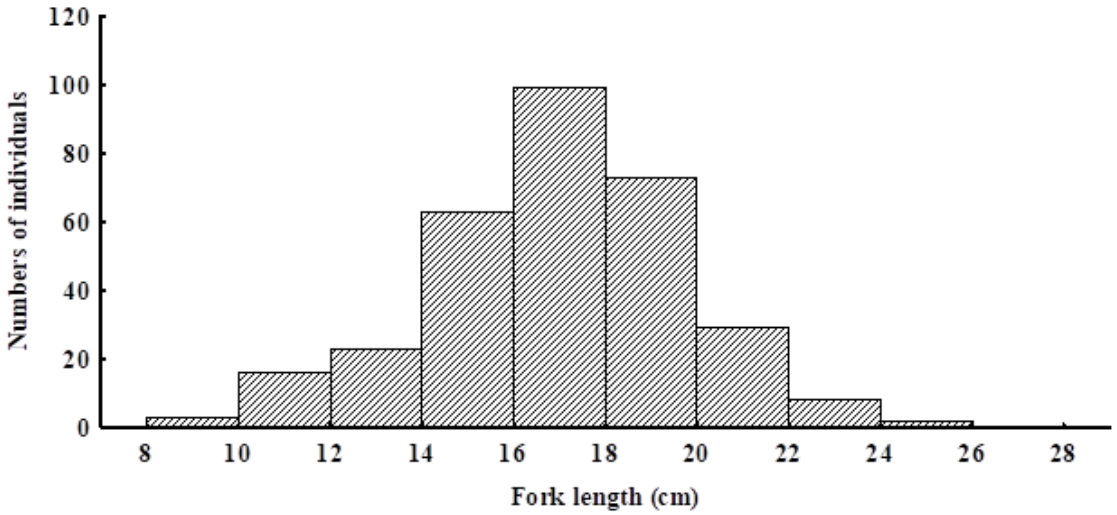

Figure 2: Frequency distribution of fork length (FL) for *Pagellus bellottii* collected in the Ivorian continental shelf from March 2016 to February 2018.

Distribution des fréquences de taille (LF) de Pagellus bellottii collecté sur le plateau continental ivoirien en mars 2016 et février 2018.

GROWTH PARAMETERS

As the study has allowed the estimation of several pairs of growth constant values, a mean value was sought by trying the Response Surface Analysis routine. The estimated von Bertalanffy growth parameters and for *P. bellottii* population were presented in table 1. The raw data were restructured with ELEFAN I, plotting the curves from the growth parameters. The catch curves showed that fisheries operate upon 4 cohorts of the population (Figure 3).

The value of growth performance index, ϕ' , estimated from the growth parameters was 2.62. The maximum age (t_{max}) was 7.14 year. The Z/K ratio was 6.85.

Table 1: Parameters of the Von Bertalanffy growth equation for *Pagellus bellottii.*

Paramètres de croissance de l'équation de Von Bertalanffy chez Pagellus bellottii.

Parameters				
L_∞ (cm)	K (year^{-1})	t_0 (year^{-1})	Φ'	t_{max} (year)
31.73	0.42	-0.38	2.62	7.14

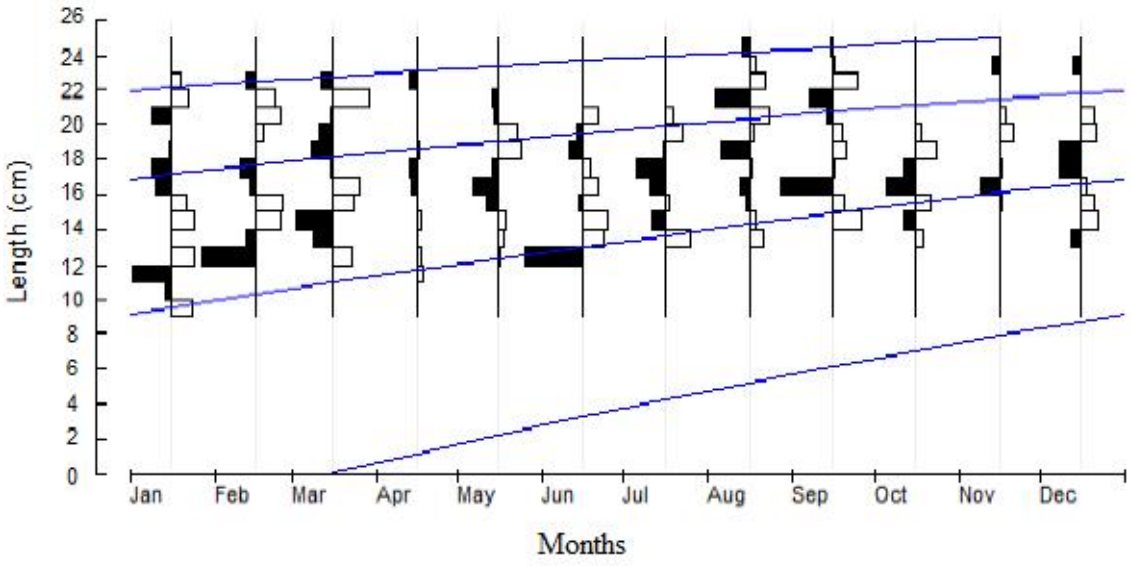

Figure 3: The length-frequency data and the growth curves estimated for *Pagellus bellottii* from March 2016 to February 2018.

Les données de fréquence de taille et estimation de la croissance de Pagellus bellottii *entre mars 2016 et février 2018.*

LENGTH-WEIGHT RELATIONSHIP

Length-weight regression parameters for all individuals for *Pagellus bellottii* is presented in Figure 4. Value of the exponent *b* was 2.98 . This value of b was significantly different from 3.00 (*t*-test for allometry; p <0.05), indicating a negative allometric growth.

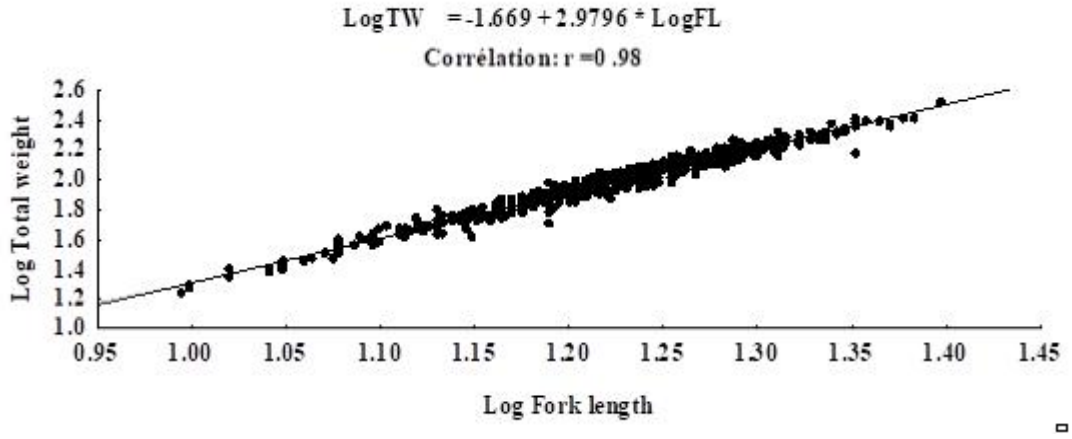

Figure 4: Fork length-Weight relationship of *Pagellus bellottii* in Ivorian continental shelf.

Relation longueur - poids de *Pagellus bellottii* du plateau continental ivoirien

MORTALITY AND EXPLOITATION RATES

The total annual instantaneous mortality coefficient (Z) from the length-converted catch curve was 2.88 year^{-1} (Figure 5). The natural mortality coefficient (M) was 0.96 year^{-1}, while the fishing mortality coefficient F was 1.92 year^{-1}. Optimum fishing mortality (F_{opt}) was 0.48 year^{-1} and limiting fishing mortality rate (F_{limit}) was 0.64 year^{-1}. The exploitation rate (E) was computed as 0.67.

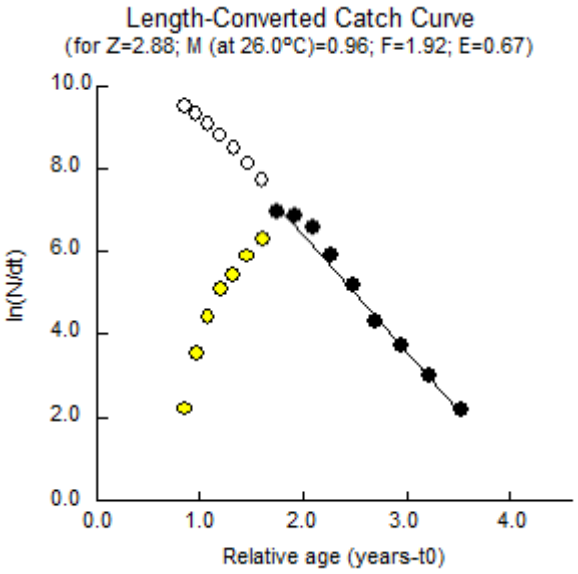

Figure 5: The length-converted catch curve for *Pagellus bellottii.*

Courbe de capture convertie en longueur de Pagellus bellottii.

RELATIVE YIELD PER RECRUIT (Y'/R) AND RELATIVE BIOMASS PER RECRUIT (B'/R)

The relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) were determined as a function of L_C/L_∞ (0.47) and M/K (2.28) (Figure 6). Estimates of (Y'/R) and (B'/R) using the Selection Ogive option in FISAT tool II were $E_{0.1}$ = 0.60, $E_{0.5}$ = 0.35 and E_{max} = 0.75. The optimum exploitation rate (E_{max} = 0.75) is indicated by the broken yellow line. The results indicated that, $E_{current}$ (0.67) is higher than 0.5 and close to E_{max} (0.75). Such assertions could lead to management measures of the specie in the study area.

RECRUITMENT

Recruitment is the process in which young fish enter the exploited area and become liable to contact for the first time with the fishing gears. In the present study, the recruitment pattern showed that *P. bellottii* was recruited in the fishery continuously throughout the year with the most important from April to July and maximum in May (22.04%) and June (17.56%) (Figure 7). Length at recruitment (Lr) estimated was 13.83 cm for *P bellottii.*

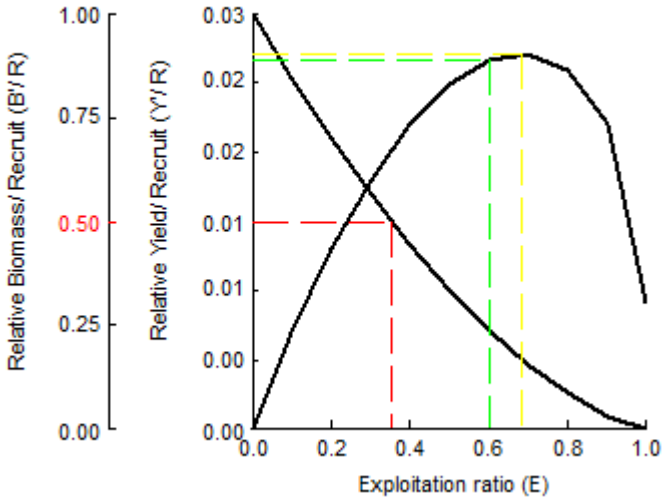

Figure 6: The relative yield and biomass per recruit plot of *Pagellus bellottii* in the Ivorian coast waters, yellow line: E_{max}, green line: $E_{0.1}$, red line: $E_{0.5}$.

Rendement relatif par recrus et la biomasse de Pagellus bellottii du plateau continental ivoirien, line jaune : E_{max}, ligne verte : $E_{0.1}$, ligne rouge : $E_{0.5}$.

LENGTH AT FIRST CAPTURE OR PROBABILITY OF CAPTURE (LC*)*.

Mean length at first capture, L_{50}, was 14.39 cm (FL) and the lengths at capture at probabilities of 0.25 (L_{25}) and 0.75 (L_{75}) were 13.84 and 14.93 cm (FL), respectively (Figure 8).

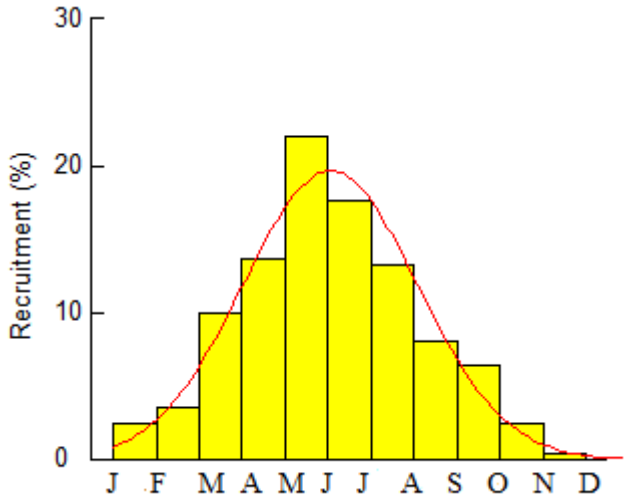

Figure 7: Recruitment pattern for *Pagellus bellottii* based on length frequency data.

Courbes de recrutement de Pagellus bellottii *basées sur les données de fréquences de tailles.*

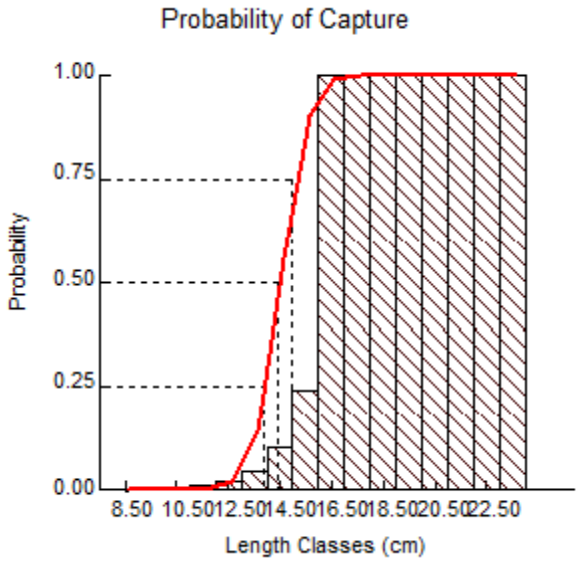

Figure 8: Probability of capture estimation from age groups.

Probabilité de capture en fonction des classes d'âge.

VIRTUAL POPULATION ANALYSIS (VPA)

Growth and exploitation parameters were used to establish the histograms of virtual populations with FiSAT II.

The Figure 9 shows the fishing mortality for each length class, the population reconstructed in number and the average biomass of the stock by length class. Survivors cumulated, populations lost by natural mortality and fishing catches, are represented on a histogram. The fishing mortality (F) curve is superimposed on the cumulative histogram. Natural mortality is higher for juveniles than for adults. Natural mortality has been steadily decreasing and this may be explained by the fact that juveniles are more vulnerable. Fishing mortality is gradually increasing, unlike natural mortality. The more mature individuals become, the more they are captured.

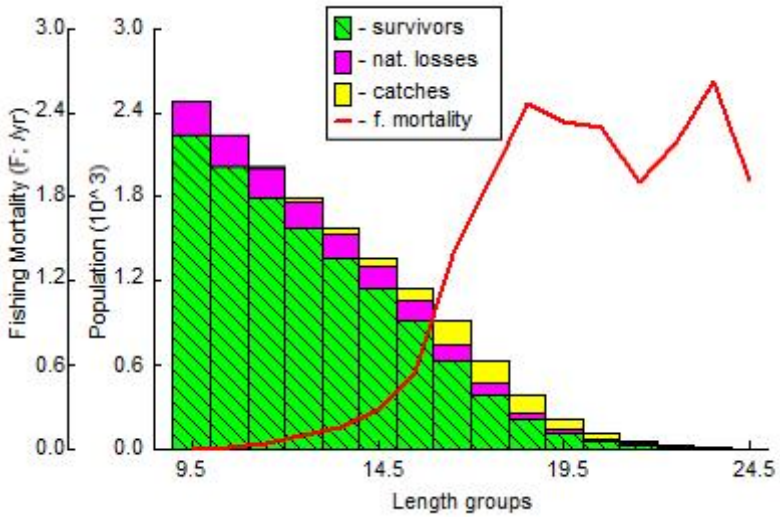

Figure 9: VPA graph showing catches, survivors and fishing mortality for the various length groups.

Graphique de populations virtuelles montrant les captures, les survivants et la mortalité par pêche basé sur les différents groupes de longueurs.

DISCUSSION

This study has established key population parameters of Red Pandora, *Pagellus bellottii*, which is exploited in the Ivorian coast. Furthermore, it demonstrates the utility of using a combination of size frequency for assessing the status of this species and providing information required for resource management purposes.

The calculated asymptotic length (L_∞) value of *Pagellus bellottii* according to this present study was 31.73 cm. It was higher to the size of the largest fish. Also, this asymptotic length was relatively higher to those of Boely *et al.* (1982); Ould Yarba *et al.* (2004) and Amponsah *et al*. (2016). Otherwise, Franqueville (1983) and AsabereAmeyaw and Blay (1999), obtained higher value for the asymptotic length than the present results (Table 2).

The variance in findings could also be due to the difference in the size of the largest fish. The growth coefficient value (k= 0.42 year^{-1}) was closed to the k value estimated for the same species in the coastal waters of Ghana (Amponsah *et al*., 2016). However, our estimates of k was higher than the earlier estimates from the same species which have been reported by Ould Yarba *et al.* (2004) and (Franqueville, 1983), whereas the estimate k value of this study was lower than that obtained by Asabere-Ameyaw and Blay (1999) (Table 2).

The reason for the variation of k values in different regions may be due to the ecological differences, physiological conditions of fish, feeding variability, fishing pressure and sampling (Biswas, 1993). The theoretical age when fish would have been at zero fork length (t_0= - 0.38^{-1} year) was found lower than Amponash *et al*. (2016), however it was higher than the results of others authors (Boely *et al.,* 1982; Franqueville, 1983; Asabere-Ameyaw and Blay, 1999 and Ould Yarba *et al.,* 2004) (Table 2).

Growth performance index (ϕ') has been used since it is the best index for expressing the fish growth. Furthermore, the value of growth performance index might represent and quantify the energetic of a given habitat or niche because this index is directly related to metabolism and food consumption (Munro and Pauly, 1983). The estimated growth performance index (ϕ' = 2.62) in the present study was outside the range (2.65 – 3.32) reported by Baijot and Moreau (1997), for fish species with fast growing performance. However, it was close to this and was higher than those estimated by Amponsah *et al.* (2016), for the same species in Ghana (Table 2). According to Adam (2010), variations in the values of the parameter of growth performance might suggest variations in the growth rate. The calculated growth performance index in this study attested that *Pagellus bellottii* has a slow growth performance according to the range (2.65–3.32) for Baijot and Moreau (1997). Amponsah *et al.* (2016), supported similar result.

Table 2: Comparison of Von Bertalanffy growth parameters for *Pagellus bellottii* with estimates from other studies.

Comparaison des paramètres de croissance de Von Bertalanffy de Pagellus bellottii *avec les estimations d'autres études.*

Authors, years	Areas	L_∞ (cm)	K (year^{-1})	t_0 (year^{-1})	ϕ '
Boely *et al.,* 1982	Senegal	30.63	1.21	-0.06	-
Franqueville, 1983	Senegal	37.16	0.24	-0.11	-
Asabere-Ameyaw and Blay,1999	Ghana	34.20	0.53	-0.31	-
Ould Yarba *et al.,* 2004	Mauritania	28.96	0.31	-0.03	-
Amponsah *et al.,* 2016	Ghana	19.43	0.42	-0.44	2.20
Present study	Cote d'Ivoire	31.73	0.42	-0.38	2.62

In this study, the calculated Z/K ratio (Z/K = 6.85) was widely higher than 1, suggesting that the mortality predominated on the growth. Similar result was reported by Amponsah *et al.* (2016). However, our Z/K (6.85) ratio estimated was greater than to these authors (Z/K= 2.58). Our results largely higher than 2 show that *Pagellus bellottii* stock in Ivorian coast would be overexploited. According to Barry and Tegner (1989), if the Z/K ratio is much greater than 2,

there is overexploitation of the species. This assertion is opposite at that to Amponsah *et al.* (2016). These authors attested that the *P. bellottii* stock within Ghana's coastal waters is a lightly exploited population.

The results of the present study show that *P. bellottii* is short lived species with the maximum age assumed to be at least 7.14 years. These results supported by Asabere-Ameyaw and Blay, 1999 and Amponsah *et al.* (2016), which reported respectively 6 years and 7 years.

The length-weight relationship is a very important tool in fisheries assessment (Haimovidici and Velasco, 2000; Arslan *et al.,* 2004) and also standing crop biomass can be estimated based on this value (Morey *et al*., 2003). The coefficient *a* and exponent *b* are input parameters in many stock assessment models like in the yield per recruit.

The exponent's value was 2.9796. It was conformed to typical values of 2.5 to 3.5 (Foese, 2006; Calender 1969). This value was closed to that of Amposah *et al*. (2016), (b=2.979), in the coastal waters of Ghana. However, this value was smaller than to that of Ould Yarba *et al.* (2004), (b=3.0506) in Mauritanian's coasts, Asabere-Ameyaw and Blay (1999), (b= 3.15) in the Cape Coast area of Ghana and Franqueville and Freon (1976), Franqueville (1983), (b=3.16) in Senegal.

The reasons for the variation of the «b» value in the different regions may be due to the sampling procedure namely sampling size and length range, sex, growth phase, gonad development, feeding intensity, availability of food (Hossain *et al.,* 2006; Morato *et al*., 2003); and environmental conditions (Baby *et al.,* 2011) Other factors such as fish size, age, season, fullness of the gut, degree of muscular development, and the amount of reserved fat may be influenced the «b» value (Bagenal and Tesch, 1978; Ujjania *et al.,* 2012; Gupta and Banerjee, 2015). According to Moutopoulos and Stergiou (2002), the b value would be affected by the differences in the number of specimens examined, the area or season effect and the differences in the observed length ranges of the specimens caught.

The total mortality can be estimated by various methods (Sparre and Venema, 1998). In the present study, it was estimated by the analysis of the catch curve which represents the relationship between the Ln of the number of fish taken by fishing at the corresponding ages, the descending part of the catch curve was used to estimates the total mortality (Pauly, 1980 b).

The instantaneous total mortality coefficient (Z) estimated in the present study was 2.88 year^{-1} Our estimate was slightly higher than those of Amponsah *et al*. (2016), from the coastal

waters of Ghana (Z= 2.58 year^{-1}). However, this value was considerably lower than that estimated by Asabere-Ameyaw and Blay (1999), (Z=3.74 year^{-1}).

The instantaneous natural mortality coefficient (M) estimated was 0.96 year^{-1} in the present study. This value was smaller than those reported by Asabere-Ameyaw and Blay (1999), (M=1.12 year^{-1}) and Amponsah *et al*. (2016), (M=1.10 year^{-1}). However, the M values for these authors were well closer. The estimate of M in this study was higher than those to Franqueville (1983), which was ranged from 0.1 to 0.4 year^{-1}.

The reason for the variation in these values in different regions may be due to the divergence of the parameters used for its determination. The factors such as the annual mean surface water temperature and the Von Bertalanffy parameters are important in natural mortality variation (Pauly, 1985).

Also, the variation in natural mortality can be explained as a natural phenomenon which is controlled by density-dependent (predation, availability of food etc.) as well as density independent factors (disease, natural calamities etc.) and varies within same species in the different location.

The estimate of the instantaneous fishing mortality coefficient (F) in the present study was 1.92 year^{-1}. It was higher than that of Amponsah *et al*. (2016), which was 1.48 year$^{-1.}$ However, our estimate was considerably lower than those of Asabere-Ameyaw and Blay (1999), (F=2.61 year^{-1}). The fishing mortality coefficient (F=1.92 year^{-1}) observed was higher than natural mortality (M = 0.96 year^{-1}). This indicating that the population is fishing mortality dominated. The investigations of Asabere-Ameyaw and Blay (1999) and Amponsah *et al*. (2016), obtained similar results.

The exploitation rate (E) was estimated as 0.67. This estimate was higher than that of (E) reported by Amponsah *et al*. (2016), which was 0.57. Our results were close to those of Asabere-Ameyaw and Blay, 1999) where E= 0.7 in the Cape Coast area of Ghana.

Also, the (E) estimate is higher than 0.5, the optimum rate, suggested for exploited fish stocks (Gulland, 1971). E was higher than 0.5 and F was higher than M indicated that the population has been heavily exploited and at higher level than optimum. According to Francis and Sikoki (2007), the optimal level of a resource is reached when the exploitation rate is higher or 0.5 or when the fishing mortality (F) is equal to or greater than the natural mortality (M). Barry *et al*. (2004); Gascuel *et al*. (2004), supported a situation of overexploitation of this species in North-West Africa. Laurans *et al*. (2001), observed a similar situation in Senegal.

The relative yield and biomass per recruit (Y'/R) and (B'/R**)** revealed the maximum exploitation rate (E_{max}) = 0.75 and $E_{0.5}$ =0.35. The present exploitation rate ($E_{current}$) = 0.67 was close to the maximum allowable limit based on the yield-per-recruit calculation (E_{max} = 0.75). It was higher than $E_{0.5}$ which was 0.35. These results signified that the exploitation of *Pagellus bellottii* stock in the Ivoirian coast has not exceeded the maximum fishing level yet. However, the present level of fishing mortality should be a great concern for the stock.

In this study, the recruitment pattern showed a single peak. The result was in contradiction those of Amponsah *et al*. (2016) which obtained two peaks in the coastal waters of Ghana.

In order to maintain a population in equilibrium it is of great importance to give each fish the chance of reproducing at least once in its lifetime to recruit the stock, and therefore the length at first capture, Lc, should be bigger than length first maturity, Lm (Amrollahi *et al.,* 2011). The length at first capture (L_{C50} = 14.39 cm) calculated in the present study was higher than length first maturity (Lm = 13.42 cm) of whole population. This signified that each fish has the chance of reproducing at least once in its lifetime to recruit the stock. The results of Amponsah *et al*. (2016) were opposite of ours. The length at first capture (L_{C50} = 9.9 cm) found by these authors was lower than length first maturity (Lm = 13 cm).

Cohort analysis or virtual population analysis has its importance in fish population dynamics. It gives important ideas on the fish abundance and instantaneous fishing mortality coefficients of the cohort at different time intervals as the instantaneous natural mortality coefficients are known (Adam, 2010).

CONCLUSION

Considering $E_{current}$, F, M and $E_{0.5}$ values, it can be concluded that the *Pagellus bellottii* in the Ivorian coast fishery is in a situation of overexploitation and to sustain this valuable fishery resource some management measures. It necessary to reduce the fishing mortality by decreasing the present level of fishing effort (the number of boats and the number of fishing trap). Athough the length at first capture is higher than the length at first sexual maturity, it is important to increase in the length at first capture by selecting the optimum mesh size which release small fish and allow each fish to produced eggs at least once in its life.

ACKNOWLEDGEMENTS

The authors wish to thank the Oceanologic Research Center which took part in the field work. This study would not have been possible without the support of this institute. Thanks to all the staff members of the Department of Aquatics Living resources of the Oceanologic Research Center (researchers, technicians and students) that assisted in carrying out the work. Also, we express our appreciation to anonymous reviewers for their valuable comments and editing of the manuscript.

REFERENCES

Adam. A. M. S., 2010. Stock assessment and management of *Diplodus* species in Abu Qir bay, Alexandria, Egypt, Thesis, Alexandria University, 146 p.

AmponsahK K. S., Ofori-Danson K. P., Nunoo K. E. F. and A. G. Ameyaw., 2016. Aspects of population dynamics of Red Pandora, *Pagellus bellottii* (Steindachner, 1882) from the coastal waters of Ghana. Journal of Scientific and Innovative Research, 5(6) : 215-224.

Amrollahi N., Kochanian P., Maremmazi J., Eskandary G. R. and V. Yavary., 2011. Stock Assessment of Silver Pomfret *Pampus argenteus* (Euphrasen, 1788) in the Northern Persian Gulf. Turkish Journal of Fisheries and Aquatic Sciences 11: 63-68.

Asabere-Ameyaw, A. 2000. Aspects of the reproductive biology of the Red Pandora *Pagellus*

bellottii (Pisces: Sparidae) in Ghana. Journal of the Ghana Science Association 2(1): 23-30.

Asabere-Ameyaw A. and J. Blay., 1999. Growth and mortality parameters of *Pagellus bellottii* (Sparidae) in the Cape Coast area of Ghana. Journal of the Ghana Science Association. 1999. 1(2): 53-62.

Arslan M., Yildirim A. and S. Bekta., 2004. Length-weight relationship of brown trout, *Salmo trutta* L., inhabiting Kan Stream, Çoruh Basin, North-Eastern Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 4, 45-48.

Baby F., Tharian J., Abraham K. M., Ramprasanth M., Ali A. and R. Ranghavan., 2011. Length-weight relationship and condition factor of an endemic stone sucker, *Garra gotyla stenorhynchus* (Jerdon, 1849) from two opposite flowing rivers in southern Western Ghats. *Journal of threatened taxa* 3(6): 1851-1855.

Bagenal T. B. and F. W. Tesch., 1978. Age and growth. In: T.B. Bagenal (ed.). Methods of assessment of fish production in fresh waters, Oxford Blackwell Scientific Publication. Pp 101-136.

Baijot E. and J. Moreau., 1997. Biology and demographic status of the main fish species in the reservoirs of Burkina Faso. In: Baijot E, Moreau J, Barry J, Bouda S (eds), Hydrological aspects of fisheries in small reservoirs in the Sahel Region. Technical Centre for Agricultural and Rural cooperation, Commission of the European Communities: Wageningen, Netherlands: 79-109.

Barry J. P. and M J. Tegner., 1989. Inferring demographic processes from size-frequency distributions: simple models indicate specific patterns of growth and mortality. US Fisheries Bulletin. 88:13-19.

Barry M. D., Laurans M., Thiao D. and D. Gascuel., 2004. Diagnostic de l'état d'exploitation de cinq espèces démersales côtières sénégalaises. In : Chavance P. *et al.* (éds), Pêcheries maritimes, écosystèmes et sociétés en Afrique de l'Ouest : un demi-siècle de changement. Edition Office des Communautés Européennes, Collection des rapports de recherche halieutique ACP-UE n° 15, Luxembourg, pp. 183-194.

Bauchot M. and J. C. Hureau., 1986. Sparidae. In: Whitehead PJP, Bauchot ML, Hureau J. C, Nielsen J, Tortonese E, Eds. Fishes of the north-eastern Atlantic and the Mediterranean 2, Paris: UNESCO 1986, 883-907.

Beverton R. J. H. and S. J. Holt., 1957. On the dynamics of exploited fish population. Fishery Investigations, Series II (London), 19: 1- 533.

Beverton R. J. H. and S. J. Holt., 1966. Manual of methods for fishstock assessment. Part II. Tables of yield function. FAO Fish. *Biology Technical Paper,* (38) 10 + 67 pp. (version 1).

Biswas S. P., 1993. Manual of Methods in Fish Biology. South Asia Publishers. Pvt. Ltd, New Delhi, 195 p.

Boely T., Freon P. and B. Stequert., 1982**.** La croissance de *Sardinella aurita* (Val.1847) au Sénégal. Tropical Oceanography I. 17(2):103 – 119.

Calander K. D., 1969. Handbook of Freshwater Fishery Biology. The Iowa State University Press, Ames, IA Lowa State 1: 752 p.FAO. 2008**.** Vue générale du secteur des pêches national, la république de côte d'Ivoire 42p.

Fischer W., Schneider M. and Bauchot M. L., 1987a. Fiches F.A.O. d'identification des espèces pour les besoins de la pêche; Méditerranée et Mer Noire (zone de pêche 37) Révision 1, volume II, Vertébrés. 769p.

Fischer W. Schneider M. and M. F. Bauchot., 1987 b. Méditerranée et mer Noire. Zone de pêche 37, révision 1. Fiches FAO d'identification des Espèces pour les Besoins de la Pêche. Volume. I. Végétaux et invertébrés. FAO. Rome.

Franqueville C., 1983**.** Biologie et dynamique de population des daurades *(Pagellus bellottii,* Steindachner, 1882) le long des côtes séné-gambiennes. *Thèse Doctorat d'Etat. Université* d'Aix-Marseille II, Faculté de Luminy 276 p.

Franqueville C. and P. Freon., 1976. Relations poids-longueur des principales espèces de poissons marins au Sénégal. Document scientifique, Centre de recherches océanographiques *de Dakar-Thiaroye,* 60 : 37 p.

Francis A. and F. D. Sikoki., 2007. Growth Coefficient of Fish Species Within the Andoni River, Niger Delta, Nigeria and Their Aquaculture implications. Journal of Fisheries International, 2 (1): 22-26.

Froese R., 2006. Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology 22: 241-253.

Garratt P. A., 1984. The biology and fishery of *Chrysoblephus puniceus* and *Cheimerius nufar*. M. Sc. Thesis, University of Natal,

Durban. 139 p.

Gascuel D., Laurans M., Sidibé A. and M. D. Barry., 2004. Diagnostic comparatif de l'état des stocks et évolutions d'abondance des ressources démersales, dans les pays de la CSRP. In : Chavance P. *et al* (Eds), Pêcheries maritimes, écosystèmes et sociétés en Afrique de l'Ouest : un demi-siècle de changement. Edition Office des Communautés Européennes, Collection des rapports de recherche halieutique ACP-UE n° 15, Luxembourg, pp. 205-222.

Gayanilo F. C. Jr., Sparre P. and D. Pauly., 2003. The FAOICLARM Stock Assessment Tools (FiSAT) User's Guide. FAO Computerized Information Series (Fisheries) 8, Rome, 176 pp.

Gayanilo F. C. Jr., Sparre P. and D. Pauly., 2005. FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised. User's guide. Computerized Information Series (Fisheries). No. 8. Revised version. FAO, Rome, 168 p.

Gheshlaghi P.; Vahabnezhad A. and S A. Taghavi-Motlagh., 2012. Growth parameters, mortality rates, yield per recruit, biomass, and MSY of Rutilus frisii kutum, using length frequency analysis in the Southern parts of the Caspian Sea. Iranian Journal of Fisheries Science. Volume 11(1), 48 – 62.

Gulland J. A., 1965. Estimation of mortality rates. Annex to Arctic fisheries working group report ICES C.M./1965/D:3. (Mimeo). Reprinted as p. 231-241. In P.H. Cushing (ed). Key papers on fish populations. Oxford.IRL Press. 1983.

Gulland J. A., 1971. The Fish Resources of the Ocean. West Byfleet Surrey. Fishing News (Books), Ltd. for FAO: 255 p.

Gupta S. and S. Banerjee., 2015. Length-weight relationship of *Mystus tengara* (Ham. -Buch., 1822), a freshwater catfish of Indian subcontinent. International Journal of Aquatic Biology, 3(2), 114-118.

Haimovici M. and G. Velasc., 2000. Length-weight relationship of marine fishes from southern Brazil. Naga, The ICLARM Quarterly, 23(1), 19-23.

Hoggarth D. D., Abeyasekera S., Arthur R. I., Beddington J. R., Burn R. W. and A S. Halls., 2006. Stock Assessment for fishery management - A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP). Fisheries Technical Paper. No. 487. FAO. Rome.2006. 261.

Hossain M. Y., Ahmed Z. F., Leunda P. M., Jasmine S., Oscoz J., Miranda R. and J. Ohtomi., 2006**.** Condition, length-weight and length-length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, Southwestern Bangladesh. Journal of Applied Ichthyology 22: 304-307.

Kahraman A. E., Göktürk D. and E. Aydin., 2014. Length-weight relationships of five fish species from the Sakarya River, Turkey. Annual Research and Review in Biology, 4 (15): 2476-2483

Karachle P. K. and K. I. Stergiou., 2012. Morphometrics and Allometry in Fishes. Morphometrics, Prof. Christina Wahl (Ed.), ISBN: 978-953-51-0172-7 [December 2012] http://www.intechopen.com/books/morphometrics/morphometrics-and allometry-in-fishes.

King M., 1995. Fisheries biology, assessment and management. Fishing News Books, Hartnolds Ltd, Bodmin, Cornwall, Great Britain. 341 pp.

Kouamé A. C., Sylla S., Arra S., Kouakou K. F. and S. S. Yao., 2018. Parameters of Reproductive biology of Red Pandora *Pagellus bellottii* (Steindachner, 1882) in the Ivoirian coast (Cote d'Ivoire). Journal of Biodiversity and Environmental Sciences, 2 (4): 185-193.

Laurans M.,Barry M. D.and D Gascuel., 2001. Diagnostic de cinq stocks sénégalais par l'approche globale (*Galeoides décadactylus*, *Pagellus bellottii*, *Pseudupeneus prayensis*, *Saparus caeruleostictus* et *Epinephlus aeneus*). In : Evaluation des stocks par l'approche globale et évolution d'abondance. Rapport de la réunion du groupe <<Analyses mono spécifiques >> du projet SIAP – Mindelo, 10-12 octobre 2001.

Le Cren E. D., 1951. The length weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviaittlis*). Journal of Animal Ecology. 20: 201 - 219.

Le Loeuff P. and E. Marchal., 1993. Géographie Littorale In : Le Loeuff P, Marchal E Amon KothiasJ B, Eds. Environnement et ressources aquatiques de Côte d'Ivoire. Tome 1. Le milieu marin. Editions de l'ORSTOM ; Paris 15-22.

Le Trong-phan and A. Kompowski., 1972. A study on *Paqellus coupei* and from the north- west African region., Actalchthyologica et Piscatoria 2 (1), 13-30.

Morato T., Afonso P., Lourinho P., Nash R. D. M.

and R. S. Santos., 2003. Reproductive biology and recruitment of the white seabream in the Azores. Journal of Fish Biology Vol. 63: 59 – 72

Morey G., Moranta J., Massuti E., Grau A., Linde M., Riera F. and B. Morales-Nin., 2003. Weight length relationships of littoral to lower slope fishes from the western Mediterranean. Fisheries Research, 62, 89-96.

Moutopoulos D. K. and K. I. Stergiou., 2002**.** Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). Journal of Applied Ichthyology 18 (3): 200–203. DOI: 10.1046/j.1439-0426.2002.00281. x.

Munro J. L. and D. Pauly., 1983. A simple method for comparing growth of fishes and invertebrates. ICLARM Fishbyte 1(1) : 5 – 6.

Ndiaye A. M., 2014**.** Etude du cycle sexuel et l'inversion sexuelle de *Pagellus bellottii* (Téléostéen : Sparidae) dans les eaux sénégalaises. Afrique Science 10 (4) : 257-266.

Ould Yarba L. Ghorbel, M. and. A. Bouain., 2004. Age et croissance de *Pagellus Bellottii* (Sparidae) des côtes Mauritaniennes. Bulletin de l'Institut. National des Sciences et de Technologies de la Mer de Salammbô, 31 : 35-42.

Oral M., 2010. Alien fish species in the Mediterranean - Black Sea Basin. J Black Sea Mediterr Environ. 16:87–132.

Pauly D., 1979. Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffys growth formula. *Berichte aus dem institute* fuer meereskunde, 63, Kiel University, Kiel.

Pauly D., 1980a. On the inter-relationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. CIEM, 39 (3): 175–192.

Pauly D., 1980b. A selection of simple methods for the assessment of tropical fish stocks. FAO, Fish. Circ.729: 54p.

Pauly D., 1984 a. Fish population dynamics in tropical waters: A manual for use with programmable calculators. — ICLARM Studies. & Reviews. 8. ICLARM, Manila. 325.

Pauly D., 1984 b. Length-converted catch curves. A powerful tool for fisheries research in the tropics. (III: conclusion). ICLARM Fishbyte, 2 (3): 9-10.

Pauly D. and J. L. Munro., 1984. Once more on growth comparisons in fish and invertebrates. Fishbyte 2 (1): 1 - 21.

Pauly D., Ingles J. and R. Neal., 1984. Application to shrimp stocks of objective methods for the estimation of vital statistics from length data. In: Penaeid shrimp their biology and management. Fishing News Books Limited Farnham, Surrey, England: 220–234.

Pauly D., 1985. Quelques méthodes simples pour l'estimation des stocks de poissons tropicaux. FAO Document Technique sur les Pêches, (234) : 56p.

Pauly D. and M. L. Soriano., 1986. Some practical extensions to Beverton and Holt's relative yield-per recruit model. In: J.L. Maclean., L.B. Dizon and L.V. Hosillo (Eds.), The First Asian Fisheries Forum: Asian Fisheries Society, Manila, Some practical extensions to Beverton and Holt's relative yield-per recruit model. In: J.L. Maclean, L.B. Dizon and L.V. Hosillo (Eds.), The First Asian Fisheries Forum: Asian Fisheries Society, Manila, Philippines: 491- 496.

Rijayec L., l973**.** Biology and dynamics of *Pagellus coupei, Pagrus ehrembergi* and *Dentex canariensis* in Ghana waters. Document scientifique. CRO Abidjan 4, 3 t 49-97.

Ricker W. E., 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191.

Rounsfell G. A., 1975. On the dynamics of exploited fish population, by R.J.H. Beverton and S. J. Holt. Limnology and Oceanography 4: 230 – 231.

Russell B. and K. E. Carpenter., 2014**.** *Pagellus bellottii,* The IUCN Red List of Threatened Species 2014*:* e.T170162A1285147**.** http://dx.doi.org/ 10.2305/IUCN.UK.2014 3. RLTS.T170162A1285147.

Skorniakov V. I., 1963**.** The fishes of the sparoides family (Sparidae) and the perspectives of their fishing of the western coast of Africa. Trudy Altantniro, 10:117.

Sparre P. and S. C. Venema., 1992. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper No. 306/1, Rev.1, FAO, Rome.

Sparre P. and S. C. Venema., 1992. Introduction to tropical fish stock assessment. In: Part 1-manual. FAO Press, Rome, 376 pp.

Sparre P. and S. C. Venema., 1998. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper*:* 306 (1): 407 p.

Tortonese E., 1973. Catalogue des poissons de

l'Atlantique du Nord-Est et de la Méditerranée. CLOFNAM I Hureau, J.C. et Monold, T.H. éd., Paris, UNESCO: 405-4015.

Ujjania N. C., Kohli M. P. S. and L. L. Sharma., 2012**.** Length-weight relationship and condition factors of Indian major carps (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) in Mahi Bajaj Sagar, India. *Research Journal of Biology*, 2 (1), 30-36.

Von Bertalanffy L., 1938. A quantitative theory of organic growth. Human Biology, 10 (2):181 - 213

Zar J. H., 1999. Biostatistical Analysis. Prentice Hall, New Jersey, USA.

Zenetos A., Gofas S., Verlaque M. and. M. E Cinar., 2010. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. *Mediterranean Marine Science* 11(2): 381-493.