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Population dynamic parameters for *Pseudupeneus prayensis* (Mullidae) (Cuvier, 1829) in Ivorian continental shelf

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ABSTRACT

The parameters of *Pseudupeneus prayensis* population exploited was studied in the Ivoirian continental shelf from January to December 2022. Its provides the first results on fishery dynamics of the species in this marine water. A total, 912 specimens collecting from the industrial fishing was investigated, measured and weighed. The parameters of growth and exploitation were estimated with the help of the software FiSAT. The length weight relationship parameters were: Log Wt = $1.69*10^{-2}$ + 3.21*Log Lf (r^2= 0.96). This species has positive allometric growth. The parameters of growth curve were L∞= 28.50 cm, K=0.48 an^{-1}, t_0 = - 0.7 and Ø = 2.59. The estimated values of the total, natural and fishing mortalities were Z = 2.50 $year^{-1}$; M = 1.12 $year^{-1}$; F=1.38 $year^{-1}$ respectively. The current exploitation rate of the species was calculated as E = 0.55. These results show that *P. prayensis* is overexploited. The results of the analysis of yield per recruit indicate that the resource is threatened. The aim of this study is to estimate important population parameters and assess the stock of this economically important fish species using length-frequency data.

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INTRODUCTION

Pseudupeneus prayensis (Cuvier, 1829) commonly called the "West African goatfish" is a demersal species of the Mullidae family the occurs in most part of the Gulf of Guinea. *P. prayensis* constitutes one of Côte d'Ivoire economically important demersal fish species targeted by industrial fishery sectors (Traore, 2019). Fish supplies naturally augment food availability, because fish is an important source of animal protein for human consumption and features prominently in the diet of many people in most parts of Africa (Akongyuure *et al.,* 2015). Study of fish growth inform of the instantaneous growth rate, growth performance and age (Baset *et al.,* 2020), whereas mortality and exploitation rates provide invaluable information about the status of fish stocks, required for recalibrating management measures for exploitation within efficient limit (Baset *et al.,* 2020). Among the Mullidae, *Pseudupeneus prayensis* is one of the most exploited species globally. According to Gascuel *et al.* (2004), this species is mainly caught by industrial fishing and is subject to targeted fishing. The species is also vulnerable (IUCN, 2015). In Côte d'Ivoire, *P. prayensis* is caught by industrial fishing and is of definite economic interest. This species is important because of its role in maintaining biodiversity. However, no study has been carried out on this species. As a result, data on the population parameters of this species are virtually non-existent. The aim of this work is to assess the exploitation of *Pseudupeneus prayensis* in order to put in place a rational management plan for its stock to ensure sustainable exploitation.

MATERIALS AND METHODS

Study area

The ivorian continental shelf covers an area of 11000 km² and extending to about 550 km. The shoreline stretching from the Cape Palmas (7°30W) and the Cape Three Points (2°W). It is influenced by two marines seasons: The cold season from December to January and from July to September, the warm season extending from February to June and October to November. The period from July to October corresponds to the major upwelling whilst a minor upwelling is usually observed between January and February (Colin, 1988). The specimens of the West African goatfish, *P. prayensis* were collected from commercial catches at the fishing harbour from the industrial bottom trawlers and artisanal.

Sampling

The specimens were sampled monthly from January to December 2022 at the fishing harbor of Abidjan. The total length of 912 individuals was measured to the nearest 0.1 cm and weighed in terms of total body mass to the nearest 0.1 g using a Sartorius electronic balance.

The length measurements were then grouped into 1 cm class intervals for the construction of monthly length distribution.

Data analysis

Length-weight relationship

The standard length and body weight of fish were used for the length-weight relationship. The length-weight relationship was calculated using the regression equation of Froese (2006).

$W = aFL^b$

The logarithmic form of the length-weight relationship is:

$Log\ W = Log\ a + b\ Log\ FL$

Where, W is the weight (g), FL is the fork length (cm), a is the intercept and b is the slope.

The parameters a and b were estimated by least squares linear regression analysis. In order to check if the b value was significantly dfferent from 3, the t-test was used at p = 0.05. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression.

Growth parameter

The parameters of Von Bertalanffy growth parameters such as the asymptotic length (L∞) and the growth coefficient (K) were estimated using the ELEFAN I (Electronic Length Frequency Analysis) module of FiSAT II software (Gayanilo *et al.*, 2005).

$L_t = L_\infty [1 - e^{-K(t-t_0)}]$

Where, Lt is the predicted length at age t, L∞ the asymptotic length, K the growth coefficient, and t_0 the theoretical age at length zero.

The empirical equation of Pauly (1979) was used to obtain the t_0 :

$$Log_{10}(-t_0) = -0.392 - 0.275Log_{10}L_\infty - 1.038Log_{10}K$$

The formula developed by (Pauly and Munro, 1984) helped us to calculate the growth performance index:

$$Ø' = Log_{10}K + 2Log_{10}L_\infty$$

Mortality and exploitation rates

The instantaneous natural mortality rate (M) was estimated from Pauly's empirical formula (Pauly, 1980) as implemented in the FiSAT II routine using mean surface temperature –T) of 28°C, L∞ and K as input parameters thus:

$$LogM = -0.0066 - 0.279\,LogL_\infty + 0.6543LogK + 0.4634LogT$$

Where, T is the mean temperature of surface water (being 26°C in the case).

The fishing mortality rate (F) was estimated using the relationship of the mortality parameter (Z = F + M).

The exploitation rate level (E) was estimated using the Beverton and Holt's equation (E = F / Z)

Probability of capture

The probability of capture 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}) and 0.75 (L_{75}).

Recruitment pattern

The Von Bertalanffy growth function parameters L∞, K and t_0 were used as inputs. Plots showing the seasonal patterns of recruitment into the fishery were obtained via backward projection of the frequencies onto the time axis of a time-series of samples along a trajectory defined by the Von Bertalanffy growth function (Dadzie *et al.*, 2007).

Relative yield per recruit (Y/R) and biomass per recruit (B/R)

The relative yield per recruit (Y'/R) and biomass per recruit (B'/R) using the knife-edge selection procedure as a function of E (exploitation rate) of the species were estimated using the model of Beverton and Holt (1966) as modified by Pauly and Soriano 1986 and incorporated into the FAO FiSAT II routine using K, M, Z and E as input parameters thus:

$$\frac{Y'}{R} = EU^{\frac{M}{K}}\left[1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right]$$

Where E= current exploitation ratio and

$m = \frac{1-E}{M/K} = K/Z$; $U = \frac{1-L_c}{L_\infty}$ where, Lc is the length at first capture; and $B'/R = \frac{Y'/R}{F}$

RESULTS

Population parameters

Size frequencies: Specimens of *Pseudupeneus prayensis* sampled on the continental shelf vary in size between 11 and 20.8 cm in standard length. The most numerous individuals (60% of the total) are between 13 and 15 cm. The size frequency distribution of these fish therefore indicates a modal class (Fig. 1). The size frequency distribution is characterised by a bell structure.

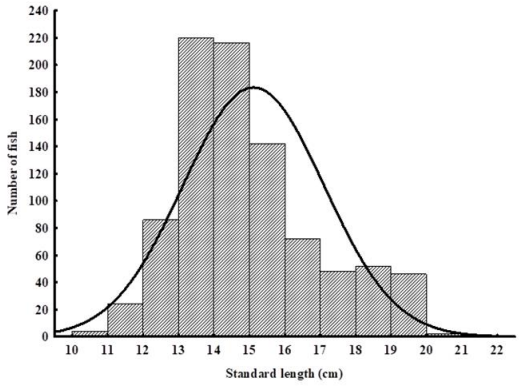


Fig. 1. Distribution of length frequency of *Pseudupeneus prayensis*

Length-weight relationship

The standard length and weight of the individuals were used to determine the length-weight relationship. Standard lengths ranged from 11 to 20.8

cm and weights from 26.5 to 209.5 g. The relationship between standard length (SL) and total weight (WT) is shown in Fig. 2. The calculated length-weight equation is as follows:

Log Wt = $1.69*10^{-2}$ + 3.21*Log SL (r^2= 0.94).

The coefficients a and b have values of 0.0169 and 3.13 respectively. The allometry coefficient of the length-weight relationship (b) is greater than 3. Consequently, the growth of this species is a majoring allometry.

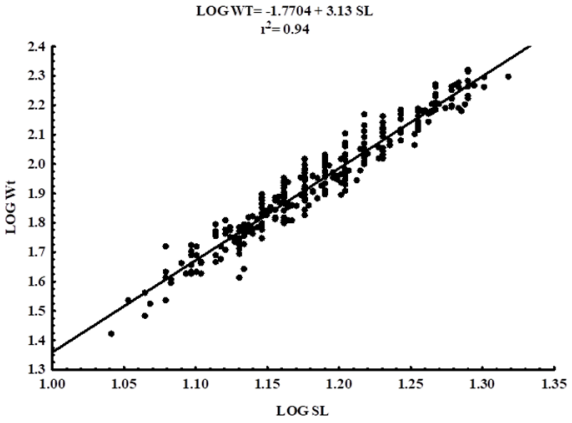


Fig. 2. *Pseudupeneus prayensis* length-weigth relationship

Estimation of growth parameters

Fig. 3 shows the curves from which the Von Bertalanffy growth parameters of *Pseudupeneus prayensis* were determined. The estimated parameters are the asymptotic standard length (L_∞) and the growth coefficient K, whose values are 28.50 cm and 0.48 $year^{-1}$ respectively. The value of t_0 calculated is -0.34, that of the growth performance index Φ' is 2.59.

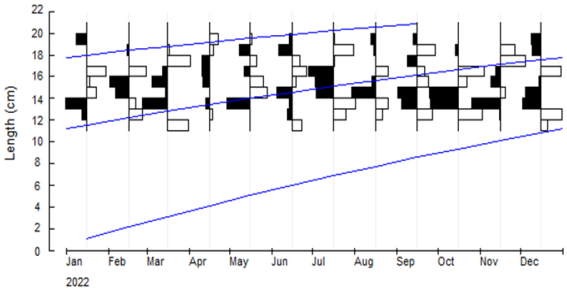


Fig. 3. FiSAT II output of the von Bertalanffy growth curves of *Pseudupeneus prayensis*

Mortality, exploitation rate and recruitment

The length converted catch curve *of Pseudupeneus prayensis* (Fig. 4) varying in age from 1 to 3 years gives a total mortality Z = 2.50 $years^{-1}$. The natural mortality (M) calculated is 1.12 $years^{-1}$ for an average temperature of 26°C and the fishing mortality (F) is 1.38 $years^{-1}$. The exploitation rate (E) calculated is 0.55. This rate is greater than 0.5. Recruitment (Fig. 5) of *Pseudupeneus prayensis* occurs almost all year round, with a peak in May to July. *P. prayensis* recruits throughout the year, with a maximum of 17.71% recruits in the sixth month.

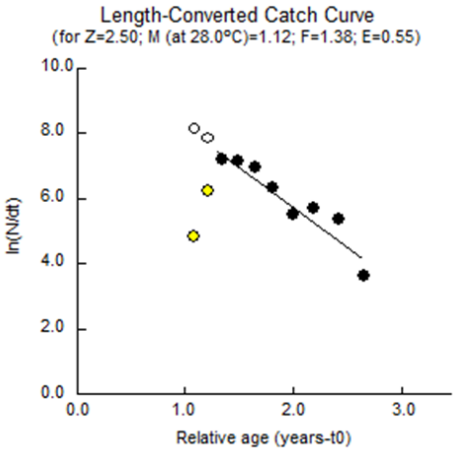


Fig. 4. FiSAT II output of length-converted catch curve of *Pseudupeneus prayensis*

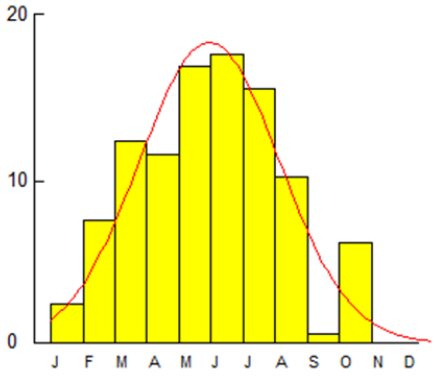


Fig. 5. FiSAT II output of recruitment pattern of *Pseudupeneus prayensis*

Yield and biomass prediction, variation in probability and virtual population

Fig. 6 shows the relative yield per recruit (Y'/R) and biomass per recruit (B'/R) curves of Berveton and

Holt modified by Pauly and Soriano for *Pseudupeneus prayensis*. These two curves as a function of the exploitation rate (E) were used to estimate the exploitation rate producing the maximum yield (E_{max}), which is equal to 0.74, the marginal exploitation rate (E_{10}), which is equal to 0.55, and the exploitation rate (E_{50}), which is equal to 0.34.

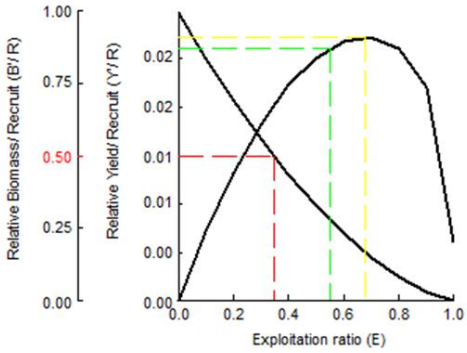


Fig. 6. FiSAT II output for yield-per-recruit and average biomass per recruit plots for *Pseudupeneus prayensis* from Ivorian continental shelf

The variations in probability (P) as a function of the size class centres (Li) are shown (Fig. 7). This makes it possible to estimate graphically the size at which 50% (Lc) of the individuals are likely to be captured. The average size of first capture determined is Lc = L_{50} = 13.24 cm.

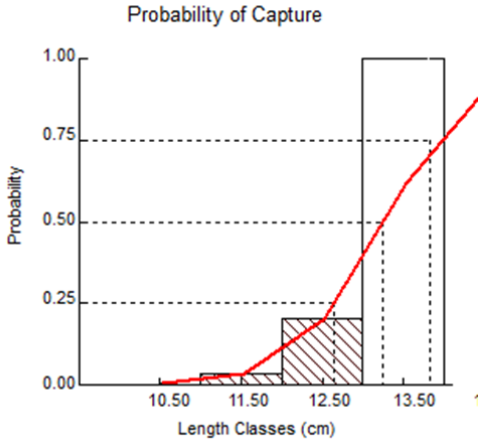


Fig. 7. FiSAT II output of probability of capture for *Pseudupeneus prayensis* from Ivorian continental shelf

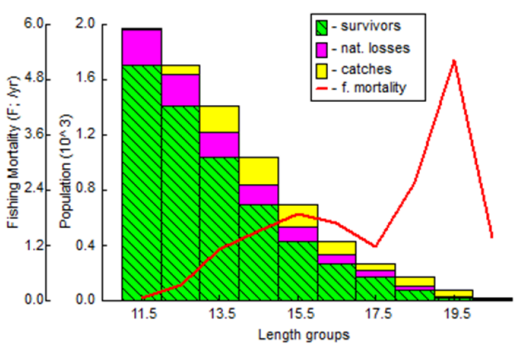


Fig. 8. FiSAT II output for virtual population analysis of *Pseudupeneus prayensis* from Ivorian continental shelf

Fig. 8 shows the histogram of virtual populations of *Pseudupeneus prayensis* based on length. It can be seen that fish between 11.00 and 13.50 cm are subject to natural mortality and fishing mortality. Natural mortality and fishing mortality affect individuals between 12.5 and 16.5 cm. Capture mortality is more pronounced in these same individuals. It gradually decreases as the size of the fish increases. Fishing mortality is noticeable from 12.5 cm upwards. It is more pronounced for individuals between 13.00 and 16.00 cm (SL). As fishing mortality increases, natural mortality decreases

DISCUSSION

The lengths frequencies obtained by the indirect method using fork lengths indicate the presence of a unimodal distribution in the sample. The most numerous individuals (60% of the sample) are between 16 and 17 cm. The high proportion of these individuals indicates that the fishery targets immature fish and a proportion of individuals that have just reached maturity. In addition, the average size of first capture (Lc = 13.24 cm) determined confirms that the fishery targets fish that have not yet reached their first sexual maturity.

The value of the allometry coefficient obtained indicates that the fish is putting on weight faster than it is growing. It reflects the fact that *P. prayensis* is fatter. This value is close to that found by Layachi *et al.* (2007) on another type of red mullet *Mullus barbatus* from the Nador coast in Morocco. This

could be explained by the abiotic conditions of the environment and the availability of food. In fact, it is well known that in tropical zones, environmental factors such as those linked to the availability of prey enable fish to grow (Castillo-Rivera, 2013).

The value of the growth coefficient K and L∞ obtained on the Ivorian continental shelf is higher than that of Chabanne (1987) (K= 0.53 and L∞ = 28.48 cm) on the Senegalese coast.

This indicates that *P. prayensis* grows rapidly in Ivorian waters. The growth of *P. prayensis* could be linked both to the genetic characteristics of its population and to the physiology of the individuals on the Ivorian continental shelf. It should therefore be pointed out that the asymptotic length L∞ has no biological value since it fluctuates according to the size of the individuals examined. Large fish at the end of their growth cycle are absent from our catches.

The value obtained for the growth performance index indicates good sampling and uniform selection of *P. prayensis* specimens. In fact, according to Baijot *et al.* (1994), the results of the study of populations in Africa using the ELEFAN I programme are only reliable if the growth performance index values are between 2.65 and 3.32.

Factors such as environmental conditions, physiological factors (disease and old age) and chance factors, i.e. encounters with potential predators, influence natural mortality (Sylla, 2010). In the present study, the high natural mortality observed in small individuals could be explained by predation. In the food web, the chain is such that individuals eat and are in turn eaten. For example, some carnivorous fish feed on smaller fish.

The exploitation rate indicates that the *P. prayensis* stock is overexploited. According to Francis and Sikoki (2007), the maximum level of exploitation of a resource is reached when the exploitation rate is greater than or equal to 0.5 or when fishing mortality (F) is greater than or equal to natural mortality (M). Barry and Tegner (1990) also demonstrated that if the Z/K ratio is greater than 1, then mortality predominates over growth. In this study, the Z/K ratio is 5.20. Our results therefore confirm that the *P. prayensis* population is overexploited in the waters of the Ivorian continental shelf. Similar results were obtained by Barry *et al.* (2004) and Gascuel *et al.* (2004) for the same species in Senegal and Ghana respectively.

The yield per recruit also shows that the *Pseudupeneus prayensis* stock is overexploited. This is a very important parameter in the management of fishery resources.

CONCLUSION

The results of this study provided useful information for the management of this species, which is an important component in the food web of Ivorian continental shelf. The population parameters of *Pseudupeneus prayensis* indicate, a rapid growth in weight than in length. The analysis of natural mortality and fishing mortality indicate that this species is being exploited to the maximum. The species studied is therefore threatened because it is overexploited. The population parameters for *P. prayensis* give an idea of the fishing pressure on this species. As the stock of this fish is under threat, it is important to implement a rational management policy for the existing stock.

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