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Assessment of population dynamic and fisheries management of *Ethmalosa fimbriata* exploited by small-scale fishery in the tropical coastal lagoon of Grand-Lahou (Côte d'Ivoire, West Africa)

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Abstract

This study aims to obtain informations on growth, mortality and exploitation rate of the stock of *Ethmalosa fimbriata* in Grand-Lahou lagoon. Samples were collected using artisanal gillnet fishery from November 2013 to October 2014. Length frequency data collected were analyzed with FISAT software using the ELEFAN package to estimate the population parameters of *Ethmalosa fimbriata*. A total of 2383 individuals of *Ethmalosa fimbriata* ranged from 5 cm to 16 cm SL (standard length) were examined. The asymptotic length ($L\infty$) and growth rate constant (K) were estimated to be 17 cm and 0.84 $year^{-1}$ respectively. Based on the growth parameters and using the catch curves procedures, the instantaneous total mortality coefficient (Z), the instantaneous natural mortality coefficient (M) and the Instantaneous fishing mortality coefficient (F) were 3.66, 1.85 and 1.81 $year^{-1}$ respectively in Grand-Lahou lagoon. The exploitation rate was estimated at 0.49. Fishing mortality (F) and exploitation rate (E) were found to be below optimum levels of exploitation and indicate that *Ethmalosa fimbriata* is not overexploited in Grand-Lahou lagoon. The Y'/R and B'/R curves as well as all year round recruitment show that the current exploitation rate could be maintained for sustainable and rational exploitation.

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Introduction

Coastal lagoons are highly productive and also serve as nursery and feeding habitats for variety of organisms (Harris *et al.*, 2004). The velocity and volume of water exchanges between the sea and the lagoon directly affects fish production via recruitment and increases lagoons fishing activities (Bourquard and Quignard, 1984). The basic purpose of fish stock assessment is to provide advices on the optimum exploitation of the resources (Sparre and Venema, 1992). The fundamental models used are based on few parameters such as growth, recruitment patterns, mortalities, exploitation rate, and fishing activities (King, 1991). The exploitation rate is an index which estimates the level of utilization of a fishery. The value of this index is based on the fact that sustainable yield is optimized when the fishing mortality rate is equal to natural mortality (Pauly, 1983). *Ethmalosa fimbriata* is common in all brackish environments along the west African coast, from Mauritania to Angola. *Ethmalosa fimbriata* was the most important fish of small-mesh size landings in Grand-Lahou lagoon with more than 225 tons (Coulibaly *et al.*, 2018). *E. fimbriata* is important ecologically and commercially and is widely exploited in lagoons and estuaries (Cormier, 1983) but commonly characterized by a high exploitation level. Although, *E. fimbriata* contributes greatly in the economy of inland fisheries in the country, information on the population parameters of the specie in Grand-Lahou lagoon is presently scarce. The present work aims at providing informations on the growth, mortality recruitment patterns and exploitation rate of *Ethmalosa fimbriata* in Grand-Lahou lagoon that could be useful for management of the specie.

Materials and methods

Study area

Located between 5° 08'-5° 03'N and 4° 51'-5° 25'W, Grand-Lahou lagoon (Côte d'Ivoire, West Africa) is an elongated open coastal water body.

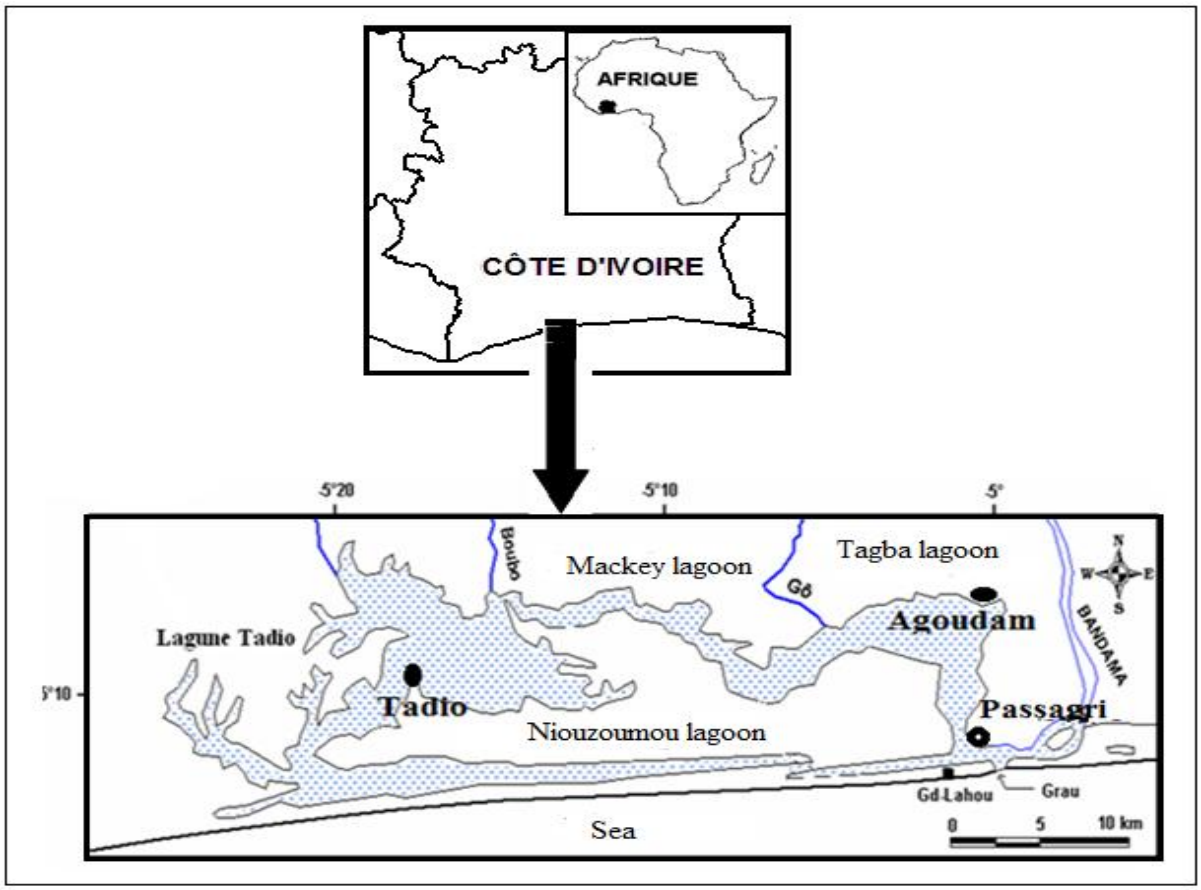

Fig. 1. Map of Grand-Lahou lagoon showing sampling stations ( ).

A channel connects the lagoon to the Atlantic Ocean in the eastern part, whereas in the north it receives freshwater discharged from three connecting rivers (Bandama, Boubo and Gô) (Laë, 1982). This aquatic system is a lagoon complex composed of four lagoons which are from east to west, Tagba (57 km2), Mackey (28 km²), Tadio (90 km²) and Niouzoumou (15 km²) (Laë, 1982).

The study zones climate was characterized by four seasons. A long dry season from december to march, a long rainy season from april to july, a short dry season from august to september and a short rainy season from october to november (Durand and Skubich, 1982). For this study, three stations (Tadio, Agoudam and Passagri) were chosen. They constitute the main fish landing sectors of the lagoon (Laë, 1982 ; Diaby *et al.*, 2012) (Fig. 1).

Fish sampling and data collection

Samples were collected between november 2013 and october 2014 during 3-4 days per month at the three stations in Grand-Lahou lagoon. Moreover, monthly fish samples were collected from commercial landings using gillnets. Fishermen were chosen by random and fishes in their catches were analyzed. Each specimen was identified to the specie level using Paugy *et al.* (2003 a, b) manual.

Then each individual collected was measured for its standard length (LS) to the nearest 0.1 cm by using a fish measuring board. The fish specimens were individually weighed to the nearest 0.01g using an electronic weighing balance model FEL-500S.

Data analysis

In the present study, *Ethmalosa fimbriata* populations from commercial catches were grouped in length class interval at 1 cm. Data analyses were based on FiSAT II (Gayanilo *et al.*, 2002). The Bertalanffy growth equation (VBGE): $Lt = L\infty (1- e^{-K (t - t_o)})$ was used to describe growth in size, where Lt is the length at age t, L_∞ the asymptotic length, K the body growth coefficient and t_o the hypothetical age at which a fish would have zero length. The values of L_∞ and K were estimated by plotting Lt versus Lt+1, while the t_o value estimated using the empirical equation Pauly (1979):

$Log10 (- t_o) = -0.392 – 0.275 Log10 L\infty - 1.038 Log10 K$. 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 performance index is defined as:
$\varphi' = log10 K + 2 log10 L\infty$.

The potential longevity of *E. fimbriata* was estimated according to the following equation (Pauly, 1985):
$Tmax = 2. 9957/ K$.

The length-converted catch curve method (Pauly, 1984a) was used to estimate the instantaneous rate of total mortality (Z) by using the FiSAT program.

The instantaneous rate of natural mortality (M) was obtained by the equations of Pauly, 1980 as:
$log M = [- 0.0066 – 0.279 log L\infty + 0.6543 log K + 0.4634 log T]$. The fishing mortality (F) was estimated by subtracting the value of natural mortality from the total mortality as $F = Z –M$, while the exploitation rate $E = F/Z$. The probability of capture was estimated from length-converted catch curve, using the running average technique to determine Lc (Pauly, 1984b).The model of Beverton and Holt (1966) incorporated in FiSAT program (Gayanilo *et al.*, 1997) was used to predict the relative yield-per-recruitment and the relative biomass per recruit as $Y`/R = EUM/K [ 1 - (3U/1+m) + (3U2/1+2m) – (U3/1+3m) ]$ where, $U = 1- ( Lc /L\infty )$, $m = (1-E)/ (M/K) = (K/Z)$ : M is the natural mortality, K is the body growth coefficient and E is the exploitation rate. The relative biomass per recruit $(B`/R) = (Y`/R)/F$ where, (Y`/R) is the relative yield-per-recruit and F is the fishing mortality.

The optimum exploitation rate which produces maximum yield was found from the yield-per-recruit and biomass-per-recruit model (E max). Also, the exploitation rate at which the marginal increase of Y′/R is 0.1 (E0.1), and that which reduces the biomass to 50% of its unexploited level (E0.5) were estimated.

Results

Length-frequency distribution

The smallest specimen of *Ethmalosa fimbriata* (n = 2383) was 5 cm SL whereas the largest specimen was 16 cm SL as showed by the length-frequency distribution (Fig. 2). Species with standard length between 9 -10 cm were numerically dominant and constitued 72.93% of the population (Fig.2).

The overall length-frequency distribution showed a modal length class of 10 cm indicating an unimodal distribution of *E. fimbriata* exploited in the Grand-Lahou lagoon (Fig. 2).

Table 1. Estimated population parameters of *Ethmalosa fimbriata* caught in Grand-Lahou lagoon from November 2013 to October 2014.

Population parameters	*Ethmalosa fimbriata*
Asymptotic length L∞ (cm)	17
Growth rate (K)	0.84
Theoretical age [t_0 (Y^r)]	-0.26
Longevity tmax (Y^r)	4.12
Growth performance index (φ')	2.38
Goodness of fit index (Rn)	0.19
Mean length at first capture L_{50} (cm)	8.89
Total mortality [Z (Y^{r-1})]	3.66
Fishing mortality [F (Y^{r-1})]	1.81
Natural mortality [M (Y^{r-1})]	1.85
Exploitation rate (E)	0.49
Allowable limit of exploitation (Emax)	0.86

Growth parameters

Fig. 3 illustrates the growth curves fitted to the monthly length-frequency distribution of *Ethmalosa fimbriata* in Grand-Lahou lagoon. Fig. 3 shows the growth curves generated from ELEFAN I program during the courses of this study for *E. fimbriata*. The estimated growth parameters (L∞, K and t_0) and derived growth performance index (φ') are given in table 1.

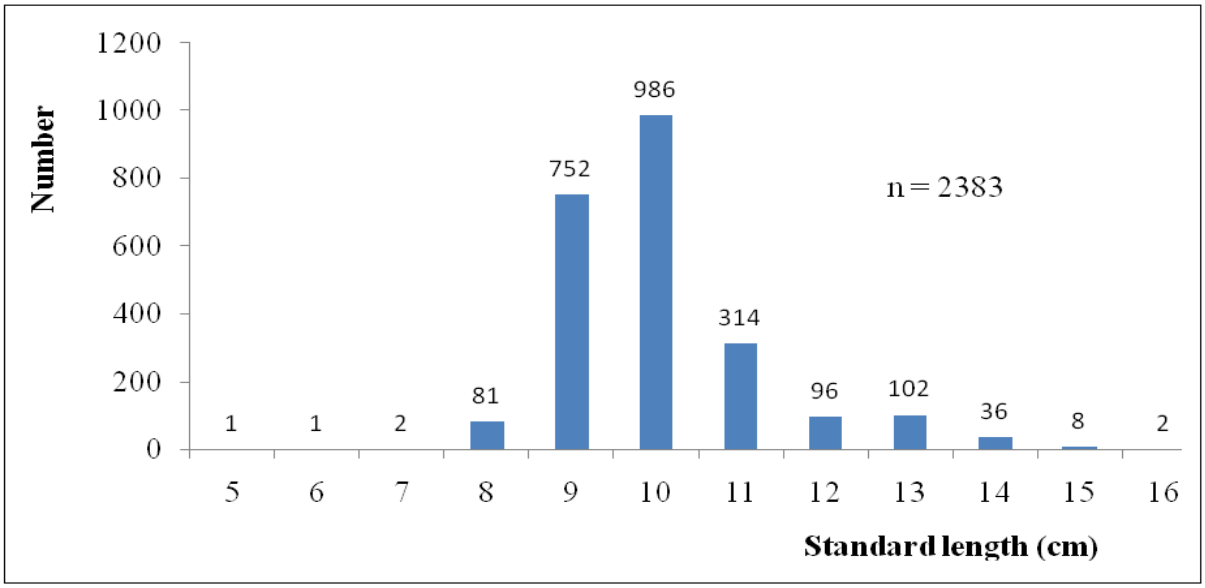

Fig. 2. Length-frequency distribution of *Ethmalosa fimbriata* in Grand-Lahou Lagoon from November 2013 to October 2014.

The asymptotic length (L∞), the growth coefficient (K) and the theoretical age at length zero (t_0) for *E. fimbriata* were L∞ = 17 cm, K = 0.84 year^{-1} and t_0 = -0.26 year. From these results, the growth performance index (φ') was 2.38 year^{-1} for *E. fimbriata* while Longevity t_{max} was 4.12 year.

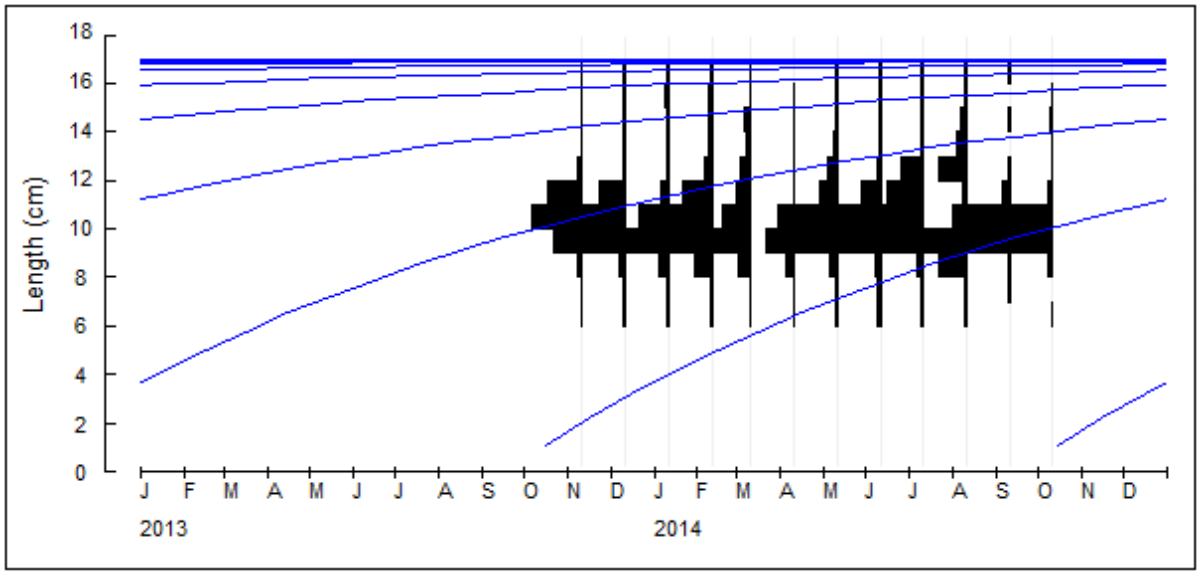

Fig. 3. Monthly length-frequency distribution of *Ethmalosa fimbriata* fitted with growth curves in Grand-Lahou lagoon from November 2013 to October 2014.

Instantaneous mortality coefficients and exploitation rates

The annual rates of total mortality (Z) derived from length frequency catch curves was 3.66 year^{-1} (Fig. 4). The natural mortality rate (M) derived from Pauly's equation was estimated at 1.85 year^{-1}. The fishing mortality rates (F) was 1.81 year^{-1}. The exploitation rate (E) was 0.49 (Table 1).

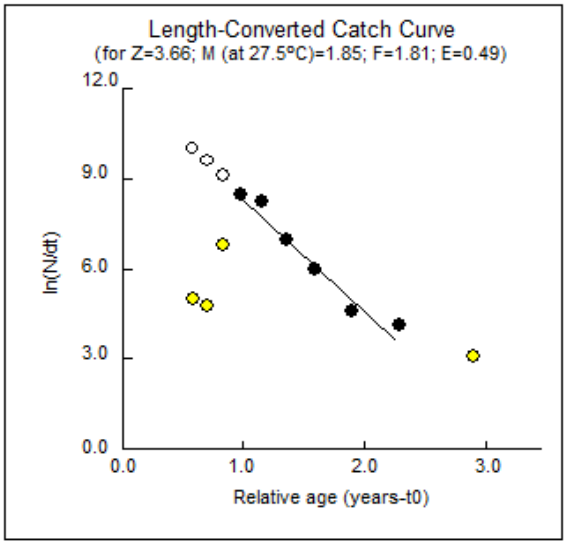

Fig. 4. Length-converted catch curve for *Ethmalosa fimbriata* in the Grand-Lahou Lagoon from November 2013 to October 2014.

Lengths at first capture and recruitment patterns

The estimated length at first capture L50 or Lc (length at which 50% of the fish entering the gear are retained) was 8.89 cm (Fig. 5).

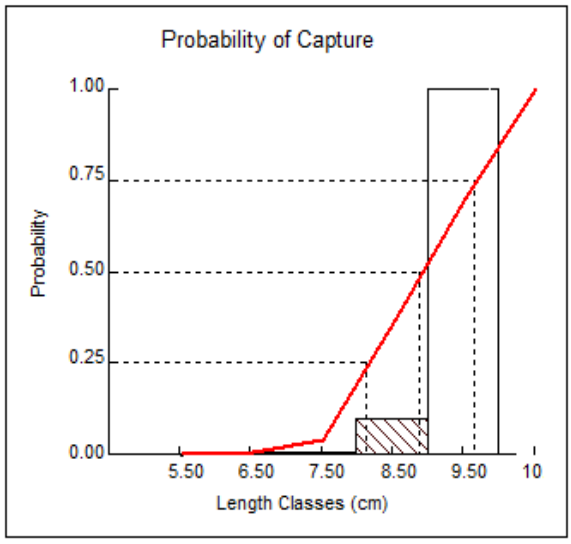

Fig. 5. Probability of capture analysis for *Ethmalosa fimbriata* in the Grand-Lahou Lagoon from november 2013 to october 2014.

The recruitment pattern was bimodal with two major peaks of recruitment. The first peaks occurred in January and February and the second peak occurred

in july (Fig. 6). The plots of relative yield-per-recruit against exploitation rate showed that the present exploitation rate (0.49) was less than the maximum exploitation rate Emax (0.86). However, the present exploitation rate was higher than the rate of exploitation at which 50 % of the biomass-per-recruit was fished (E present > E50) (Fig. 7).

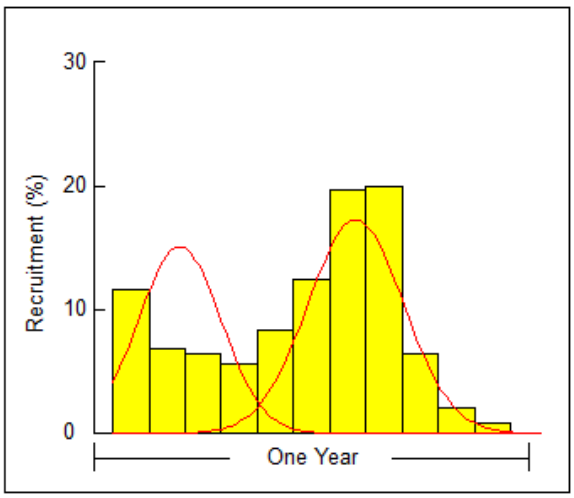

Fig. 6. Recruitment pattern of *Ethmalosa fimbriata* in the Grand-Lahou Lagoon from november 2013 to october 2014.

Discussion

The sizes distribution of this study was different to the results obtained for *Ethmalosa fimbriata in* Senegalese waters by Alioune (2014). According to the author, the sizes for this specie were distributed in the estuary between 12 and 26 cm. The parameters that describe growth in length for *E. fimbriata* in the present study ($L\infty$ =17 cm ; K = 0.84 year^{-1} ; φ' = 2.38 year^{-1}) are lower than those observed by others authors. Gerlotto (1976) estimated infinity length, growth coefficient, and growth performance index of *E. fimbriata* in Ebrié lagoon at 24.5 cm, 0.96 year^{-1} and 2.76 year^{-1} respectively. Ama-Abasi *et al.* (2004) recorded $L\infty$ of 31.2 cm, K of 0.90 year^{-1}and φ' of 2.94 year^{-1} in lagos lagoon in Nigeria for *E. fimbriata*. The estimated total mortality (Z=3.66 year^{-1}) and natural mortality 1.85 year^{-1} for *Ethmalosa fimbriata* in the present study were less than the results obtained by Villanueva (2004) in Ebrié lagoon. The total mortality rate of others clupeids such as *Pellonula leonensis and Stolothrissa tanganicae*, in Côte d'Ivoire and the north of Tanganyka respectively were higher (Koné *et al.*, 2014 ; Mubamba, 1993). The highers natural mortality rates obtained could be explained by predation factor. Indeed, clupeids species constitute the prey of many fish species such as *Hydrocynus forskalii, Lates niloticus and Malapterurus electricus* (Otobo, 1979). Sexual maturity value of 9.6 cm (SL) was recorded in Aby lagoon (N'goran, 1991). This value of first length at sexual maturity (Lm) was higher than the length at first capture Lc of the specie recorded in the present study. Fish should be allowed to reach sexual maturity prior to exploitation.

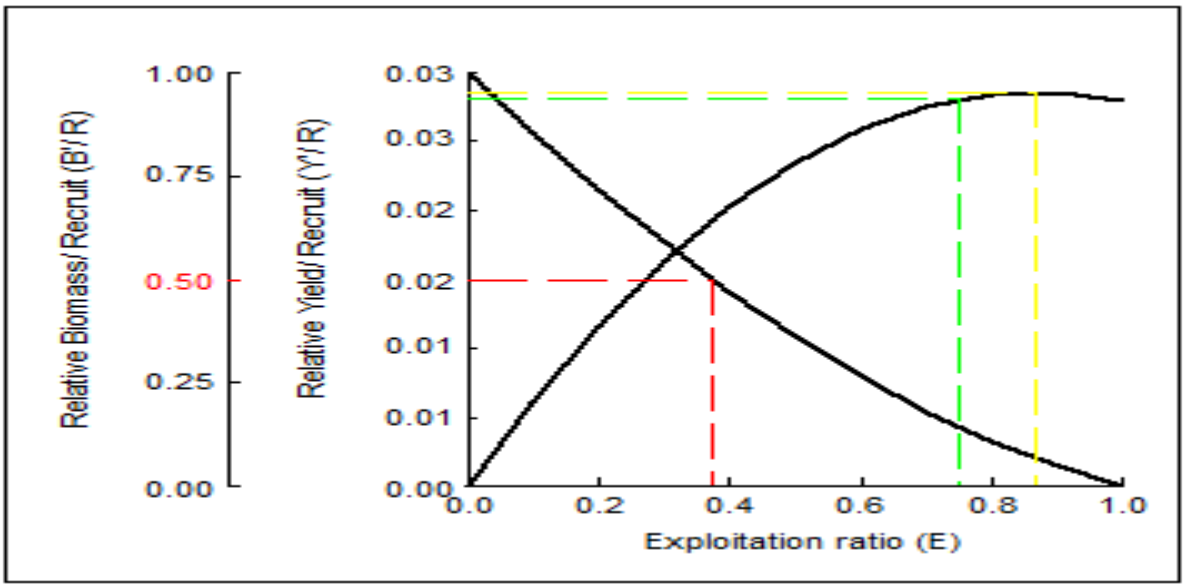

Fig. 7. Relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) plot for *Ethmalosa fimbriata* at different rates of exploitation in the Grand-Lahou Lagoon from november 2013 to october 2014.

This is best achieved by making their L50 larger than Lm (Sendecor and cochren, 1980). Exploitation rate (E present) which has'nt reached the maximum level (Emax) for *Ethmalosa fimbriata*, suggests that (E present) could be applied for sustainable exploitation of the *E. Ethmalosa* fishery. However, the B'/R curve of this specie in Grand-Lahou lagoon, which indicated that E present > E0.5 implied that a considerable increase in the current exploitation rate of the stock could lead to depletion of the fish stock. Theoretically, options such as, increase the mesh size, reduce effort, regulate number of boats in the fishery could lead to the fishery management.

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