



Growth and exploitation parameters of *Ethmalosa fimbriata* (Bowdich, 1825) (Clupeidae) in a Tropical Coastal Lagoon: Ebrié Lagoon (Aghien-Potou Sector, Côte d'Ivoire)

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Abstract

Length monthly data composition of *Ethmalosa fimbriata* landed in Ebrié lagoon (Aghien-potou Sector, Côte d'Ivoire) was used to estimate growth and exploitation parameters of the stock. A total of 1932 individuals of *E. fimbriata* ranged from 4 cm to 25 cm were analyzed with FISAT software using the ELEFAN package. The asymptotic length (L_{∞}), the growth rate constant (K) and the growth performance index, (Φ') were estimated to be 26.00 cm, 0.66 year⁻¹ and 2.64 respectively. The theoretical age t_0 was estimated at -0.55 while longevity (t_{max}) was 4.54 year. Based on the growth parameters and using the catch curves procedures, the instantaneous total mortality coefficient (Z), the instantaneous natural mortality coefficient (M), the Instantaneous fishing mortality coefficient (F) and the exploitation rate (E) were 4.95 year⁻¹; 1.40 year⁻¹, 3.55 year⁻¹ and 0.72 respectively.

The study shows value of fishing mortality (3.55 year⁻¹) superior than that of natural mortality (1.40 year⁻¹). *E. fimbriata* has an overexploitation statut in Ebrié Lagoon (Aghien-Potou sector) with an exploitation rate (E) of 0.72 close the allowable limit of exploitation ($E_{max} = 0.74$) and higher than $E_{0.5}$ (0.35).

Keywords: *Ethmalosa fimbriata*, exploitation, lagoon, aghien-potou, Côte d'Ivoire

1. Introduction

The basic purpose of fish stock assessment is to provide advices on the optimum exploitation of the resources^[45]. The fundamental models used are based on few parameters such as growth, recruitment patterns, mortalities, exploitation rate, and fishing activities^[23]. Fish is the most important source of protein in most of the countries and vital in reducing hunger and poverty for millions persons^[14]. In west Africa, the exploitation of the halieutic resources relate mainly to fish and shrimps. Concerning fishes, the clupeid *Ethmalosa fimbriata* along the coast of western Africa from Mauritania to Angola^[11] is the most abundant fish species by both number and biomass, and it is heavily exploited by a small-scale fishery^[15]. An increase of fishing effort can lead to a decrease of the number of old fishes in a fishery and a depletion of the stock. Moreover, this species is mainly exploited by artisanal fisheries which impact seriously its abundance by of unorthodox method use small mesh sized nets. Several types of fishing gears are used by different communities in Ebrié lagoon (Aghien-Potou Sector)^[6]. Thus *E. fimbriata* could be regarded as being threatened in this sector of the Ebrié lagoon. This ecologically and commercially important specie is widely exploited in lagoons and estuaries^[12] and commonly characterized by a high exploitation level. Although, *E. fimbriata* contributes greatly to the catches of the sector, no information on the population parameters of the specie in Ebrié lagoon (Aghien-Potou Sector) is available. There is an urgent need for the regular stock assessment of this specie to provide fisheries managers and government agencies informations on which to base protection legislation. Among these informations estimations of some parameters such as asymptotic length, growth rate, length at first capture, recruitment and mortalities are

essential for an understanding of the general biology and population dynamics and for implementation of management plans. The objective of this study is to estimate the growth and exploitation parameters of the specie and appreciate the current level of exploitation of this resource in the Ebrié lagoon (Aghien-Potou Sector).

2. Materials and methods

2.1. Study area

The Ebrié Lagoon system with a area of 566 km², extends in the east on 125 km along the littoral of Côte d'Ivoire between 340-450W. It comprises the Ebrié lagoon itself (523 km²) and the Aghien-Potou lagoon system (43 km²). Located between 515-527 N and 343-356 W, the Aghien-Potou lagoon system extends on 72 km from perimeter and 32 km length from the median axis^[46] (figure 1). In Potou lagoon, the influence of the intrusion saltworks is sensitive in dry season (from January to May), while remaining moderate (< 9), and the water being soft from May to December^[18].

The climate of the study zone is an equatorial type characterized by four seasons including one high dry season from December to March, a high rainy season from April to July, a small dry season from August to September and a small rainy season from October to November. It is a zone where interannual precipitations rank above 1500 mm. This zone contains a significant hydrographic network, composed of the Bété, Djibi and Mé Rivers. The Bété and Djibi rivers emerge directly in the Aghien lagoon whereas the Mé River emerges in the natural channel connecting the Potou lagoon to the lagoon Aghien^[47]. The Potou lagoon is characterized by low depths (< 3 m). The most significant depths are recorded on the level of the channels connecting the Aghien lagoons and Potou (5 to 7 m) on the one hand and the Potou

lagoon with the remainder of the lagoon Ebrié (7 m) [29].

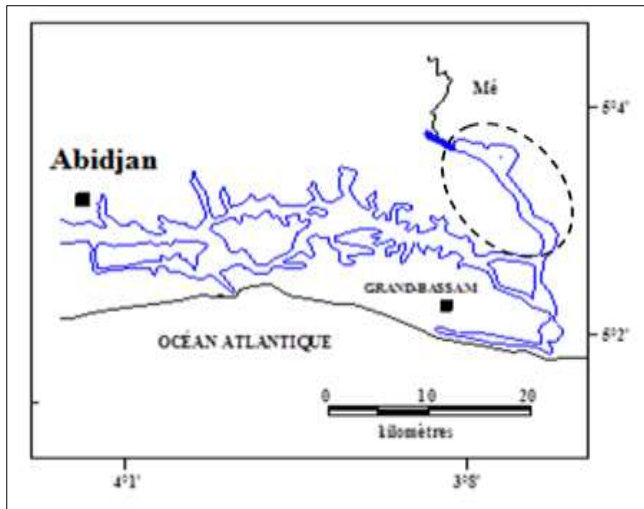


Fig 1: Map of Ebrié lagoon showing sampling zone (Aghien-Potou Sector)

2.2. Fish sampling and data collection

Samples were collected between April 2004 and March 2006 during 3-4 days per month in Ebrié Lagoon (Aghien-Potou Sector). Moreover, monthly fish samples were collected from commercial landings at random using gillnets and beach seines. Fishermen were chosen by random and fishes in their catches were analyzed. Each specimen was identified to the species level by using [31, 32] 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.

2.3. Data analysis

For this study on the fishing impact on *Ethmalosa fimbriata* population of the Ebrié lagoon (Aghien-Potou Sector), the sizes structure was considered on three levels:(1) the global size spectra of by the various types of gears used by fishing activities in the Aghien-Potou lagoon system;(2) the spectra sizes by fishing gear. The sizes were gathered in classes of 1 cm [24, 21] to allow to have a representative number of individuals. These classes sizes are represented by their median points. The average sizes of the species were determined by the following formula

$$\bar{X} = x_i \times \frac{f_i}{n}$$

\bar{X} average size of specie i; x_i = fork length class (Lf); f_i = individual number corresponding to each Lf and n = individual number of the sample.

In the present study, *Ethmalosa fimbriata* populations from commercial catches were grouped in length class interval of 1 cm. Data analyses were based on FiSAT II [17]. The Bertalanffy growth equation (VBGE): $L_t = L_\infty (1 - e^{-K(t - t_0)})$ was used to describe growth in size, where L_t is the length at age t , L_∞ the asymptotic length, K the body growth coefficient and t_0 the hypothetical age at which a fish would have zero length. The values of L_∞ and K were estimated by plotting L_t versus L_{t+1} , while the t_0 value estimated using the empirical equation [33]:

$$\text{Log}_{10}(-t_0) = -0.392 - 0.275 \text{Log}_{10} L_\infty - 1.038 \text{Log}_{10} K.$$

The fitting of the best growth curve was based on the ELEFAN I

program [36], which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. An index of goodness of fit, called R_n , was determined by automatic computer [17].

The overall growth performance index (ϕ') was quantified using the model of [40]. The performance index is defined as: $\phi' = \log_{10} K + 2 \log_{10} L_\infty$.

The potential longevity of *E. fimbriata* was estimated according to the following equation [39]:

$$T_{max} = 2.9957 / K.$$

The length-converted catch curve method [37] was used to estimate the instantaneous rate of total mortality (Z) by using the FiSAT program. A stock of a species undergoes an evolution characterized by gains (inputs) and losses (outputs). Gains are represented by the annual recruitment and fish growth while losses are due to total mortality (Z). Total mortality (Z) is the sum of fishing mortality (F) generated by the various fishing operations and a natural mortality (M) which expresses mortality from any cause other than fishing [10]. Total mortality was estimated from length-converted catch curves by the method of the curve catches modified from age-structured catch curves with the ELEFAN in R software [42].

The different methods of estimating total mortality, which use linearized catch curve according to the size classes, were derived from the catch curve method based on ages [43]. For estimation of natural mortality, several methods can be used. In the present work, the method of [34, 37], which is recommended for pelagic fish was used. [34] links natural mortality and growth parameters (L_∞ and K), and the annual average temperature of the environment (T°) by the formula: $\ln(M) = -0.0066 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.4634 \ln(T)$ where M is natural mortality; L_∞ is the asymptotic length that an average fish would achieve if it continued to live and grow, K is the Von Bertalanffy curvature parameter; T is annual average temperature of the environment ($T = 29.5^\circ\text{C}$ at the estuary; $T = 27.4^\circ\text{C}$ at sea). Fishing mortality here expresses the quantity of *Ethmalosa fimbriata* picked up by fishing activities in a year. After calculating M and Z , fishing mortality was deducted by the formula: $F = Z - M$. Exploitation rate (E), which represents the proportion of deaths due to fishing was given by the following equation [39]: $E = F / (F + M) = F / Z$ where E is the exploitation rate, F is the fishing mortality, M is the natural mortality and Z is the total mortality. This rate indicates whether a stock is overfished or not depending on whether its value is greater or less than 0.5 (optimal value of E (E_{OPT}) is close to 0.5

The probability of capture was estimated from length-converted catch curve, using the running average technique to determine L_c [38].

The model of [9] incorporated in FiSAT program [16] was used to predict the relative yield-per-recruitment and the relative biomass per recruit as $Y^*/R = EUM/K [1 - (3U/1+m) + (3U^2/1+2m) - (U^3/1+3m)]$ where, $U = 1 - (L_c/L_\infty)$, $m = (1-E)/(M/K) = (K/Z) : M$ 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 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 the probability of capture by length [41]. As a result, the maximum exploitation rate (E_{max}), which implies exploitation rate producing maximum yield, exploitation rate at which the stock is 10%

of its virgin stock ($E_{0.1}$) and $E_{0.5}$ indicating exploitation rate under which the stock is reduced to half of its virgin biomass were computed using the Knife-edge option incorporated in the FISAT II Tool.

The length at first maturity (L_{m50}) for the assessed species was estimated using the procedure by [20] as Length at first maturity (L_{m50}) = $2/3 * (L_{\infty})$. The input parameters for the model included asymptotic length only (L_{∞}).

3. Results

3.1. Population size structure

In Aghien-Potou Sector, *Ethmalosa fimbriata* specimen (n =1932) sizes are distributed between 4 cm and 25 cm as shown by the length-frequency distribution (Figure 2). Species with standard length 10 to 12 cm were numerically dominant and constituted 83% of the population (Figure 2). The overall length-frequency distribution showed a modal interval class length of 10-12 cm (Figure 2).

3.2. Growth parameters (L_{∞} , K, t_0 and ϕ')

Figure 3 illustrates the growth curves fitted to the monthly length-frequency distribution of *E. fimbriata* in Ebrié lagoon (Aghien-Potou Sector).

The asymptotic length (L_{∞}), the growth coefficient (K), and the theoretical age at length zero (t_0) year⁻¹ for *E. fimbriata* were respectively 26.00 cm, 0.66 year⁻¹, and -0.55 year. From these results, the growth performance index (ϕ') was 2.64 while longevity (t_{max}) was 4.54 years (Table 1)

Table 1: Estimated population parameters of *Ethmalosa fimbriata* caught in Ebrié lagoon (Aghien-Potou Sector) from April 2004 to March 2006.

Population parameters Values	
Asymptotic length (L_{∞} , cm)	26
Growth rate (K, year ⁻¹)	0.66
Longevity (t_{max} , year)	4.54
Theoretical age (t_0 , year)	-0.55
Growth performance index (ϕ')	2.62
Natural mortality (M, year ⁻¹)	1.40
Fishing mortality (F, year ⁻¹)	3.55
Total mortality (Z, year ⁻¹)	4.95
Current exploitation rate (E)	0.72
Allowable limit of exploitation (E max)	0.74
Mean length at first capture L_{50} (cm)	8.26
Length at first maturity L_{m50} (cm)	17.33

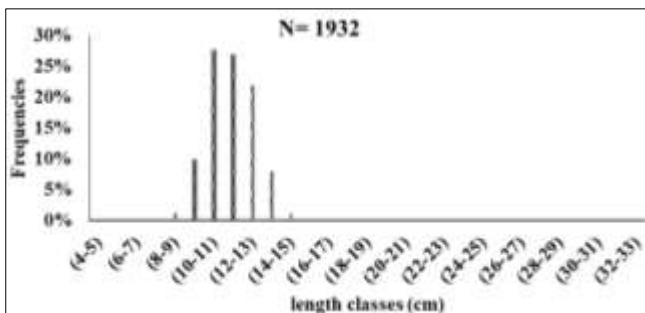


Fig 2: Length-frequency distribution of *Ethmalosa fimbriata* in Ebrié Lagoon (Aghien-Potou Sector) from April 2004 to March 2006.

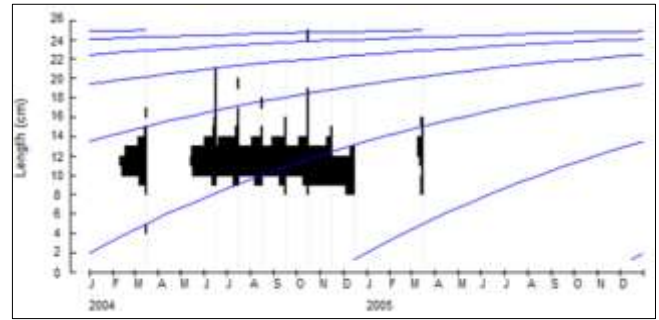


Fig 3: Monthly length-frequency distribution of *Ethmalosa fimbriata* fitted with growth curves in Ebrié lagoon (Aghien-Potou Sector) from April 2004 to March 2006.

3.3. Estimation of mortality coefficients and exploitation rates

The annual rates of total mortality (Z) derived from length frequency catch curves was 4.95 year⁻¹ (Figure 4). The natural mortality rate (M) derived from Pauly's equation was estimated at 1.40 year⁻¹. The fishing mortality rates (F) was 3.55 year⁻¹. The exploitation rate (E) was 0.72 (Table 1).

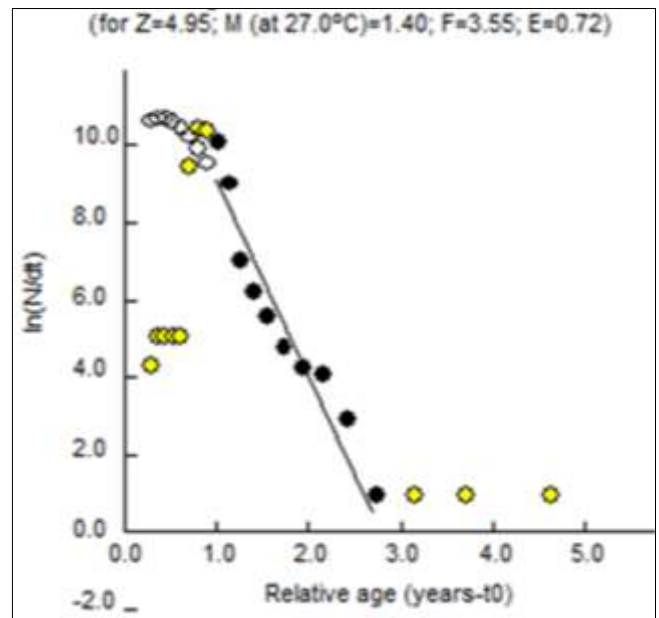


Fig 4: Length-converted catch curve for *Ethmalosa fimbriata* in Ebrié lagoon (Aghien-Potou Sector) from April 2004 to March 2006

3.4. Probability of capture and recruitment patterns

The estimates of probabilities of capture and length at first capture (L_c) values were calculated using the length converted catch curve method which was plotted in Figure 4. The estimated length at first capture L_{50} or L_c (length at which 50% of the fish entering the gear are retained) was 8.26 cm (Figure 5). As shown in figure 6, the annual recruitment pattern of *E. fimbriata* in the Ebrié Lagoon (Aghien-potou Sector) indicated that recruitment occurred throughout the year. The recruitment pattern of the FISAT II tool outlined a two-recruitment pulse with the major pulse in May and the

minor one in October (Figure 6).

The plot of relative yield-per-recruit against exploitation rate showed that the current exploitation rate ($E_{current}$: 0.72) was close to the maximum exploitation rate (E_{max} : 0.74) (Figure 7). However, the present exploitation rate was higher than the rate of exploitation at which 50% of the biomass-per-recruit was fished ($E_{current} > E_{0.5}$).

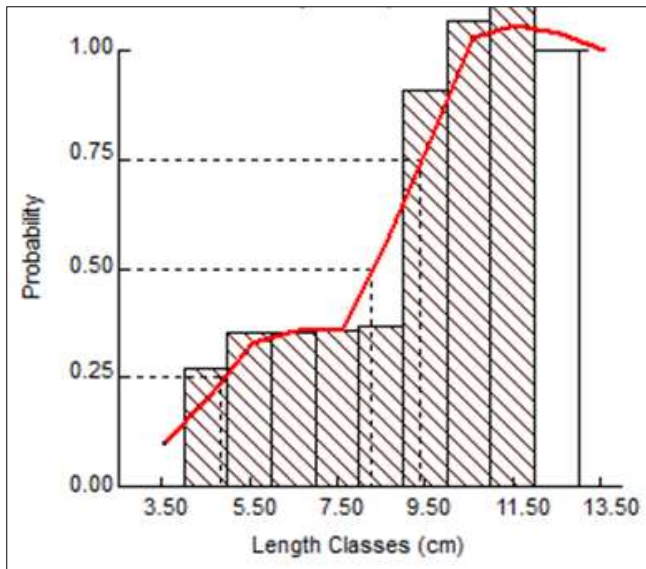


Fig 5: Probabilities of capture pattern of pooled population of *Ethmalosa fimbriata* in Ebrié lagoon (Aghien-Potou Sector) from April 2004 to March 2006.

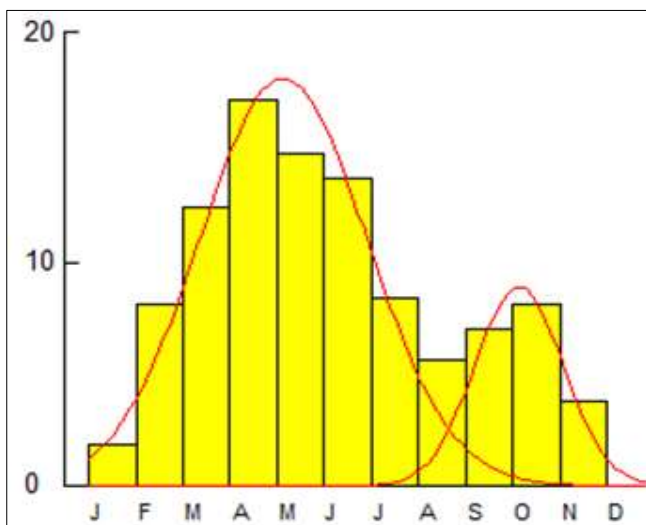


Fig 6: Recruitment pattern of *Ethmalosa fimbriata* in Ebrié lagoon (Aghien-Potou Sector) from April 2004 to March 2006.

4. Discussion

The size ranges in this study (4-25 cm) were similar to those of [30] in Saloum estuary (Senegal). However other authors have sampled much smaller sizes for *Ethmalosa fimbriata*. It was the case of [5] in Grand Lahou lagoon where sizes of this specie were ranged from 4 to 16 cm. The difference in the size ranges could be due to the types of fishing gears used to catch the specie and some environmental factors. Fishing has a prominent effect on the size structure of the exploited stocks. When comparing L_{∞} and the growth coefficient K values in table 2, most of the results are in agreement with [7] who pointed that the two parameters of growth are inversely proportionally to each other. It implied that fishes with high

L_{∞} should be with lower K value. Moreover, the estimate growth rate K was within the range 0.34 per year and 0.67 per year for intermediate growing fish species [22] suggesting that *E. fimbriata* is an intermediate growing fish specie. The calculated growth performance index ($\phi = 2.64$) outside the range (2.65–3.32) designated for fish species with fast growing performance [4, 26], indicating that *E. fimbriata* has a slow growth performance in Ebrié lagoon (Aghien-Potou Sector).

Table 2: Comparison of growth parameters for *Ethmalosa fimbriata* with estimates from other studies

Authors	Locations	L_{∞} (cm)	K (year ⁻¹)	(ϕ')
[5]	Grand-Lahou lagoon	17	0.84	2.38
[1]	Sénégal	29.10	0.36	2.48
[30]	Sénégal	27	0.48	2.54
Current study	(Aghien-Potou Sector)	26	0.66	2.64

The estimate of the natural mortality 1.40 year⁻¹ for *Ethmalosa fimbriata* in Ebrié lagoon (Aghien-Potou Sector) could be considered like normal as much as M/K ratio (2.12) for the lagoon specimen is within the range of 1.12-2.50 calculated for most fish populations [7]. Fishing mortality (F : 3.55 year⁻¹) was higher than natural mortality (M : 1.40 year⁻¹) accounting for 71.71% of the total mortality, thus indicating that the population is fishing dominated. [2] observed a similar situation in the cross-river estuary in Nigeria where the fishing mortality (F : 5.30 year⁻¹) was higher than the natural mortality (M : 1.61 year⁻¹). This observation portrayed that *E. fimbriata* could be less vulnerable to natural mortality related conditions. Moreover, natural mortality rate (M) computed from the study was higher than (M : 0.49 year⁻¹) estimated by some researchers [27] in Cross river (Nigeria). The total mortality value (Z : 4.95 year⁻¹) is lower than the one recorded by [4] in Grand-Lahou lagoon (3.66 year⁻¹). This high mortality in Ebrié lagoon (Aghien-Potou Sector) could be explained by the fact that *E. fimbriata* is an important component of the landings of the coastal fishery [28] and the used of beach seine. Sexual maturity value (L_m : 17.33 cm) was higher than the length at first capture L_c or L_{50} (8.26 cm) of the specie recorded in the present study. The size at first maturity value of *E. fimbriata* in the present study was similar to the value (17.5 cm) recorded in Sine Saloum estuary (Senegal) by [13] and higher than the value reported in Aby lagoon by [28] (9.6 cm). Moreover, fish should be allowed to reach sexual maturity prior to exploitation. This is best achieved by making their L_{50} larger than L_m [44]. Instantaneous rate of mortality (Z) of 4.95 year⁻¹ and exploitation rate of 0.72 show fishing pressure on *E. fimbriata*. This is based on the assumption of [19] that in an optimally exploited stock, the natural and the fishing mortality should be equal and $E = F/Z = 0.5$. A similar value of exploitation rate was recorded in the Cross River estuary (0.77) in Nigeria by [3]. This result is confirmed by ratio Z/K (7.5). Indeed, according to [25], if $Z/k < 1$, translates the prevalence of the growth on mortality in a fish population. When $Z/K = 1$, the population is in balance (mortality in balance with the growth). On the other hand, at the time that in a fish $Z/K > 2$, mortality prevails on the growth. The current exploitation rate (0.72) higher than 0.5, $E_{0.5}$ (0.35) and close to E_{max} (0.74) confirms the assertion of overfished of *E. fimbriata* in Ebrié lagoon (Aghien-Potou Sector). This result could be explained by the fact that *E. fimbriata* is a target specie in Ebrié lagoon (Aghien-Potou Sector). It is

caught by several fishing gears such as seines and gillnets. The presence of two recruitment peaks (one major and one minor) from the study was in line with the description of the recruitment pattern for tropical fishes put forward by^[35].

Conclusion

The study has revealed that *E. fimbriata* population in Ebrie lagoon (Aghien-Potou sector) is currently overexploited. Therefore, urgent management interventions in form of monitoring fishing efforts and mesh size regulation (to increase length at first capture) are needed to safeguard this commercially important fish specie from possible collapse in the future.

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