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Population Dynamics of Mangrove Oyster, *Crassostrea gasar* of the Lagoons Ebrié and Aby (Côte d'Ivoire)

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Abstract

(This work characterizes the population dynamics of mangrove oyster, *Crassostrea gasar* of two lagoons of Côte d'Ivoire: the Ebrié lagoon; on the level of Grand-Bassam and Azito and the Aby lagoon; on the level of Assinie. Thus, a monthly sampling of 30 oysters per site for 12 months (October 2015 at September 2016), for each month, the sampled oysters were grouped in size class of 10 mm and treaty with FiSAT II software for the determination of the population dynamics parameters. Thus, the results showed that the site of Azito records the best growth coefficient (1.80 years$^{-1)}$. The coefficient in this locality is 2.05 and 3.10 times respectively higher than that of Grand-Bassam and Assinie. However, the longevity of the specimens of Assinie remains higher (5.17 years) compared to that of Large-Bassam (3.47 years) and Azito (1.67 years). The individuals of the three localities record an average size of 99mm. A similar report is done concerning asymptotic length and the coefficient of growth performance. The recruitment of oysters is continuous all the year. However, of the peaks are observed on the level of each site. It appears in addition that the oysters of the lagoons Ebrié and Aby are in a situation of overexploitation. The data of this study will make it possible to pose the bases of a rational exploitation of mangrove oysters.

Keywords: Population Dynamics; Mangrove Oyster; *Crassostrea gasar*; Lagoons; Côte d'Ivoire.

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1. Introduction

The mangrove oyster *Crassostrea gasar* constitutes an important economic potential and a source of animal protein for the coastal populations and the residents of the towns of many African countries [1]. Indeed, in certain countries like Benin and Senegal, it constitutes a source of animal protein and an important income for the coastal populations [2, 3, 4]. Côte d'Ivoire does not make exception. Indeed, present in its lagoons, in particular, the lagoons Ebrié and Aby, this oyster is subject of an intense exploitation by the bordering populations [5].

However, according to Christensen and Pauly [6], the intensity of fishing can modify the capacity of reception or "carrying capacity" of an ecosystem by deteriorating the structure of trophic flows and their potential productivity. In addition, according [7], anthropic pressure causes a continual degradation of the ecosystems of mangrove, which could upset their functioning and to cause a reduction of the organisms which are present. Vis-a-vis this situation, it becomes imperative to find solutions which could ensure the perennity of oysters of our lagoons. However, that is not possible without knowledge of the dynamics of the population. Thus, this study aims at establishing a data base on dynamics of oyster population of our lagoons. This data base will help to pose an optimal and efficient management to stock available.

2. Material and methods

2.1. Material

- ***Study area***

The sampling of this work was carried out in two coastal lagoons of Côte d'Ivoire. In particular, the Ebrié lagoon and the Aby lagoon. Concerning the Ebrié lagoon, two localities were retained: that of Grand-Bassam and Azito. While Assinie was the only locality retained for the Aby lagoon. The Figure 1 gives a glance of the study zone **(figure 1)**.

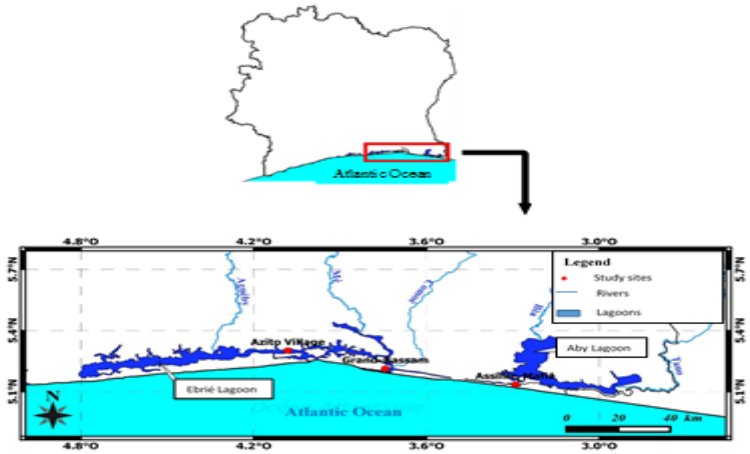


Figure1: Geographical situation of the study sites (Assinie, Grand-Basszam and Azito) on the level of lagoons ebrie and Aby

- ***Biological material***

The study was carried out on a sample of 1080 oysters because of 360 oysters per site. The size of the individuals varied from 53 to 109 mm for Grand-Bassam; from 41 to 112 mm for Assinie and from 44 to 101 mm for Azito. As for the weights, it varied from 17.65 to 105.22g for Grand-Bassam, 26.11 to 155.25g for Assinie and 17.81 to 129.8g for Azito.

2.2. Methods

- ***Data sampling and Processing***

A monthly sampling of thirty (30) oysters was carried out for 12 months. In particular, from October 2015 to September 2016. The various sampled oysters were grouped, for each month, in size class of 10 mm of length (Lt). The different classes of size were subjected to the equation of Von Bertalanffy [8] which is defined as follows:$Lt = L\infty(1 - e^{-K(t-t0)})$. In this equation, Lt is the length at the moment t. L∞ is the asymptotic length, K the growth coefficient and t_0 the age of oyster supposed to the size t_0.These parameters were estimated thanks to ELEFEN 1. (Electronic analyze of size frequencies) [9].

- ***Growth performance index***

Linear growth performance index (Φ') is given starting from the equation of Pauly and Munro [10] according to the formula: $\Phi' = \log10(K) + 2\log10(L\infty)$

While the modal progression is analyzed thanks to the method of Bhattacharya [11].

- ***Longevity (t_{max})***

The longevity (tmax) of the oysters (age to which 95% of the asymptotic size is reached) is estimated through the equation of Pauly [12]:

$$tmax = \frac{3}{K}$$

- ***Recruitment***

Recruitment is characterized by the entry of a lower size group in the stock of the exploitable size group. It is given starting from the distribution of size frequency [13].

- ***Estimate of mortality***

The estimate of total mortality (Z) is made starting from the capture curve. This curve is founded upon the length, at a sample or a presumed stable population. (Data of size frequency with a class of constant size). It uses for its realization, the parameters L∞, K and T. Natural mortality (M) as for it, is determined by the method

of Pauly [14]. As regards the mortality caused by fishing (F), it is determined by the difference between Z and M. The Parameters required for the determination of Z, M and F are L∞, K and T (annual average temperature of the habitat in °C). In the present study, the average temperature was of 28.27°C at Assinie, 28.54°C at Grand-Bassam and 28.08°C at Azito.

As for the rates of exploitation of the specimens (E) and the percentage of survival of the specimens (S), they are given starting from the empirical formula of Pauly [14] and [15]. This formula is as follows:

$E = F/Z$; $S = \text{Exp}(-Z)$ at the age t_0.

The age t_0 is calculated starting from the equation of Pauly [16]:

$$\text{Log10}(-t0) = -0{,}392 - 0{,}275\log10(L\infty) - 1{,}038\log10(K)$$

t_0: theoretical conventional age for which the oyster has a null length; L∞: asymptotic size and K: growth rate.

- ***Analyze of virtual population***

The Analyze of the virtual population (APV) describe the state of exploitation and does the reliable evaluations of the management of stock. It is used to estimate the size of stock and fishing mortality. It is based on the size classes definite, Ft (0.5), M, L∞, K, the recruitment and the allometry coefficients of the relationship of length-weight.

- ***Relative output by recruit (Y'/R)***

The relative output by recruit is expressed by the model of Beverton and Holt [17]. It makes it possible to determine the relationship between the output and the effort of fishing starting from the sizes of first captures. The expression of Y'/R is:

$$Y'/R = EUM/K\left[1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right] \text{ with } m = \frac{1-E}{M/K} \text{ and } U = 1 - \frac{Lc}{(L\infty)}$$

The output of the relative biomass by recruit is determined by the following formula: (B'/R) = (Y'/R) * F

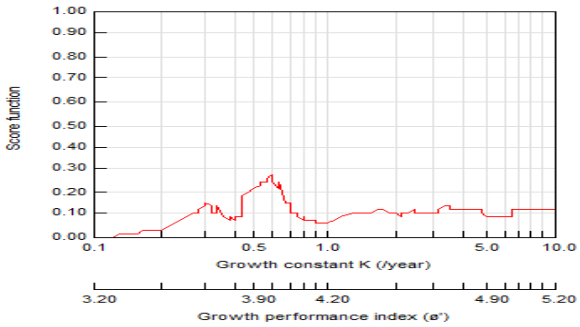
The software FiSAT II, 1.1.0 version, allowed the application of the model of Beverton and Holt [18].

3. Results

3.1. Growth Coefficient

The figure 2 presents the estimated values of the growth coefficient (K) of oysters of the three sites. In particular Assinie, Grand-Bassam and Azito. The analysis of the aforementioned figure shows that the best estimated values of the growth coefficient (K) of the sites of Assinie, Grand-Bassam and Azito are respectively 0.58 year^{-1}.0.88 year $^{-1}$ and 1.80 years^{-1}. Thus, the site of Azito presents the best coefficient of growth. Moreover, the

value of the coefficient in this site is 2.05 and 3.10 times respectively higher than that of Grand-Bassam and Assinie.



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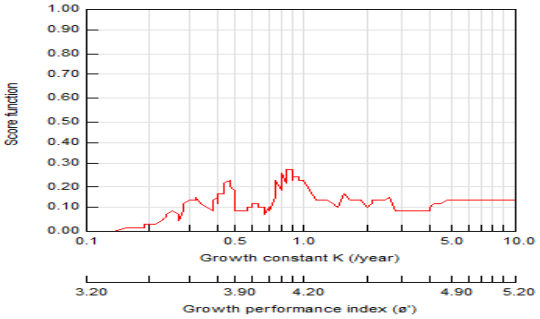

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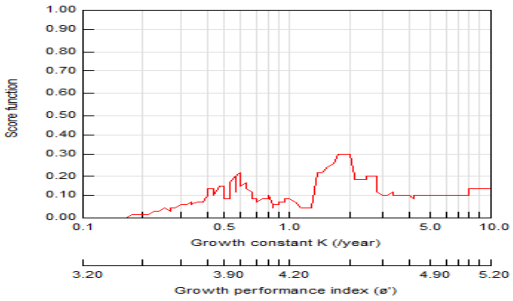

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Figure 2: Growth constant K and growth performance index of Assinie (A), Grand-Bassam (B) and Azito (C)

3.2. Asymptotic length and growth performance Index

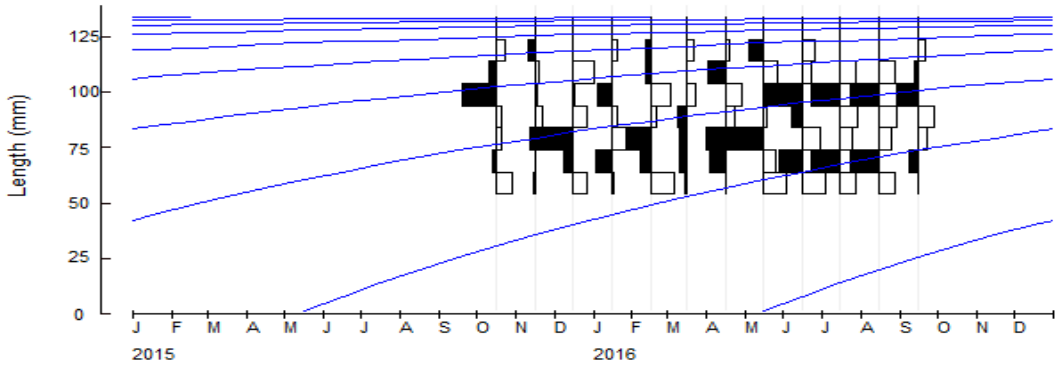
The growth parameters, in particular, the asymptotic length and the growth performance index obtained at *Crassostrea gasar* in the localities of Assinie, Grand-Bassam and Azito are consigned in table 1. The analysis of this table shows an asymptotic length identical to the level of the three sites (135.45). However, with regard to the growth performance index, it differs from one locality to another and the greatest value is recorded in Azito. While Assinie records the low value of this index.

Table 1: Growth parameters of *C. gasar* in the study zones

Localities	Growth parameters		
	Number	L∞ (mm)	Φ'(year^{-1})
Assinie	360	135.45	4.03
Grand-Bassam	360	135.45	4.21
Azito	360	135.45	4.52

3.3. Growth curves of oysters of Assinie, Grand-Bassam and Azito

The growth curves were represented starting from the values of the parameters determined through the restructuring of lengths distribution in figure 3. The asymptotic length reached by the oysters of the three sites of study is equal to 135.45mm. However, the growth (K) coefficient determined in Assinie, Grand-Bassam and Azito, is respectively 0.58 year^{-1}, 0.88 year^{-1} and 1.80 year^{-1}.



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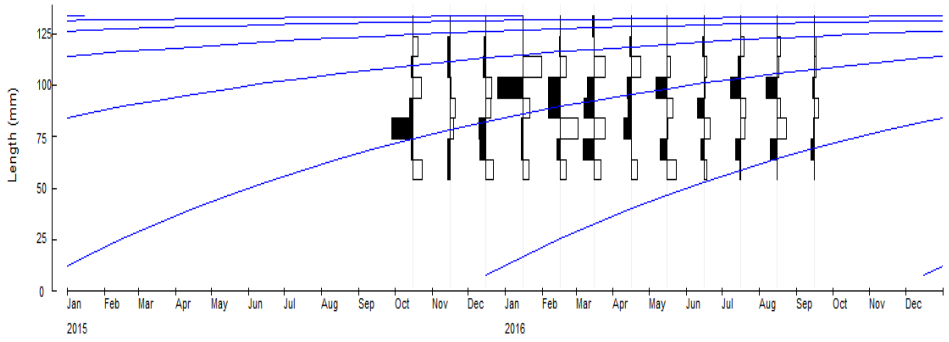

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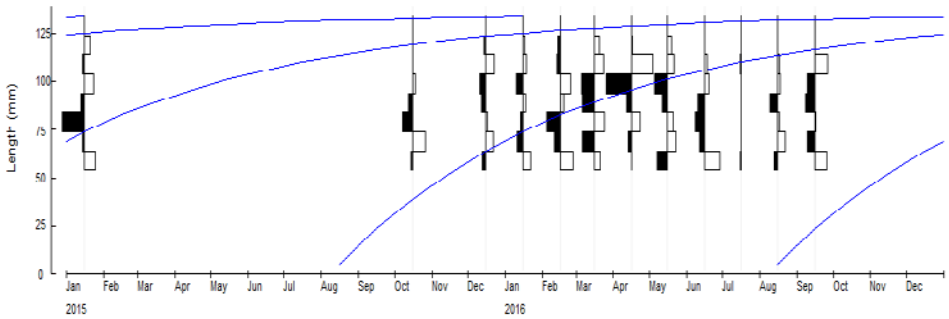

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Figure 3: Oysters growth curves of Assinie (A), Grand-Bassam (B) and Azito (C)

3.4. Estimate of the age t_0 and t_{max}

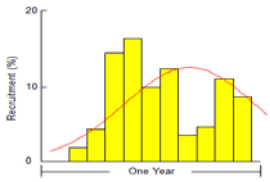
The theoretical age t_0 of oysters of Assinie, Grand-Bassam and Azito, is respectively -0.48 years^{-1}, -0.40 years^{-1} and -0.29 year^{-1} (Table 2). Concerning longevity ($t_{max.}$), it is higher at oysters of Assinie (5.17 years). The longevity of the individuals of this site is 1.52 times and 3.10 times respectively larger than that of Grand-Bassam and Azito. These results show that the specimens of Azito have one lifespan shorter than those of the two other sites.

Table 2: Theoretical age t_0 and longevity ($t_{max.}$), estimated at the oysters of the lagoons Ebrié and Aby

Age	Ebrié Lagoon		Aby Lagoon
	Azito	Grand-Bassam	Assinie
t_0 (year^{-1})	-0.29	-0.40	-0.48
t_{max} (years)	1.67	3.47	5.17

3.5. Recruitment and size of first capture

For each site, recruitment is done upon all the year. However, only one peak of recruitment was recorded in the stock of each site (figure 4). In the locality of Assinie, the recruitment peak was observed in May (12.21%). This peak intervened during the time of Mars to June and has represented 67.23% of annual total recruitment. The period of recruitment of the specimens of Grand-Bassam was carried out during the time going from January to April, with a percentage of 83.21%.The peak of recruitment being located in April with a percentage of 22.93%. This peak pass to 3.85% for the locality of Azito, and takes place in March. Recruitment for this site is intense from January to May and represents 80.42 % of annual total recruitment.



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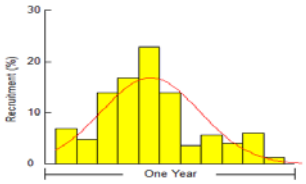
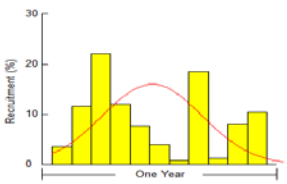




B **C**

Figure 4: Histogram of recruitment of oysters in the population exploitable on the level of the localities of Assinie (A), Large-Bassam (B) and Azito (C) for the period from October 2015 to September 2016

According to table 3, the size of first capture (LC or L50) of the individuals of Assinie is higher than that of the two other localities, in particular, Grand-Bassam and Azito. This size is 105.66 mm at Assinie, 104.05 mm at Grand-Bassam and 98.36 mm at Azito.

Table 3: Sizes of selection of captures of oyster populations exploited in the localities of Assinie, Grand-Bassam and Azito

Localities	L_{25} (mm)	LC or L_{50} (mm)	L_{75} (mm)
Azito	84.45	98.36	112.27
Grand-Bassam	89.76	104.05	118.33
Assinie	91.17	105.66	120.15

L25 = size for which the capture probability is 25%

L50 = size for which the capture probability is 50% (or size of first capture Lc);

L75 = size for which the capture probability is 75%.

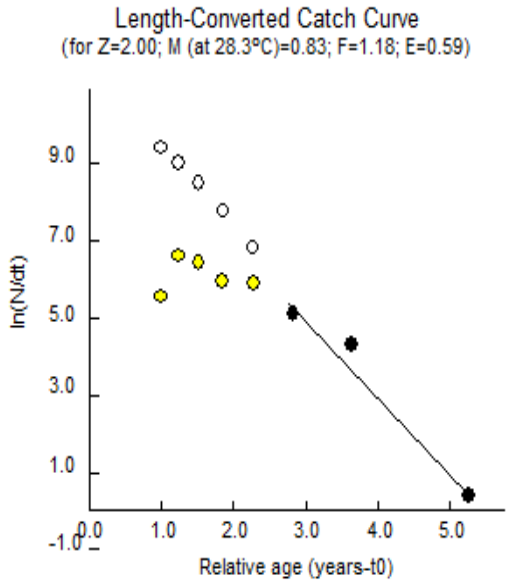
3.6. Mortality parameters

The figure 5 presents the capture curves obtained starting from measurements of size of oysters of the three localities (Assinie, Grand-Bassam and Azito). On the level of Assinie, the average temperature obtained for one years of sampling was 28.27°C.

For this period, total mortality (Z) determined was 2 $year^{-1}$. Natural mortality (M) was 0.83 $year^{-1}$, and in end, mortality by fishing (F) was 1.18 $year^{-1}$. As for exploitation rates (€) and of survival (S), they were respectively 0.59 $year^{-1}$ and 0.135 $year^{-1}$.Compared with Assinie, the values of these parameters know an increase on the level of Grand-Bassam and Azito.

Indeed, the estimated values of the specimens in the locality of Grand-Bassam are: Z = 3.04 $year^{-1}$, M = 1.09 $year^{-1}$, F = 1.95 $year^{-1}$, E = 0.64 and S = 0.048 for an average temperature of 28.54°C. On the level of Azito where the average temperature recorded is 28.06, these values are even higher. Indeed, in this locality, total mortality (Z) determined is 3.34 and 2.19 times respectively larger than that of Assinie and Grand-Bassam. The same report is made as for natural mortality (M) and mortality by fishing (F).

Natural mortality (M) of Azito is 2.08 and 1.59 times respectively larger than that of Assinie and Grand-Bassam. As regards mortality by fishing (F), its superiority at Azito compared to Assinie is 4.19 times and compared to Grand Bassam of 2.54 times.



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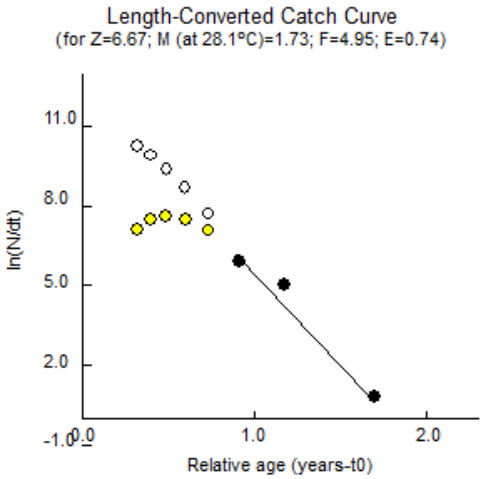
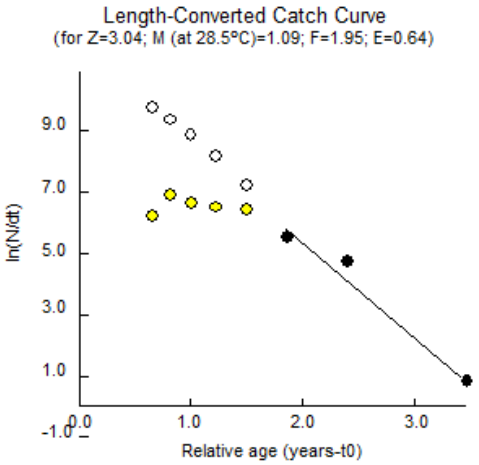




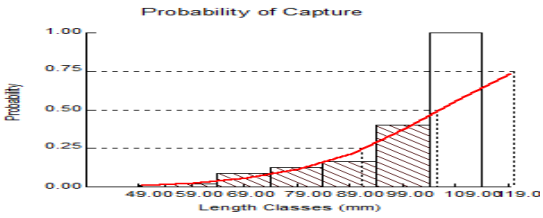
B C

Figure 5: Curve of captures based on the size of oysters in the localities of Assinie (A), Grand-Bassam (B) and Azito (C) for the period October 2015 to September 2017

3.7. Analyze of virtual population (VPA)

- ***Probability of capture***

The size of first capture LC or L50 is estimated at 105.66 mm in the locality of Assinie. At Grand-Bassam, this size is estimated at 104.05 mm. At Azito, the value of the size of first capture is 98.36 mm (figure 6).



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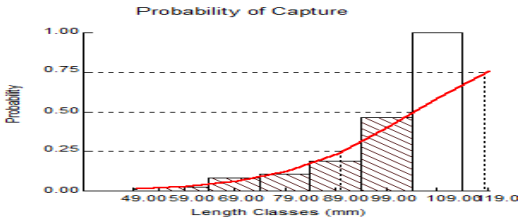
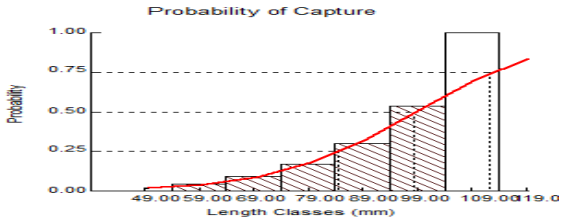


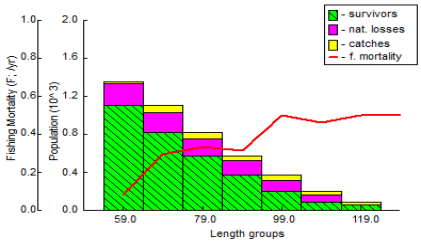


B **C**

Figure 6: Probability of capture of oysters of Assinie (A); Grand-Bassam (B) and Azito (C)

- ***Vulnerability size of stock***

The size most vulnerable at the moment of the oyster fishing in the three localities (Assinie, Grand-Bassam and Azito), is represented by the individuals having an average size of 99 mm (89mm < 99mm < 109mm) (figure 7).



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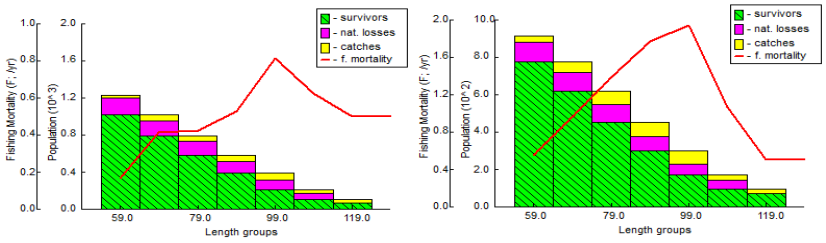


B C

Figure 7: Representation of the rebuilt population of the average biomass of oyster stock and curve of mortality by fishing according to the various classes of size: (A) Assinie; (B) Large-Bassam and (C) Azito

- ***Relative analysis Y/R and B/R by using the warhead of selection (Model of Beverton and Holt)***

The model of relative production per recruit used is based on the model of Beverton and Holt [18] modified by Pauly and Soriono [19]. Growth parameters and exploitation (LC/L_∞, M/K and E) obtained previously have permitted to estimate the relative output by recruit Y'/R and the relative biomass by recruit B'/R (table 4). The tracing of Y'/R and B'/R according to E (F/Z) made it possible to estimate the rates of exploitation Emax, $E_{0.1}$ and $E_{0.5}$ (figure 8). Thus, the table 4 informs about the data of the dynamics of the oyster population by the method of FiSAT. While the figure 8 presents the layouts of Y'/R and B'/R according to E (F/Z) having made it possible to estimate the rates of exploitation E_{max}, $E_{0.1}$ and $E_{0.5}$.

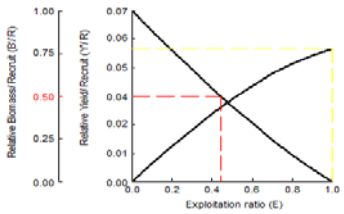
Table 4: Parameters of growth and exploitation of studied oysters**.**

Localities	L_C/L_∞	M/K	$E_{0.1}$	E_{max}	$E_{0.5}$	≤ E
Azito	0.726	0.961	0.857	0.942	0.427	0.74
Bassam	0.768	1.239	1	1	0.439	1.95
Assinie	0.780	1.431	1	1	0.444	0.59

E_{max}: Exploitation with maximum productive output,

$E_{0.1}$: Rate of exploitation for an increase in Y'/R of 1/10ème compared to E=0;

$E_{0.5}$: Value of E under which stock was decreased by 50% of the unexploited biomass.



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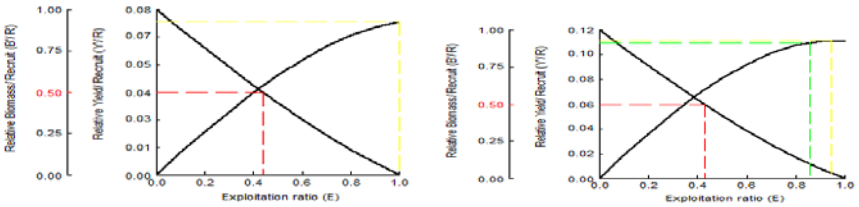

B **C**

Figure 8: Curves of exploitation of *Crassostrea gasar* in the localities of Assinie (A), Grand-Bassam (B) and Azito (C).

4. Discussion

The majority of works relating to the dynamics of the population use as tool for analysis the FiSAT software [20, 21, 22, 23, 24, 25]. Indeed, it allows an efficient management of the mollusc resources and a knowledge of the various parameters relating to the dynamics of the population, such as the estimate of the parameters of growth. In the present study, the execution of the equation of Von Bertallanfy has been used to determine the characteristics of the population dynamics of each site. Indeed, the three sites of study record the same asymptotic length (135.45mm). However, the maximum length observed varies from one site to another. The maximum one at Assinie (112mm) is higher than that of Large-Bassam (109mm) and Azito (101mm). In the same way, the growth coefficient K and the growth performance index (Φ'), vary also from one site to another. These differences observed could be caused by the physico-chemical parameters and possibly to the environmental stress. The results of this work agree with those of Nadira [26]. Indeed, this author had noted during his work made on the moulds, a difference between these same parameters and had allotted this difference to the physico-chemical conditions of the environment. In addition, several works showed that with bivalves, the physical and nutritional condition of the environment [27, 28] and the physiological parameters [29] would have an influence on their speed of linear and ponderal growth. The specimens of Assinie live longer than those of Bassam and Azito. This observation is the resultant of the environmental factors with which the oysters are confronted. In a recent study, it was brought back the data of the physicochemical parameters of each site of study [30]. According to these authors, natural mortalities of oysters are recorded at certain periods of the year on the level of these sites. In this study, mortality (Z) is more significant respectively in Azito, Grand-Bassam and Assinie. In addition, the rate of exploitation (E) obtained in each locality is higher than the standard of 0.5 (Pauly et Munro [31]. These results show that the oysters are overexploited in the localities of study. In Azito, in addition to being consumed, the oysters are used like bait for fishing while in the two other localities, they are intended only for the consumption of the populations. Except the locality of Assinie, the strongest level of recruitment of the species *C. gasar* takes place for the majority in dry season. The desynchronization between times of recruitment on the level of the three sites would be related to the environmental factors. Indeed, the works of Yapi [30] showed that lagoons of Côte d'Ivoire have a salinity lower than 10‰. However, works of Grisel [32] showed that the oyster thrives in environments where salinity varies between 10‰ and 60‰ and the temperature between 27°C and 38°C. Moreover, the results of this work go in the same direction as those of [33, 34]. Indeed, these authors during their work had recorded peaks of recruitments varying from one locality to another. They had allotted the fact to the interactions between the Biological factors, chemical factors and physical factors. However, according to [35], this difference of the period of the peak of recruitment would be due to the difference of the values of the growth rate. The size of the first capture (LC or L50) most vulnerable is that of Azito. This size estimated at 98.36mm is lower in comparison with that of the other localities. These values are appreciably equal to the average size of the exploited individuals (99 mm). Under these conditions, the renewal of stock could be compromised [36].

5. Conclusion

This study reveals that the site of Azito records the best coefficient of growth with a value 1.80 $years^{-1}$. Moreover, the value of the coefficient in this site is 2.05 and 3.10 times respectively higher than that of Grand-

Bassam and Assinie. The specimens of Assinie live longer than those of Bassam and Azito. The average size of the individuals exploited in the various lagoons is of 99mm. However, the oysters of the three localities record the same asymptotic length and a similar growth performance. The recruitment of young oysters in the exploitable population this fact all the year. However, a peak of recruitment is recorded on the level of each locality. This peak varies from one site to another. It arises in addition that the oysters of the lagoons Ebrié and Aby are in a state of overexploitation. With the sight of these results, it would be interesting to push this study by a histopathologic characterization of the oysters of our lagoons.

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