Adaptatives Responses of the Species *Ethmalosa fimbriata* in Biétri Bay, a Highly Disturbed Environment

Moussa Side (Corresponding author)

Université Nangui Abrogoua, UFR SN, Pôle Pêche et Aquaculture, 02 Bp 801 Abidjan 02, Côte d'Ivoire; E-mail: sidmoses@yahoo.fr, Tel: +225-07-07-58-22-03

Eby Yoboué Gnamma Honorine Alla

Université Nangui Abrogoua, UFR SN, Pôle Pêche et Aquaculture, 02 Bp 801 Abidjan 02, Côte d'Ivoire, E-mail: honoeby@yahoo.fr

Behiri Innocent Kakou

Université Nangui Abrogoua, UFR SN, Pôle Pêche et Aquaculture, 02 Bp 801 Abidjan 02, Côte d'Ivoire, E-mail: kakoubehiri001@yahoo.fr

Béatrice Abouo Adepo-Gourene

Université Nangui Abrogoua, UFR SN, Pôle Pêche et Aquaculture, 02 Bp 801 Abidjan 02, Côte d'Ivoire, E-mail: bgourene@gmail.com

Abstract

The growth and size at first sexual maturity of the species *Ethmalosa fimbriata* were studied in two sites in the Ebrié lagoon: Bietri, a highly anthropized environment and Vitré 2, a reference site. Growth parameters estimated from size frequencies showed that growth in both size and weight was faster in females than in males regardless of habitat. On the other hand, specimens from Biétri bay have a slower growth rate than those from Vitré 2. In Bietri bay, individuals are characterized by early sexual maturity. They reach sexual maturity at the age of 0.55 years (about 7 months), corresponding to a size of 6.13 cm for males and 8.42 cm

for females; whereas in Vitré 2, they reach sexual maturity at the age of 0.82 years (about 10 months) corresponding to a size of 10.22 cm and 12.94 cm for males and females respectively. These results show that in a highly antropic environment, the growth of *Ethmalosa fimbriata* is affected and individuals reproduce earlier.

Keywords: Biétri bay; Ebrié lagoon, ELEFAN/FiSAT II, *Ethmalosa fimbriata*, growth, Vitré 2, sexual maturity

1. Introduction

The lagoons, generally shallow areas and confined to the interface of continental and marine waters, are characterized by salinity gradients and variable environmental conditions. In addition to a high degree of natural variability, these coastal areas are exposed to anthropogenic pressures, both industrial and urban. These pressures can lead to various environmental pollutions, which can be the cause of the disappearance of certain animal and or plant species in certain ecosystems Gold (2002). In addition Legendre and Ecoutin (1991) and Duponchelle and Panfili (1998) have shown that certain fish species exhibit ecophysiological adaptations and / or develop adaptations affecting growth and / or reproduction phenomena: variation in growth, dwarfism, maturity early sexual; this in response to environmental disturbances due to increasing anthropogenic pressure.

The lagoon environments in Côte d'Ivoire are no exception to the above considerations. In fact, many studies establish direct links between the state of pollution of the Ebrié lagoon, and the domestic and industrial wastewater that is directly discharged there without any preliminary treatment (Chantraine and Dufour, 1983; Durand et al, 1994). These different aggressions lead to a qualitative and quantitative imbalance in these environments. Moreover, Biétri Bay, one of the bays of the Ebrié lagoon, is considered the most polluted of the Ivorian lagoon system. In this polluted bay, lives and reproduces the clupeid *Ethmalosa fimbriata*. Species which manage to maintain themselves in such an environment exhibit remarkable physiological adaptations. Adaptation can involve changes in reproduction or growth patterns. In Ebrié lagoon, it is one of the most abundant fish species in terms of both number and biomass, and is heavily exploited by the small-scale fishery (Durand *et al.*, 1982). Previous studies have documented changes in the life history features of *Ethmalosa fimbriata* with environmental conditions (Charles-Dominique 1982, Charles-Dominique & Albaret 2003). For instance, the average size at first maturity appeared to be very low in biétri bay, must lower than in the rest of Ebrié lagoon. It ranged between 8.1 and 8.4 cm, for males and females, respectively, in Bietri lagoon, Ivory Coast (Albaret & Charles-Dominique 1982), and 18.5 cm for females in the Gambia River (Scheffers 1976). The low size at first sexual maturity observed in biétri bay could be explained by either an early maturation and/or a dwarfism phenomenon. However, no growth studies has been carried out on this species to demonstrate a decrease in age at maturity in this highly disturbed environment; although the estimation of growth parameters of a species is essential for the study of the dynamics of its population. Indeed, growth parameters are essential to the understanding of general biology and population dynamics data. Knowledge of these parameters also makes it possible to develop certain mathematical models of population dynamics, which are essential for good

demographic analyzes. Thus, the objective of this study is to analyze the growth and sexual maturity of ethmalosis in a highly anthropized environment. This work is a contribution to the scientific evidence required for the implementation of management plans.

2. Materials and Methods

2.1 Study Site

The Ebrié lagoon, the largest lagoon in West Africa, has many bays, including that of Biétri (Figure 1). This bay, generally S-shaped, is generally oriented west-east. Located in the heart of the Abidjan agglomeration, between latitude 5° 15 and 5°18 north and longitude 3° 58 and 4° 00 west, it is a confined environment that communicates with the rest of the lagoon system only through a narrow channel to the west and buzzards with the bay of Koumassi to the east. It has a surface area of 545 ha and an average depth of 3 to 4 metres. The coastline of the Bay of Biétri is characterised by strong urban and industrial activity. It receives the discharge of various and important effluents, i.e. about 18,000m3 per day (Arfi *et al.,* 1981), thus generating a strong pollution of the environment. It is extremely eutrophic and is considered to be the most polluted bay in the Ebrié lagoon (Durand *et al.,* 1994). The Vitré 2 station (5°27 N and 3°74 W) is located in the eastern part of the Ebrié lagoon. This area is considered as a whole as an area with low fishing activity (Durand *et al.,* 1978). This part of the Ebrié lagoon is influenced by the Comoé and Bia river waters. It is a site remote from anthropogenic activities (industrial, agricultural factories, aquaculture, and domestic waste) and considered as a relatively preserved environment, therefore a reference site compared to Biétri bay.
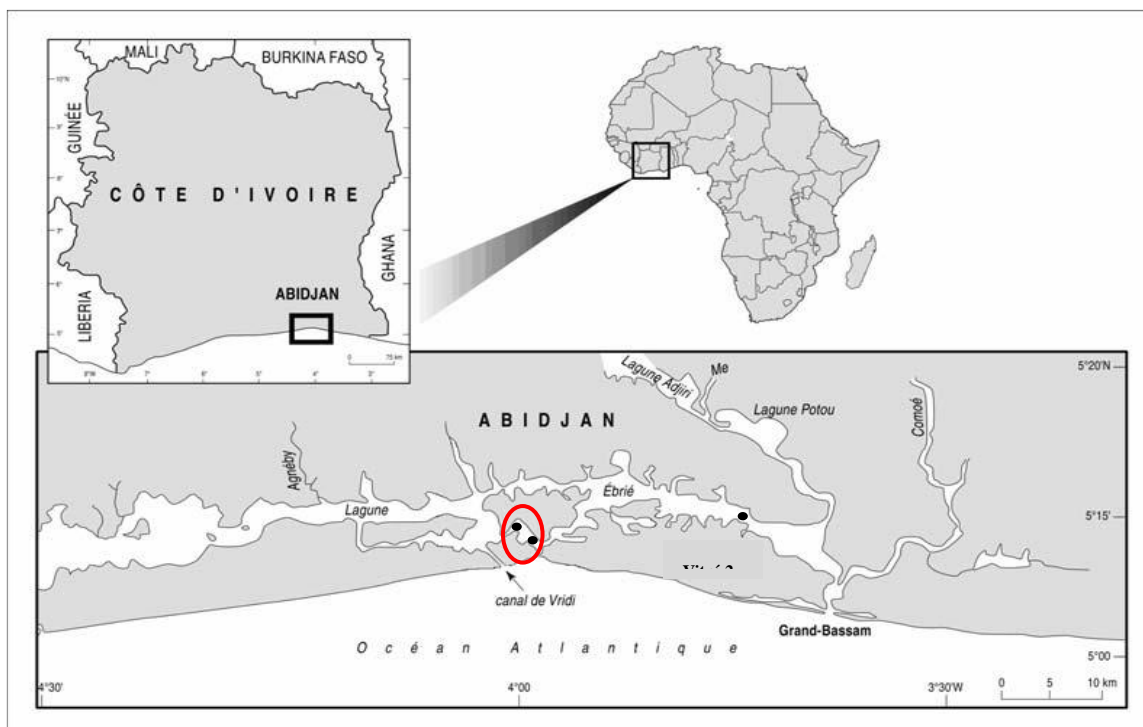
Legend
- Sampling station
- Biétri bay

Figure 1. Location of sampling sites in Ebrié Lagoon

2.2 Data Collection

The fish were sampled twice in the month with an interval of two weeks for a period of twelve months. The fishers used gillnets. At each sampling station, the gillnets were placed at 5 p.m the day before and visited the next day at 6 a.m. Specimens were stored in coolers containing ice and transported to the laboratory for further analysis. In total, 1080 specimens were collected at Biétri bay and 364 specimens at Vitré 2. At the laboratory, the fish were eviscerated and the gonads were collected to determine the sex and stage of maturity. The maturity stage of the gonads was determined macroscopically, following the methods and descriptions of **Fontana (1969).** For each fish, the following morphometric parameters were measured: total length (Lt), standard length (Ls), weight of eviscerated fish (W). Fish size and weight measurements were made using a caliper and an electronic balance.

2.3 Data Analysis

2.3.1 Growth

The study of linear growth was done using Von Bertalanffy's model whose equation is: $L(t) = L\infty * (1 - e - K (t - t0))$

Where L(t) = length of the fish at time t considered,

L∞ = asymptotic length. Theoretically, it's the average size of a fish that can live and grow indefinitely. K= growth coefficient. It characterizes the speed with which the species grows towards L∞.

t0 = theoretical age of fish when its size is zero (year). The parameter t0 has been estimated by the following relation:

$Log10 (-to) = -0.392 - 0.275 Log10 L\infty - 1.038 Log10 K$

The growth parameters L∞ and K were estimated from the ELEFEN I / FISAT II program.

The performance index 'φ' has been estimated from the growth parameters L∞ and K by the following relationship:

$\varphi' = Log10K + 2log10 L\infty$

Longevity or maximum age (t_{max}) is the age that the fish can have when 95% of its asymptotic size L∞ is reached. It was calculated using the formula of **Cailliet *et al.,* 1992**:

$t_{max} = 5Ln2/K$

For several species of fish, weight is related to length by a non-linear relationship expressed as follows:

$W = a Ls^b$

By logarithmic transformation, this equation can be linearized as:

Log W = b log Ls + log a

W: weight (g)

a: Proportionality constant

Ls: Standard length (cm)

b: coefficient of allometry; the latter provides information on the proportionality of linear and weight growth.

If b = 3, the growth is isometric and if b≠ 3 the growth is allometric.

When b > 3, the allometry is major or positive and when b < 3, the allometry is minor or negative.

The weight growth equation is a combination of the length-age and length-weight equations **Gulland and Holt (1959),** expressed as follows:

$W(t) = W_\infty (1 - e^{-K(t-t_0)})^b$

With W (t) the weight at time t and W∞ the asymptotic weight corresponding to L∞

2.3.2 Size at first Sexual Maturity

The size at first sexual maturity L50 is the size at which 50% of the specimens caught are mature. The equation used to estimate sexual maturity is as follows:

P = 1 / 1 + exp – [a + (b. Ls)], Pope *et al*. (1983)

With P the percentage of mature individuals and Ls the standard length.

Ls50 = -a/b

3. Results

3.1 Growth

Table 1. Linear growth parameters of *Ethmalosa fimbriata* in Biétri bay in Ebrié lagoon

Sites	Parameters					Equations
	L∞ (cm)	K (an^{-1})	t$_0$	φ'	Number	
Males	15,96	0,51	-0,397	2,31	631	$L(t)= 17,58*(1-e^{-0,51 (t + 0,397)})$
Females	18,85	0,58	-0,47	2,42	449	$L(t)= 20,16*(1-e^{-0,58 (t + 0,47)})$
All	17,58	0,53	-0,425	2,42	1080	$L(t)= 20,16*(1-e^{-0,53 (t + 0,425)})$

Table 2. Linear growth parameters of *Ethmalosa fimbriata* in Vitré 2 in Ebrie lagoon

Sites	Parameters					Equations
	L∞ (cm)	K (an^{-1})	t_o	φ'	Number	
Males	18,80	0,60	-0,489	2,31	174	L(t)= 18,8*(1-e$^{-0,6\,(t + 0,489)}$)
Females	21,84	0,66	-0,548	2,42	190	L(t)= 21,84*(1-e$^{-0,66\,(t + 0,548)}$)
All	20,16	0,64	-0,526	2,42	364	L(t)= 20,16*(1-e$^{-0,64\,(t + 0,526)}$)

The parameters of the Von Bertalanffy equation obtained are recorded in Tables 1 and 2. The asymptotic size L∞ and the growth constancy (K) of females is greater than that of males regardless of the environment.

The growth coefficient as well as the asymptotic length for all specimens (males + females) of Vitré 2 is higher than those of Biétri bay.
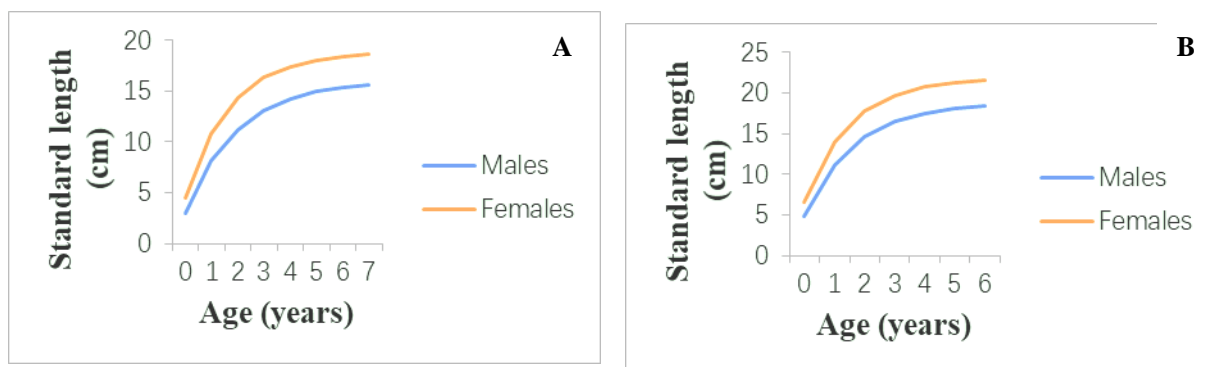

Figure 2. Theoretical linear growth curve of *Ethmalosa fimbriata* in Biétri bay (A) and Vitré 2 (B) in Ebrié lagoon
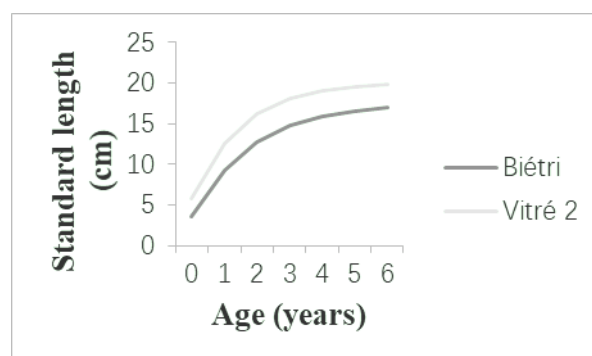

Figure 3. Theoretical linear growth curve of *Ethmalosa fimbriata* (all sex combined) in Biétri bay and Vitre 2 in Ebrié lagoon

The linear growth curves shown in Figure 2 show that growth curves of males and females

have similar gaits. However, it appears that females grow faster than males. Furthermore, a comparative examination of the growth curves of the ethmalosis population (sexes combined) shows that growth of fish from Vitré 2 is faster than that of fish from Biétri bay (Figure 3). This difference in growth manifests itself in the first year of their life and always remains in favor of Vitré 2 specimens.

Figures 4 and 5 show the results of the variation in the relationship between fish weight and standard length in each habitat. There is a strong positive correlation between the two variables that are length and weight; the values of the correlation coefficients r being very close to 1. The values of the slopes of the regression lines (b) obtained are 2.931 for males, 2.934 for females and 2.937 for all (males and females) in Biétri Bay. These b values significantly lower than 3 ($p \leq 0.05$), indicate a minor allometry for this fish. For fish from Vitré 2, the b coefficient value of 2.99 for males is not significantly different from 3, whereas for females and all sexes combined (males + females), the b coefficient value is significantly lower than 3. These results indicate isometric growth for males, whereas for females and in the general population (males + females), growth is characterized by a minor allometry
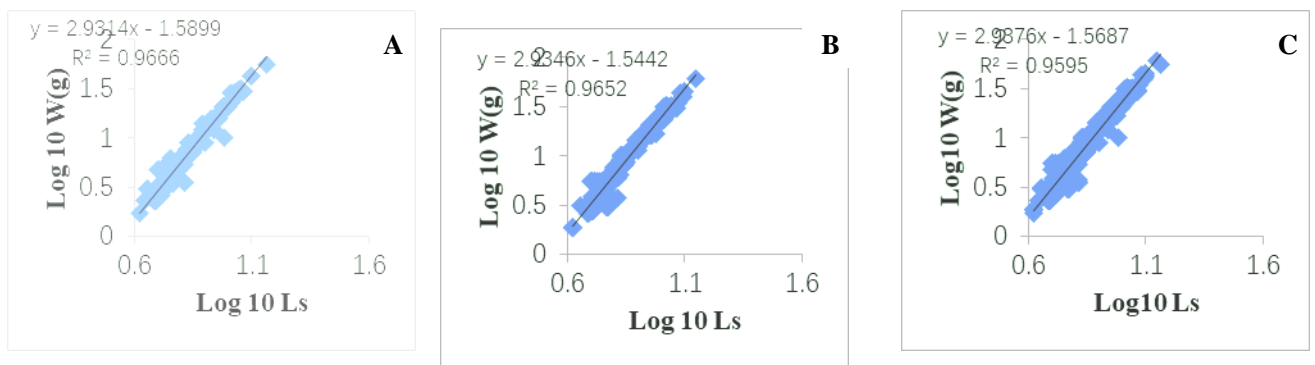

Figure 4. Length-weight relationship of *Ethmalosa fimbriata* for males (A), females (B), and all sex combined (C) in Bietri bay
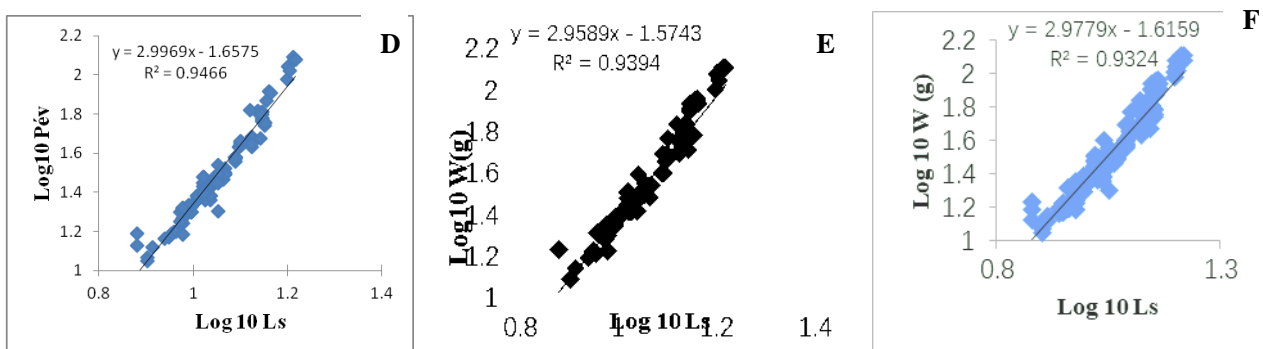

Figure 5. Length-weight relationship of *Ethmalosa fimbriata* for males (D), females (E), and all sex combined (F) in Vitre 2

Table 3. Weight growth parameters of *Ehtmalosa fimbriata* in Biétri bay in Ebrié lagoon

Sex	Parameters					Equations
	P_∞ (g)	K (an^{-1})	t_o	b	φ'	
Males	96,87	0,51	-0,397	2,93	631	$P(t)= 96{,}87*(1-e^{-0{,}53\,(t + 0{,}397)})^{2{,}93}$
Females	123,16	0,58	-0,47	2,93	449	$P(t)= 123{,}16*(1-e^{-0{,}64\,(t + 0{,}47)})^{2{,}93}$
all	116,61	0,53	-0,425	2,93	1080	$P(t)= 116{,}61*(1-e^{-0{,}64\,(t + 0{,}425)})^{2{,}93}$

Table 4. Weight growth parameters of *Ehtmalosa fimbriata* in Vitre 2 in Ebrié lagoon

Sex	Parameters					Equations
	P_∞ (g)	K (an^{-1})	t_o	b	φ'	
Males	144,88	0,6	-0,489	2,99	174	$P(t)= 144{,}48*(1-e^{-0{,}6\,(t + 0{,}489)})^{2{,}99}$
Females	181,27	0,66	-0,548	2,95	190	$P(t)= 181{,}27*(1-e^{-0{,}66\,(t + 0{,}548)})^{2{,}95}$
all	170,74	0,64	-0,526	2,97	364	$P(t)= 170{,}74*(1-e^{-0{,}64\,(t + 0{,}526)})^{2{,}97}$

The weight growth equations obtained are shown in Tables 3 and 4. The curves reflecting these equations show that the weight growth is differential between sexes (Figure 6) and habitats (Figure 7). Indeed, the growth is in favor of females regardless of the habitat. In addition, the weight growth of individuals from Vitré 2 is faster than that of individuals from Biétri bay. At equal size, specimens from Vitré 2 reach a higher asymptotic weight than that of individuals from Biétri bay.
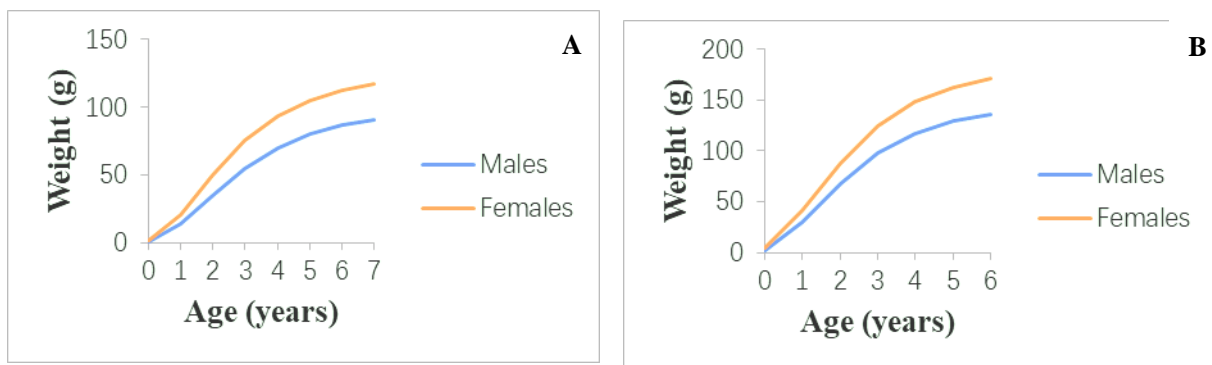

Figure 6. Theoretical weight growth curve for *Ethmalosa fimbriata* in Biétri bay (A) and Vitre 2 (B) in the Ebrié lagoon
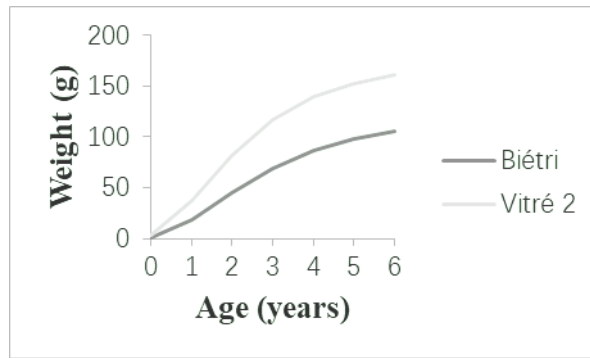
Figure 7. Theoretical weight growth curve (all sex combined) for *Ethmalosa fimbriata* in Biétri bay and Vitre 2 in the Ebrié lagoon

3.2 Size at First Sexual Maturity

In Biétri Bay, size at first sexual maturity is 6.13 cm (Ls) for males and 8.42 cm (Ls) for females. The L50 values obtained for individuals of Vitre 2 are 12.94 cm (Ls) and 10.22 cm (Ls) for females and males respectively (Figure 11). The results of the Chi-deux test reveal that regardless of the site, L50 is not significantly different between sexes. On the other hand, L50 of specimens from Vitré 2 is significantly higher than that of individuals from Biétri Bay.
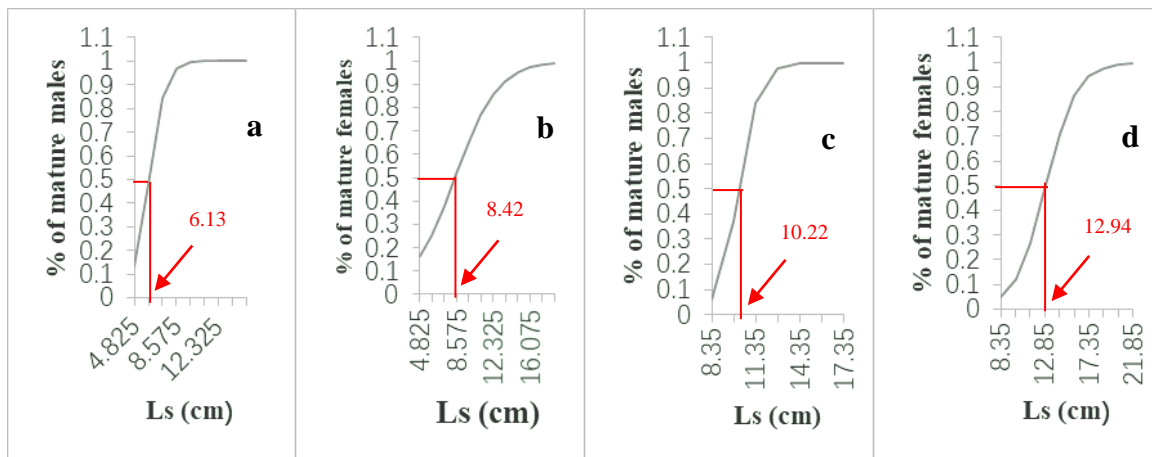

Figure 11. Curve for determining size at first sexual maturity for males (a) and females (b) in Biétri bay, and for males (c) and females (d) at Vitré 2

4. Discussion

4.1 Growth

Growth parameters L∞ and K estimated in this work differ according to the environment. The values (L∞; K) obtained for specimens from Biétri bay (18.85 cm; 0.53 year^{-1}) are lower than that obtained at Vitré 2 (20.16 cm; 0.64 year^{-1}). These values are also lower than that determined by Showers (1996) in Sierra Leone (35.95; 0.9 year^{-1}). Differences in results noted from one environment to another could be due to genetic factors, environmental variables, food availability and population density (Beverton and Holt, 1957; Odo and Inyang, 2001; Francis et Sikoki, 2007).

The analysis of growth curves indicates not only faster growth of female individuals, regardless of their living environment, but also faster growth of Vitré 2 individuals. This difference in growth from one environment to another could be linked to the ecological characteristics specific to each environment such as the availability of food resources, space, temperature and competition between individuals as underlined by Mérona *et al*. (1998) and Poulet, 2004. According to these authors, differences in growth can be observed for the same species from one environment to another. The comparison of the growth of Ethmalosa fimbriata in Biétri bay with that observed for the same species in the sub-region reveals slower growth of specimens from Biétri bay. This slow growth could be an adaptation to the stresses that fish undergo in this environment. Indeed, Biétri bay is a confined area and this bay is described as the most polluted bay in the Ebrié lagoon (Duffor et Slepoukha, (1975); Maurer (1978) and Affian *et al*., 2002). Ethmalosa fimbriata would therefore adapt its growth to maintain itself in this environment. Stresses have effects on the metabolism and growth of fish (Van weerd and Komen 1998). Such differential growth for the same species has also been observed in Gambia and the Siné Saloum (Panfili *et al*., 2004). In Sine Saloum, the quasi-permanent hyper salinity upstream causes much slower growth than in other environments. Indeed, adaptation to such salinities requires osmoregulation and additional energy expenditure (Cardona, 2000; Schallenberg *et al*., 2001; Panfili *et al*., 2004).

Variations in growth, expression of adaptation to various environments, were also reported by Fagade (1974) for tilapia in the Lagos lagoon, by Pauly (1976) for *Sarotherodon melanoteron* in the Sakumo lagoon II (Ghana) and by Lae (1992) in Lake Togo as well as by De Silva *et al*. (1988) in several dams in Sri Lanka for the species *Oreochromis mozambicus*. It is also possible to mention the variations in growth observed for *Oreochromis niloticus* in many African lakes reported by Froese et Pauly (2004). The influence of salinity on the growth of *Mugil cephalus* was also mentioned by Cardona (2000) in the Mediterranean.

The inferiority of the growth performance index (φ') for specimens from Bietri Bay (φ'=2.22) compared to those from Vitré 2 (φ'=2.42) confirms the hypothesis of a slower growth of individuals from Bietri Bay. Furthermore, φ' values collected in the bibliography vary from 2.48 to 2.94. These values are all higher than those obtained for individuals from Bietri bay, thus indicating slower growth of the latter. This situation could be explained by the high population density of *Ethmalosa fimbriata* in Bietri bay. Indeed, in environments with high density, lower growth rate may be due to competition for food.

The analysis of growth coefficients b indicates an allometric growth in favor of length both in Biétri bay (b = 2.93) and in Vitré 2 (b = 2.97). However, some authors have described isometric growth for the same species. Thus, Ecoutin and Albaret (2003) determined for the coefficient b respective values of 3.235 in the Ebrié lagoon and 3.162 in the Sine Saloum (Senegal). Similarly Abowei *et al.,* 2009 in the Niger Delta (Nigeria) obtained a b value of 3.19. The discrepancy between the results could be closely linked to the number of samples or to the pairs of values taken into account to establish the size-weight relationship; the coefficient b increasing with the length of the fish.

4.2 Size of First Sexual Maturity

Knowledge of size at sexual maturity of fish is essential for determining the minimum catch size (Mehanna, 2007). The sexual maturity of individuals is dependent on certain factors (biological and / or ecological). In a natural environment, size at first sexual maturity of fish is linked to the extent of the water body (Fryer and Iles, 1972), to the density of fish (Legendre and Ecoutin, 1989) and to various states of existing stress within fish populations (Lowee-Mc Connell, 1987). In this study, size at first sexual maturity estimated for males and females was not significantly different. The average age corresponds to the size at first sexual maturity is roughly the same for both sexes. It is 0.551 years and 0.552 years respectively for males and females in Biétri bay and 0.82 years for both sexes at Vitré 2. However, males reach maturity at smaller sizes than females. This would be due to the differential growth observed for most teleosts (Toguyemi *et al.,* 1997; Poulet, 2004). In many cases, size differences are associated with gender differences related to the relative distribution of energy for gamete production (Weatherley and Gill, 1987).

The size at first sexual maturity of individuals from Biétri bay is significantly smaller than that of specimens of Vitré 2. These results reveal that specimens from Biétri bay reach sexual maturity at a much smaller size. Similar observations were made by Albaret and Charles-Dominique (1982) in the same bay. These authors note first sexual maturity at a size of 8.08 cm for males and 8.35 cm for females. Two hypotheses were put forward by these authors concerning this reduction in size at first sexual maturity of *Ethmalosa fimbriata* in Bietri bay. The first hypothesis would be that *Ethmalosa fimbriata* reaches sexual maturity early. The second hypothesis would be, on contrary, that in Bietri bay, ethmalosis constitute a population of dwarf individuals having reached sexual maturity at a normal age. The first hypothesis is consistent with our results because the mean age at first sexual maturity of specimens from Bietri bay (0.55 years) is significantly lower than that of individuals from Vitré 2 (0.82 years).

The difference in size at sexual maturity observed between the two study areas is due to the difference between these two living environments. Indeed, for the same species living in different environment, growth and size at first sexual maturity can also be very different (Wague and M'Bodj, 2002). More generally, reduction of size at first sexual maturity for different species may reflect an adaptive response to overexploitation (Smith, 1994). The size of sexually mature fish may be linked to high adult mortality. In a population where adult mortality is too high, fish breed younger. Fishing of ethmalosis is very intense in Biétri Bay. This fish represents 92% of catches (Ecoutin, 1992), this can be one of the causes of the difference in size at the first sexual maturity between these two areas.

Our results confirm the results of previous studies relating to this aspect of reproduction in Biétri Bay. Indeed, Guyonnet *et al*., 2013 found a size at first sexual maturity of 8.08 cm and 8.35 cm respectively for males and females, compared to 12.5 cm for males and 13.57 cm for females in Cocody Bay. Albaret and Charles-Dominique (1982) note the attainment of first sexual maturity at the size of 8.1 cm for males and 8.4 cm for females in Biétri bay. In the sub-region, it varies greatly from one region to another. In Senegal, it is 17.5 cm for males

and 18 cm for females (Diouf, 1996). In Gambia, Panfili *et al*., 2004 found a size of 20.2 cm for males and 19.1 cm for females.

The analysis of different L50 values found in literature reveals that L50 is much smaller in Biétri bay. For Guyonnet *et al*., 2003, this reduction of L50 of *Ethmalosa fimbriata* in Biétri bay is linked to the degree of pollution in this bay. For these authors, L50 is inversely proportional to the extent of pollution. L50 reducing would be a strategy for the species to adapt to extreme environmental stress. Indeed, several studies qualify Biétri bay as the most polluted in Ebrié lagoon. In this environment with particularly unfavorable conditions, ethmalosis would have adopted an adaptation strategy tending to preserve its reproductive potential. Adaptation strategies generally take form of change in reproduction, use of space and / or use of resources. We might therefore think that in Biétri bay, the ethmalosis, to fight against environmental stress, attribute most of its energy to its reproduction and its metabolism to the detriment of the growth of its body. This phenomenon has already been observed in two species of tilapia, *Oreochromis niloticus* and *Oreochromis aureus* in Mariut lake in Egypt (Bakhoum, 1994). A decrease of size at first sexual maturation, adaptation due to stress (hypersalinity, overfishing and / or pollution) was observed by Pauly (1976) in Sakumo lake and by Panfili *et al*., 2004 in the Sine-Saloum estuary. It is also possible to cite variations in reproductive characteristics (size at sexual maturity, reproductive season) due to environmental stress for *Oreochromis niloticus* in several artificial lakes in Côte d'Ivoire as reported by Duponchelle *et al*., 1998) and Duponchelle et Legendre (2001).

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