Reproductive biology of ethmalosis *Ethmalosa fimbriata* (Bowdich) in Bietri bay, an estuarine area of Ebrie lagoon, Côte d'Ivoire

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Abstract: This study on the reproduction of bonga *Ethmalosa fimbriata* in Bietri Bay was carried out between December 2016 and November 2017. On a sample of 1080 specimens, certain reproduction parameters were studied in order to contribute to a rational management and sustainable exploitation of this resource. Parameters such as sex ratio, Gonado-somatic Index (GSI), size at first sexual maturity (Ls50), and fecundity were used to assess reproduction. The results obtained showed that reproduction of this fish is a continuous activity throughout the year with maximum intensity during the long dry season from November to March. The overall sex ratio (1:0.70) revealed a predominance of males over females. The size at first sexual maturity was estimated at 6.13 cm and 8.42 cm respectively for males and females. Absolute fecundity varies from 5363 to 30604 oocytes per ovary with relative fecundity between 110 and 320 oocyte per gram of female body weight.

Keywords : *Ethmalosa fimbriata*, Biétri Bay, Ebrié Lagoon, Reproduction, fecundity

I. Introduction

The clupeid *Ethmalosa fimbriata* is abundant along the West African coast. It is estuarine and tropical fish, distributed from Mauritania to Angola (Charles Dominique, 1982; Levéque et al., 1990). Ethmalosis is one of the main fish species caught along the West African coast with total catches estimated at around 250,000 tonnes in 2011 (FAO, 2011). In Ebrié lagoon, it is the most abundant fish species by both number and biomass, and heavily exploited by artisanal fishing (Durand et al., 1982). It represents more than 75% of catches in Bietri bay, an estuarine area of Ebrié lagoon. However, the stock is very fragile and experienced a collapse in 1981 (Charles-Dominique, 1984).
In Côte d'Ivoire, some scientific investigation has been carried out on the ecobiology of ethmalosis (Gourène et al., 1993; N'goran, 1991; Charles-Dominique, 1982; Gerloto, 1979; 1976; Albaret and Gerlotto, 1976). But, the most recent study in Ebrie lagoon on the reproduction of this species was carried out by Gerloto, 1979. In a context of great variability in estuarine and lagoon environments, these data appear old for analyzing the viability of the species in this environment.
This study aims to update data relating to the biology of Ethmalosis in Biétri bay necessary for the implementation of an eco-responsible management plans for the specie.

II. MATERIALS AND METHODS

2.1. Study site

The Ebrié lagoon, the largest west African lagoon, has many bays, including that of Biétri. It is an estuarine area that is located in the center of the coastal area bordering the city of Abidjan.This bay, generally S-shaped, is a confined environment which only communicates with the rest of the lagoon system through a narrow pass to the west and nozzles with the bay of Koumassi to the east. Its surface area is 545 ha with an average depth of 3 to 4 meters. The coastline of Biétri Bay is characterized by strong urban and industrial activity. It under the influence of marine and continental water supplies linked to the succession of dry and wet seasons. The ebrie lagoon belongs to a transitional equatorial climate region (**Eldin, 1971**). This climate has four annual seasons.The great dry season begins in december and ends in march. The main rainy season extends from april to july. The small dry season sets in from august to september and the small rainy season is between october and november.

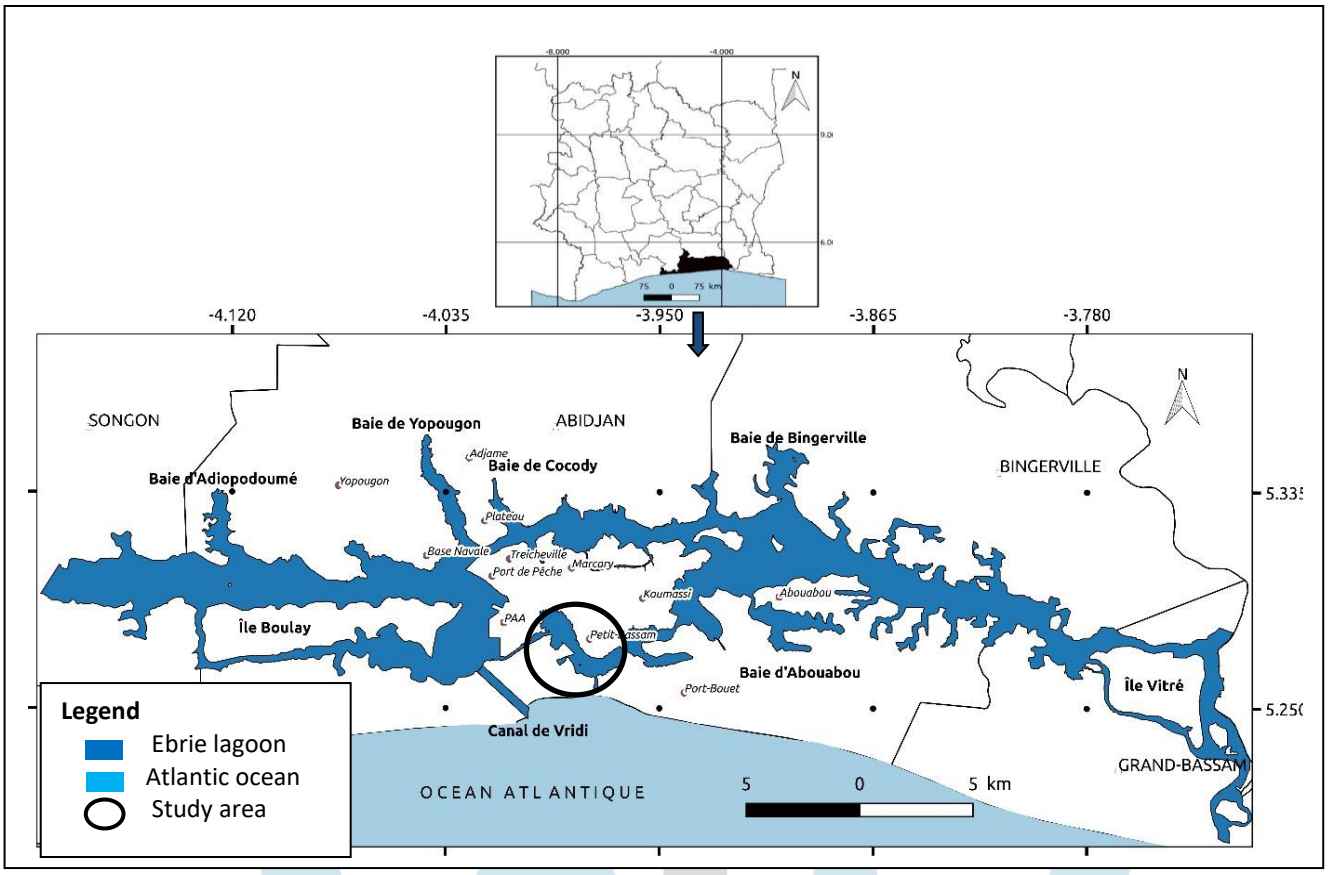


Figure 1 : Location of Bietri bay in Ebrie lagoon

2.2. Sampling protocol

Sampling was conducted from December 2016 to November 2017. The fish specimens used in this study were from experimental and commercial captures. They were captured using gill nets. A total of 1080 specimens were collected. Each specimen was measured with a caliper and weighed with an electronic scale. Gonads were collected and weighed. The sex of each specimen was identified after examination of the gonads according to Fontana (1969) scale. For each fish, the following variables were measured: total length (Lt), standard length (Ls), total weight (Pt), eviscerated weight (Pev), and gonad weight (Pg).

2.3. Study of reproduction

The different measurements and samples allowed the calculation of the following reproductive parameters: sex ratio (Sr), Gonado-Somatic Index (GSI), size at first sexual maturity (Ls50) and fecundity.

2.3.1. Sex-ratio

The sex ratio is the ratio that gives information on the respective proportions of males and females in a given group of individuals.

$$\mathbf{SR} = \frac{M}{F} \quad \text{ou} \quad \mathbf{SR} = \frac{F}{M}$$

SR = sex ratio; M = number of males; F = number of females.

This is an important biological index because the proportion of males and females can affect reproductive success in a given population.

2.3.2. Size at first sexual maturity (Ls 50)

The size at first sexual maturity Ls50 is the size at which 50% of captured specimens are mature. Ls50 is estimated by the following equation :

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

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

$$\text{Ls } 50 = \frac{-a}{b}$$

2.3.3. Gonado-somatic Index (GSI)

The gonado-somatic Index (GSI) is defined as the ratio of gonad weight to eviscerated fish weight. It is used to describe the relative growth gonads to the body mass. The representation of the variations of the gonado-somatic Index as a function of time allows to materialize the different phases of the sexual cycle (Farrugio and Quignard, 1973). In addition to indicating the stage of gonadal development, the shape of the annual evolutionary curve of the GSI can also give an indication of the spawning strategy and period of a species (Mahé et al., 2005; West, 1990). According to Kone (2000), and Fermond (1996), the use of eviscerated fish weight in the formulation is justified by the fact that it eliminates not only the weight of the gonads, but also the ingested food factor (weight of the digestive tract and its contents) which can bias any comparison. A very high GSI indicates an advanced state of gonad maturation. On the other hand, when the GSI is low, the species is in sexual rest state or they are immature (Ouattara, 2000). The GSI allows the estimation of sexual activity and has the advantage of being simple, but is still coarse (Paugy and Leveque, 1999). It is expressed as a percentage of the ratio of gonad weight to eviccated weight. The formula used to evaluate the GSI is the following:

$$\textbf{GSI} = \frac{Pg}{Pév} \times 100$$

Where Pg = weight of gonads (in grams); P = weight of eviscerated fish (in grams)

2.3.4. Fecundity

Absolute fecundity (number of oocytes in an ovary) and relative fecundity (number of oocyte per unit body weight) were assessed to determine the reproductive potential of the specie. Fecundity was determined from oocyte counts in an ovary fraction of known weight. Only the ovaries of mature females were taken into account. The total number of oocytes in the ovary (N) and the relative fecundity (Fr) are calculated by the following formulas:

$N = n \times Pg / P$; $Fr = N / Pt$

N: total number of oocytes in the ovary or absolute fecundity; n: the number of oocytes in the sample;
Pg: ovary weight (g); P: sample weight (g); Pt: total fish weight (g).

2.4. Statistical Analysis

Statistical analysis and graphics were performed with Excel and statistica 7.1. The student t test and chi- square test were used to verify the significance of certains results.

III. RESULTS

3.1. Sex-ratio

Out of a set of 1080 sampled specimens, 631 are males and 449 are females. This corresponds to an overall sex ratio (ratio of males to females) of 1 male to 0.71 females. This sex ratio is significantly different from the theoretical sex ratio (1:1) ($\chi 2$ = 30.47, $p \leq 0.05$) (Table 1). Monthly variation of sex ratio show that sex-rato is in favor of males except for the months of February, December and March. Seasonal variation of sex ratio indicates that females predominate in samples during the long dry season with a sex ratio of 1:1.44 ($\chi 2$ = 11.5; $p \leq 0.05$) while during the other seasons the sex ratio is in favor of males.

3.2. Determination of the percentage of mature individuals in the catches

The percentages of mature and immature individuals are grouped in Table 2. The analysis of this table indicates that out of a total of 1080 fish sampled, 560 or 51.85% have not yet reached the size at first sexual maturity.

Table 1 : Monthly variation in the proportion of male and female specimens and the sex ratio of *Ethmalosa fimbriata*

.Mounth	Number of males	Number of Females	Total	Sex-ratio M : F	χ^2
December	30	47	77	1 :1,56	3,7*
January	42	46	86	1 :1,09	0,18
February	40	62	102	1 :1,55	4,74*
March	29	49	78	1 :1,68	5,12*
April	60	39	99	1 :0,65	4,45*
May	50	30	80	1 :0,6	5*
June	102	33	135	1 :0,32	35,25*
July	87	39	126	1 :0,44	18,28*
August	33	10	43	1 :0,30	12,3*
September	41	33	74	1 :0,80	0,86
October	42	31	73	1 :0,74	1,65
November	75	30	105	1 :0,40	19,28*

Total	631	449	1080	1 :0,70	30,47*
GDS	141	204	345	1 :1,44	11,5*
GRS	299	141	440	1 :0,47	56,76*
SDS	74	43	117	1 :0,58	8,21*
SRS	117	61	178	1 :0,52	17,61*

* : significant difference
GDS = Great Dry Season (November to March) ; GSP = Great Rainy Season (March to July) ; SDS = Small Dry Season (July to September) ; SRS = Small Rainy Season (September to November)

Table 2: Proportion of mature and immature individuals of *Ethmalosa fimbriata* in catches

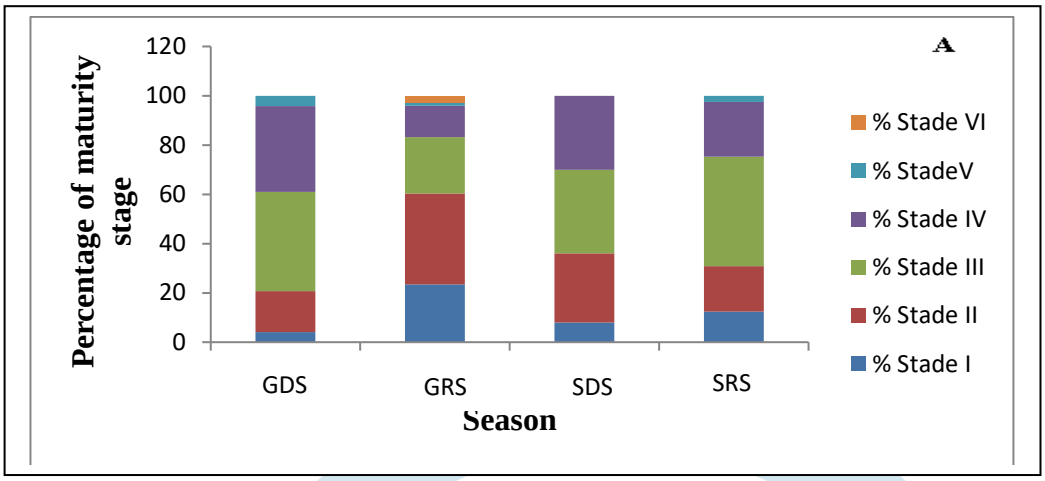
	Maturity degree	Immature individual		Mature individual		Total
	Sex	Number	%	Number	%	
Bietri bay	Males	350	55,46	281	44,53	631
	Females	210	46,77	239	53,23	449
	Total	560	51,85	520	48,15	1080

3.3. Temporal evolution of sexual maturity

The percentages of the different stages of sexual maturity are shown in figure 2. In general, individuals at different stages of sexual maturity are found in samples throughout the year, but with varying proportions. The proportions of mature males and females (stage III, IV, V) are greater than 50% for all seasons, except the main rainy season for which the proportions of mature individuals are 39.59% for females and 24.63% for males. The highest proportions of mature individuals are observed during the long dry season, from December to March, with proportions of 79.3% and 76.13% for females and males respectively. The proportion of mature males decrease progressively from March and reach their lowest values of 10.53% and 12.82% in June and July respectively. The observations are similar for females. Indeed, there is a large period of abundance of mature females from December to March with a peak of 89.48% in December. Immature females (stage I and II) are observed in large numbers in June and July.

3.4. Gonado-Somatic Index(GSI) and reproductive period

Monthly variations of gonad condition were quantitatively determined by following GSI values. Figure 3 illustrates the variations of the GSI. The mean monthly GSI ranged from 1.5 to 5.08% and from 1.95 to 9.61% for males and females respectively. In general, the amplitude of variations in the GSI of males is lower than that of females. However, mature individuals were observed in both males and females throughout the year.The temporal evolution of the Gonado-Somatic Index (GSI) highlights two peaks of the GSI for females. The first with a value of 9.61% was observed in December and the second with an amplitude of 8.9% occurred in October. In addition, there are secondary peaks. For males, two peaks of lower amplitude than that of females are also observed. The first peak, with a value of 5.08%, is observed in January and the second peak, with a value of 4.91%, is observed in November. The lowest GSI value for both sexes was recorded during the long rainy season. This minimum GSI value (1.55%) is reached in May for males and females (1.95%) in July.



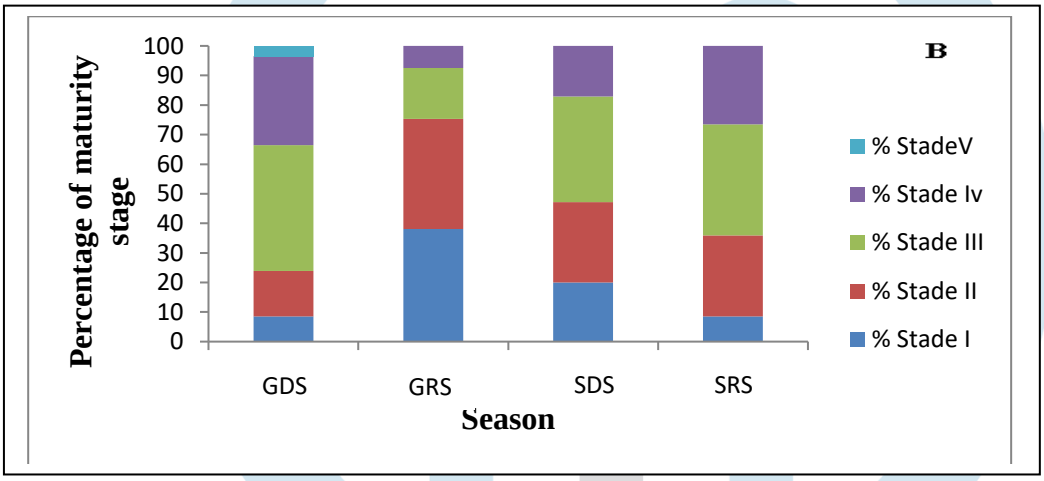


Figure 2: evolution of proportions of the different stages of sexual maturity of male (A) and female (B) specimens according to the seasons

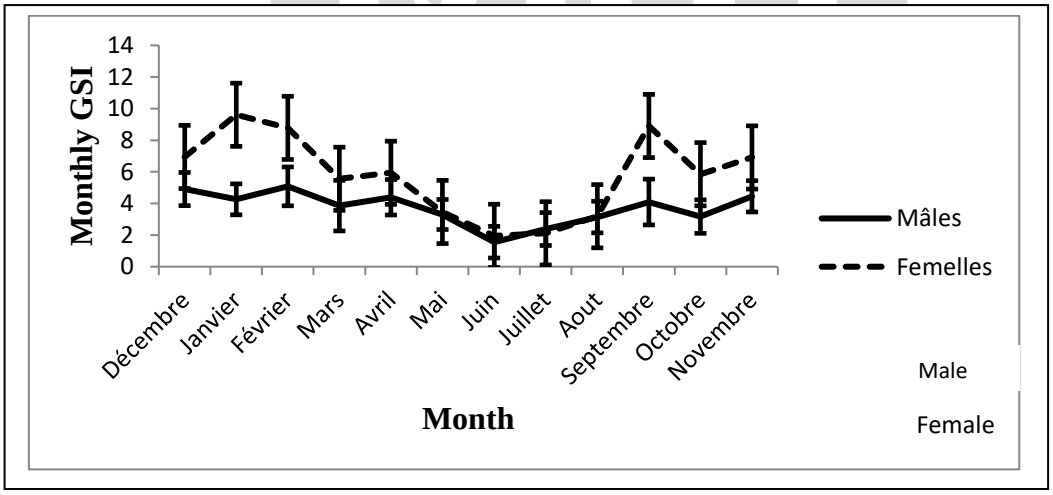


Figure 3 : monthly evolution of the gonado-somatic index (GSI) of *Ethmalosa fimbriata*

3.5. Size at first sexual maturity

The size at first sexual maturity (Ls50) was estimated at 6.13 cm for males and 8.42 cm for females (Figure 4). The difference in size at first sexual maturity between sexes was not significant ($\chi^2 = 0.02$; $p > 0.05$). The smallest mature individual obtained was 5.4 cm for males and 5.7 cm for females.

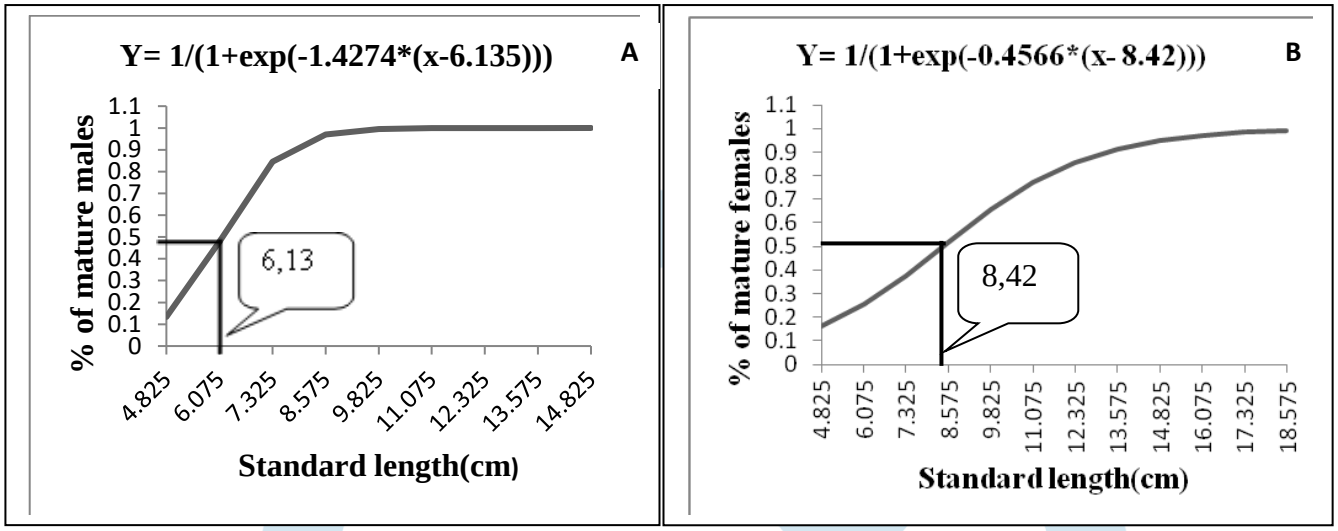


Figure 4 : size at first sexual maturity of males (A) and females (B) *Ethmalosa fimbriata*

3.6. Fecundity

The number of oocytes per ovary (absolute fecundity) varies from 5363 to 30604 oocytes with a mean value of 12482 oocytes for a standard length between 12,1 and 21,5 cm and a weight between 48,7 and 95,6 g. The relative fecondity was between 110 and 320 oocytes per gram of body weight, with an average value of 269 oocytes.

IV. DISCUSSION

No apparent outward character of sexual dimorphism has been observed in bonga. For all Ethmalosa fimbriata catches, the sex ratio of 1 male to 0.7 female indicates a predominance of males over females. This result corroborates the work carried out by Boely et al. (1976) and Scheffers et al (1976) in Senegal. This sex ratio in favor of males could be explained by a stronger resistance of males to pollution compared to females. As a result, the longevity of the latter would be greater than that of females, hence the presence of a greater number of male individuals. However, the seasonal variation of sex ratio reveals a predominance of females during the long dry season. This seasonal variation in the sex ratio could be due to reproductive activity. Indeed, for E. fimbriata, spawning is collective and takes place in open water. During the spawning period, fish are agitated on the surface and shortly after eggs can be collected from the surface of the water (Albaret and Gerlotto, 1976).This phenomenon could lead to greater vulnerability of females during this period and would thus justify the high number of females in catches during the long dry season from December to March.

During the sexual cycle, ovarian and testicular weight variations are synchronous. The evolution of the GSI coupled with the variations of the macroscopic stages of sexual maturation show that the reproduction of *Ethmalosa fimbriata* is a continuous activity due to the fact that mature females were encountered throughout the year. However, this activity is maximal during the long dry season (December to April). Albaret and Gerlotto (1976) showed that the spawning period of ethmalosis in Ebrié Lagoon is spread over several months, from November to June. N'Goran (1995) determined two reproduction periods for the same species in Aby lagoon, very close together in the year. The first one takes place from February to June followed by a second one from July to August. Moreover, the reproduction periods of ethmalosis found in literature vary according to the region. In Senegal, Scheffers et al. (1972) observed a breeding period from March to August, January to June in the Sine Saloum (Faye et al. (2014)). In Sierra Leone, ethmalosis reproduction occurs from July to January (Salzen, 1958).

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 the natural environment, the size at first sexual maturity of fish is related to the size of the water body (Fryer and Iles, 1972), the density of fish (Legendre and Ecoutin, 1989) and various stress states existing within fish populations (Lowe-Mc Connell, 1987). In this study, size at first sexual maturity of males and females were not significantly different. This size is 6.13 cm and 8.42 cm for males and females respectively. In the sub-region, size at first maturity is much larger, and varies greatly from one country to another. In Senegal, it is 17.5 cm for males and 18 cm for females (Diouf, 1996). In Gambia, Panfili et al (2004), recorded the size of 20.2 cm for males and 19.1 cm for females. This size differences observed between the different areas would be due to the difference of the different living environments. Indeed, for the same species living in a different environment, growth and size at first sexual maturity can also be very different (Wague and M'Bodj, 2002).

In this study, absolute fecundity ranged from 5363 to 30604 oocytes with a mean value of 12482 oocytes and relative fecundity ranged from 110 to 320 oocytes per gram of body weight with a mean value of 269 oocytes. These results are comparable to

those of Albaret and Gerlotto, 1976). These authors indicated a value of 150 to 300 oocytes per gram of female. However, the relative fecundity found in the present study is different from that of Fagade (1974) in Nigeria which is 500 oocytes. The fecundity study reveals that ethmalosis has a very high fecundity. This high productivity could be a reproductive strategy of the species to limit the effects of environmental instability. This reproductive strategy based on maximizing the number of eggs produced is intended to increase the probability that at least a fraction of the population will reach recruitment and thus ensure the survival of the species.

V- CONCLUSION

The present work has allowed to bring elements to the knowledge of the biology of *Ethmalosa fimbriata* in Biétri Bay. The reproductive parameters such as the sex ratio, the size at first sexual maturity and the fecundity were estimated. The reproductive period was determined by following the evolution of the different stages of sexual maturity, and the monthly variation of GSI. These data can be used as a basis for rational management of the species. For the sustainable management of *E. fimbriata*, nets with mesh sizes that allow the capture of individuals with a standard length of less than 8.42 cm should not be allowed in water bodies.

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