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Reproductive Biology of *Ethmalosa fimbriata* (Bowdich) in Senegalese Coastal Waters

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Abstract

Ethmalosa fimbriata is a very abundant species in marine and estuarine waters of Senegal. It is caught only by artisanal fisheries. Some aspects of its reproduction are studied in order to provide some contribution to a rational and sustainable management of the fishery. To evaluate the reproduction of *Ethmalosa fimbriata*, the sex ratio, the size at first maturity, the evolution of sexual maturity stages and the gonadosomatic index (GSI) were used. The results show that the sex ratio is 46% of males and 54% of females in the estuary while at sea it is 42% of males against 58% of females. Size at first maturity is 16.2 cm for males and 17.5 cm for females in the estuary, while at sea these sizes are respectively equal to 17.2 and 18.7 cm for females and males. The main breeding periods are during the cold season in the estuary and the hot season at sea. *Ethmalosa fimbriata* is a species with small eggs and high fecundity. The absolute and relative fecundity are higher in the estuary than at sea.

Keywords: *Ethmalosa fimbriata*, Estuary, Sea, Reproduction, Fecundity.

1. Introduction

Most of the landings of the artisanal fisheries of Senegal consist of small pelagic. *Ethmalosa fimbriata* is one of the most important small pelagic inhabiting coastal and estuarine waters of Senegal. In 2009, catches of *Ethmalosa fimbriata* were estimated at 6000 tons, about 2 percent of the total catch of small pelagic species in Senegal (FAO, 2011). The report of the Working

Group of the FAO (2010) on small pelagic in the region of North-West Africa, considers that the Bonga stock in this region is fully exploited. Catches of Bonga decreased from 13 000 tons in 2003 to less than 6 000 tons in 2006, a decrease of over 45%. The Bonga catches in The Gambia and Senegal show a downward trend since 2003, with some fluctuations. In the Senegambian region, Bonga stock is overexploited. This operating level concern mainly small sizes (FAO, 2011). This overexploitation is the result of consuming plenty of bonga in Senegal, its export in the sub-region, but also a lack of a management of its fishery.

Biology of *Ethmalosa fimbriata* has been the subject of previous studies in Senegal by Blanc (1951) and Boely Elwertowski (1970); Scheffers et al. (1972); Scheffers (1973); Conand and Scheffers (1976), Diouf (1996); Panfili et al. (2004). Its biology has also been studied in other West African countries (Gambia, Ivory Coast, Nigeria, Sierra Leone, Cameroon, Ghana, etc.). In Senegal, the first biological data back from the 1950s and 1970s. The most recent study in Senegal on this species was made by Panfili et al. (2004) in the Saloum estuary. It appears from this literature review that available biological data on *Ethmalosa fimbriata* still remain insufficient and old for fishing in Senegal.

It was recommended by the COPACE (2012) a biological sample of *Ethmalosa fimbriata* for different fisheries of Senegal to estimate biological parameters. The objective of this study is to contribute to the updating of biological data of *Ethmalosa fimbriata* by the studying its reproduction for better monitoring and good management of its fishery.

2. Materials and Methods

2.1 Sampling Sites

Sampling is performed in major centers landings in the region of Thies: Mbour (14°24' 42'' N and 16°57' 57'' W) and Joal (14°10' 00'' N and 16°49' 59'' W), and Fatick Saloum Island (Foundiougne: 14°07' 59'' N and 16°28' 00'' W).

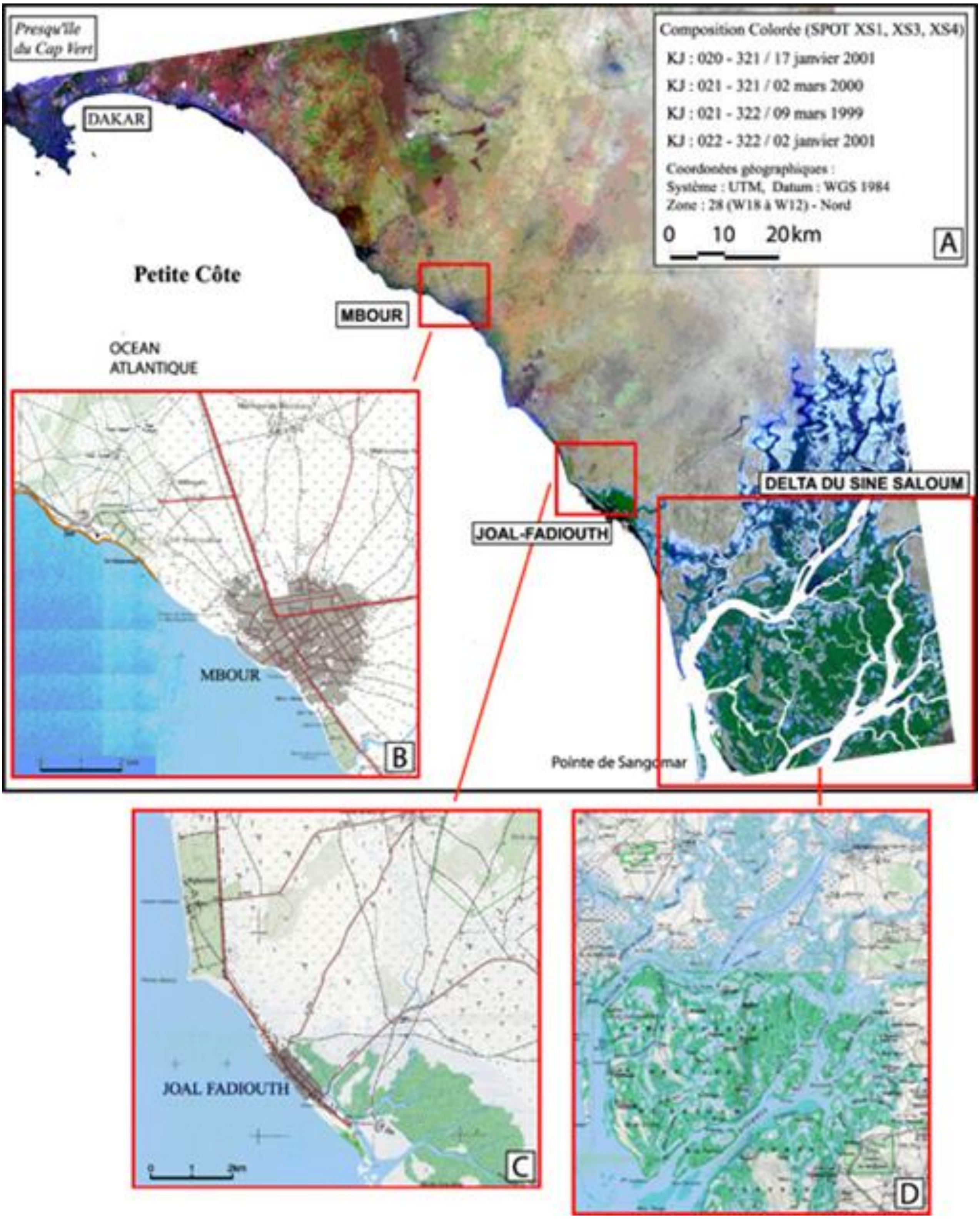

Figure 1. Location map of the sampling sites (Source: http://www.vertigo.revues.org/docannexe/image/2206/img-1.jpg)

2.2 Sampling Strategy

Sampling was realized in large centers landings of Mbour and Joal (sea) and Sine-Saloum (estuary). The samples were collected monthly from March 2012 to February 2013 and from catches of commercial scale fishing. We did not get samples at Mbour and Joal (sea) in April and October 2012 because there was no landing of *Ethmalosa fimbriata*. Sampled fish were and measured with a graduated rule and weighed with an electronic balance. In total, 1197 fish of which 547 at sea and 650 in estuary were measured and weighted. The variables studied are the total length (Lt), the fork length (Lf), standard length (Ls): total weight (Pt), eviscerated weight (Pev), gonad weight (Pg).

2.3 Study of Reproduction

The sex ratio is defined as the proportion of male or female individuals in relation to the total workforce. It gives an idea about the gender balance within the population. The sex ratio is expressed in this study as a percentage of males and calculated according to the following formula (Layachi et al 2007):

$$SR = M \times 100 \times \frac{1}{(M + F)}$$

Where SR = Sex ratio, F = female and M = male.

The size at first sexual maturity (L50) is the length at which 50% of fish are sexually mature (Fontana, 1969; Conand, 1976). The percentage of size class (1 cm intervals) females or males which have reached stage III was calculated relatively to the total number of sexually mature females or males during the spawning period. A logistic function between the percentages of mature fish and the average length of the interval (Ghorbel et al. 1996) was used. This function is written:

$$\%M = \frac{100}{1 + e^{-a(Lf - L_{50})}}$$

Where %M is the percentage of mature fish by size class; L50: the size at first sexual maturity Lf: center class fork length, a: parameter of the relationship.

Determining the breeding season was realized with changing sexual maturity stages and changes gonadosomatic index (GSI). The percentages of sexual stages relative to the total number of females sampled were calculated. Stages I and II are grouped and considered as immature and from stage III, all individuals are considered mature. Only females were considered for the study of the evolution of sexual maturity stages because their sexual maturity stages are easier to recognize (Fontana, 1969). Gonadosomatic index (GSI) is the percentage of gonad weight relative to eviscerated weight (Bougis, 1952). This ratio is given by the following formula:

$$GSI = \frac{Pg}{Pev} \times 100$$

Where Pg: gonad weight and Pev: weight of eviscerated fish.

The absolute fecundity (number of oocytes in the ovary) and relative (number of oocytes per unit of body weight) were estimated in order to determine the reproductive potential. Absolute fecundity (FA) was determined from the number of oocytes present in a fraction of ovarian stage IV or V on the total weight of the gonad. The relative fecundity (FR) is obtained by dividing the absolute fecundity by eviscerated weight. Relative fecundity is used to compare the fertility of fish from diverse backgrounds (Albaret and Dominique, 1982).

Absolute fecundity:

$$AF = \frac{n \times Pg}{P}$$

Relative fecundity:

$$RF = \frac{AF}{Pev}$$

Where AF = absolute fecundity, RF = relative fecundity, n = the number of oocytes in the sample of 0.05g Pg = the ovary weight (g), P = weight of sample (g), Pev = eviscerated weight (g).

2.4 Statistical Analysis

Statistical analysis and graphics were performed with Excel and R. The Student t test and chi-square test were used to verify the significance of certain results.

3. Results

3.1 Sex Ratio

The observations made on different samples from the estuary and the sea led to the gender distribution of *Ethmalosa fimbriata*. This species exhibits a sex ratio slightly in favor of females (54%) compared to males (46%) in the estuary. However, at sea, the percentage of females (58%) is slightly higher than that of males (42%). The sex ratio by size class in the estuary indicates that males are more numerous in the smaller sizes (Figure 2). Beyond 20 cm, females are becoming more numerous in the samples up to 100% (Figure 2). At Sea, beyond 18 cm the sex ratio per size class is in favor of females (Figure 3).

Figure 2. Sex ratio by size class of *Ethmalosa fimbriata* in estuary

Figure 3. Sex ratio by size class of *Ethmalosa fimbriata* at sea

3.2 Sexual Maturity

The size at first maturity, size at which 50% of individuals are mature (L50) is 16.20 cm for males and 17.50 cm for females in the estuary (Figure. 4). The difference in size at first maturity between the sexes was significant ($p < 0.05$). The L50 values found at sea (Figure 5) for females (18.70 cm) and males (17.20 cm) were significantly different ($p < 0.05$).

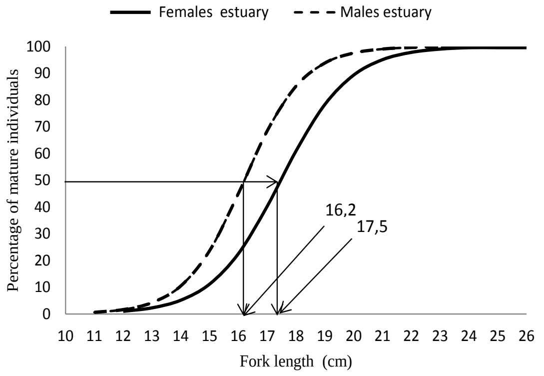

Figure 4. Size at first sexual maturity of males and females *Ethmalosa fimbriata* in estuary

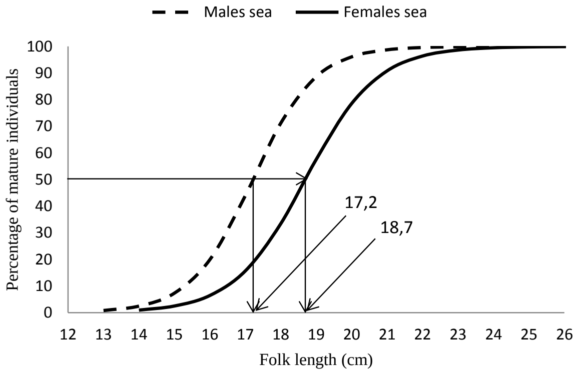

Figure 5. Size at first sexual maturity of males and females *Ethmalosa fimbriata* at sea

3.3 Periods of Reproduction

3.3.1 Evolution of Sexual Maturity Stages

These figures 6 and 7 showed the evolution of sexual maturity stages of females in estuary and at sea. The stages of pre-spawning and spawning (IV and V) are more represented in the cold season (November to May) in estuary. But at sea these stages are more frequent in the hot season (June to October). For now, we can assume the reproduction occurred during the cold season in the estuary and in the hot season at sea.

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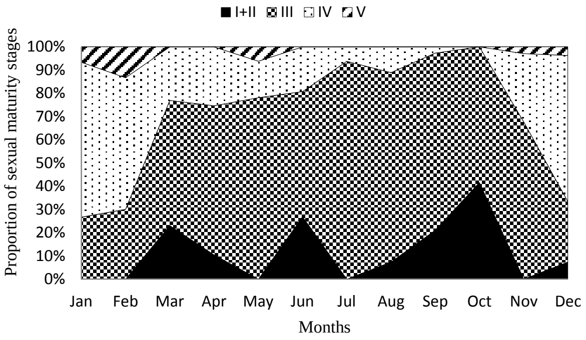

Figure 6. Evolution of the stages of sexual maturity of female *Ethmalosa fimbriata* in estuary

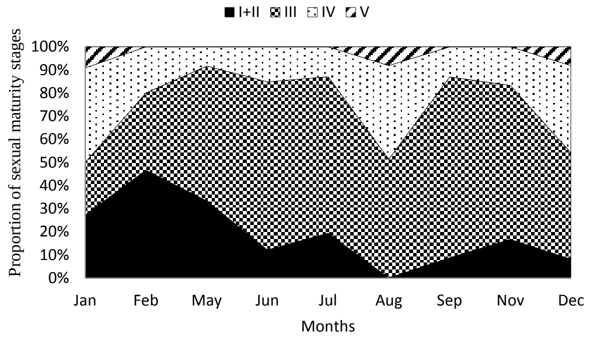

Figure 7. Evolution of the stages of sexual maturity of female *Ethmalosa fimbriata* at sea

3.3.2 Gonadosomatic Index (GSI)

In estuary, spawning covers a long period of the year (Figure 8). However, it is more intense from January to June (cold season) with a single peak in April (4.27). The GSI is significantly higher in the estuary during the cold season ($p < 0.05$). Figure 9 shows that the reproduction is spread throughout the year at sea. But, sexual activity of *Ethmalosa fimbriata* is significantly greater during the hot season ($p < 0.05$). The maximum period of gonadal maturation was observed in August (5.57).

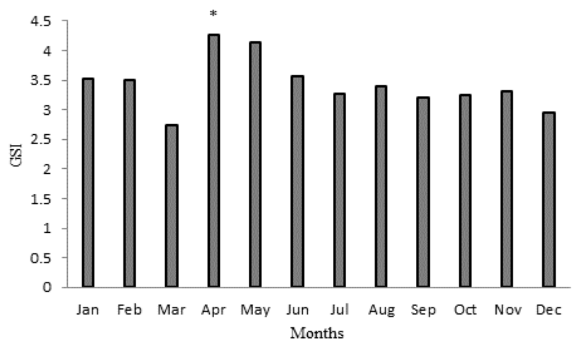

Figure 8. Monthly gonadosomatic index (GSI) of *Ethmalosa fimbriata* estuary

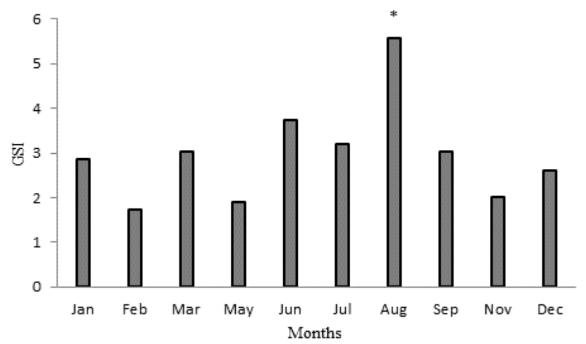

Figure 9. Monthly gonadosomatic index (GSI) of *Ethmalosa fimbriata* at sea

3.4 Fecundity

At sea, absolute fecundity and relative fecundity are respectively equal to 50694 and 257 eggs per gram of female. However, in estuary, the two fecundities are respectively equal to 51083 eggs and 317 eggs per gram of female. *Ethmalosa fimbriata* has a very high fecundity. The difference between absolute fecundity at sea and estuary is not significant ($p > 0.05$). However, the relative fecundities in both environments are significantly different ($p < 0.05$).

4. Discussion

4.1 Sex Ratio

In estuary, the sex ratio expressed as a percentage of male is equal to 46% while at sea it is 42 %.These results are in agreement with those of Gerlotto (1979) in Côte d'Ivoire; Scheffers et al. (1976) in The Gambia; Fagade and Olanyan (1972) in Nigeria and Olsen and Lefevere (1966) in Nigeria . However, the results of Boely et al. (1979) and Scheffers et al. (1972) in Senegal; Olsen and Lefevre (1966) in the Niger Delta, as well as those of Salzen (1958) in Sierra Leone, showed a sex ratio in favor of males. The sex ratio in favor of females could be due to factors such as the movement for search of food and growth differential between the two sexes (Panfili et al. 2004). Indeed, the sex ratio often reflects the adjustment mechanisms in food availability (which is also depending on the density). In Clupeidae, the number of females is slightly often higher than males (Boely et al. 1979).The predominance of females in large sizes during breeding periods would be due to a greater vulnerability during this period. The effect of fishing gear may be one of the causes. Females being larger than males in large classes generally, they may be more vulnerable to a given mesh (Gerlotto 1979). The hypothesis of a higher natural mortality for males is not to exclude (Caverivière, 1982).

Table 1. Sex ratios *Ethmalosa fimbriata* percentage of male according to various authors

Countries	Sex-ratio	Number of individuals	Authors
Estury (Senegal)	46%	650	Present study
Sea (Sengal)	42%	547	
Senegal	50%	667	Boely and Elwertowski (1979)
Senegal	50%	3259	Scheffers et al. (1972)
Gambia	29%	2337	Scheffers and Conand (1976)
Gambia	45%	13962	Scheffers and Conand (1976)
Ivory Coast	35%	852	Gerlotto (1979)
Sierra Leone	54%	2265	Salzen (1958)
Nigeria	47%	348	Fagade and Olanyan (1972)
Niger	63%	-	Olsen andLefevere (1966)

4.2 Sexual Maturity

The analysis of fish during the breeding season, indicate that 50% of females are mature from 18.7 cm at sea and 17.5 cm in estuary. This percentage is reached from 16.2 cm for males in estuary and 17.2 cm at sea. Size at first sexual maturity depends on the growth of individuals. These differences in size are associated with gender differences related to the relative distribution of energy in the production of gametes (Weatherley and Gill, 1987). Males reach sexual maturity earlier than females. Indeed, males mature and grow and die rather less rapidly than females (Al -Hakim et al. 1980). The size differences observed between the same sexes of the two areas would be due to the difference of the two living environments. Thus, for the same species living in different environments, growth and size at first sexual maturity can also be very different (Wague and M'Bodj, 2002). More generally, the reduction in the size of maturity for different species may reflect an adaptive response to overexploitation (Smith 1994). The size of sexually mature fish may be related to adult mortality. In a population where adult mortality is too high, the fish breed in a very young size. Fishing of *Ethmalosa fimbriata* is more intense at the Saloum estuary than the sea (DPM, 2010), this can be one of the causes of this difference in size at first maturity between these two environments. These results corroborated with those reported for the same species by Scheffers et al (1972) in Senegal, Scheffers (1976) Gambia, Salzen (1958) Sierra Leone (Table 2). The works of Albaret and Dominique (1982) and Albaret and Gerlotto (1976) in Ivory Coast, and Fagade Olanyan (1972) in Nigeria and N'goran (1991) Ivory Coast showed that males reach sexual maturity first. However, the sizes at first maturity are low for both sexes.

Table 2. The sizes at first sexual maturity observed for *Ethmalosa fimbriata* in different countries

Countries	Size at first sexual maturity (L50)		Authors
	Male	Female	
Estuary Senegal	L50 =16.2 cm	L50 = 17.5 cm	Present study
Sea (Senegal)	L50 =17.2 cm	L50 = 18.7cm	
Gambia	L50 =20.2cm	L50 = 19.1 cm	Panfili et al. (2004)
Senegal	L50 =17.3cm	L50 =15.3 cm	
Senegal	L50 = 17.5 cm	L50 = 18 cm	Diouf (1996)
Senegal	L50 = 16 cm	L50 = 17 cm	Scheffers et al. (1972)
Gambia	-	L50 = 18.5 cm	Scheffers (1976)
Sierra Leone	L50 : 20 cm		Salzen (1958)
Ivory Coast	L50 = 13 cm	L50 = 14 cm	Albaret and Gerlotto (1976)
Ivory Coast	L50 = 8.1 cm	L50 = 8.4 cm	Albaret and Charles- Dominique (1982)
Nigeria	L50 = 10 cm	L50 = 14 cm	Fagade and Olanyan (1972)

4.3 Reproduction Periods

4.3.1 Evolution of Sexual Maturity Stages

In summary, the percentage of mature females is much more important during the cold season in the estuary while at sea this percentage is higher in the hot season. This suggests that the reproduction of *Ethmalosa fimbriata* at sea is in the hot season. The rate of mature females significantly higher than that of immature females in the estuary during the cold season is confirmed by the works of Albaret et al. (2005). They show that in the dry season, adults and juveniles are present in the estuary with more breeding adults, whereas at the end of the rainy season, there are essentially so many juveniles. This shows that the major spawning period in the estuary is at cold season. The evolution of sexual maturity stages of Ethmalosa fimbriata has not been the subject of many studies. Scheffers et al. (1972), contrary to our results; showed a predominance of immature during the period from September to November, while December to June the mature females are superior.

4.3.2 Gonadsomatic Index (GSI)

The maximum value of GSI in estuary is recorded in April (4.27), while in the sea, GSI is

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higher in August (5.57). Thus, the maximum spawning in the estuary is the cold season, while at sea this maximum is observed in the hot season. These results are confirmed by the evolution of the different stages of sexual maturity. In estuary, the results found in this study are similar to those of Albaret and Gerlotto (1979) in Ivory Coast; Fagade and Olanyan (1972) in Nigeria; N'goran (1991) Ivory Coast and Panfili et al. (2004). The results found in the sea are consistent with those of Salzen (1958) and Bainbridge (1961). Seasonal difference of the reproduction observed between *Ethmalosa fimbriata* at sea and those of the estuary could be due to the fact that breeding of *Ethmalosa fimbriata* is related to salinity (Scheffers et al. 1972). Some environmental parameters such as salinity affect reproduction (Charles -Dominique, 1982). Indeed, the salinity is higher in the estuary of Saloum in the cold season (after the rainy season) with a maximum from May to April (Panfili et al. 2004). Thus, changes in the GSI combined with the evolution stages of sexual maturity can locate the main breeding periods January to June estuary and January-February and July-September at sea.

Table 3. Period reproduction *Ethmalosa fimbriata* in Senegal and elsewhere

Countries	Reproduction Periods												Authors
	J	F	M	A	M	J	J	A	S	O	N	D	
Sea (Senegal)	■	■				■	■	■	■				Present study
Estuary (Senegal)	■	■	■	■	■	■							
Senegal and Gambia	■	■	■	■	■	■	■	■	■				Panfili et al. (2004)
Ivory Coast			■	■	■			■					N'goran (1991)
Senegal and Gambia			■	■	■	■	■	■					Scheffers et al. (1972)
Ivory Coast	■	■	■	■	■							■	Albaret and Gerlotto (1976)
Sierra Leone	■						■	■	■	■	■	■	Salzen (1958) and Bainbridge (1961)
Nigeria	■	■	■								■	■	Fagade and Olanyan (1972)

4.4 Fecundity

At sea, the absolute and relative fecundity found in this study are equal to 50694 and 257 eggs per gram of female. In Estuary, both fecundities are respectively equal to 51083 and 317 eggs per gram of female. These results are similar to those of Albaret and Gerlotto (1976) in Côte d'Ivoire. These authors showed that the relative fecundity of *Ethmalosa fimbriata* is between 150 to 300 eggs per gram of female. However, the values of relative fecundity found in this study are different with those of Panfili et al. (2004) in the Saloum estuary (150 oocytes) and Gambia (110 oocytes) and those of Fagade (1974) Nigeria (500 oocytes). The differences in relative fecundity observed between the sea and the estuary may be due to several factors. In estuarine and lagoon environments, a reproductive strategy aims on the one hand to limit the negative effects of the instability of the environment and on the other hand to fight against the spread of eggs, larvae and embryos outside the estuary. Thus, the oviparous develop two tactics. The first tactic is based on maximizing the number of eggs made and it has the effect of increasing the likelihood that at least a fraction of the population can be transported in a favorable place to ensure recruitment (example: *Ethmalosa fimbriata*). The second attempts to maximize the survival of eggs, larvae by limiting the number of eggs issued and using parental care (*Sarotherodon*) (Dadzie et al. 2008). Thus, it can be assumed that depending on environmental conditions, fecundity acts as a regulator of the survival of the species.

5. Conclusion

This work has highlighted the sex ratio of *Ethmalosa fimbriata* in the estuary and at sea. Sizes at first sexual maturity in the estuary and at sea were also determined. Reproduction periods are determined by studying the evolution of the different stages of sexual maturity, and changes of gonadosomatic index (GSI). The absolute and relative fecundities in the estuary and at sea were estimated. The application of these results may help treat certain problems of population dynamics, thus helping to management stock. Indeed, knowledge of the size at first sexual maturity informs on the fraction of the stock that is capable of ensuring the renewal of the species and therefore it provides information about the minimum legal size of fish that can be caught. From the reproduction periods determined, possible biological rest can be made. This work helped to provide some understanding of the reproduction of *Ethmalosa fimbriata* living at sea and in the Saloum estuary. In the future, this work deserves to be continued to define migration of *Ethmalosa fimbriata* which exist between the estuary and the sea that are hitherto poorly understood.

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