Reproductive Biology of Round Sardinella (*Sardinella Aurita*) (Valenciennes, 1847) in Senegalese Coastal Waters

Ismaïla NDIAYE

Université Cheikh-Anta-Diop (UCAD)/Institut Universitaire de Pêche et d'Aquaculture (IUPA), Dakar, Sénégal.

Alassane SARR (Corresponding author)

Université Cheikh-Anta-Diop (UCAD)/Institut Universitaire de Pêche et d'Aquaculture (IUPA), Dakar, Sénégal.

Alioune FAYE

Université Cheikh-Anta-Diop (UCAD)/Institut Universitaire de Pêche et d'Aquaculture (IUPA), Dakar, Sénégal.

Modou THIAW

Institut Sénégalais de Recherches Agricoles (ISRA)/Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), Dakar, Sénégal.

Malick DIOUF

Université Cheikh-Anta-Diop (UCAD)/Institut Universitaire de Pêche et d'Aquaculture (IUPA), Dakar, Sénégal.

Kamarel BA

Institut Sénégalais de Recherches Agricoles (ISRA)/Centre de Recherches

Océanographiques de Dakar-Thiaroye (CRODT), Dakar, Sénégal.

Waly NDIAYE

Université Cheikh-Anta-Diop (UCAD)/Institut Universitaire de Pêche et d'Aquaculture (IUPA), Dakar, Sénégal.

Najih LAZAR

Department of Fisheries, University of Rhode Island East Farm, Kingston, Rhode Island, United States of America.

Omar Thiom THIAW

Université Cheikh-Anta-Diop (UCAD)/Institut Universitaire de Pêche et d'Aquaculture (IUPA), Dakar, Sénégal.

Abstract

In this study, a total of 1068 specimens *Sardinella aurita* of which 553 females and 515 males were examined. The objectif of this study was to determine the reproductive parameters of *Sardinella aurita*. The sex ratio was significantly in favor of females (55%). The size at first sexual maturity was estimated at 18.9 cm for females and 18.0 cm for males. The monthly variation of sexual maturity stages and gonado-somatic index (GSI) allowed to locate the reproduction periods from February to June and from September to December. The mean absolute fecundity was estimated at 110.794 ± 7582 oocytes whereas relative fecundity was about 422 ± 26 oocytes per gram of female.

1. Introduction

The coastal waters of the Northwest African region benefit from favorable conditions. The system of trade-winds (the upwelling phenomenon) and the Canary Current make this area is one of the most productive in the world (Binet, 1988; Roy, 1992; Chavance *et al.,* 2004). During the period 1990-2010, total catches of small pelagic fish have fluctuated with an average of about 1.8 million tons in the six countries of the Sub-Regional Fisheries Commission (SRFC) and Morocco (CSRP, 2012).

In Senegal, the small coastal pelagic fishery is strongly characterized by a dominance of the sardinellas. Indeed, the sardinellas occupy 70% of the total landings of artisanal fisheries (*Sardinella aurita* and *Sardinella maderensis* respectively with 38% (116,000 tonnes) and 32% (100,000 tonnes) of the catches (DPM, 2011).

Further to scientific assessments at sub-regional level in 2010, FAO recommended to reduce the total fishing effort of fisheries at 50% and to limit catches to 220 000 tonnes for sardinellas. Moreover, scientific studies on sardinellas in the North East Atlantic are considered insufficient and a lack of biological monitoring for several years has been reported (CSRP, 2012). Therefore, it appears difficult to make a good stock assessment to estimate the recruitment and identify different segments of the exploited stock. All these lacks make it necessary to conduct additional research.

Thus, the main objective of this work is to study the aspects of reproduction *of Sardinella aurita* in senegalese coastal waters in order to contribute to sustainable management of its fishery.

2. Materials and Methods

2.1. Study Area

Sampling was conducted in the landing sites of Kayar (14 °55' N and 17 °07' W), Mbour (14 °24' N and 16 °58' W) and Joal (14 °10'N and 16 °51' W) (Figure 1). The importance of these sites can be explained partly by its strategic positions on the coast and by the large quantities of *Sardinella aurita* landed. In 2011, these three sites combined have ensured 66% of *Sardinella aurita* landings in Senegal (DPM, 2011).
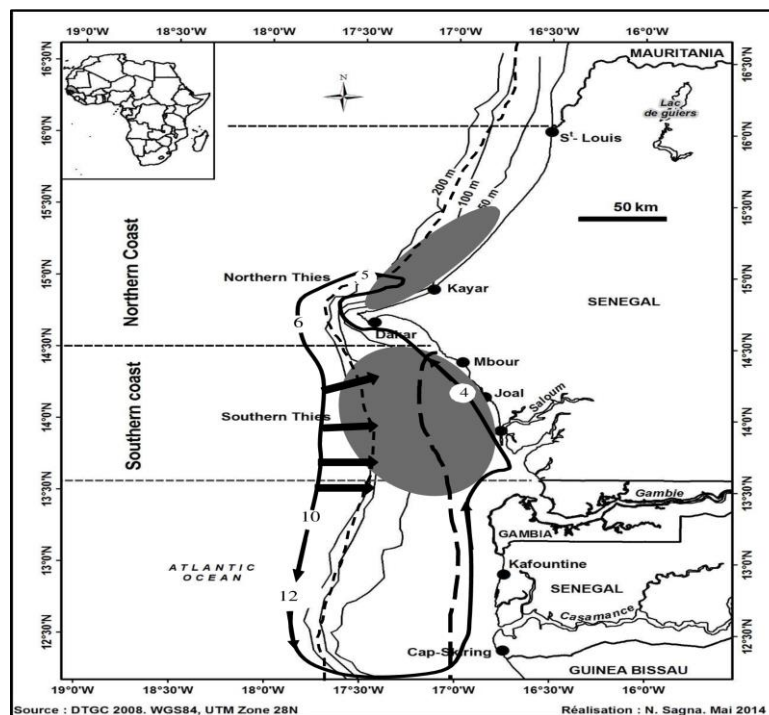

Figure 1: Location of sampling sites (Ba *et al.,* 2016)

2.2. Sampling Procedure

Sampling was carried out monthly between March 2012 and February 2013. In each site, fish were sampled randomly for different artisanal fishing gears used to catch *Sardinella aurita*.

A total of 1068 individuals were collected from the three landings centers. In the laboratory, biometric data on fork length (FL) and body weight (W) were recorded. FL was measured to the nearest 1cm and W to the nearest 0.01 g body weight. All specimens were dissected in order to determine the sex, the sexual maturity stages, the eviscerated weight (EW) and the gonad weight (GW).

2.3. Sex-ratio

The sex ratio was calculated globally for each locality considered but also according to the sizes of individuals. The sex ratio is defined as the proportion of male or female individuals in relation to the total number. In this study the sex ratio is expressed as a percentage of the females. It is calculated according to the following formula (Kartas and Quignard, 1984):

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

(F = female and M = male).

2.4. Size at First Sexual Maturity

Several definitions are given to the size at first sexual maturity. The one most often accepted is: the length at which 50% of fish in a population are sexually mature during the spawning period. Size at first sexual maturity was determined from female and male by calculating the proportion of mature female and male in 1 cm size class in the breeding period. Individuals with stage 3, 4 and 5 in the gonad development stage were considered to be mature (Dorman, 1989; Fontana, 1969; Zorica *et al*., 2011; Bilgin *et al.,* 2014). The proportion of mature females and males by size were fitted to the logistic equation:

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

(% M = percentage of mature individuals by size class; a = constant; FL = Fork length; L50 = constant corresponding to the average length of first sexual maturity).

2.5. Reproductive Periods

It is determined from monthly evolution of the percentages of the different sexual maturity stages and the monthly variation of mean values of the gonadosomatic index (GSI) as:

$$GSI = \frac{GW}{EW} \times 100$$

(GSI = gonadosomatic index; GW: gonad weight and EW: eviscerated weight).

The maturity stages of *Sardinella aurita* specimens were determined within five categories, based on morphological characteristics of the ovaries and testes, modified by Dorman (1989): stage 1: virgin or immature, stage 2: early developing and resting, stage 3: mature, stage 4: ripe, and stage 5: spawning.

2.6. Fecundity

The absolute fecundity (number of oocytes in the ovary) and relative (number of oocytes per unit of body weight) were evaluated in order to determine the reproductive potential of *Sardinella aurita*. Absolute fecundity (AF) was determined from the number of oocytes present in a fraction of ovary stage 3 and 4 on the total weight of the gonad. The relative fecundity (RF) is obtained by dividing the absolute fecundity by eviscerated weight. The relative fecundity will be used to compare the fecundity of fish from different areas (Albaret and Dominique, 1982).

$$\text{Absolute fecundity:} \quad AF = \frac{n \times GW}{G}$$

$$\text{Relative fecundity:} \quad FR = \frac{FA}{P\text{関}}$$

(AF = absolute fecundity, fecundity RF = relative; n = eggs number of fish gonad subsample (0.05 g), GW = the gonad weight, G = subsample gonad weight of fish gonad; EW = eviscerated weight).

3. Resultats

3.1. Sex-ratio

A sample of 1068 individuals of which 553 females and 515 males was used to study the sex ratio. This number corresponds to a sex ratio of 55% of females and 45% of males. The analysis of this result shows a significant predominance ($p < 0.05$) of females compared to the males.

The monthly variation in sex ratio indicates a dominance of females exceptionally in July (Figure 2) where the males are slightly more numerous. The sex ratio according on the size class shows a predominance of males in the smaller sizes (LF <18 cm) and in sizes ranging from 22 cm to 26 cm. Beyond 20 cm females become more and more numerous in the samples up to 100% (Figure 3).
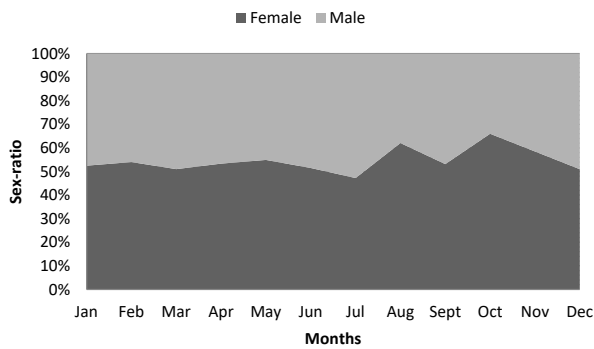
**Figure 2**: Monthly variation in sex-ratio of *Sardinella aurita*
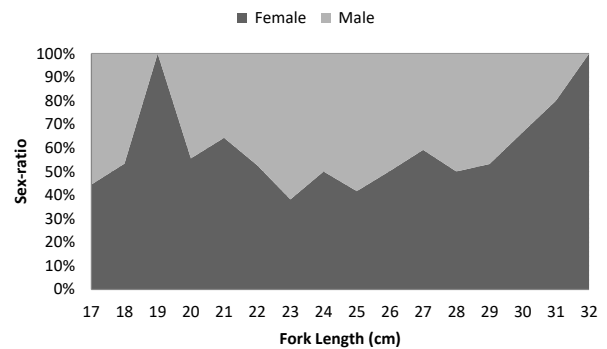
Figure 3: Sex ratio according size class of *Sardinella aurita*

3.2. Size at First Sexual Maturity

The size at first sexual maturity has been established for females and males combined on the one hand and separated on the other hand (Figure 4). It has been calculated also for each season and each site (Figure 5 and 6). The analysis of the results indicates that for both sex combined (male and female), *Sardinella aurita* reached the size at first sexual maturity at 18.4 cm. Females and males are mature respectively at 18.9 cm and 18.0 cm (fork length).

The size at first maturity according to the sites are equal to 19.7 cm, 17.7 cm and 17.6 cm respectively in Kayar, Joal and Mbour (Figure 5). The sizes at first maturity at Kayar is significantly different from those found at Joal and Mbour ($p < 0.05$). The size at first maturity of *Sardinella aurita* sampled during the cold season (18.7 cm) is significantly ($p < 0.05$) higher than these in the hot season (17.8 cm) (Figure 6).
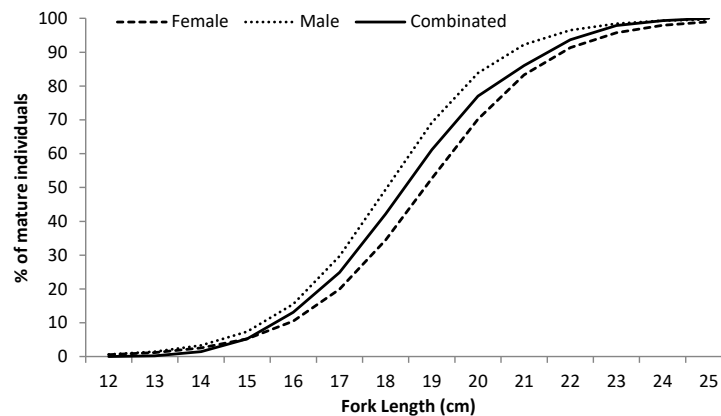
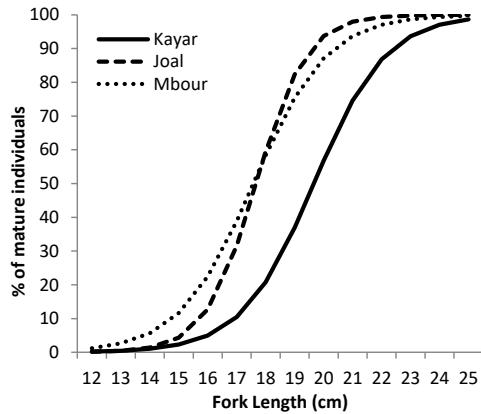Figure 4: Size at 50% sexual maturity for females, males and combined

Figure 5: Size at first maturity sex according to the sites for both sexes combined
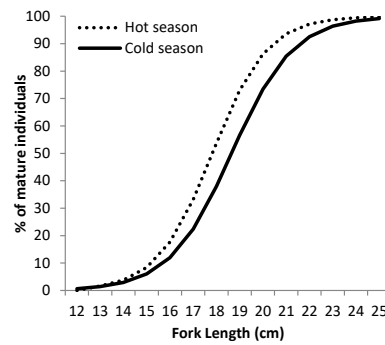
Figure 6: Size at first maturity sex according to the seasons for both sexes combined

3.3. Reproduction Period

The monthly evolution of sexual maturity stages shows a high presence of immature (Stage 1 and 2) in July and August. Fish in mature (stage 3) and ripe (stage 4) stage are met throughout the year. However the maxima of spawning stages (stage 5) is met in March and November.
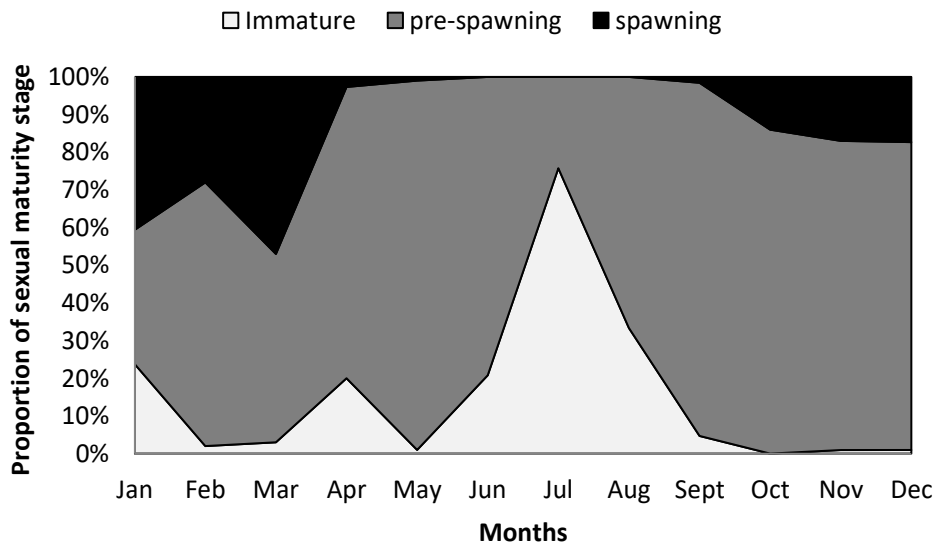

Figure 7. Monthly variations of ovary (females) and testis (males) maturity stages of *Sardinella aurita.*

The monthly change in average GSI for both sexes combined shows two breeding periods. The first peak occurred in March (4.91 $\pm$ 0.46) and the second in November (4.82 $\pm$ 0.69) (Figure 8) with a sexual rest period in July where immature fish are more numerous in the landings. GSI male and female separately established follow the same pace as the GSI for sexes combined. The upward parts of the GSI curves correspond to the periods of gonadal maturation and downward parts represent the spawning periods for females and sperm emission for males. These spawning periods are separated by sexual rest periods where sexual activity decreases.
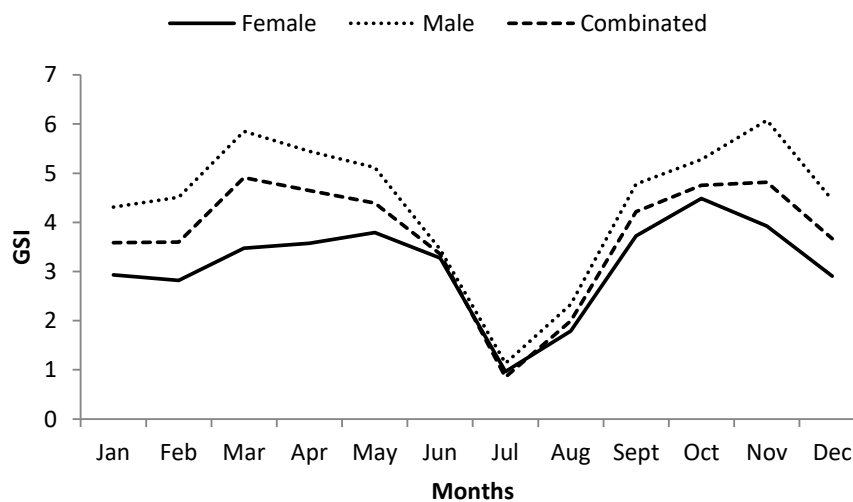

Figure 8. Monthly variations of gonadosomatic index (GSI) of female, male and combined

3.4. Fecundity

The estimate of fecundity focused on a sample of 106 females. The values of the absolute fecundity (AF) are between 35 604 and 260 260 oocytes with an average of 110 794 $\pm$ 7 582 oocytes per female. On the other hand, the relative fecundity (RF) varies between 130 and 893 eggs per gram with an average of 422 $\pm$ 26 oocytes per gram of female.

The relationships between absolute fecundity and size class on the one hand and on the other hand eviscerated weight are established. Absolute fecundity is strongly correlated with the size and the eviscerated weight (Table 1).

Table 1. Relationships between fecundity absolute and fork length (FL) and eviscerated weight (EW)

Relationships	Number	R ^{2}
AF = 32.71 $\times$ FL$^{2.49}$	106	0.99
AF = 934 $\times$ EW$^{0.86}$	106	0.99

4. Discussion

4.1. Sex-ratio

Sardinella aurita present a sex ratio in favor of females (55%). Similar results were reported by other authors (Conand, 1977; Boëly, 1982; Goudiaby *et al*., 2010 in Senegal and Wague and M'Bodj, 2002 in Mauritania; Gassman *et al*., 2008 in Venezuela) (Table 2).

Sex ratio could be influenced by the availability of food (Nikolsky (1963; 1969). When food is abundant, females predominate, with the situation inverting in regions, where food is limited. Feeding activity, in this case, would be influencing metabolism through hormonal activity, resulting in changes in production of individuals of a given sex. Females requiring better environmental conditions than males and suffering in their development when environmental conditions deteriorate had been reported (Nikolsky, 1969; Lawson and Doseku, 2013).

The predominance of male in July corresponding to the end of the first spawning period could be due to the fact that females have left the spawning area s that are often very coastal.

Females generally dominated the higher length classes in the northern Aegean, Algerian (Bensahla Talet *et al.,* 1988) and Tunisian waters (Gaamour *et al.,* 2001), while differences in the size-specific sex-ratios have been reported for other Mediterranean marine fishes (e.g. Stergiou *et al*., 1996). The differences in the size-specific sex-ratio were also reported for Libyan waters (Pawson and Giama, 1985) and were related to sexual differences in growth, mortality or energetic cost of reproduction (Tsikliras and Antonopoulou, 2006).

Table 2: Sex ratio of *Sardinella aurita* expressed in percentage of female according to various authors

Contries	Sex-ratio	Number	Authors
Senegal	55%	1068	Present study
	50.5%	3947	Goudiaby *et al* (2010)
	55%	9645	Boëly (1982)
	52%	1334	Conand (1977)
Nigeria	58.13%	256	Lawson and Doseku (2013)
Venezuela	55.47%	3 736	Gassman *et al* (2008)
Mauritania	55%	3073	Wague and M'Bodj (2002)

4.2. Size at first sexual maturity

Size at sexual maturity is one of the important parameters that can be used in defining minimum mesh and landing size (*Bilgin et al*., 2014). In the present study, size at first maturity for both sexes and combined site is 18.4 cm. This observation is similar to that of Boëly (1982), Fontana and Planet (1973) and Freon *et al* (1997).

The results indicate that males reach sexual maturity earlier than females. Similar results are found in others areas (Table 3). In many cases, the differences in size sexual maturity are associated with sex differences in the relative distribution of energy for the production of gametes (Weatherley and Gill, 1987).

The size at first maturity varies depending on the site and the season. It is higher for individuals sampled at Kayar than those collected at Mbour and Joal. This difference between sites and seasons could be due to the spatial and temporal variability of the spawning period (early or late spawning according to an area or a season) and the corresponding recruitment. Accordin to *Bilgin et al* (2014), difference on size at first sexual maturity may be due to different length composition which used to calculate size at maturity or different fishing pressure levels among the researcher areas. Indeed, the fishing effort is very high at the Mbour and Joal (over 2000 active canoes). In addition to these two sites are the main landing centers for *Sardinella aurita* in Senegal (DPM 2011).

Table 3. The sizes at first sexual maturity of *Sardinella aurita* observed in different countries.

Contries	Size at first sexual maturity (L50)		Type of length	Authors
	Male	Female		
Senegal	18 cm	18.9 cm	FL	Present study
Senegal	23.39 cm	26.07 cm	TL	Goudiaby *et al* (2010)
Senegal	_	18.5 cm	FL	Boëly (1982)
Ghana	16.7 cm	17.1 cm	_	Quaatey and Maravelias, (1999)
Congo	_	19 cm	LF	Fontana and Planet (1973)
Mauritania	28-29 cm		FL	Wague and M'Bodj (2002)
Venezouela	19.7 cm		TL	Fréon *et al* (1997)
Venezouela	20 cm		TL	Gassman *et al* (2008)
Tunisia	14.1 cm	15 cm	_	Gaamour *et al* (2001)
Ageria	_	14.1 cm	_	Bouaziz *et al* (2001)

4.3. Reproductive Periods

The high percentage of immature (stage 1 and 2) shown by the evolution of different sexual maturity stages corresponds to the end of the first spawning period (July and August). The pre-spawning stages (stage 3 and 4) have encountered throughout the year attest that *Sardinella aurita* is a multiple spawning species. So the monthly evolution of RGS combined with the monthly evolution of sexual maturity stages show two main reproductive periods of *Sardinella aurita* in Senegal. The first runs from February to June and the second from September to December. These results are similar to those obtained by Boëly *et al* (1978), Cury and Fontana (1988) and Goudiaby *et al* (2010) (Table 4). However, others studies on the reproduction of *Sardinella aurita* in others regions show a reproduction period between June and September (Boëly *et al.,* 1978 in Sahara and Cap Blanc; Wague and M'Bodj, 2002 in Mauritania) and between May and August (Boëly and Freon, 1979 in Sahara and Cap Blanc) (Table 4). The shift of breeding periods of *Sardinella aurita* between Senegal and the others countries of the subregion could be due to environmental factors. According to Roy *et al* (1989) and Roy (1992), changes in periods of upwelling affect spawning periods for certain species of clupeid as *Sardinella aurita*; there is a maximum shift of the RGS, which can be interpreted as a sign of delayed reproductive activity of the species.

Table 4. Reproductive periods of *Sardinella aurita* according to various authors and West African areas.

Areas	J	F	M	A	M	J	J	A	S	O	N	D	Authors
Senegal		█	█	█	█	█			█	█	█	█	Present study
Senegal				█	█	█	█			█	█		Goudiaby *et al* (2010)
Senegal		█	█	█	█	█							Cury and Fontana (1988)
Senegal		█	█	█	█					█			Boëly *et al* (1978)
Sahara and Cap Blanc						█	█	█	█				Boëly *et al* (1978)
Sahara and Cap Vert					█	█	█	█					Boëly and Fréon (1979)
Mauritania						█	█	█	█				Wague and M'Bodj (2002)

4.4. Fecundity

The estimation of fecundity focused on a sample of 106 females. Absolute fecundity ranged from 35 604 to 260 260 oocytes with an average of 110 794 $\pm$ 7 582 oocytes per female. While, the relative fecundity (RF) varies between 130 and 893 oocytes/g with an average of 422 $\pm$ 26 oocytes/g of female. These results are similar to those of Conand (1977) in Senegal who found an average relative fecundity of 400 oocytes per gram of female. However lower values of relative fecundity (250 to 300 oocytes/g of fish) were observed by Ghénon and Fontana (1981) in Congo. These differences may be related firstly to the techniques used to sample ovary, the other hand also to the size of fish considered in studies but also to interannual and spatial variability (Conand, 1977).

5. Conclusion

This study allowed characterizing the reproduction of *Sardinella aurita* in Senegal. It appears that the sex ratio was significantly in favor of females. The size at first maturity has a variability following sex, site and season. It also resort to this study that this species is a multiple spawning species. However the main breeding seasons seem to be correlated with the period of the upwelling in Senegal. The estimated absolute fecundity values indicate that *Sardinella aurita* is relatively a high fecundity species.

These results provide data which could help to develop strategies for sustainable management of fishing for this fish in Senegalese waters.

In a future perspective, this study based on the macroscopic observation of the breeding *Sardinella aurita* deserves to be continued and confirmed by histological study of gametogenesis.

Acknowledgements

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