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Analysis of the exploitation and management of the artisanal shrimp fishery (*Farfantepenaeus notialis*) in the Saloum Delta

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ABSTRACT

The management of the coastal small-scale shrimp fishery in the Saloum delta is based on the opening and closing of the fishery. This approach is highly contested by many fishermen who still pursue fishing activities. To reach this goal, samples of 500 grams of shrimp are purchased once a month from the catches of fishing gear targeting shrimp in the following areas: Foundiougne, Sibassor, Djirnda, Missira and Betenti. On site, the cephalothoracic length and individual weight of shrimp are measured to the nearest tenth of a millimeter, using an electronic caliper and weighed to the nearest tenth of a gram using a precision field scale. The relative importance of the two sexes in the catches of the different fishing gears is analysed every month using a 300 g sample of the biggest shrimp. Sex is determined by naked-eye observation of the shrimp, based on the sex recognition key developed by Schneider (1992) and Vries and Lefèvre (1967). The analysis of the evolution of the sizes of the shrimp caught in the different fishing areas allows us to locate the optimal period of closure of the fishery between the months of June and October, which corresponds to the main reproduction period of the white shrimp in the Saloum delta.

Keywords: Saloum Delta, fishery, white shrimp, seasonal closure.

INTRODUCTION

In Senegal, the coastal shrimp (*Farfanpenaeus notialis)* is exploited by small-scale fishermen (Caverivière and Thiam, 2002; Charles-Dominique and Ndiaye, 2003; Thiao et al., 2004; Ziegler et al., 2009; Thiaw, 2010; Niane et al., 2012) at the mouth of the Senegal River and in the estuaries of the Sine Saloum-Gambia and Casamance (Figure 1). Throughout the fishing area, the capture, possession and sale of shrimp whose mussel size is greater than 200 individuals per kilogram is prohibited by Article 8 (Order N°: 005329 of 6th August 2003).

Three fishing gears are used to catch shrimp (Charles-Dominique and Ndiaye, 2003) such as the spread net or fixed net, the filter net or fele fele and the canal net or mujas (Figure 2).

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It plays an important role in the exploitation of fisheries resources in the Sine Saloum estuary. The revenue generated from it is estimated at 985 million of CFA francs out of the 2 billion of CFA francs of revenues derived from the exploitation of continental fisheries resources, in the same region, in 2000 (Dème et al., 2000; Niane, 2005). A substantial proportion of the proceed from this activity (80-100%) is used to cater to the daily expenses of fishermen's households (Thiao and Diadhiou, 2003).

To ensure the sustainability of its exploitation, the regional services of the directorate of marine fisheries of Fatick and Kaolack collaborate with the beach committees of the two regions to observe each biological rest in August of the year. In addition, if the average number of shrimp contained in one kilogram of products exceeds 200 individuals, it is necessary to observe the biological rest of the month before or after depending on the year.

This paper looks into the relevance of having the biological recovery of the fishery during the month of August for all shrimp fishing areas in the Saloum Delta. It also aims at stressing the relevance of having a single closure period of fishery for all the fishing areas.

MATERIALS AND METHODS

Presentation of the Sine Saloum delta

The Sine Saloum mangrove is located in the intertropical zone, between 12° 30' north and 16° 30' north latitude and 11° 30' west and 17° 30' west longitude, about 150 km south of Dakar. The catchment area of the Sine Saloum estuary covers an area of about 80,000 ha (less than 0.6%).

The Sine Saloum natural region is now divided into two administrative regions (Fatick and Kaolack). Land pressure is very high (23, 945 sq. km for a population of 1,314,000 inhabitants) with densities exceeding 60 inhabitants per sq. km). Other characteristics include the degradation of the environment (wind and water erosion), the decline in rainfall (varying between 600 and 800 mm), a Sudanese-type climate characterized by two clearly defined seasons, a dry season lasting seven months (from November to May) and a rainy season lasting five months (from June to October). It also has heterogeneous production systems, a decline in soil productivity in recent years, a maritime area extending from the tip of Sangomar to the Gambian border, and a continental area consisting of the Saloum estuary and its tributaries.

The hydrographic system of this complex is made up of three main arms: the Saloum (110 km long) to the north and northeast, the Bandiala (18 km) to the south and southeast, and the Diomboss (30 km) in between. These rivers are surrounded by a network of very dense bolons. They, as well as the main arms, are bordered by intertidal mudflats more or less colonized by mangroves.

Methodological approach

Samples of 500 grams of shrimp are purchased once a month from the catches of fishing gear targeting shrimp in each of the areas of Foundiougne, Sibassor, Djirnda, Missira, and Bétenti. On-site, the cephalothoracic length and individual weight of shrimp are measured to the nearest tenth of a millimeter using a digital caliper and weighed to the nearest tenth of a gram using a precision field scale.

The relative importance of the two sexes in the catches of the different fishing gears is analyzed every month from a 300 g sample of the largest shrimp. The determination of the sex is made by naked eye observations of the shrimp based on the sex recognition key developed by Schneider (1992). For the sexual maturity stages of females, the determination key proposed by Vries and Lefèvre (1967) was used:

Stage 1 « Virgin » (Immature): the ovaries are present but not developed, hardly visible to the naked eye around the digestive tract;

Stage 2 «Maturing virgin »: the ovaries, not very developed, appear in cross-

section as two translucent circles around the digestive tract;

Stage 3 «Developed »: the ovaries are presented in the form of two trapezoids which, varying from white to light yellow; occupy a quarter of the triangle;

Stage 4 «Gravid » (full): the ovaries of an orange-yellow, occupy half of the triangle;

Stage 5 «Ripe » (maturing): the orange-red ovaries occupying three-quarters of the abdominal cavity;

Stage 6 «Spent resting »: the ovaries are empty, leaving a large cavity in the triangle.

The collected data are entered in Excel and then transferred to Fish base to be analyzed and represented graphically.

Fishbase was developed by the International Center for Living Aquatic Resources Management (ICLARM) in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and other partners. Since 2000, FishBase has been led by the FishBase Consortium, comprising ten (10) institutions, of which the Muséum national d'Histoire Naturelle, MNHN (Paris, France) is a founding member.

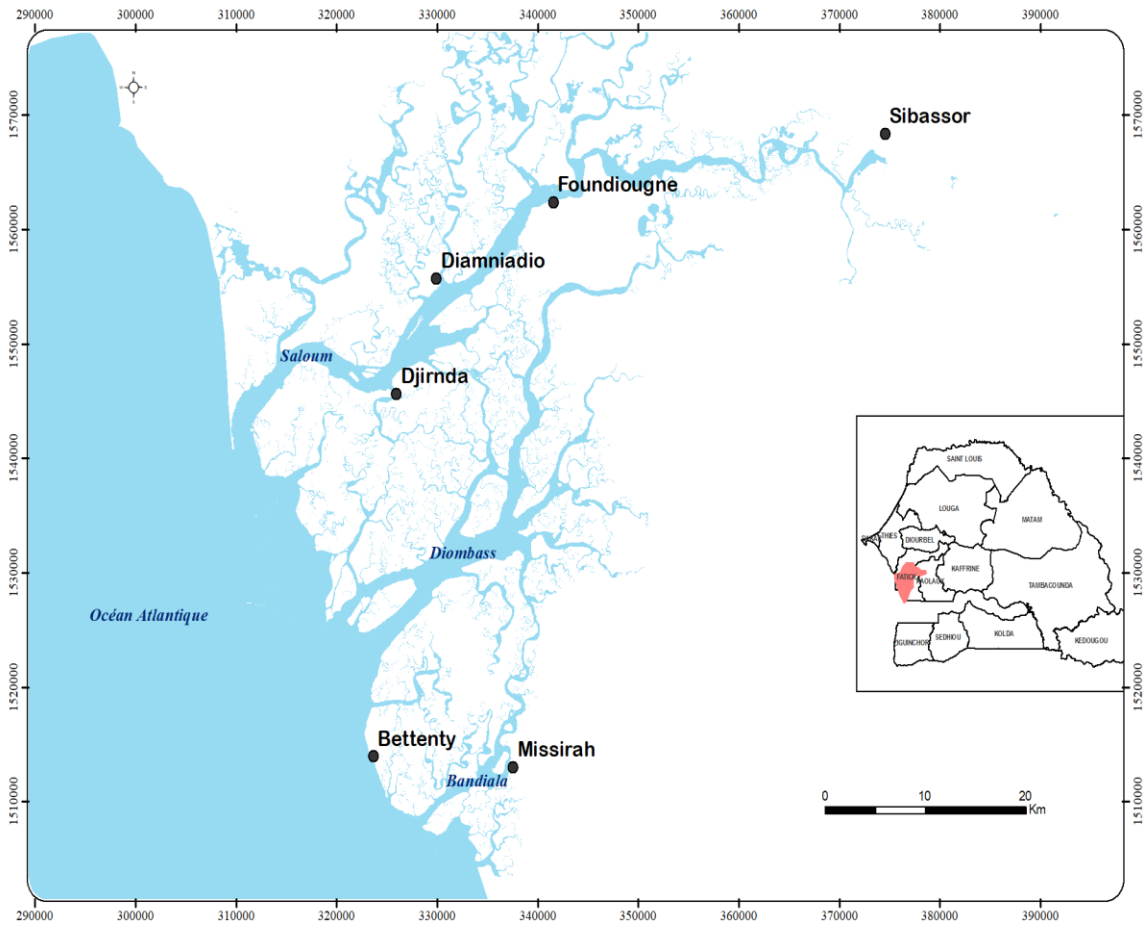

Figure 1: Location map of the main sampling sites in the Saloum Delta.

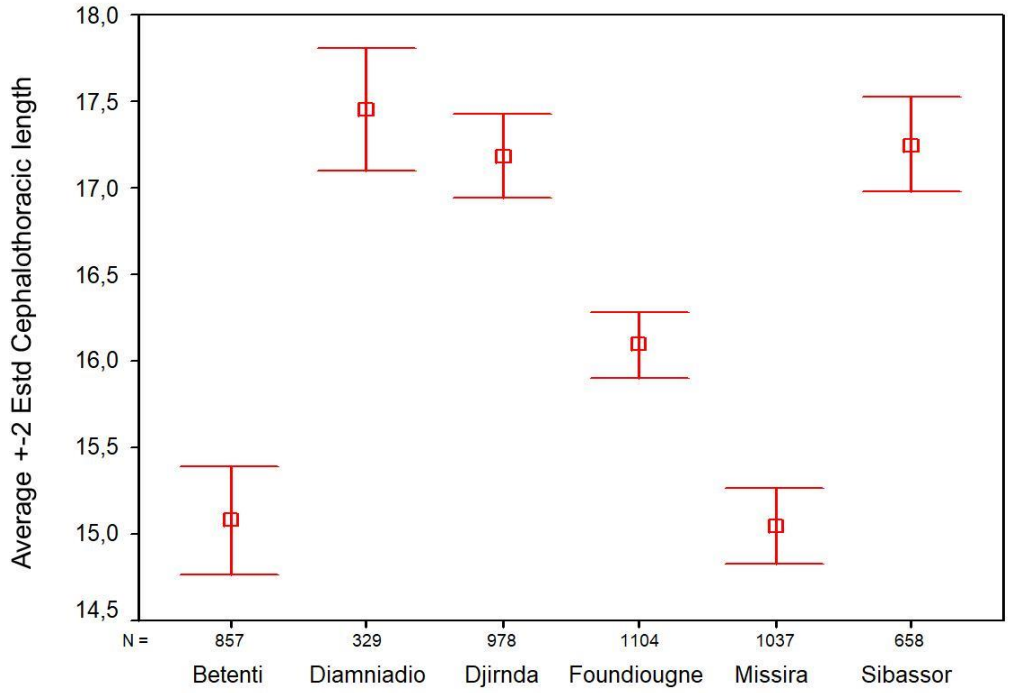

Figure 2: Average cephalothoracic Length of shrimp analysed in the different study sites.

RESULTS

Size is one of the main biological elements used in the regulatory texts for shrimp fishing in Saloum, and the descriptive analysis of the main parameters observed in the framework of this study will essentially revolve around shrimp size.

Size of shrimp caught at the different sampling sites

The monthly variations in the average size of shrimp caught at the different sampling sites are presented in Figure 3.

For all samples, the average cephalothoracic length (CL) of shrimp caught by the killer drag net and the set net (canal net) at Diamniadio, Djirnda, and Sibassor is significantly greater than that caught at the other study sites (Bétenti, Foundiougne, and Missira) (Tables 1 and 2). The largest average size of shrimp caught (average CL around 17.5 mm) is recorded in Diamniadio followed by Djirnda and Sibassor (average CL around 17.2 mm). The smallest shrimps were recorded in Bétenti and Missira (average CL around 15 mm). Those recorded in Foundiougne are around 16 mm.

Tests comparing the average size of shrimp caught at the various sites sampled revealed three homogeneous subsets of sites (Table 3):

- Missirah and Bétenti (average CL around 15 mm);
- Foundiougne (average CL around 16 mm);
- Djirnda, Sibassor, and Diamniadio (average CL around 17 mm).

According to the CL values observed, the following groupings are observed:

- Missirah and Bétenti (with an average of around 15 mm);
- Foundiougne (with an intermediate average of 16.09 mm);
- Sibassor, Djirnda, and Diamniodio (average LC around 17 mm).

Size of shrimp caught with the 'killi' and 'canal' nets

It has been established that the average size of shrimp caught with the fixed net is larger than that caught with the drag net in the various study sites. In the same vein, we can observe that the shrimp from Diamniadio and Djirnda are bigger than those caught at the other sites (Figure 3). At Sibassor, the average size of the shrimp caught by the two fishing gears is more or less the same (average CL around 17 and 17.8 mm). The shrimp caught at Bétenti and Missirah by the dragnewasre is the smallest of all the study sites (mean CL around 15 mm).

Size of shrimp caught by sex

Indeterminates (or immatures) are observed in the size range below 16 mm (Figure 4). The size differences observed for sex are significantly different (Tables 4, 5, and 6). The largest individuals (CL around 22 mm) are almost exclusively females. Between 20 and 22 mm, there is a mixture of sexes, males and females.

The cephalothoracic length (CL) is significantly different according to the sex of the individuals observed at a very high level (Proba < 0.000).

Group means of homogeneous subsets are displayed. CLs are different according to sex (male: 19.85 mm, female: 21.25, and immature: 15.06 mm).

Evolution of the size of shrimp caught over time (period)

The average size (CL) of shrimp caught at the different study sites during the study period (June to December) is presented in Figure 5. Shrimp caught during sampling from 30 July to 1 November are significantly larger than those caught on either side of this period. Various shrimps from different 'cohorts' invade the fishery between June and December. The Student-Newman-Keuls and Duncan tests point to homogeneous groups with samples collected over different periods (Tables 7 and 8).

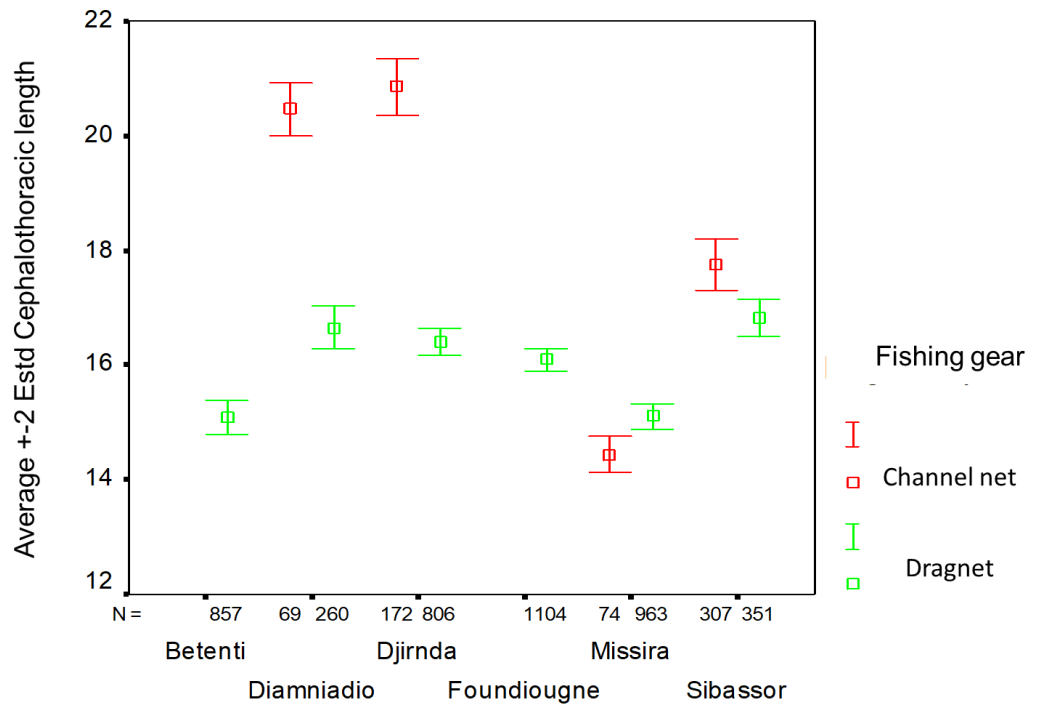

Figure 3: Average size (CL) of shrimp caught by the different types of fishery.

Table 1: Homogeneity test of LC variances.

Levene's statistics	ddl1	ddl2	Significance
21.628	5	4957	.000

Table 2: ANOVA on LC.

	Sum of the squares	ddl	Average of the squares	F	Significance
Inter-groups	4628.195	5	925.639	67.835	.000
Intra-group	67640.080	4957	13.645		
Total	72268.2	4962			

Table 3: Comparison tests of the mean LC (S-N-K homogeneity test).

			Subset for alpha = .05		
Collection centre		**N**	**1**	**2**	**3**
Student-Newman-Keuls	Missirah	1037	15.0517		
	Bétenti	857	15.0819		
	Foundiougne	1104		16.0939	
	Djirnda	978			17.1848
	Sibassor	658			17.2496
	Diamniadio	329			17.4473
	Signification		**.879**	**1.000**	**.381**
Duncan	Missirah	1037	15.0517		
	Bétenti	857	15.0819		
	Foundiougne	1104		16.0939	
	Djirnda	978			17.1848
	Sibassor	658			17.2496
	Diamniadio	329			17.4473
	Significance		**.879**	**1.000**	**.213**

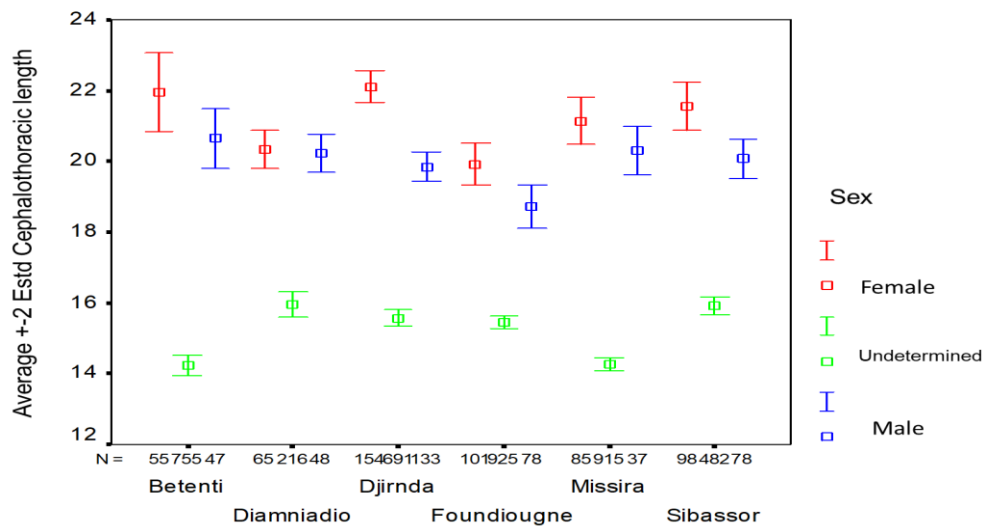

Figure 4: Average size (CL) of shrimp caught by sex.

Table 4: LC variance homogeneity test.

Levene's statistics	ddl1	ddl2	Significance
20.284	2	4960	.000

Table 5: Comparison of cephalothoracic lengths (ANOVA with LCs).

	Sum of the squares	ddl	Average of the squares	F	Significance
Inter-groups	25039.463	2	12519.731	1314.830	.000
Intra-groups	47228.812	4960	9.522		
Total	72268.275	4962			

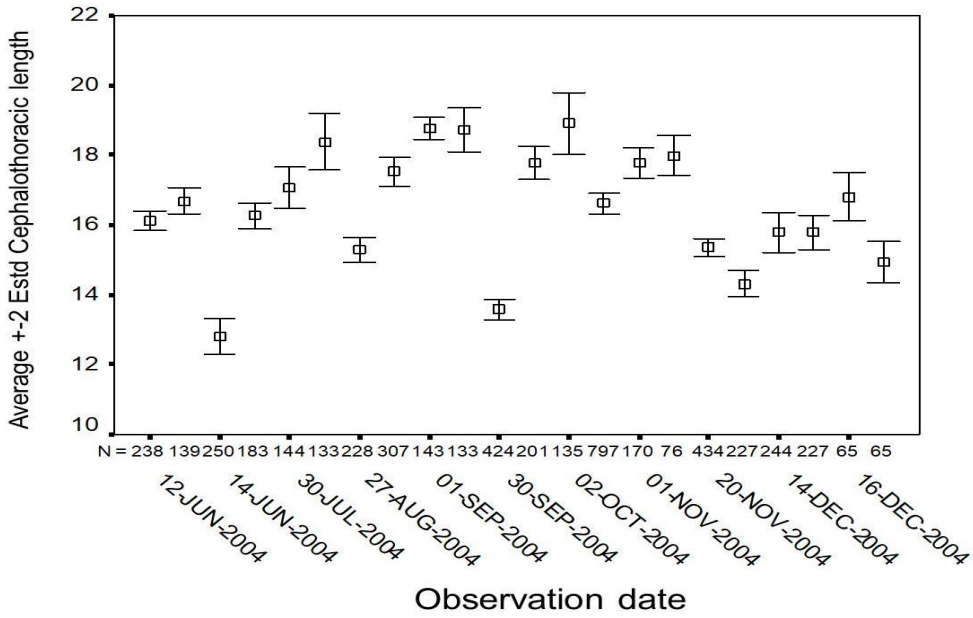

Figure 5: Evolution of shrimp size (Lc) over time.

Table 6: Multiple comparison of LCs (homogeneity test).

		N	Subset for alpha = .05		
	Sex		1	2	3
Student-Newman-Keuls	Immature	3984	15.0563		
	Males	421		**19.8513**	
	Females	558			**21.2488**
	Significance		1.000	1.000	1.000
Duncan	Immature	3984	15.0563		
	Males	421		19.8513	
	Females	558			21.2488
	Significance		1.000	1.000	1.000

Table 7: Test of homogeneity of LC variances with time.

Levene's statistics	ddl1	ddl2	Significance
21.628	5	4957	.000

Table 8: Comparison test of mean lengths (ANOVA of LCs).

	Sum of the squares	ddl	Average of the squares	F	Significance
Inter-groups	4628.195	5	925.639	67.835	.000
Intra-groups	67640.080	4957	13.645		
Total	72268.275	4962			

DISCUSSION

The study of Spatio-temporal variations in the size and reproduction of *P. notialis* shrimp in the Saloum estuary revealed differences according to the sites, the fishing gears used, and the sex. It was found that the average size (LC) of the shrimp exploited by artisanal fishermen is larger in Diamniadio, Djirnda, and Sibassor, a fishing center where the fixed net is the main fishing gear used by the fishermen. This trend remains valid if we refer to the period. The largest shrimp caught during the different sampling periods are always found at these same sites. However, a slight difference is noted when considering the sex of the individuals. Females are generally larger than males. The immatures constitute the smallest individuals. When looking at the average size of shrimp, the largest females were observed at Bétenti. All females observed belong to the immature stage I.

The difference in the average size of the shrimp caught comes from the fishing gear used. The fixed nets or 'canal' nets and the drift nets or *killi* nets function as bags. The size of shrimp caught by each of these fishing gears depends on the demographic structure of the populations they exploit and the mesh size used. *Killis* are used in areas where the current is not strong, on the shallows on either side of the channel. Small shrimps are abundant in these areas (Parker, 1970; Galois, 1975; Stafles, 1980; Le Reste, 1982). Channel nets are set in the channel where the current is stronger. They catch larger shrimp (Le Reste, 1994). In the Casamance estuary, the sizes of migrating shrimp that are caught depend on several factors: fishing effort, net mesh size, current speed, and the length of time the shrimp stay in the estuary (Le Reste, 1987). The mangrove, a source of trophic enrichment of the estuarine environment, presents a contrasting situation in the three sites where the largest shrimps are observed. The fishing effort on shrimp is as important in the Sibassor, Djirnda, and Diamniadio sites as in the other sites studied. The mesh of the shrimp nets in the different fishing gears studied are more or less of the same size in the case of our study. The largest shrimp is not only observed at sites where the current speed is high. This observation also applies to the mangrove. It is not larger where the mangrove is best preserved (Bétenti). When it comes to the length of stay of shrimps, we have no study in this respect in the Saloum. The presence of large shrimp noted at Sibassor, Djirnda, and Diamniadio, regardless of the type of fishing used, must be investigated in the study of this factor.

Small-scale fishing is characterized by catches comprising mainly of small shrimp (average size 16 mm CL) that may or may not have completed their estuarine phase (Diadhiou et al., 2018). These authors studied

the impacts of the selectivity of artisanal fishing gear on shrimp catches in the Saloum delta. In Betenti, this phenomenon is also analyzed according to the periods of high (*waame*) and low (*niokok*) tide in 2010. The results obtained show an increase in the size of the shrimp and availability of the resource at all the sampling stations at the end of August 2010 and during the same period in Betenti, whatever the month, between April and October 2010. The fixed biological recovery period in August this year had a positive effect on the quality of the shrimp exploited. This result made it possible to propose the biological recovery period around August and September to allow the shrimp to grow to increase their profitability. A biological recovery period is a management tool for the sustainable exploitation of resources. It allows for the balanced and optimal exploitation of resources. However, the positive effects that the "biological recovery period" can bring achievement if a set of coherent management measures are taken and applied. Most of these measures are recalled by the Restricted Technical Committee on the extension of the "biological recovery period" (IDEE Casamance, 2017). These are included: (1) to preserve a sufficient quantity of spawners, belonging to different age classes, to allow individuals to reproduce and contribute to the sustainability of the stock; (2) to protect nursery areas and allow juvenile fish to develop before entering the fishing grounds or the exploitable phase; (3) to ensure compliance with the regulations on the size of the mesh of the gear and the size of the first catch to avoid the capture of juveniles; and (4) adjust the fishing effort by a set of measures such as controlling the flow of fishermen, limiting the fishing capacity of the units and the number of daily fishing trips.

The difference in size between males and females in favor of the latter group is reported in *P. notialis* by authors like Lhomme and Garcia (1984). The opposite situation noted in the samplings between 13 June, 1 September, and 2 October could be explained by the presence of several cohorts in the fisheries. The succession of modes observed over time in the different centers monitored could explain this phenomenon. The existence of micro-cohorts in the shrimp *P. notialis* was reported by these authors, who put this phenomenon down to migration and the variation in the ability to catch individuals according to their sex.

None of the 4963 shrimp analyzed in this study had reached sexual maturity. That is in line with what has been described so far by authors like Lhomme, Garcia, or Le Reste. Aquaculture experiments carried out at the Katakalouss shrimp culture station in Casamance in the 1980s showed that the quality of the water in the estuary (inverted estuary as in the Saloum) does not favor the maturation of *P. notialis* in this type of environment (Charles-Dominique and Ndiaye, 2003).

Many scientists around the world have proposed size at first sexual maturity as a fishery management measure to rationalize the fishery (Lucas et al., 1979; Chang Cheng, 1984; Sluczanowski, 1984; Somers, 1985; Nichols, 1986; Caddy, 1987; Courtney et al., 1991; Die and Watson, 1992; Le Reste and Diallo, 1994).

Studies carried out by Lhomme and Garcia put the size at first spawning of Saloum shrimp (Roxo-Bissagos stock) at 28 mm CL. According to these authors, the reproduction of shrimp from this stock is continuous and takes the form of irregular peaks in chronology and intensity. Important peaks are observed in the warm season (August), in the transition period (November), and also in the middle of the cold hydrological season (January). The main spawning season is between August and January.

Conclusion

Given the results obtained, the closure of the shrimp fishery from June to October seems appropriate, especially as the shrimp present in the centers studied were mainly small individuals. The number of shrimp per kilogram generally exceeded 200 individuals

during this period in practically all shrimp fishing areas.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS CONTRIBUTIONS

HDD implemented the research protocol and supervised data collection in the field. SN assisted in the analysis and interpretation of the results. ID assisted in the review of the article.

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