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Contribution to the Study of the Size Structure, the Length-Weight Relationship, the Condition Factor and the Sex-ration of Shrimp Farfantepenaeus notialis (Pérez Farfante, 1967) in the Estuary of Sine-Saloum (Senegal)

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Abstract

This study was carried out within the context of USAID/COMFISH project for establihing a biological data base for some fish species including shrimp *Farfantepenaeus notialis* to support management plans for these species. This study on *Farfantepenaeus notialis* in the Sine-Saloum estuary revealed that the sampled individuals are relatively small sizes.

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The average cephalothoracic sizes are less than 20 mm at Bettenty (male = 18.0 ± 2.9; female=18.5 ± 3.9) and at Foundiougne (male = 17.6 ± 2.9; female = 18.5 ± 3.8). The allometric rate «b» is more important at Bettenty (b = 2.94) than at Foundiougne (b = 2.75) and condition factor K is higher during the hot season in both locations (Bettenty: K = 0.80 in hot season; K = 0.78 in cold season; Foundiougne: K = 0.82 in hot season, K = 0.75 in cold season). The sex ratio of *Farfantepenaeus notialis* is in favor of females at Bettenty (54.6%) and at Foundiougne (51.2%). The size classes show that below 15 mm and beyond 20 mm, the number of female is higher than that of male. Beween 15 to 20 mm, male are higher.

Keywords: allometry; Estuary; Farfantepenaeus notialis; Shrimp; Sine-Saloum.

1. Introduction

Farfantepenaeus notialis is found in the Atlantic Ocean and its tributaries, particularly on the West African coast from Mauritania to Angola. It is a species with a short lifetime, about twenty months [1]. Its life history is complex; with a juvenile stage in lagoon or estuary and adult phase at Sea [2, 3, 4, 5, 6].

It is, therefore, the main species of Penaeidae exploited along the West African coast [3]. Farfantepenaeus notialis, like most exploitable shellfish, plays an important role in the ecosystem by the main place it occupies, particularly in energy transfers, and by its total biomass [7].

For long time, the presence of Farfantepenaeus notialis was detected in Senegalese waters [8]. Two stocks of shrimp Farfantepenaeus notialis were identified, one located in north of Cape Verde, between the pit of Cayar and St. Louis and the other in the south, between Senegal (Sine-Saloum, Casamance) and Guinea-Bissau. The main difference between these two stocks reside in a much lesser importance of freshwater inflows, a lower scale fishing and more limited nurseries in the north [4, 9]. Farfantepenaeus notialis is one of the most fished shrimp species in Senegal both by artisanal and industrial fisheries. It constitutes 71.2% of the total catch of shellfish landed by artisanal fishery [10].

In the Sine-Saloum, fishing for this species is beneficial throughout the year, with a strong peak at the beginning of the hot season. In 1966, the exported production was approximately 120 tons [8]. In the Sine-Saloum, Farfantepenaeus notialis is one of the most coveted species in recent years. Indeed, it occupies an important place in the exploitation of fishery resources. Much of the population in Sine-Saloum live directly from the use of this resource commonly sold in the fish processing units, hotels, tourist camps and the local markets. The annual incomes from this activity occupy an important weight in the economy of the area. They are estimated at over 900 million francs [11]. The main objective of this study is to update some aspects of the biology of this species for better management and rational exploitation of its fishery in this region.

2. Materials and Methods

2.1. Study Areas

Fishing, essential for economic and social development of the region of Fatick, contributes significantly to reduce unemployment, satisfy the food needs of the population, increase incomes of local communities and

reduce poverty. The region of Fatick is ranked fifth for fish production. It has a wide delta area with a front of about 70 km, where small fishing villages are scattered in the vast islands inside the delta [12].

It is in this region of Fatick that sampling was carried out precisely in the localities of Bettenty (13° 44' 53" N, 16° 33'15" W) and Foundiougne (13° 45' 0" N, 16° 30' 0" W) located in the estuary of the Sine-Saloum from March 2012 February 2013. The Sine-Saloum estuary has an inverse functioning unlike what happens in the estuaries called "normal". This inverse functioning is due to pluviometric deficit in recent decades which has greatly reduced freshwater inflows of continental origin to profit the marine influence. During the years of pluviometric deficit, salinity in the estuary of Sine-Saloum is everywhere higher than the salinity in the sea. Previous studies indicate an increasing salinity gradient from downstream to upstream [13].

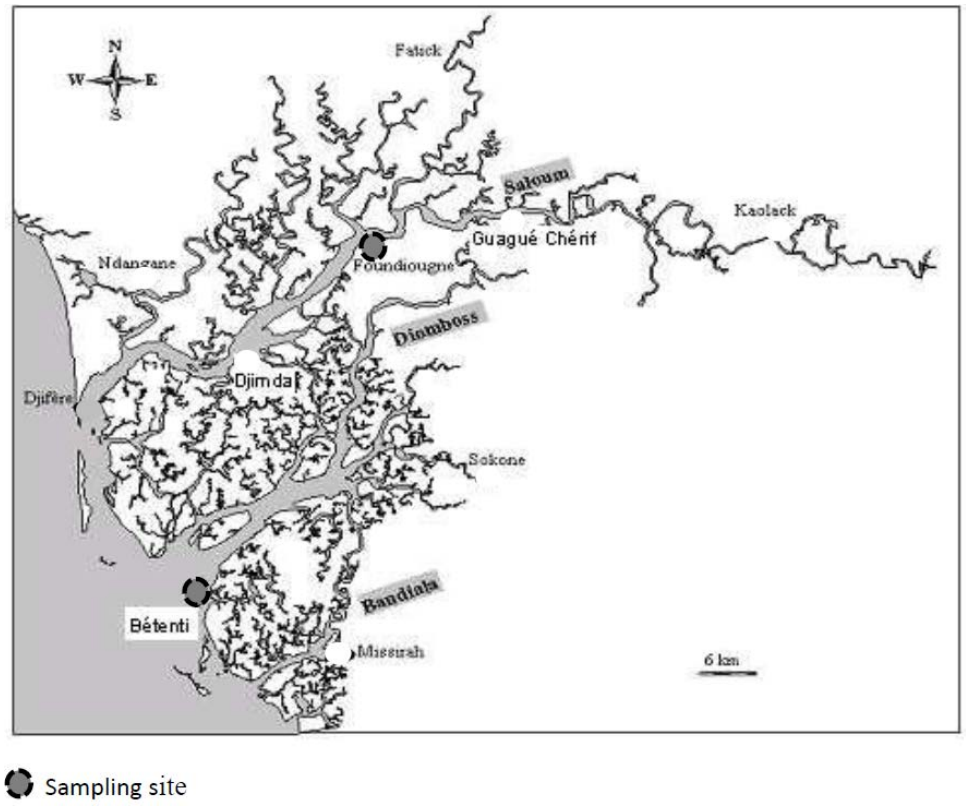

Figure 1: The estuary of the Sine Saloum - Senegal

2.2. Sampling protocol

The data used in this study come exclusively from fishing operations carried out by the fishermen of Bettenty and Foundiougne using the walk trawl as fishing gear called "Killi". The "Killi" is an elongated bag-shaped net, kept open during the fishing operation by two sticks and held by two fishermen who dive in water up to the chest. The pocket has a length between 5 to 10 m with a horizontal opening between 2 to 3 m, a vertical opening of 1.5 m and a uniform mesh of 12 mm side. Samples of shrimps are bought just when the fishermen landed. For each pair of fishermen, the total catch has been given and a sample of a kilogramme of shrimps was bought. All the shrimps sampled were measured (cephalothorax length) and weighed (total weight) and sexed at the laboratory.

The length used in this study is the carapace length (CL). It is measured with a digital caliper to 1/100 mm. It corresponds to the length between the indentation of the eye and the posterior medial edge of the carapace. The choice of the cephalothorax length was justified by the fact that it can be determined quite accurately. The total length varies according to the particular state of stretching of the abdomen and the state of the rostrum which is often broken. Finally, the individual and total weight were obtained with an accuracy of one milligram electronic scale.

2.3. Structure size

This is the frequency distribution of size. Measurements on individuals have helped to draw size structures to observe its evolution. Individuals were grouped by the size of 1 mm.

2.4. Length-weight relationship

Generally, weight and size are linked by a relationship of the form [14]:

$$W = a \times CLb \quad (1)$$

(Where W is the fresh weight in gramme (g), CL is the cephalothorax length in millimeter (mm) and «a», «b» are the parameters to be determined, «a» is the constant of regression and «b» the allometric coefficient). This relationship can be linearized by logarithmic transformation to reduce variability and homogenize the two variables (W and CL) [15]:

$$\log W = a + b \times \log CL \quad (2)$$

The coefficient «b» is often close to 3. It expresses the relative shape of the body of the species. When it is equal to 3, growth is called isometric. When it moves away, or at least is different from 3, growth is allometric. A coefficient «b» greater than 3 indicates a better growth in weight than in length and inversely [16].

2.5. Condition factor (Kc)

Condition factor (K) is used to estimate seasonal stoutness changes under the influence of external (environment) or internal (physiological) factors [16]. It is defined by the following relationship:

$$K = (W \times 100)/CL3 \quad (3)$$

(W = total weight of shrimp, CL = cephalothorax length).

2.6. Sex ratio

The sex ratio was calculated globally for each locality considered and according to the sizes of individuals. It 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 was expressed in this study as a percentage of females.

It was calculated according to the following formula [17]:

$$SR = (F \times 100) \times (1/ (F+M)) \quad (4)$$

(F = female; M = male).

2.7. Statistical analysis

Statistical analysis and graphics were performed with Excel and R software. After verifying the normality of distributions, the Student's t-test was used to assess differences of cephalothorax lengths sampled in both locations during the year, but also between males and females. The cephalothorax lengths-weight relationship data, after logarithmic transformation, were tested for homogeneity and slopes analysis of covariance to compare the intercepts. To confirm the presence or absence of a significant difference in this parameter between the sexes, the statistical test of conformity of chi-square type was used. For all statistical tests, a significant difference is admitted for $p < 0.05$.

3. Results

3.1. Structure size

The measurements of data allowed to draw the size structure of Farfantepenaeus notialis sampled in the area of Bettenty and Foundiougne. In total 8807 individuals have been measured and weighed of which 4494 at Bettenty and 4313 at Foundiougne.

The sizes of the samples collected at Bettenty are distributed between 10 and 39 mm while at Foundiougne they oscillate between 10 and 33 mm. The modes are 17 and 16 mm and the mean of cephalothorax lengths are 18.3±3.5 and 18.2±3.4 mm, respectively at Bettenty and Foundiougne (Figure 2). However, the essential of catch consists of individuals whose cephalothorax lengths are between 13 and 23 mm. The results of statistical analyzes showed, regardless of gender, significant differences ($p < 0.05$) between individuals sizes caught during the year in both localities.

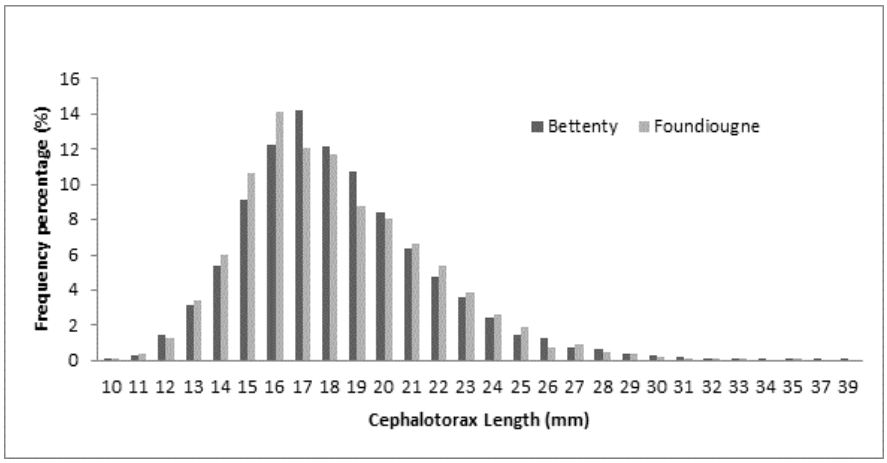

Figure 2: Frequency distribution of size of Farfantepenaeus notialis at Bettenty and Foundiougne

The cephalothorax length of male range from 10 to 33 mm at Bétanti and from 10 to 29 mm at Foundiougne while for females sizes vary between 10 and 39 mm and 10 and 33 mm respectively in both locations (Figure 3 and 4). The distribution is asymmetric for both males and females in both localities by the presence of a long tail for the big sizes class. The results of statistical tests show significant differences ($P < 0.05$) between cephalothorax lengths of males and females at Bétanti and at Foundiougne too. However, cephalothoracic lengths of males and females sampled at Bettenty are slightly greater than those of the males and females collected at Foundiougne.

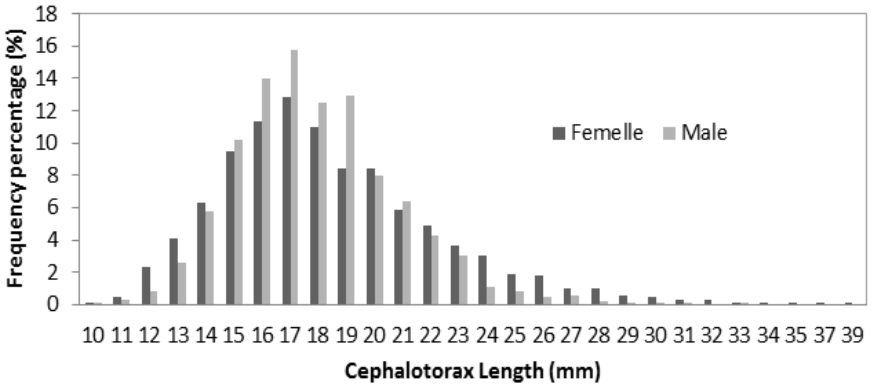

Figure 3: Frequency distribution of size of male and female of Farfantepenaeus notialis at Bettenty

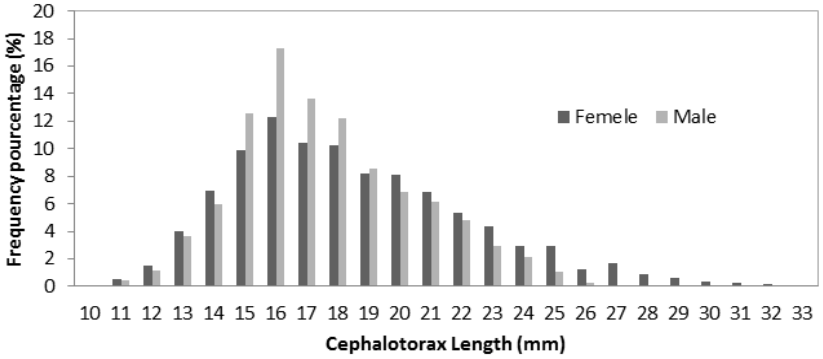

Figure 4: Frequency distribution of size of male and female of Farfantepenaeus notialis at Foundiougne

Table 1: Mean cephalothorax lengths of Farfantepenaeus notialis at Bettenty and at Foundiougne

Site	Bettenty		*Foundiougne*	
Sex	Male	Female	*Male*	*Female*
Mean LC (mm)	18.0±2.9	18.5±3.9	*17.6±2.9*	*18.5±3.8*

3.2. Length-weight relationship

The parameters of the length-weight relationships of male and female of Farfantepenaeus notialis at Bettenty and Foundiougne are shown in Table 2. The results of t-test Student show that there is no significant difference ($p > 0.05$) between the allometric coefficients of male and female in each locality.

The length-weight relationships of Farfantepenaeus notialis at Bettenty and Foundiougne for both sexes are represented by Figures 5 and 6 respectively. The confidence intervals for the coefficient b of the two relations shows a typical allometric growth for individuals sampled at Bettenty as for those sampled at Foundiougne. The growth in cephalothorax length is proportionally greater than the growth in weight for Farfantepenaeus notialis in both localities. However, the rate of weight gain is slightly faster at Bettenty (b = 2.94) than at Foundiougne (b = 2.75).

The equations below are obtained from the logarithmic transformation of the following equation:

$W = a \times CLb$ (5)

$Ln(W) = -6.96+2.94 \times ln(LC)$; $R^2 = 0.9327$ (6) «b» varying between 2.92 and 2.96: Bettenty

$Ln(W) = -6.44+2.75 \times ln(LC)$; $R^2 = 0.9092$ (7) «b» varying between 2.73 and 2.78: Foundiougne

Table 2: Parameters of length-weight relationship of Farfantepenaeus notialis

Parameters of length-weight relationship					
Locality	Sex	a	b	R^2	N
Bettenty	Male	0.001	2.92	0.92	2028
	Female	0.0009	2.95	0.93	2436
Foundiougne	Male	0.0018	2.71	0.89	2103
	Female	0.0015	2.78	0.92	2205
Bettenty	Both Male and Female	0.0009	2.94	0.93	5218
Foundiougne	Both Male and Female	0.0016	2.75	0.9092	4901

3.3. Condition factor (K)

The condition of *Farfantepenaeus notialis* factor have been calculated globally but also seasonally in both localities for both sexes. Global values of condition factor are 0.79 at Bettenty and 0.78 at Foundiougne and with a non-significant difference ($p > 0.05$). Figures 7 and 8 show the condition factor during the hot season and cold season respectively at Bettenty and Foundiougne. The mean values of the condition factor at Bettenty are equal to 0.78 and 0.80 in the cold season and the hot season respectively, while at Foundiougne they are 0.75

and 0.82. Overall, there is a significant ($p < 0.05$) seasonal effect on the condition factor of *Farfantepenaeus notialis* in both localities.

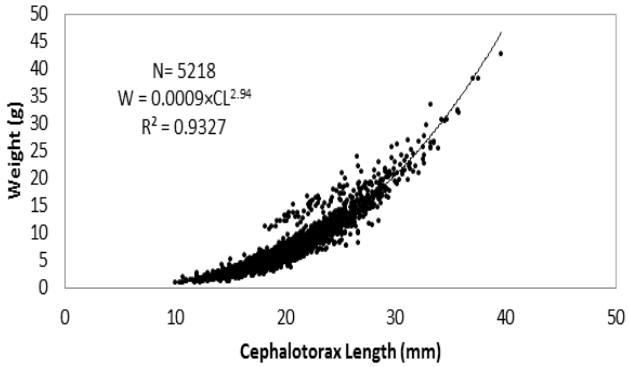

Figure 5: Length-weight relationships for Farfantepenaeus notialis at Bettenty

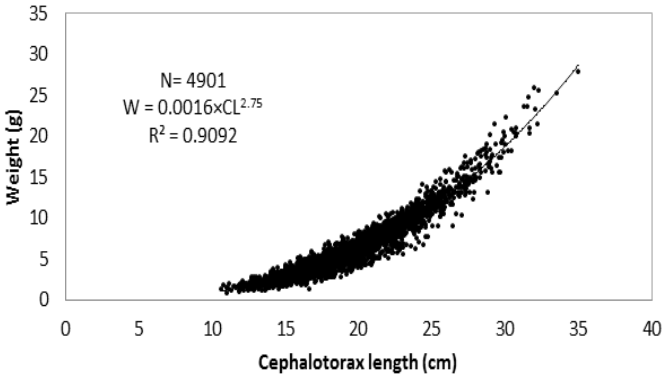

Figure 6: Length-weight relationships for Farfantepenaeus notialis at Foundiougne

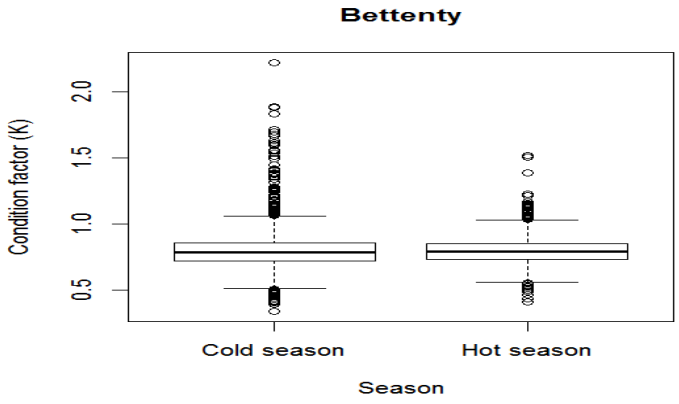

Figure 7: Condition factor (K) of Farfantepenaeus notialis at Bettenty

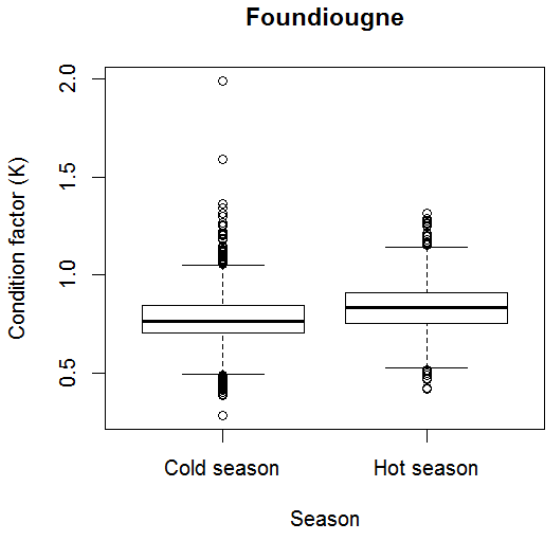

Figure 8: Condition factor (K) of Farfantepenaeus notialis at Foundiougne

3.4. Sex ratio

A total of 8772 individuals was used to study the sex-ratio Farfantepenaeus notialis. Observations made on different samples from Bettenty and Foundiougne allowed to the gender distribution of F. notialis. This species shows a sex-ratio slightly in favor of females with 54.6% and 51.2% respectively at Bettenty and Foundiougne (Table 3). However, the chi-square test shows no significant difference (P> 0.05) between the sex ratio of males and females in both localities.

Table 3: Value of sex-ratio of males and females at Bettenty and Foundiougne

Site	Sexe	Number	Sex-ratio
Bettenty	Female	2436	54.6%
	Male	2028	45.4%
Foundiougne	Female	2205	51.2%
	Male	2103	48.8%

The sex ratio shows also variations according to the size. In fact, below 15 cm, the females are more numerous and beyond 15 mm the number of male becomes slightly higher up to 20 mm. Beyond 20 mm, females again become more numerous until reaching 100% in older individuals size class (Figure. 9 and 10).

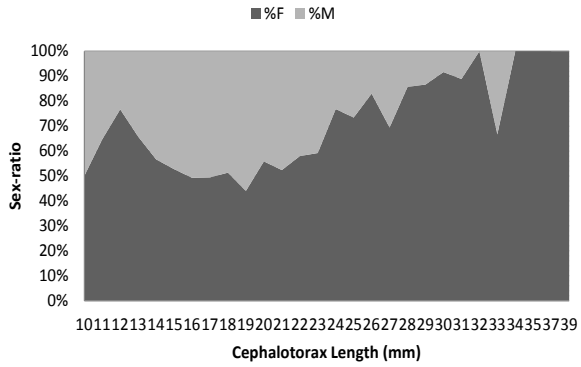

Figure 9: Sex ratio by size class of Farfantepenaeus notialis at Bettenty

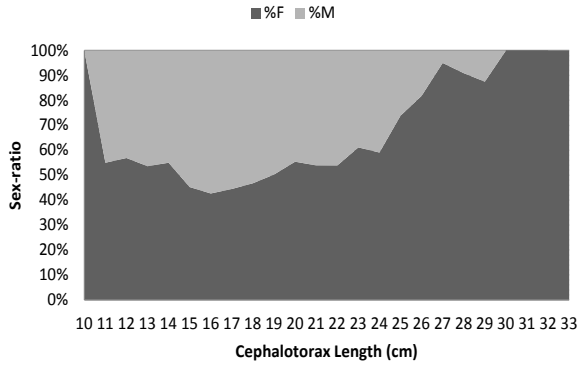

Figure 10: Sex ratio by size class of Farfantepenaeus notialis at Foundiougne

4. Discussion

The contraints and limitations of this study are related to sampling which is done from the catches of commercial artisanal fishing and not from experimental fisheries. So it lacks some class sizes, for example smaller and larger sizes. In fact the fishing gear ("Killi") used by fishermen selects a certain class size. That is why some growth parameters have been treated in this study.

4.1. Structure size

The difference in mean cephalothorax length between males and females found in the present study has also been described by other authors. The authors in [18, 19, 20, 21] showed mean cephalothorax lengths of females greater than those of males.

The difference observed between the sizes of individuals of Bettenty and those of Foundiougne could be due to a difference in environmental conditions such as salinity. Indeed, changes in salinity show that it is higher in Foundiougne waters than in Bettenty's [12]. Moreover, the authors in [2] shows that another impact of the increasing of salinity in the estuary is the reduction of the size and weight of some fish species. The shrimp abundance increases with salinity; however the modal size decreases with increasing of salinity. Indeed, during

periods of high salinity, shrimp are small, and when the salinity decreases, the shrimp increase in size [12]. Furthermore this could be explained by the distance of fishing aeras of the two localities in relation to the sea. Indeed Bettenty is closer to the sea than Foundiougne. Thus there is a strong chance that at Bettenty, fishermen catch shrimp during their migration to the sea since this species has a juvenile stage in lagoon or in estuary and adult phase at Sea [2].

4.2. Length-weight relationship

Weight gain difference observed between Bettenty and Foundiougne could be due to the difference of trophic richness between the fishing aeras of the two clocaities. Indeed, b depends on both biotic and abiotic factors, and especially on the availability of food and the type of habitat [22]. Likewise, habitat degradation reduces food availability. Studies on the ecology of the Saloum mangrove swamp show its low productivity due to the high salinity and nutriment deficit.

However, R^2 values found reveal a strong correlation between the weight and the cephalothorax length. The results of the present study agree with those in [9, 23] (Table 4).

Table 4: Parameters of length-weight relationship of Farfantepenaeus notialis compared with other results

Country	**Sexe**	**A**	**b**	**R^2**	**N**	**Authors**
Senegal (Bettety)	Male	0,001	2,923	0,925	2028	Present study
	Female	0,0009	2,953	0,932	2436	
Senegal (Foundiougne)	Mâle	0,0018	2,712	0,888	2103	
	Female	0,0015	2,781	0,918	2205	
Senegal (Bettenty)	Both Male and Female	0.0009	2.94	0.933	5218	
Senegal (Foundiougne)	Both Male and Female	0.0016	2.75	0.909	4901	
Senegal	Male	0.0017	2.75	0.95	130	[9]
	Female	0.0022	2.68	0.98	177	
	Male	0.0018	2.72			[23]
	Female	0.0022	2.66			
Mexico	Male	0,00041	3,18			[24])
	Female	0,00039	3,20			

4.3. Condition factor

The value found in the condition factor for all sexes and all seasons combined is slightly higher at Bettenty than at Foundiougne. This could be related with probably a difference of factors prevailing in the two localities. Indeed, the weakness of the slope along the estuary, low intakes of streaming from upstream and retention effected by the mangrove and evaporation do that the complex is affected now by an original type of hydrodynamic functioning, that of a reverse estuary [25], characterized by the predominance of tidal phenomena throughout the river system. The results of this are a reduction of the continental waters influence in favor of that of the sea and strong salinity gradient of water from downstream to upstream [26]. Thus, almost all of the sedimentary supply of Sine Saloum estuary would come from the sea. Bettenty being located on the mouth and downstream of Diomboss would have fishing areas with higher trophic wealth than those of Foundiougne which is distant from the sea. The authors in [26] show that in the Diomboss, the downstream and upstream parts are richer in nutriments because the downstream part is enriched by the ramifications which end in it and the upstream part has the contributions of Bandiala.

The analysis of seasonal condition factor shows that it is higher during the hot season in both localities. The condition factor is a parameter indicative of the nutritional state of the animal and therefore it is an indicator of interactions between biotic and abiotic factors on the physiological conditions [27]. These results suggest that the rainy season, which causes changes in the aquatic species habitat, would favor the growth of shrimp. Indeed, it is during the rainy season that higher availability of natural food is observed [15]. In other words, the authors in [4] showed that the growth of *Farfantepenaeus notialis* is fast in the hot season and strongly disrupted in the cold season and apparently during spawning. In the cold season, this species may be required to bear the maximum salinity conditions in the estuary because salinity is much higher dring this season [28]. In the hot season and especially during the rainy season there is an enrichment of the estuary. Indeed high temperatures accelerate the remineralization of organic matter. Rain contributes to environmental enrichment by steaming [29]. In the cold season, the total chlorophyll is low in the three main arms of the estuary while during the rainy season when the hot contents in chlorophyll are slightly higher [26].

4.4. Sex ratio

The sex ratio, expressed in percentage of female, is equal to 54.6% at Bettenty and 51.2% at Foundiougne. This sex ratio in favor of females of this species has been demonstrated in Ivory Coast [30, 5, 31, 18, 3].

However the authors in [32] in the estuarine aeras show equal proportions of males and females. This phenomenon is attributed to a selectivity difference for both sexes. At equal cephalothorax length, females are better retained by the trawl [3]. This dominance of females could also be due to a higher female recruitment or higher rates mortality of males.

At Bettenty and Foundiougne, dominance of the females beyond 20 mm of cephalotorax length is due to a difference in the laws of growth between males and females [33]. However, below 15 mm, the higher rate of females could be attributed to a difference of selectivity for both sexes [32]. In general, males are relatively more numerous in smaller sizes and females in larger sizes.

5. Conclusion

The present information on the biology of *Farfantepenaeus notialis* may be used for the assessment of shrimp stocks in Senegal. Furthermore, the analysis of the sample size structure of the two localities showed that the essential of catches is made up of individuals of relatively small sizes.

Indeed, fishermen of Bettenty and Foundiougne fish *Farfantepenaeus notialis* in the estuary or in the mouth which would be concentration area of this species. Weight gain has highlighted a minorante allometry in both localities. However, the growth is more important at Bettenty. As for the condition factor, the highest values were recorded during the hot season. The results obtained in this study show that the sex ratio is in favor of females in the two areas and also varies with the size class. The various biological parameters estimated in this work will be very useful for eventual population dynamics studies of this species and will, secondly, allow to understand better its biology.

We retain here that *Farfantepenaeus notialis* caught in the estuary has a small size. So it is urgent to set up a more elaborate development plan for the sustainable exploitation of this species.

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