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Fertility of Caribbean Freshwater Shrimp *Atya scabra* (Leach, 1815) in the Bia River, South-East Region, Côte d'Ivoire

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Abstract

Freshwater *A. scabra* is an endemic species of the Bia river precisely in Aboisso and Biaka. A total of 720 individuals were collected from August 2014 to July 2015 in the above-mentioned localities. No significant difference of the sex ratio have been observed (Aboisso: 1.2 M/F; Biaka: 1.16 M/F). The initial volume of eggs has increased during incubation of 66.25 and 79.17% of stage I to III respectively in Aboisso and Biaka. Thus, the size (Lt) at first maturity obtained respectively in males and females was estimated at 8.28 and 8.21 cm at Aboisso and 8.13 cm and 8.01 cm at Biaka.

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It was a respectively variation of 0.15 cm and 0.20 cm in males and females of both study sites. Aboisso absolute fecundity ranged from 7876 eggs (2.5 cm Lc and 6.4 cm Lt) to 33156 egg (4.1 cm Lc and 11.7 cm Lt) while at Biaka, it fluctuated between 6941 eggs (2.3 cm Lc and 6.7 cm Lt) to 37721 eggs (4.3 cm Lc et 12.4 cm Lt).The relative fecundity (FR) was 704 ± 86 eggs/g at Aboisso and 744 ± 97 eggs/g in the locality of Biaka. The correlation between the carapace length, total length and absolute fecundity (FA) were respectively $FA=9.816Lc^{3.285}$ (r=0.923), $FA=4.384Lt^{2.827}$ (r=0.704) for Aboisso and $FA=15.737Lc^{2.762}$ (r=0.814), $FA=5.328Lt^{2.640}$ (r=0.634) for Biaka.

Keywords: Freshwater shrimp; *Atya Scabra*; Bia river; fecundity; Côte d'Ivoire.

1. Introduction

The exploitation of *Atya scabra* (Leach, 1815) from Bia river is undeniable an economic fishery resource for residents of this region [18, 17]. Unfortunately, the lack of control and the high fishing effort could affected the stock [1, 17]. In order to preserve the species and perennial fishing, studying the reproduction of *A. scabra* is imperative [17]. Some aspects of its reproduction have been studied in Brazil by [15, 14, 8]. In Ivory Coast, the reproduction of this species has not been yet studied. Existing data on the shrimp are brought to the species *Macrobrachium vollenhovenii* and *M. macrobrachion* [6, 5]. This study aims to understand the reproduction of this species in order to educate fishing actors in the localities of Aboisso and Biaka. Then will focus on the maturation of eggs, determination of age at first maturity, sex ratio, and fertility.

2. Material and methods

2.1. Study zone

River Bia is located between 5°0'7°5' North latitude and 2°6 '3°3' West longitude. It takes origin in Ghana and measures 290 km within 120 km in the Ivory Coast. The coastal river covers 9650 km2 basin and flows into the lagoon Aby in south east [9]. Two dams (Ayame 1 and Ayame 2) were built on the main courses, respectively 22 to 28.7 km from the Aby lagoon [11]. The implementation of these two works was held in 1959 for the dam Ayame 1 and 1965 for dam Ayamé 2. Our study was conducted in the main course of the river Bia, specifically at Biaka and Aboisso (Figure 1), both are located downstream of Dam Ayame. Thus, two stations: T1 (5°27' N and 3°12' W) and T2 (5°28' N and 3°12' W) in Aboisso, while stations T3 (5°28' N, 3°11' W) and T4 (5°30' N and 3°11' W) were identified at Biaka (Figure 1).

2.2. Biological sampling

Freshwater shrimp specimens have been caught monthly on the main stem of the river Bia into two localities (Aboisso and Biaka) from August 2014 to July 2015. Thirty (30) individuals were collected monthly on each study site with a total of 720 individuals that components Total lenght (Lt) and The carapace length (Lc) were measured using a rock slide (200±1mm) and their sex determined by the observation of the second abdominal segment (pleura).

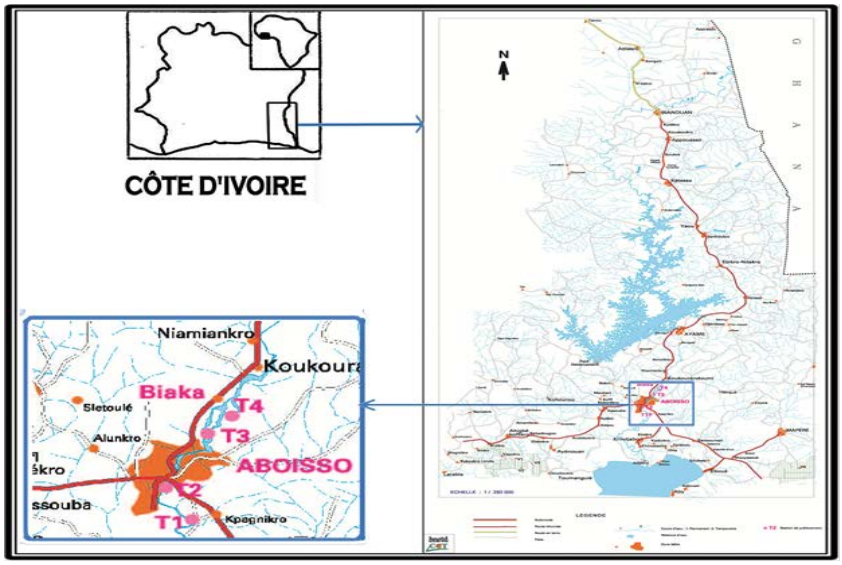

Figure 1: Geographical location of the stations Aboisso (T1 and T2) and Biaka (T3 and T4).

2.3. Study of Fertility

The counting of eggs was carried out by the method of sampling weights [10] and adapted by [7]. This study involved 70 Ovigerous including 30 in Aboisso and 40 Biaka. Berried shrimp were captured for the study of fertility in the months of June, July, October and November 2015. After noting the biometric data, the eggs were weighed and stored in Eppendorf tubes containing 5% formalin. A portion of 0.05 g of eggs drained on blotting paper was removed. Eggs are arranged in line in a petri dish and counted using a magnifying glass.

The relative fertility of each individual is determined by the number of eggs per unit of body weight in grams [16]. The absolute and relative fecundity were calculated using the following mathematical expressions:

FA = (N x P) / 5.10-2,

FR = FA / weight of the individual,

FR : relative Fertility, FA : absolute Fertility, P : Total weight of the eggs, N : Number of eggs in 0.05 g

2.4. Study of the sex ratio

Determining the sex ratio was made monthly and annually by the method used by [16]. In the present work, we used the sex ratio (the number of male divided by the number of females).

2.5. Investigations of eggs

This study involved 70 Ovigerous with 30 from Aboisso and 40 from Biaka. Eggs were measured, scraped using a spatula, weighed and preserved in 5% formalin. Thus, 30 eggs per female berried were measured to determine their volume (V) according to the following formula:

V = 1/6 (πd12d2) [8].

The mean diameter (d) of the egg is obtained by the following formula:

d = (d1 + d2) / 60 [7].

These measurements were performed by using WILD HEERBRUDG binocular (× 250, precision 0.1mm).

2.6. Size at first maturity

The determination of the size at first maturity was coupled with the gonad development status within the gender. Monitoring the sexual maturity of male and female was conducted monthly by histological sections of gonads [16, 5]. It has concerned individuals from Aboisso (164 females, 196 males) and from Biaka (167 females, 193 males). The percentage of mature females has concerned the stages 3, 4, 5 from the microscopic scale of sexual maturity. Groups had been made up within the size. The proportion of mature males and females in their specific size class Lt and L50, were integrated in the following logistic model:

$Pr = 1 / (1 + e^{(-a * [Lt-L50])})$ [16].

2.7. Statistical Analyses

Data collected have been treated with a G test that is the equivalent of the chi-squared test ($\chi 2$). The Student test (t) was used to assess the fertility of females and intraspecific relations fertility biometric parameters in both localities. R Version 2.10.1 software was used to carry out these tests. The significance of these tests was $\alpha = 0.05$.

3. Results

3.1. Study of Fertility

3.1.1. Gender identification

Females second abdomen segment was significantly developed than males. This predisposition is related to the amount of incubated eggs by females. In contrast, males have a larger body than females. The first pair of pereiopods and thorns of males are more developed than the females one.

3.1.2. Relation between the number of eggs and their maturity

In total, 70 Ovigerous from Aboisso (N=30) and Biaka (N=40) were taken to determine the mean number of eggs produced by female. Females from Aboisso has produced 656,628 eggs with an average of 21888 ± 7341 eggs. The smallest amount of eggs was 7876 and was obtained within the female that measured 2.5 cm (Lc) and 6.4 cm (Lt). Female of 4.1 cm (Lc) and 11.7 cm (Lt) had the highest nesting (33156 eggs products) (Figure 2).

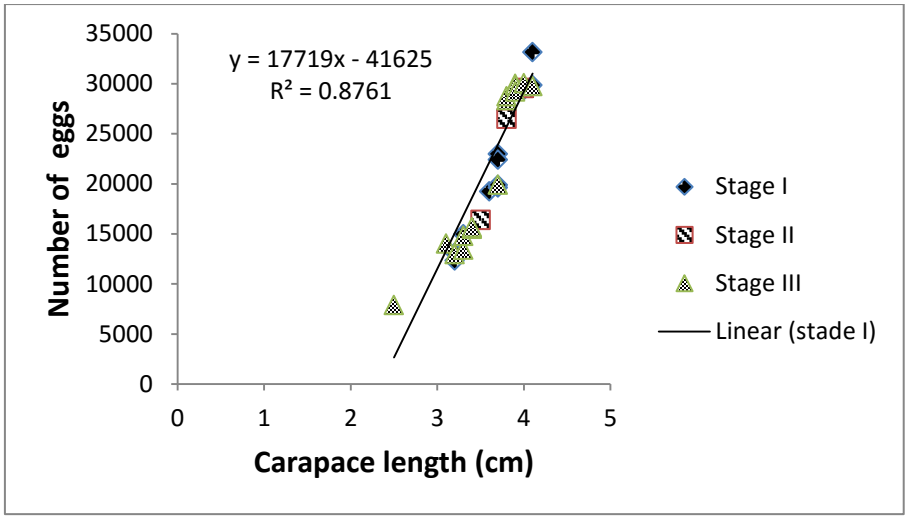

Figure 2: Correlation of number of eggs and maturity stage of *A. scabra* in the locality of Aboisso (N=30)

In the locality of Biaka, 40 ovigerous issued in 79065 eggs together. The average egg products was 19766 ± 7328 eggs. The female (2.3 cm (Lc) and 6.7 cm (Lt)) had the smallest egg production which was estimated in 6941 eggs. The largest number of eggs was obtained with a female (37721 eggs) having 4.3 cm (Lc) and 12.4 cm (Lt). The average eggs of *A. scabra* laid in two locations is not significantly different (t = 1.198, df = 68, P = 0.235) (Figure 3).

The relative fecondity (FR) was 21105 eggs / g with an average of 704 ± 86 eggs / g in Aboisso and 29754 eggs / g with an average of 744 ± 97 eggs / g in the locality of Biaka.

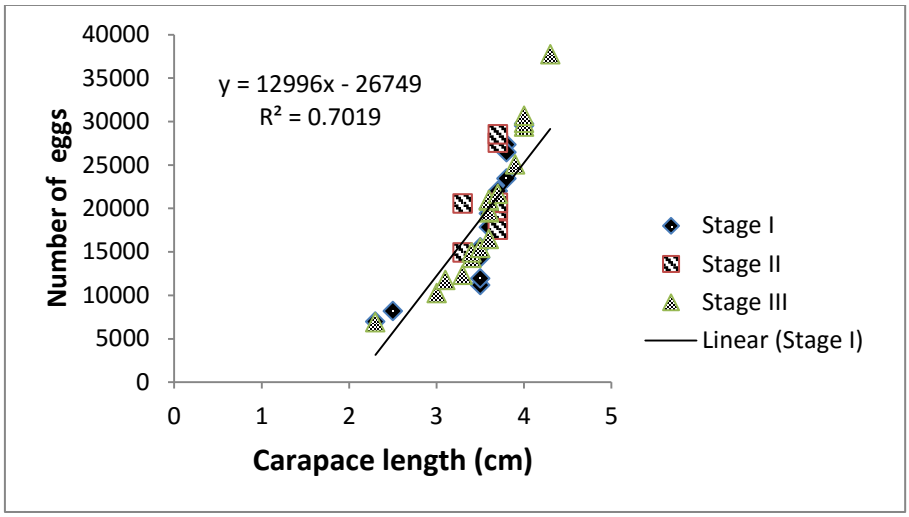

Figure 3: Correlation of number of eggs and maturity stage of *A. scabra* in the locality of Biaka (N=40)

3.1.3. Relation between the number of eggs and morphometric parameters

Three (3) equations ($FA = aLc^b$, $FA = aLt^b$ and $FA = aW^b$) that made a relation between absolute fecundity to length carapace (Lc) and total length (Lt) and total weight (W) in both localities were studied to appreciate

females fertility.

Table 1 shows that the correlation between the number of eggs and the carapace length is higher compared to the weight and the overall length of the individual (Table 1).

A part from the relation between absolute fecundity (FA) to the total weight (W) of shrimp, FA significantly faster than changing the carapace length and the total length in the respective localities Aboisso and Biaka ($P < 0.05$).

Table 1: Comparison of relations linking the absolute fertility *Atya scabra* weight, total and carapace lengths in localities Aboisso and Biaka

	Aboisso				**Biaka**							
Relations	**n**	**a**	**b**	**r**	**n**	**a**	**b**	**r**	**Valeur de t**	**Ratio F variance**	**P variance**	**P>F**
FA/Lc	30	2,484	3,285	0,923	40	2,756	2,762	0,814	17,325	2,786	0,005	0,000
FA/Lt	30	1,478	2,827	0,704	40	1,673	2,640	0,634	7,681	1,466	0,287	0,000
FA/W	30	2,799	1,031	0,895	40	2,799	1,049	0,893	-1,767	1,216	0,589	0,082

n : Number of egg-bearing females, a : regression constant, b : regression coefficient, r : correlation coefficient, t : value of Student's t FA : absolute Fertility, Lc : Length carapace, Lt : Total length, W : Total freshwater shrimp mass.

3.2. Determination of the sex ratio

During the 12 sampling months (August-July), 360 individuals were collected from each study site. In the town of Aboisso, 196 males and 164 females were counted. The sex ratio obtained was 1.2 (M/F), not significantly different ($\chi 2 = 0.7896$, df = 1; $P = 0.3742 > 0.05$) (Table 2). Males were predominant for five (5) months (1.62 M/F) and females the other months (0.78 M/F). 193 males and 167 females were captured during the test at Biaka (Table 3). . The sex ratio was 1.16 M/F. The Khi 2 test shows that there were not significant difference between the sex ratio ($\chi 2 = 0.5217$, df = 1 ; $P = 0.4701 > 0.05$). During six (6) months, males ratio were more important than the females (1.59 M/F; 0.68 M/F).

Table 2: Number of males and females sampled by month and sex ratio at Aboisso

	Aug.	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Jul.**
Males	20	18	12	14	21	15	14	13	15	18	23	13
Females	10	12	18	16	9	15	16	17	15	12	7	17
Sex-ratio	2	1,50	0,67	0,88	2,33	1	0,88	0,76	1	1,5	3,29	0,76
Khi^2	11,3*	4,03*	4,03*	0,44	16,46*	0	0,44	1,78	0	4,03*	29,98*	1,78
Total	30	30	30	30	30	30	30	30	30	30	30	30

*, Probability P < 0.05

Table 3: Number of males and females sampled by month and sex ratio at Biaka

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Jul.
Males	20	20	13	12	17	11	12	15	16	21	22	14
Females	10	10	17	18	13	19	18	15	14	9	8	16
Sex ratio	2	2	0,76	0,67	1,31	0,58	0,67	1	1,14	2,33	2,75	0,76
Khi^2	11,33*	11,33*	1,79	4,03*	1,79	7,19*	4,03*	0	0,44	16,46*	22,64*	1,78
Total	30	30	30	30	30	30	30	30	30	30	30	30

*, Probability P < 0,05

3.3. Maturation of eggs

Three (3) colorations of issued eggs were observed in ovigerous females. Stage I, II and III respectively correspond to the coloration of eggs « brown », « light brown » and « Dark brown ». At Aboisso, ovigerous females (N = 30) obtained have a carapace length (Lc) between 3.58 and 3.76 cm with a mean of 3.68 cm ± 0.34 cm. As for the total length (Lt), it is between 9.74 and 10.23 cm with the average 10.06 ± 0.62 cm. Ovigerous stage III had the lower Lc (3.58 cm) and the upper Lc (3.76 cm) was concerning the female in stage II. The average volume of eggs varies from 0.053 ± 0.029 mm 3 in stage I and increases at the end of embryogenesis 0.08 ± 0.05 mm^3. From stage I to stage II, the volume increases of 92.98% and 71, 25% stage II to stage III or an increase of 66.25% from stage I to III (Table 4).

Table 4: Measures (Lc, Lt) berried females of *A. scabra* and the average volume of eggs in Aboisso

	Stage I	Stage II	Stage III
Female Lc (cm)			
Average	3,69	3,76	3,58
± SD	0,28	0,25	0,45
Max.	4,1	4,0	4,1
Min.	3,2	3,5	2,5
Female Lt (cm)			
Average	10,22	10,23	9,74
± SD	0,83	0,60	0,13
Max.	11,7	10,8	11,4
Min.	8,6	9,6	7,1
Egg volume (mm^3)			
Average	0,053	0,057	0,08
± SD	0,011	0,019	0,02
Max.	0,075	0,094	0,12

Min.	0,029	0,027	0,05
N	12	3	15

SD: Standard deviation, N: Number of individuals

In the town of Biaka, carapace length of ovigerous females (N = 40) ranged from 3.48 to 3.58 cm with a mean of 3.54 ± 0.39 cm and Lc 9.54 to 9.78 cm with a mean of 9.67 ± 0.99 cm Lt. The lower average of 3.48 cm and 9.54 cm Lt were observed in ovigerous females in stage I and the highest average was that of females in stage II (Lc 3,58 cm, 9.78 cm Lt). Eggs volume increases from 0.038 ± 0.007 mm^3 to 0.048 ± 0.008 mm^3 at the end of incubation (stage III). The volume of the egg increases of 97.44% from stage I to stage II and 81.25% of stage II to stage III. The increased volume of the egg stage I to III is therefore 79.17% (Table 5).

Table 5: Measures (Lc; Lt) berried females of *A. scabra* and the average volume of eggs to Biaka

	Stage I	**Stage II**	**Stage III**
Female Lc (cm)			
Average	3,48	3,58	3,55
± SD	0,46	0,19	0,45
Max.	4,0	3,7	4,3
Min.	2,3	3,3	2,3
Female Lt (cm)			
Average	9,54	9,78	9,68
± SD	1,23	0,41	1,24
Max.	10,8	10,4	12,4
Min.	6,7	9,4	7,0
Egg volume (mm^3)			
Average	0,038	0,039	0,048
± SD	0,007	0,008	0,008
Max.	0,049	0,051	0,066
Min.	0,02	0,02	0,032
N	15	7	18

SD: Standard deviation, N: Number of individuals

3.4. Size at first maturity

Figures 4, 5, 6 and 7 showed percentage change based on size range.

Thus, the size (Lt) at first maturity obtained respectively in males and females was estimated at 8.28 and 8.21 cm at Aboisso and 8.13 cm and 8.01 cm at Biaka. It was a respectively variation of 0.15 cm and 0.20 cm in males and females of both study sites.

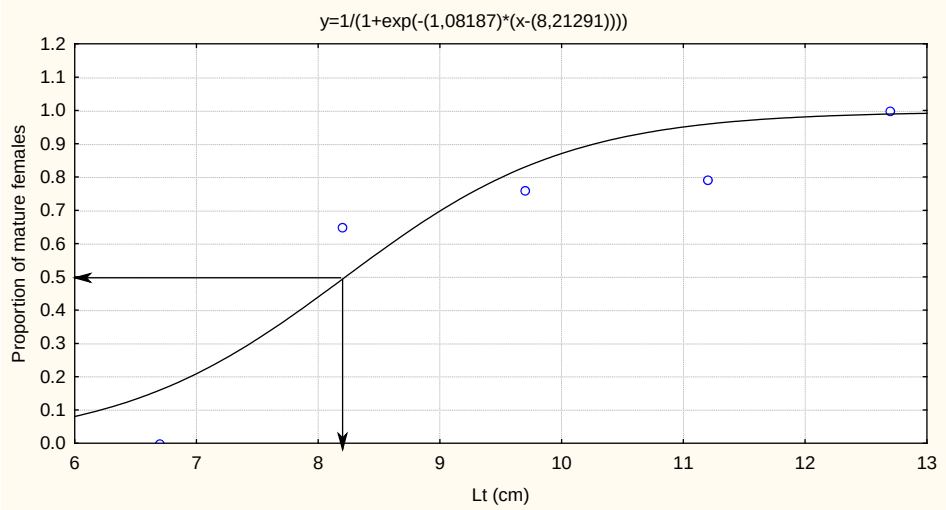

Figure 4: Percentage of mature females based on size range in *A. scabra* in locality Aboisso (n = 164)

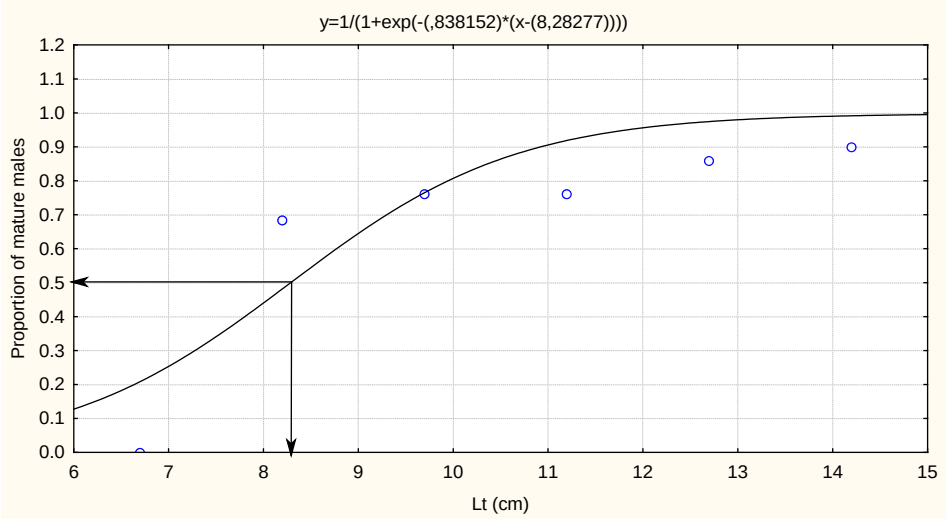

Figure 5: Percentage of mature males according to the sizes range in *A. scabra* in locality Aboisso (n = 196)

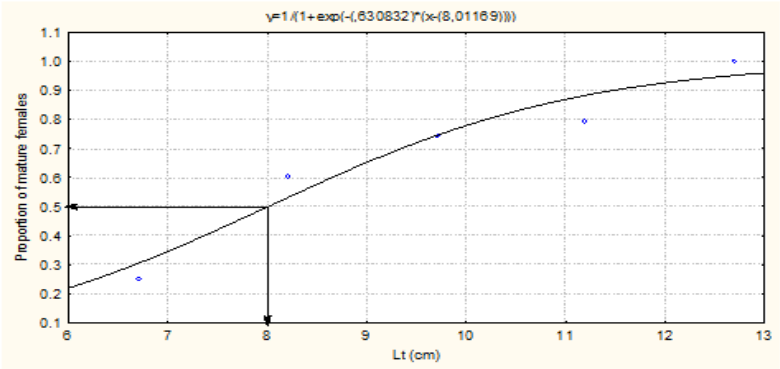

Figure 6: Percentage of mature females based on size range in *A. scabra* in locality Biaka (n = 167)

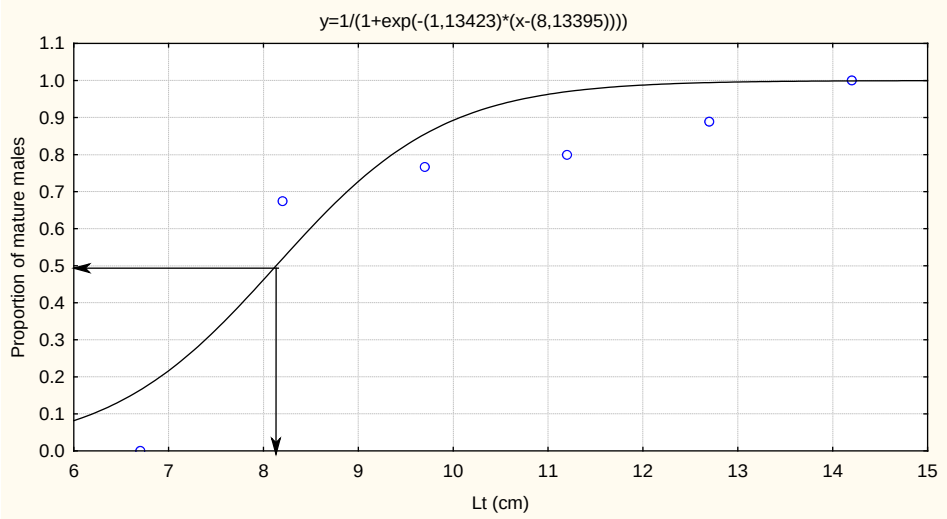

Figure 7: Percentage of mature males according to the range sizes of *A. scabra* in the locality of Biaka (n = 193)

4. Discussion

The sex ratio of *A. scabra* have been towards males and especially during periods of reproduction. According to some authors this balance of males could be due to their intrinsic nature and the continuous reproduction [14]. This study has shown that *A. scabra* breeds during the main rainy season (May, June and July), the short dry season (August and September) and the short rainy season (October and November).

In fact crustaceans reproduction is characterized by the presence of egg-bearing females in the catch. In some species like the mantis, the males are more abundant during reproduction in the decision because the females burrowed to incubate the eggs [16]. Some authors attribute the change in the sex ratio of *A. lanipes* Holthuis [2] and *A. margaritacea* [13] because of streams flood. These observations are controversial by [15] in Brazil with a sex ratio in favor of females (0.4 M/F). It is the same with *Macrobrachium macrobrachion* [3, 5].

The average harvested eggs per female of *A. scabra* in localities Aboisso and Biaka are similar. The fertility obtained is higher than the fertility reported in the area of São Sebastião [8] and in the North East region of Brazil [14]. This difference between the number of eggs stored would probably be related to the size of the females of *A. scabra*. [12] have observed that absolute fertility changed with the size of females shrimp. Fecundity in *A. scabra* is positively correlated with the size [14].The volume of eggs of *A. scabra* is highest in stage III than stage I, compared to data obtained by [8]. These observations on *A. scabra* are similar to results obtained in *A. margaritacea* [13]. The volume of the egg of *A. scabra* could be a form of stored energy for reproduction [4]. Indeed, some authors attribute this predisposition to *A. scabra* which spend an amphidromic life, whose juvenile stage happens in freshwater and larval into brackish water [14]. In contrary, this study has demonstrated that the species *A. scabra* realized its life cycle in freshwater (River Bia).

The size (Lt) at first maturity of males were 8.28 cm (Aboisso) and 8.13 cm (Biaka) when females were measured 8.21 cm (Aboisso) and 8.01 cm (Biaka). Males and females were almost having the same size. These

results are higher than 2.53 cm obtained by [14] within ovigerous females captured in Brazil and the one captured by [13] in Mexico which smallest female size was 3.2 cm. The results obtained on size at first maturity were significantly higher compared to the data of the above kind Atya authors. Similar studies have been done on other species like *M. vollenhovenii* and *M. macrobrachion*. Size at first maturity of 10.26 cm for females and Lt 11.42 Lt cm for males have been observed in the species *M. macrobrachion* in the Bandama river [5].

5. Conclusion

This study has shown that in the species *A. scabra*, sexual dimorphism is pronounced. The capture of specimens is predominated by males than females, and especially during the breeding season. Absolute fecundity is changing significantly faster with carapace length than the total length. Egg development is characterized by an increase in volume. The size at first maturity is similar for both sexes in each locality. It would be interesting to conduct a study on the storage cycle of energy reserves during reproduction in this species.

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