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First data on reproductive biology of *Macrobrachium macrobrachion* (Palaemonidae Decapoda), from River Bandama (Côte d'Ivoire)

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ABSTRACT: Reproductive biology of palaemonid prawn, *Macrobrachium macrobrachion* (Herklots, 1857), were investigated in Bandama River (Côte d'Ivoire), from January to December 2009. A total of 465 shrimps were collected during this period. Significantly more females than males (male: female ratio, 1.0: 1.38) were observed. The size at sexual maturity was 11.42 cm total length (TL) for males and 10.26 cm (TL) for females. The gonadosomatic index (GSI) varied monthly, reaching maximum (2.50 ± 0.83 %) in June and September (1.68 ± 0.56 %), and a minimum (0.12 ± 0.04 %) in December for female. For males, GSI had their maximum in July (0.33 ± 0.11 %) and a minimum in December and January (0.05 ±0.02 %).The gonadosomatic index (GSI) and maturity stages indicated that the reproductive period of *Macrobrachium macrobrachion* occurred from May to October. The absolute fecundity ranged from 574 eggs (TL = 8.80 cm) to 36.933 eggs (TL = 11.30 cm). The relative fecundity was 735 ± 439 eggs g^{-1} of females. The relationships between the total weight (TW) and fecundity (number of eggs = F), total length (TL) and fecundity (F) were $F_w = 1213\ TW^{1.513}$ (R^2= 0.824) and $F_L = 599.6\ TL^{2.738}$ (R^2= 0.969) respectively.

KEYWORDS: *Macrobrachium macrobrachion*, Reproductive period, Fecundity, Côte d'Ivoire.

1 INTRODUCTION

The worldwide prawn production surpassed 240.000 t in 2000, which corresponds approximately 20% of the total amount manufactured an according to [1] and [2]. Species of prawns can be characterized by their life cycle [3]. Reference [4] mentioned that the prawn females keep their eggs in the abdomen until spawning time. Most of the prawn species interested by the commercially belong to the *Macrobrachium* Bate, 1868. This genus is distributed globally in most biogeographical regions, with more than 240 named species [5], [6]. Several shrimp species of genus *Macrobrachium* inhabit fresh and brackish water of West Africa [7], [8].According to [9], only two of the 7 shrimp species registering in the Rivers of Côte d'Ivoire are exploited by fishing activities: *Macrobrachium vollenhovenii* (Herklots, 1851) and *Macrobrachium macrobrachion* (Herklots, 1857). *Macrobrachium* species are relished by indigenous consumers due to their large size, nutrient value and pleasant taste [10], [11]. They are commercially important prawn species common in West African waters and sustaining viable artisanal fisheries in some rivers and estuaries within the region. Shrimp fishery sector provide direct and secondary employment [12], [11], [13]. Shrimps are considered in Côte d'Ivoire a valuable fishing resource and their market prices are appreciably higher than those of fishes [9].

Several studies have been performed on the reproduction and ecology of Palaemonid shrimp. The tolerance limit against environmental factors, such as, water temperate, pH and dissolved oxygen was reported [14]. Comprehensive research of Palaemonids includes studies on the differences in habitation, ecology and reproduction between Palaemonid shrimps [15]. Also, the works of [16] and [17] emphasized respectively the biological aspect and the population structure of *M. vollenhovenii.*

Considering the lack of data on the reproductive biology of *M. macrobrachion* from Côte d'Ivoire River, the aims of this study were to evaluate the different periods of its reproductive activity, Fulton's condition index and the relationship between energy reserves of the hepatopancreas and the gonad development of this specie in Bandama River and similar water. Key parameters required for stock assessments including sex ratio, first maturity size, and reproductive season and also fecundity are estimated.

2 MATERIAL AND METHODS

2.1 STUDY AREA

Bandama River (Fig. 1) has a main channel stretching over a distance of 1.050 km and a catchment area of 97.500 km^2. The river rises in the north of the country, between Korhogo and Boundiali, and enters the sea at Grand-Lahou lagoon. It is two tributaries are Marahoue (550 km length) and N'zi (725 km length). Two hydroelectric dams, Kossou lake (drainage area: 900 km^2) and Taabo lake (drainage area: 69 km^2) were built on the main course of the river [18].Data were collected downstream Taabo hydroelectric dams located between 4°80'- 5°00'W and 5°80' - 6°20'N from January to December 2009into three main shrimp fishery at the Bandama River, Taabo, Singrobo and Tiassalé.

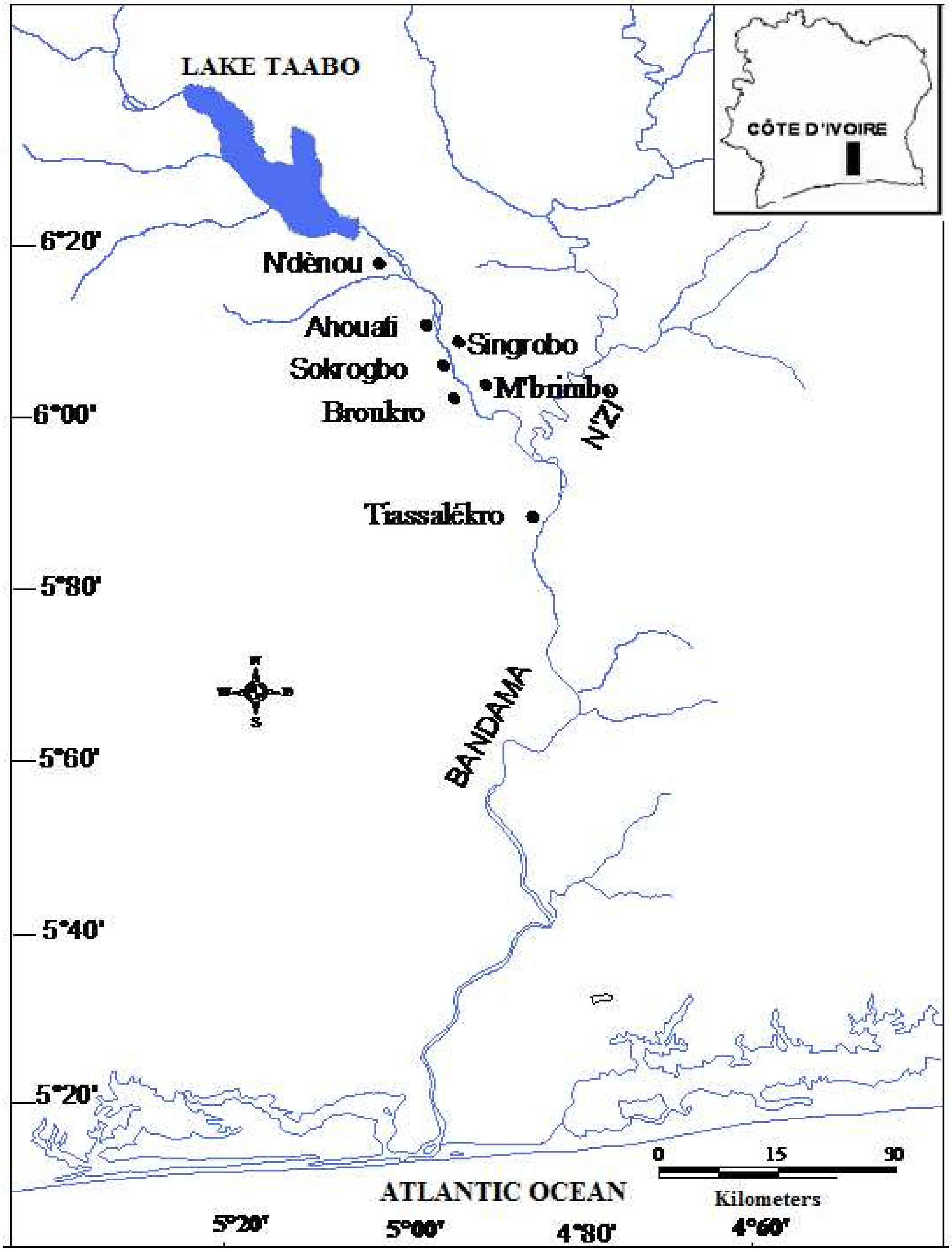

Fig. 1. Map of the study area showing the sampling stations (●) of Macrobrachium macrobrachion from January to December 2009 in Bandama River (Côte d'Ivoire).

2.2 SHRIMPS SAMPLING

Shrimps were collected monthly from commercial fishery landing with hoop nets. Traps were installed during the afternoon, and withdrawn the next morning. Shrimps captured were identified following[9].Data on Total Length (TL) in cm was measured to the nearest 0.01 cm for each shrimps using digital slide calipers (Mitutoyo, CD-15PS), and total weight (W) in g were recorded with a top loading Sartorius balance model BP 310S with 0.01 g accuracy.

The sex of each specimen was determined by visual observation of the base of the fifth and third pair of periopods [3]. Shrimps were dissected, gonad and the hepatopancreas were weighed. Gonad development was classified in five stages, according to [19] and [20].

2.3 DATA ANALYSIS

2.3.1 SEX RATIO

Sex-ratio deviation from 1:1 was checked with the Yates-corrected goodness-of-fit chi-square test on data from adult specimens [21]. All statistical analyses (α = 0.05) followed [21].

2.3.2 SIZE AT FIRST SEXUAL MATURITY

Sex was determined and a maturity classification was made [22][23] where stages III and above were considered to be mature for males and females respectively. The size at first sexual maturity (LT_{50}) was determined by calculating the proportion of mature individuals in each size class. The size at which 50% of individuals were mature was taken as the size at which prawns reach maturity for the first time [24]. The logistic model was used to determine the size at first sexual maturity [25]:

$$P = \frac{e^{(\alpha + \beta LT)}}{1 + e^{(\alpha + \beta LT)}} \text{ where } LT_{50} = \frac{-\alpha}{\beta}$$

P = proportion of mature individuals; LT = total length; α and β = constants

2.3.3 REPRODUCTIVE INDICES

Three reproductive indices were measured to estimate the condition of prawns: gonadosomatic index (GSI), hepatosomatic index (HSI) and Fulton's condition factor (Kc). These three indices were determined [24] as:

$$GSI = \frac{Wg}{Wb} \times 100 \;;\; HSI = \frac{Wh}{Wb} \times 100 \;;\; Kc = \frac{W}{TL^3} \times 100$$

Where Wg = gonad weight (g); Wh = hepatopancreas weight (g); Wb = wet body weight (g); W = Weight of prawn (g) and TL = Total Length of prawn (mm).

Measurements average of GSI, HSI and Kc were taken for each monthly collection and recorded accordingly. There were sequentially arranged in time series in order to delineate spawning season.

2.3.4 ABSOLUTE FECUNDITY

A subsample of the eggs was weighted (g) and counted (n). The absolute fecundity (F) was the total number of eggs per female, which is obtained by applying the following formula according [26]:

$F = \frac{Wg}{Wss} \times n$; where Wg = weight of eggs total mass(g); n = number of eggs and Wss = weight of sub samples (g).

2.3.5 RELATIVE FECUNDITY

The relative fecundity (RF) was the number of eggs per unit weight (g) of prawns [26].

$RF = \frac{F}{TW}$; where F = absolute fecundity and TW = weight of prawns

All these analyses were carried out using statistica7.1 and adopted for all the *p*-value with significance level of 0.05.

3 RESULTS

3.1 SEX-RATIO

A total of 465 individuals of *Macrobrachium macrobrachion* were sexed, comprising 270 females and 195 males, with a sex ratio of 1.38 females per male (Table 1).A chi-square goodness of fit test showed that the ratio was not significantly different from a 1:1 ratio ($\chi^2 = 1.71$; *p-value* > 0.05). Monthly chi-square values for *M. macrobrachion* showed that there were significant differences in March, April, June, July, September, October and December.

Table 1. Chi-square values for monthly sex ratio of Macrobrachium Macrobrachioncaptured in Bandama River from January to December 2009; (*) Significant difference (p < 0.05).

Month	Females	Males	M:F ratio	χ^2
January	31	23	1:1.35	1.31
February	21	19	1:1.11	0.11
March	25	13	1:1.92	6.91*
April	29	10	1:2.90	15.76*
May	20	14	1:1.43	2.17
June	15	8	1:1.88	6.06*
July	61	25	1:2.44	12*
August	14	13	1:1.08	0.11
September	16	7	1:2.29	10.86*
October	5	25	1:0.20	30.52*
November	19	12	1:1.58	3.24
December	14	26	1:0.54	6.06*
Pooled	270	195	1:1.38	1.71

3.2 SIZE AT FIRST SEXUAL MATURITY

The length at first sexual maturity (L_{50}) is 10.26 cm TL for females and11.42 cm TL for males (Fig. 2). At 11.10 cm TL, 100 % of female attained sexual maturity therefore at 12.40 cm TL, 100% of the males reached maturity. In fact, the smallest female matured at 8.2 cm total length, whereas in the males it was 7.7 cm total length. No significant differences were found between size at first maturity of both sexes ($\chi^2 = 0.27$; *p-value*> 0.05).

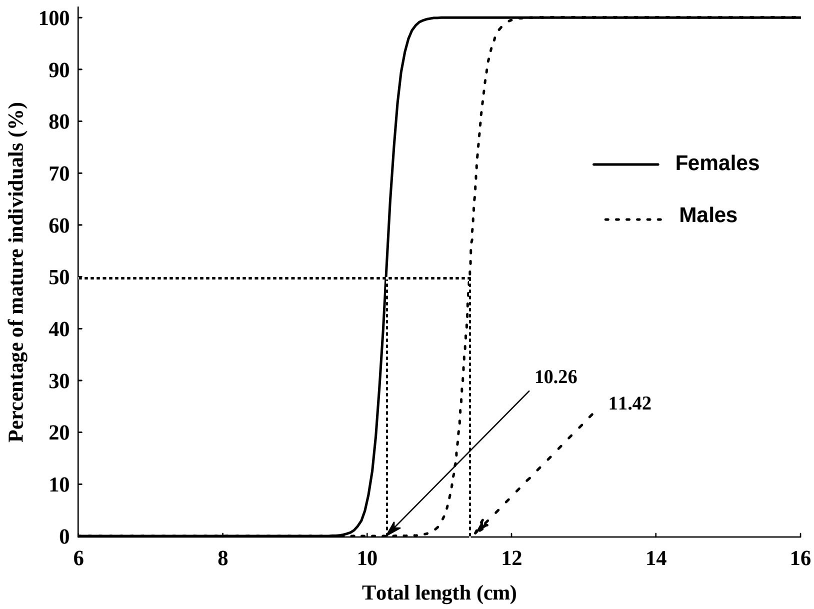

Fig. 2. Logistic equation indicating size (Total length) at first sexual maturity (L_{50}) for males and females of Macrobrachium macrobrachion from January to December 2009 in Bandama River

3.3 GONADO-SOMATIC INDEX AND REPRODUCTIVE PERIOD

Monthly variations of maturity stages (stages 3, 4 and 5) and GSI (fig. 3) showed highest percentage of mature females (≥ 60 %) from May to July and September to October. Maxima of GSI (> 1.5 %) were recorded from June to October with two peaks. The first highest, in June (2.50 ± 0.83 %) and the second, slightly smaller (1.68± 0.56 %), in September. This indicates that *M. macrobrachion* in Bandama River underwent a reproductive period between May and October.

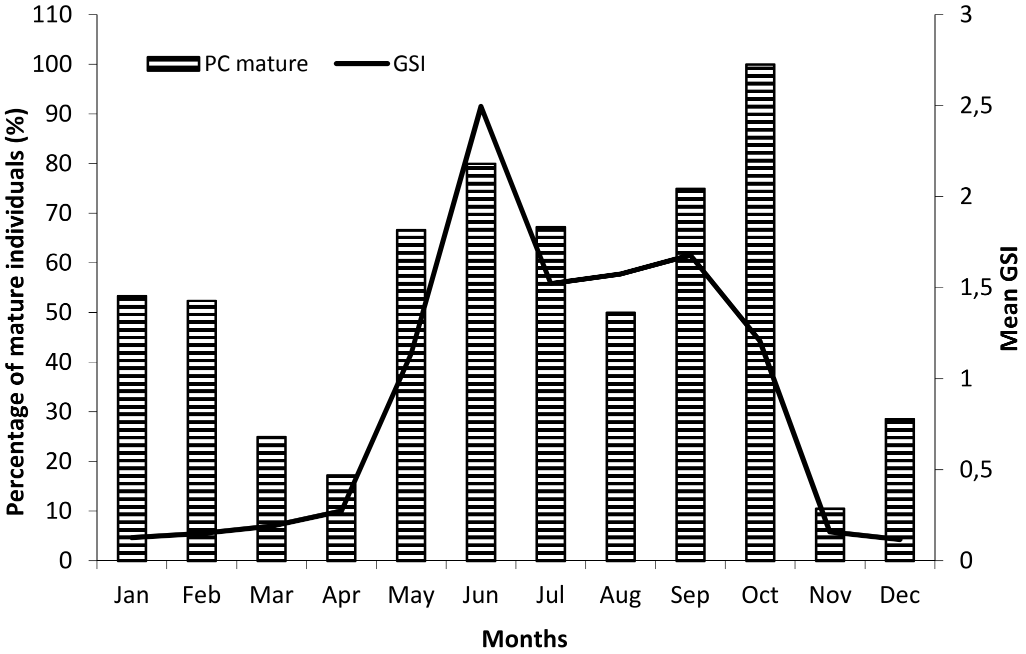

Fig. 3. Relationship between percentages of females mature and GSI mean of Macrobrachium macrobrachionin River Bandama from January to December 2009

3.4 HEPATO-SOMATIC INDICES

The trend of GSI and HSI for females (Fig. 4) was either at the same for males (Fig. 5). Variation of HSI showed an inverse relationship with GSI. The red lead month varied from May to July and September to November. The lowest HSI values showed in July (4.43 % ± 2.28) for females while the lowest was in May (2.84 % ± 1.55) for males. Two distinct peaks months were observed in March and August, respectively for both sexes.

3.5 CONDITION FACTOR

The values of condition factor (K) obtained range from 0.0015 to 0.0017 for females and 0.00014 to 0.0018for males. Peak values for females were recorded in August and in September for males (Fig. 6). The lowest values were observed in July and November for females and males respectively.

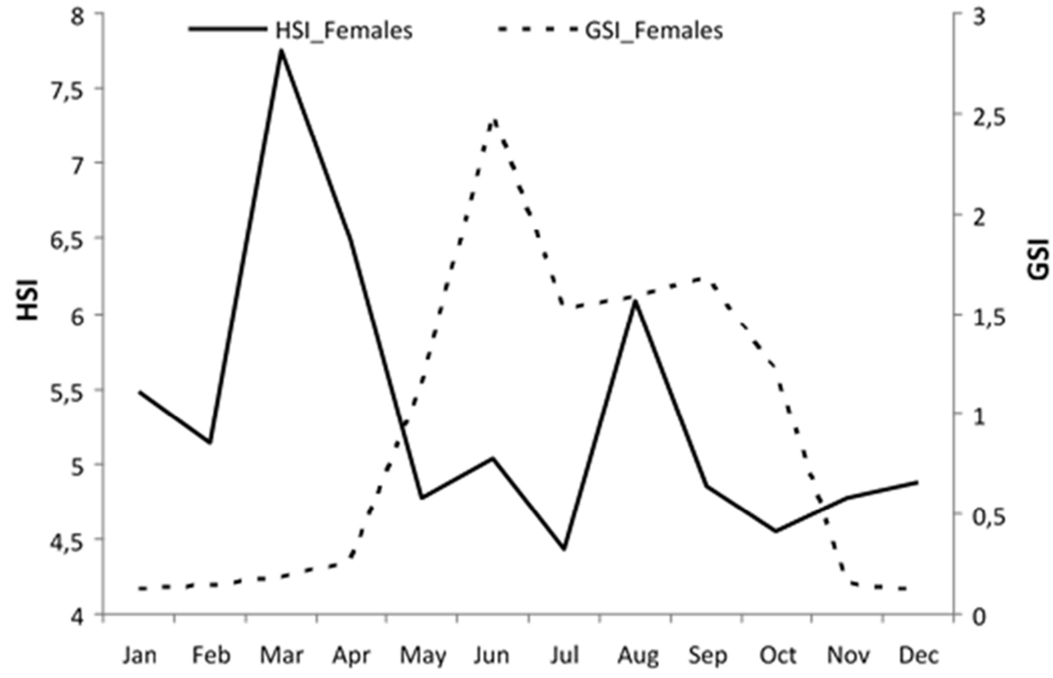

Fig. 4. Gonadosomatic (GSI) and Hepatosomatic indices (HSI) of female of Macrobrachium macrobrachion in Bandama River from January to December 2009

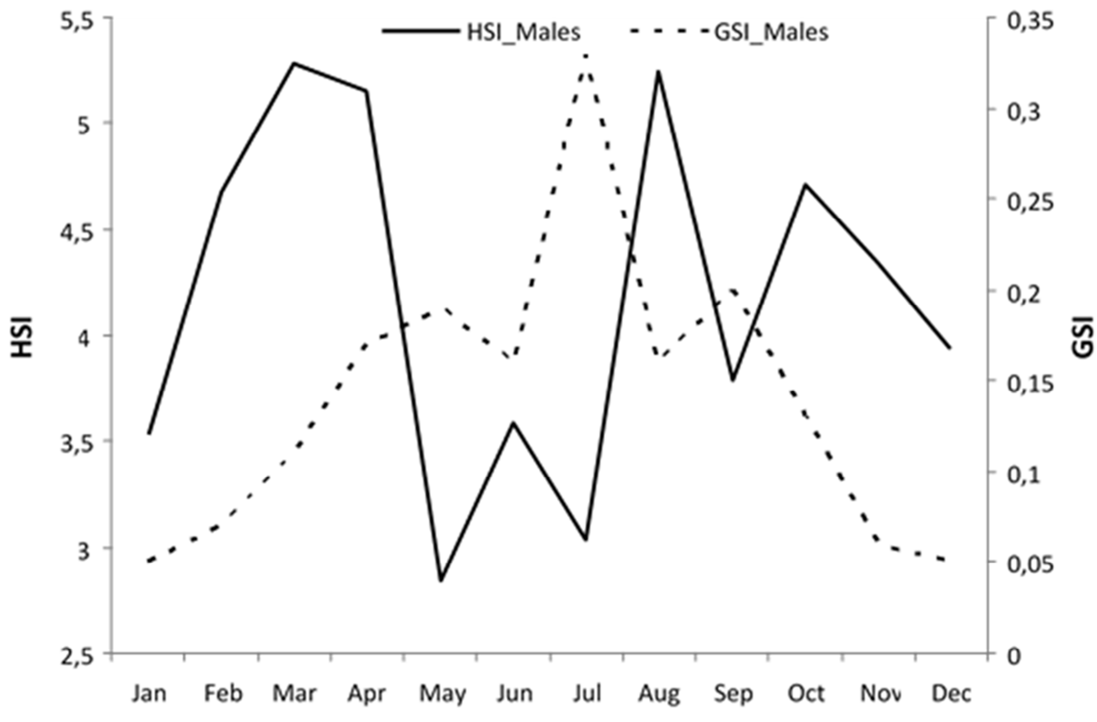

Fig. 5. Gonadosomatic (GSI) and Hepatosomatic indices (HSI) of male of Macrobrachium macrobrachion in Bandama River from January to December 2009

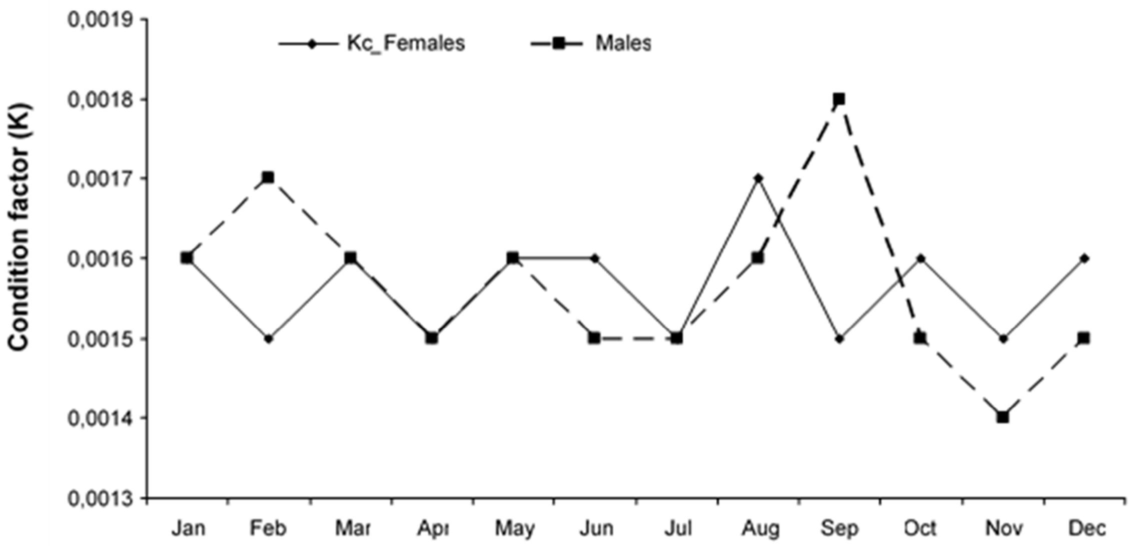

Fig. 6. Condition factor (K) of female and male of Macrobrachium macrobrachion in Bandama River from January to December 2009

3.6 FECUNDITY ESTIMATION

The absolute fecundity ranged from 574 to 36933 eggs with a mean of 19906 ± 6640 eggs, in females total lengths between 8.8 cm to 11.3 cm and body weight from 9.06 g to 23.34 g. The relative fecundity varied from 63 to 1327 eggs/g with a mean of 735 eggs/g.

The relationship between absolute fecundity (F), total length (T_L) and total weight (T_W) was investigated and the adjusted equations are:

$F_L = 599.6\ TL^{2.738}$; $R^2 = 0.969$.

$F_w = 1213\ TW^{1.513}$; $R^2 = 0.824$.

Correlation analysis showed significant relationships between fecundity and body weight on one side, fecundity and body length (*p-value*< 0.05) on other side. The number of eggs increases with increase in weight and carapace length.

4 DISCUSSION

Sex ratio

The overall ratio was not significantly different from the theoretical 1:1 ratio. Similar sex ratio was observed by [27]. Sex ratio may not always be static, as they vary from season to season and from year to year within the same population [28]. In our study, except in October and December the monthly sex ratio revealed that there is in favor of females. This result is in accordance with [29] and [30], who reported that the females of *Macrobrachium macrobrachion* were more than the males in number. Several non-exclusive hypotheses may explain this pattern: (1) predation and environmental differences, which can act differently on sexes [31], 1996), (2) reproductive strategies, involving the migration of one of the sexes, looking for better conditions to hatch [32], and (3) copulatory process, during the breeding season, males are concentrated around females.

Size at first maturity

Sizes at first maturity observed are 10.26 cm (TL) for females and 11.42 cm (TL) for males. All females and males are mature at about 11.10 cm and 12.40 cm (TL) respectively. Data from this study are very different from those found by [14] in the Bia River (Côte d'Ivoire). For this author, reproduction of *M. macrobrachion* indicate that the size of the smallest mature individual is 4.2 cm standard length (SL). The value of L_{50} is 6.1 cm SL, while L_{100} is 8 cm. In the Warri River, Nigeria, [23] reported L_{50} equal to 9 cm for male and 10 cm for female in *M. vollenhovenii*. These differences with our results would firstly related to the extent of water bodies surveyed and secondly to the density of the organisms [33].

Cycle of gonadal maturation and breeding

The dominance of mature individuals caught from May to October and highest GSI values observed suggest that reproductive period extends in these months. This period correspond to flooding which depends on opening and closing of the hydroelectric dam of Taabo and rainfall (April-July). Our results were similar with those obtained in Côte d'Ivoire by [14] in the Bia River and [16], [32] in Ebrié lagoon. Reproduction of *M. macrobrachion* specie is not continuous throughout the year. During the breeding season, the phenomenon of successive spawning was observed. This is confirmed by the presence of females in Stage 5 and ovigerous females from May to October. Contrary to our observations, [34] and [35] reported a continuous reproduction throughout the year in the specie *Macrobrachium amazonicum.*

There is an absence of significant variability in the mean monthly K. However peaks emerge in August. This peak corresponds to favorable moment for reproduction. Variation of HSI showed an inverse relationship with GSI. HSI and K have a similar evolution, however, is contrary to that of GSI. While the GSI increase, HSI and K decrease. During sexual rest November to March where GSI values are low, those of HSI are high. Shrimp would therefore lean individuals. These results indicate an investment of the hepatopancreas energy reserves in the ovarian development by the females. April and May are in the late dry season and early rainy seasons. Gonads maturation is initiated while the food is relatively rare in the study area. Consequently, reproduction is related and requires mobilization of organic reserves from storage sites to the epidermis and gonad, a process coordinated by hormones [36]. This explains the lower HSI. These results are consistent with those of [37] observed in *Macrobrachium malcomsonii*, *M. rosenbergii* and *M. lammarei*. These authors demonstrated that the amounts of protein in the reserve hepatopancreas gradually regressed based on stages of oocytes maturation.

During the months of June and July, GSI and HSI evolve simultaneously. June to July is mid - rainy season characterized by an abundance of food in study area. This leads to a simultaneous growth of GSI and HSI. Indeed, the fact that the GSI, the HSI and the K factor have increased during the ripening period is explained by the non-use of hepatopancreas' reserves as an energy source for vitellogenesis. If reserves are mobilized from these organs, they seem to be compensated by those obtained through diet, as reported in *Sciaena umbra* in Tunisia by [38].

Fecundity

Absolute fecundity of *M. macrobrachion* in the present study ranged from 574 to 36,933 eggs, with a mean of 19,906 eggs. Reference [39] reported 180 to 5,800 eggs for an average of 1,403 eggs; [40] reported 63 to 14,531with a mean of 4,420.58 eggs in this species. The results reported in this work are higher than the values reported by those authors. However, *M. macrobrachion* captured in Bandama River presents a smaller fecundity compared to those found in Lagos and Lekki Lagoons. Indeed, [30] reported 17,625 - 20,240 eggs per female from interconnecting fresh/Brackish water. The absolute fecundity values obtained for *M. macrobrachion* were highly variable. The reasons adduced for the differences in fecundity could be attributed to differences in egg size [41], sampling techniques and total length [39]. Moreover, the variations found for fecundity may also be due to differences in physiological conditions, food supply, season and environment parameters [42]. Reference [43] explained that in *Macrobrachium*species, the fecundity is extreme associated with the female age, and that it can increase while the female becomes mature. The increase in the number of eggs according to female's size could be explained by differential use of food energy at different ages in shrimp [44]. Generally, in older individuals who have a low growth rate, much of the energy was used in the production of eggs. Contrary to these, in smaller individuals, energy is preferably used for growth, rather than for egg production. The relative fecundity per unit length is greater than the relative fecundity per unit body mass.

5 CONCLUSION

The present work is a first of its kind on the Bandama River. This is a contribution to population studies of aquatic organisms of economic interest. The indices related to reproduction namely the gonad index, the hepato-somatic ratio, condition factor and the frequency of occurrence of sexual maturity stages were followed monthly. The monthly distribution of maturity stages and the variation of gonad index indicate that studied shrimp admit one breeding season which runs from May to October. It corresponds to the rainy seasons. During the breeding season, females abound in the catch. The hepatosomatic report reveals that the shrimp would lean individuals, which are nutrient reserves in the hepatopancreas for the purposes of reproduction. Furthermore, the condition factor indicates good adaptation of the species.

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