Relationships between morphometric characteristics of brackishwater prawn, *Macrobrachium macrobrachion* (Herklots, 1851), of Côte d'Ivoire (West Africa)

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Abstract

The present study describes the length-weight relationship (LWR), length-length relationship (LLR) and condition factor of the wild population of the shrimp *Macrobrachium macrobrachion* from the rivers of Côte d'Ivoire (West Africa). Samples were randomly collected from small-scale shrimp fisheries using bamboo traps. Of the thirteen analyzed morphometrics characters, only the second pleura width significantly varies between males (13.11 mm) and females (14.78 mm). All relationships between the considered variables were significantly linear, r^2 ranging from 0.66 to 0.97. For length-length relationships, the allometry coefficient varied depending on groups, environments and characters, and ranged between 0.64 and 1.26. The three allometry types (negative allometry, isometry and positive allometry) were observed in this relation. In length-weight relationship, the coefficient ranged from 2.02 to 2.78, indicating a negative allometry. The condition factor values showed that females (0.70±0.06) were in better condition than males (0.657±0.07). Overall, the condition factor followed an east-west gradient, decreasing from eastern (0.70) to western (0.63) regions. These results constituted an important biological database on *M. macrobrachion* from the rivers of Côte d'Ivoire for further studies as ecology, reproductive biology, and aquaculture potentialities of this species.

Keywords: Morphometry, Length relationships, Condition factor, *Macrobrachium macrobrachion*, West Africa

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Introduction

Macrobrachium macrobrachion (Herklots, 1851) is a brackish river prawn found commonly in freshwater areas including ponds, lakes, rivers and even in irrigation ditches as well as in estuaries (Opeh and Udoh, 2014). According to the same authors, *M. macrobrachion* belongs to the few indigenous *Macrobrachium* species that have potential for aquaculture in West Africa. In Côte d'Ivoire Rivers, this species is one of the most abundant *Macrobrachium* species and occurs in all important rivers (Konan *et al*., 2008). Previous information on ecology and biology of *M. macrobrachion* concerned its reproductive strategy and daily diet in the Bia River (Gooré Bi *et al*., 2001, 2004), and its morphometric variation in comparison to the congener *Macrobrachium vollenhovenii* (Konan *et al*., 2008). No allometric growth and condition factor studies have been carried out on *M. macrobrachion* from Côte d'Ivoire. However, allometric and condition factor are important for biological, physiological and ecological processes, and fisheries assessments (Santos *et al.*, 2002; Rahman *et al.*, 2004). They allow for seasonal variations in growth (Rickter *et al.*, 2000), estimations of weight from length (Beyer, 1991), and conversion of growth-in-length equations to growth-in-weight (Pauly, 1993). Moreover, they are fundamental for calculating the production and biomass of a population (Anderson and Gutreuter, 1983), and morphological comparisons among different species or between populations from different habitats and/or regions (Gonçalves *et al.*, 1997).

In other West African countries such as Bénin and Nigeria where studies on allometry growth of *M. macrobrachion* were conducted, authors used total length as the reference dimension (Lawal-Are and Owolabi, 2012; Adite *et al*., 2013, Andem *et al.*, 2013). But, according to Grandjean *et al.* (1997) and Diaz *et al.* (2001), the carapace length (CL) was used as the reference dimension for developing allometric relationships in crustaceans because it was the easiest, fastest and the most reliable length measurement to obtain. In the present investigation, allometric growth and condition factor of *M. macrobrachion* were evaluated using the carapace length as reference measurement. This study is the first on the weight–length and length–length relationships and condition factor for this species from the rivers of Côte d'Ivoire.

Material and methods

Sampling and measurements

Morphometric measurements were taken from 183 specimens of *M. macrobrachion*, randomly collected from small-scale prawn fisheries using bamboo traps in five rivers (Fig. 1) in Côte d'Ivoire. These rivers are the Bia in the eastern region, Comoé in the central-eastern region, Bandama in the central region and Sassandra in the central-western region. Table 1 presents the location coordinates and sample size at each site.

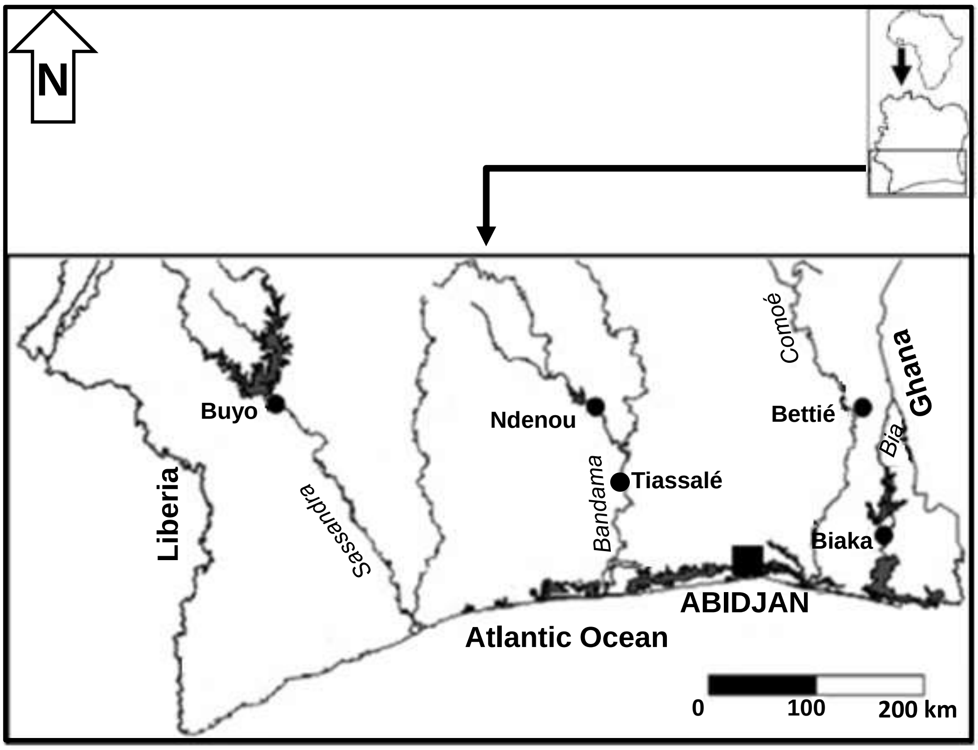

Figure 1: Map showing the location of study sites (Konan *et al.*, 2010, modified). ●: sampling sites.

Table 1: Location coordinates of sampling sites and samples size of different populations of *Macrobrachium macrobrachion* collected.

Rivers	Locality	Latitude, Longitude	Sample size
Bia	Biaka	05°50'N, 03°19'W	27
Comoé	Bettié	06°11'N, 03°43'W	25
Bandama	N'denou	06°20'N, 05°04'W	25
	Tiassalé	05°52’N, 04°49’W	33
Sassandra	Buyo	06°28'N, 06°99'W	73

All prawns were collected in the middle course of the rivers during the rainy season in 2007 and were transported on ice to the laboratory for measurements, including weight within 24 hours. Sex was determined by the presence or absence of a masculine appendix on the endopod of the second pair of the pleopod or a protuberance at the centre of the ventral side of the first abdominal somite (Rao and Tripathi, 1993). Individuals with missing or regenerating limbs or a damaged rostrum were excluded. Only populations with specimen number≥10 were used in our assessment, as implemented by Lalèyè (2006) and Konan *et al*. (2007).

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All dimensions were measured to the nearest 0.05 mm with a Vernier calliper. Measurements were selected according to the criterion followed by Konan *et al*. (2008). The length of the second pereiopod, measured along the external lateral line, was taken from the major leg of prawns, for which the chelipeds differ in size. Where pereiopods were of equal size, measurements were taken of the right leg. The dimensions used were as follows: total length (TL), carapace length (CL), rostrum length (RL) and second pereiopod length (L2), ischium length (IL), merus length (ML), carpus length (CaL), palm length (PL), dactylus length (DL), tail length (TaL), abdominal length (AbL), telson length (TeL) and second pleura width (SPW). The CL was used as a reference dimension for developing allometric relationships because it was the easiest, fastest and the most reliable length measurement to obtain (Grandjean *et al*., 1997; Diaz *et al*., 2001). Wet weight (W) of the total body was determined using a digital balance (± 0.01 g).

Data analysis

For each character, differences of mean values between both sexes were evaluated by Student's t-test. Before performing the t-test, all morphometric characters were standardized according to the equation $M_S = M_0 (L_S/L_0)^b$ (Thorpe, 1976; Ihssen *et al*., 1981; Hurlbut and Clay, 1998) in order to remove the effect of size. M_S is the standardized measurements, M_0 is the length of measured character, L_S is the arithmetic mean of the standard length (carapace length) for all shrimp specimens from all samples in each analysis and L_0 is the standard length of each specimen. The value of the parameter b was estimated for each character from the observed data by allometric growth equation described by the non-linear power function $M = aL^b$ (Ricker, 1973). The parameters a and b were estimated by least-squares regression based on the predictive or Type I linear regression model (Sokal and Rohlf, 1995); the coefficient of determination (Zar, 1999) was calculated using the natural-logarithm transformation ($\ln M = \ln a + b \ln L$).

For length-length and weight-length relationships, M is the dependent variable, representing the measurements of the body parts or the total body weight; L is the independent variable (CL). The coefficient of determination (r^2) was used as the index of strength of the linear association. Student's *t*-test was applied to verify whether the declivities of regression (constant b) presented a significant difference of 3 or 1 for the length–weight and length–length relationships, respectively. With regard to the *b* value, the following three types of growth were indicated: (1) when b = 3 or 1, the type of growth is described as isometric; (2) when b > 3 or 1, the growth type is positively allometric; and (3) when b<3 or 1, the growth type is negatively allometric (Huxley, 1932; Spiegel, 1991).

The condition factor (K) was calculated in accordance with Hile (1936) by using the mean values of CL and W, using the following formula: $K = (W \times 10^3)/CL^3$ (Pauly, 1984; Wootton, 1992). Differences in the condition factor were examined between males and females, and among different populations with a one-way ANOVA. When only two categories were compared, the Student's *t*-test for independent samples by group was used. A statistical significance of 95% was chosen. All statistical procedures were performed using STATISTICA software version 7.1 (StatSoft, 2006).

Results

Morphometry

Morphometric characteristics of both sexes are presented in Table 2. A total male sample of 161 individuals with total length ranging from 90.09 to 120.46 mm, carapace length ranging from 21.42 to 47.45 mm and weight ranging from 7.70 to 60.85 g were analysed. For females (22 individuals), TL varied from 107.83 to 111.59 mm, CL from 19.94 to 42.00 mm and weight from 10.35 to 55.58 g. With the exception of SWP, all considered characters vary slightly (Student t test, $p>0.05$) between males and females. The mean value of the second pleura width is 14.78 for females and 13.11 for males. The Student t test presented a significant variation of this character between the both sexes ($p<0.001$).

Allometric growth

The parameters of allometric growth in males, females and combined sexes from all populations are presented in Table 3. In the three groups, all relationships between the considered variables were significantly linear, r^2 ranging from 0.76 to 0.96, 0.73 to 0.95 and from 0.66 to 0.97 for combined sexes, males and females, respectively.

In combined sexes and males, each analysed parameter displayed the same allometric types. For the growth in relation to carapace length, an isometric growth was observed for L2 and the SPW, while a negative allometry was obtained for the others characters. Considering the growth in relation to the second pereiopod length, three growth types were noted. An isometric growth was observed for ML and CaL.

Table 2: Mean values of morphometric characters and weight of both sexes, males and females of *Macrobrachium macrobrachion* from the rivers of Côte d'Ivoire.

Characters	Both sexes					Male					Female				
	N	Min	Max	Mean	S.D.	N	Min	Max	Mean	S.D.	N	Min	Max	Mean	S.D.
Total length	183	81.32	120.46	107.99	4.40	161	104.5	120.46	109.29	8.39	22	81.32	111.59	107.83	3.38
Carapace length	183	21.42	47.45	31.6	5.22	161	21.42	47.45	31.66	5.30	22	28.98	42.00	31.16	4.66
Rostrum length	183	20.02	28.16	26.59	1.52	161	21.77	31.75	26.71	1.39	22	20.02	28.16	25.74	2.09
Second pereiopod length	183	53.50	118.65	78.11	6.66	161	57.04	118.65	78.02	6.17	22	53.50	88.25	78.78	9.41
Head length	183	8.92	14.90	12.69	0.92	161	9.99	14.90	12.66	0.84	22	8.92	14.50	12.91	1.31
Telson length	183	10.53	17.65	15.01	1.16	161	11.44	17.65	15.00	1.05	22	10.53	17.22	15.09	1.72
Tail length	183	9.25	17.38	14.19	1.38	161	10.14	17.38	14.16	1.29	22	9.25	16.97	14.35	1.89
Second pleura width	183	12.95	25.36	19.54	1.99	161	13.20	25.36	19.50	1.83	22	12.95	23.07	19.83	2.90
Abdomen length	183	12.02	21.12	17.51	1.54	161	12.05	21.12	17.48	1.41	22	12.02	19.84	17.79	2.32
Rostrum length	183	45.31	67.05	58.64	2.50	161	49.30	67.05	58.55	2.05	22	45.31	61.98	59.36	4.55
Second pereiopod length	183	35.56	54.83	48.93	2.14	161	40.90	54.83	48.96	1.59	22	35.56	51.05	48.77	4.05
Head length	183	9.24	18.80	13.67	0.79	161	10.39	18.80	13.70	0.65	22	9.24	14.23	13.48	1.31
Telson length	183	9.05	17.83	13.31	1.14	161	11.13	17.83	13.11	0.92	22	9.05	16.30	14.78	2.00
Tail length	183	34.29	58.60	45.04	2.56	161	37.38	58.60	44.92	2.36	22	34.29	48.22	44.59	3.77
Body weigth	183	7.7	60.85	22.42	10.75	161	7.7	60.85	22.20	10.61	22	10.35	55.58	24.02	11.85

N: number of specimens, Min: minimum, Max: maximum, S.D.: standard deviation.

Table 3: Allometric relationships length-length and length- weigth in combined populations of both sexes, males and females of *Macrobrachium macrobrachion* from the rivers of Côte d'Ivoire. A: Allometry, r^2 : Coefficient of determination.

Parameters	Both sexes				Male			
	Regression equation	r^2	T-test absolute value	A	Regression equation	r^2	T-test absolute value	A
Growth in relation to carapace length								
Body weigth	BW = -5.87 + 2.57CL	0.90	6.63	-	BW = -5.81 + 2.55CL	0.90	6.53	-
Total length	TL = 1.74 + 0.85CL	0.91	7.38	-	TL = 1.85 + 0.82CL	0.85	6.72	-
Rostrum length	RL = 0.45 + 0.82CL	0.84	6.77	-	RL = 0.59 + 0.78CL	0.78	6.75	-
Second pereiopod length	L2 = 0.78 + 1.04CL	0.78	0.92	0	L2 = 0.90 + 1.00CL	0.73	0.01	0
Head length	HL = 0.76 + 0.91CL	0.90	4.27	-	HL = 0.90 + 0.87CL	0.85	4.56	-
Telson length	TeL = -0.10 + 0.79CL	0.85	8.96	-	TeL = -0.01 + 0.76CL	0.80	8.09	-
Tail length	TaL = 1.21 + 0.83CL	0.90	8.27	-	TaL = 1.32 + 0.80CL	0.84	7.39	-
Second pleura width	SPW = -0.76 + 0.97CL	0.76	0.74	0	SPW = -0.61 + 0.92CL	0.75	1.89	0
Abdomen length	AbL = 0.95 + 0.83CL	0.84	5.61	-	AbL = 1.08 + 0.79CL	0.79	6.63	-
Growth in relation to second pereiopod length								
Ischium length	IL = -1.24+0.87 L2	0.91	6.75	-	IL = -1.22 + 0.86 L2	0.91	6.47	-
Merus length	ML = -1.54 + 0.98L2	0.96	1.60	0	ML = -1.51 + 0.97L2	0.95	1.90	0
Carpus length	CaL = -1.85 + 1.03L2	0.94	1.72	0	CaL = -1.85 + 1.03L2	0.94	1.63	0
Palm length	PL = -1.71 + 1.08L2	0.93	3.52	+	PL = -1.73 + 1.08L2	0.93	3.47	+
Dactylus length	DL = -1.71 + 1.05L2	0.94	2.59	+	DL = -1.71 + 1.05L2	0.94	2.36	+

Table 3 continued:

Parameters	Female			
	Regression equation	r^2	**T-test absolute value**	**A**
Growth in relation to carapace length				
Body weigth	BW = -6.47 + 2.78CL	0.92	1.29	0
Total length	TL = 1.70 + 0.87CL	0.92	2.36	-
Rostrum length	RL = 0.08 + 0.93CL	0.87	0.97	0
Second pereiopod length	L2 = 0.90 + 1.01CL	0.77	0.05	0
Head length	HL = 0.49 + 0.98CL	0.92	0.25	0
Telson length	TeL = -0.48 + 0.89CL	0.66	0.78	0
Tail length	TaL = 1.04 + 0.88CL	0.91	1.96	-
Second pleura width	SPW = -0.97 + 1.06CL	0.91	0.61	0
Abdomen length	AbL = 0.70 + 0.91CL	0.90	1.44	0
Growth in relation to second pereiopod length				
Ischium length	IL = -1.33 + 0.89 L2	0.93	2.16	-
Merus length	ML = -1.86 + 1.05L2	0.97	1.28	0
Carpus length	CaL = -1.91 + 1.05L2	0.95	0.91	0
Palm length	PL = -1.45 + 1.02L2	0.94	0.30	0
Dactylus length	DL = -1.66 + 1.04L2	0.95	0.78	0

A regressive allometry was observed for IL (b = 0.87 and 0.86 for combined sexes and males, respectively) while a positive allometry was obtained for PL and DL. In females, two growth types (isometry and negative allometry) were observed. All morphometric traits presented an isometric growth except for TL (b = 0.87), TaL (b = 0.88) and IL (b=0.89) that displayed a negative allometry.

A comparative analysis of length-length and weight-length relationships in the sampled sites is presented in Table 4, and Fig. 2 and Fig. 3, respectively. Females were not analysed separately because the female sample size in each sampling site did not reach ten individuals. In Bia River, for the growth in relation to carapace length, all shrimp specimens (combined sexes and males) displayed the growth types as all shrimps from all populations (Table 4); an isometric growth for L2 and SPW, and a negative allometry for the other characters. For the growth in relation to the second pereiopod length, all characters exhibited an isometric growth with the exception of IL in combined sexes that exhibited a negative allometry.

In Comoé River, concerning length-length relationships, all characters except for L2 displayed the same growth type; isometric for SPW and DL, and regressive allometry for others. L2 exhibited an isometric growth (b=1.15) in combined sexes and progressive allometry in males (b=2.26).

Table 4 : Allometric relationships length-length and length-weigth in each population of both sexes and males of *Macrobrachium macrobrachion* from the rivers of Côte d'Ivoire. A: allometry, r^2 : Coefficient of determination.

Parameters	Both sexes				Male			
	Regression equation	r^2	T-test absolute value	A	Regression equation	r^2	T-test absolute value	A
				Bia				
Growth in relation to carapace length								
Total length	TL = 2.26 + 0.69CL	0.80	4.42	-	TL = 2.37 + 0.65CL	0.76	3.80	-
Rostrum length	RL = 0.93 + 0.66CL	0.63	3.30	-	RL = 1.15 + 0.59CL	0.64	3.76	-
Second pereiopod length	L2 = 0.64 + 1.07CL	0.72	0.54	0	L2 = 0.91 + 0.99CL	0.67	0.07	0
Head length	HL = 1.08 + 0.80CL	0.82	2.62	-	HL = 1.22 + 0.76CL	0.78	2.30	-
Telson length	TeL = -0.11 + 0.78CL	0.84	3.12	-	TeL = 0.06 + 0.73CL	0.84	3.35	-
Tail length	TaL = 1.70 + 0.68CL	0.74	3.91	-	TaL = 1.81 + 0.64CL	0.70	3.46	-
Second pleura length	PL = -0.43 + 0.88CL	0.51	0.67	0	PL = -0.24 + 0.81CL	0.56	1.04	0
Abdomen length	AbL = 1.47 + 0.67CL	0.44	2.17	-	AbL = 1.48 + 0.66CL	0.59	2.50	-
Growth in relation to second pereiopod length								
Ischium length	I = -1.01+0.80 L2	0.76	2.13	-	I = -0.91 + 0.78 L2	0.69	1.68	0
Merus length	M = -1.62 + 0.99L2	0.98	0.43	0	M = -1.57 + 0.97L2	0.97	0.59	0
Carpus length	C = -2.01 + 1.07L2	0.96	1.45	0	C = -1.93 + 1.05L2	0.96	0.80	0
Palm length	P = -1.68 + 1.08L2	0.91	1.14	0	P = -1.71 + 1.09L2	0.88	0.86	0
Dactylus length	D = -1.56 + 1.02L2	0.94	0.40	0	D = -1.60 + 1.03L2	0.94	0.45	0
				Comoé				
Growth in relation to carapace length								
Total length	TL = 1.95 + 0.80CL	0.90	3.49	-	TL = 1.90 + 0.81CL	0.90	3.43	-
Rostrum length	RL = 0.86 + 0.71CL	0.82	3.98	-	RL = 0.88 + 0.71CL	0.78	3.90	-
Second pereiopod length	L2 = 0.41 + 1.15CL	0.72	0.95	0	L2 = 0.04 + 1.26CL	0.81	2.13	+
Head length	HL = 1.14 + 0.81CL	0.83	2.45	-	HL = 1.13 + 0.81CL	0.90	2.41	-
Telson length	Te = 0.08 + 0.74CL	0.89	4.69	-	TeL = 0.01 + 0.76CL	0.90	4.43	-
Tail length	TaL = 1.53 + 0.75CL	0.93	5.37	-	TaL = 1.46 + 0.77CL	0.95	6.34	-
Second pleura length	PL = -1.22 + 1.12CL	0.83	1.05	0	PL = -1.11 + 1.08CL	0.91	1.20	0
Abdomen length	Ab = 1.23 + 0.76CL	0.91	4.43	-	AbL = 1.16 + 0.78CL	0.93	5.07	-
Growth in relation to second pereiopod length								
Ischium length	I = -0.88+0.80L2	0.97	6.42	-	I = -0.94 + 0.81 L2	0.98	6.50	-
Merus length	M = -1.40 + 0.95L2	0.99	2.36	-	M = -1.43 + 0.96L2	0.99	2.07	-
Carpus length	C = -2.06 + 1.09L2	0.97	3.39	+	C = -2.11 + 1.10L2	0.99	3.52	+
Palm length	P = -2.16 + 1.17L2	0.97	4.07	+	P = -2.13 + 1.16L2	0.97	3.52	+
Dactylus length	D = -1.70 + 1.04L2	0.96	0.91	0	D = -1.63 + 1.02L2	0.97	0.53	0
				Bandama1				
Growth in relation to carapace length								
Total length	TL = 1.88 + 0.81CL	0.98	7.41	-	TL = 1.86 + 0.81CL	0.98	6.80	-
Rostrum length	RL = 1.00 + 0.65CL	0.82	5.03	-	RL = 0.98 + 0.66CL	0.82	5.15	-
Second pereiopod length	L2 = 0.77 + 1.04CL	0.93	0.57	0	L2 = 0.71 + 1.05CL	0.92	0.72	0
Head length	HL = 0.85 + 0.88CL	0.98	4.02	-	HL = 0.86 + 0.87CL	0.92	2.33	-
Telson length	Te = 0.09 + 0.78CL	0.93	4.51	-	TeL = -0.12 + 0.79CL	0.92	4.34	-
Tail length	TaL = 1.50 + 0.74CL	0.89	4.62	-	TaL = 1.55 + 0.72CL	0.68	2.91	-
Second pleura length	PL = -0.17 + 0.78CL	0.69	1.98	-	PL = -0.14 + 0.77CL	0.69	2.07	-
Abdomen length	Ab = 1.23 + 0.72CL	0.89	4.87	-	AbL = 1.24 + 0.73CL	0.89	4.79	-
Growth in relation to second pereiopod length								
Ischium length	I = -0.88 + 0.80L2	0.97	3.70	-	I = -0.71 + 0.73L2	0.86	4.46	-
Merus length	M = -1.40 + 0.98L2	0.99	0.67	0	M = -1.38 + 0.93L2	0.94	1.50	0
Carpus length	C = -1.38 + 0.91L2	0.97	1.48	0	C = -1.11 + 0.85L2	0.85	2.13	-
Palm length	P = -2.02 + 1.15L2	0.95	2.49	+	P = -1.78 + 1.10L2	0.90	2.37	+
Dactylus length	D = -2.27 + 1.19L2	0.98	5.51	+	D = -2.04 + 1.14L2	0.95	2.72	+

Table 4 continued:

Parameters	Both sexes				Male			
	Regression equation	r^2	T-test absolute value	A	Regression equation	r^2	T-test absolute value	A
				Bandama 2				
Growth in relation to carapace length								
Total length	TL = 1.97 + 0.78CL	0.82	3.29	-	TL = 2.00 + 0.77CL	0.84	3.60	-
Rostrum length	RL = 0.54 + 0.80CL	0.82	2.97	-	RL = 0.51 + 0.81CL	0.83	2.81	-
Second pereiopod length	L2 = 0.40 + 1.16CL	0.91	2.56	+	L2 = 0.37 + 1.17CL	0.92	2.69	+
Head length	HL = 0.69 + 0.93CL	0.91	1.36	0	HL = 0.65 + 0.94CL	0.96	1.52	0
Telson length	Te = -0.12 + 0.79CL	0.95	5.10	-	TeL = -0.12 + 0.79CL	0.95	5.75	-
Tail length	TaL = 1.29 + 0.81CL	0.89	3.78	-	TaL = 1.28 + 0.81CL	0.89	3.53	-
Second pleura length	PL = -0.59 + 0.92CL	0.85	1.16	0	PL = -0.56 + 0.91CL	0.85	1.23	0
Abdomen length	Ab = 1.50 + 0.66CL	0.54	3.07	-	AbL = 1.41 + 0.69CL	0.62	2.99	-
Growth in relation to second pereiopod length								
Ischium length	I = -0.91 + 0.79L2	0.92	5.13	-	I = -0.92 + 0.79L2	0.92	4.85	-
Merus length	M = -1.41 + 0.94L2	0.95	1.36	0	M = -1.41 + 0.94L2	0.95	1.31	0
Carpus length	C = -1.71 + 1.01L2	0.96	0.22	0	C = -1.70 + 1.00L2	0.98	0.12	0
Palm length	P = -2.11 + 1.17L2	0.88	2.16	+	P = -2.10 + 1.17L2	0.88	2.01	+
Dactylus length	D = -1.89 + 1.09L2	0.96	2.25	+	D = -1.89 + 1.09L2	0.97	2.34	+
				Sassandra				
Growth in relation to carapace length								
Total length	TL = 1.89 + 0.81CL	0.90	5.95	-	TL = 1.89 + 0.81CL	0.90	5.94	-
Rostrum length	RL = 0.78 + 0.73CL	0.83	6.82	-	RL = 0.79 + 0.73CL	0.83	6.91	-
Second pereiopod length	L2 = 0.72 + 1.05CL	0.77	0.67	0	L2 = 0.72 + 1.04CL	0.78	0.64	0
Head length	HL = 0.97 + 0.85CL	0.90	4.45	-	HL = 0.97 + 0.85CL	0.90	4.51	-
Telson length	Te = 0.25 + 0.70CL	0.73	6.90	-	TeL = 0.25 + 0.69CL	0.73	6.23	-
Tail length	TaL = 1.31 + 0.80CL	0.89	5.92	-	TaL = 1.32 + 0.80CL	0.89	5.91	-
Second pleura length	PL = -0.80 + 0.97CL	0.76	0,44	0	PL = -0.79 + 0.97CL	0.76	0.48	0
Abdomen length	Ab = 1.06 + 0.79CL	0.88	5.82	-	AbL = 1.06 + 0.79CL	0.88	5.84	-
Growth in relation to second pereiopod length								
Ischium length	I = -0.96 + 0.81L2	0.96	9.30	-	I = -0.97 + 0.81L2	0.96	9.19	-
Merus length	M = -1.25 + 0.91L2	0.98	6.64	-	M = -1.25 + 0.91L2	0.98	6.54	-
Carpus length	C = -1.51 + 0.96L2	0.95	1.72	0	C = -1.51 + 0.96L2	0.95	1.68	0
Palm length	P = -2.16 + 1.17L2	0.98	7.97	+	P = -2.16 + 1.17L2	0.98	7.97	+
Dactylus length	D = -2.30 + 1.19L2	0.98	8.47	+	D = -2.29 + 1.18L2	0.98	8.47	+

In Bandama 1, with the exception of CaL, all morphometric traits presented the same growth type for both the groups. An isometric growth (b = 0.91) was observed in combined sexes and a negative allometric growth (b = 0.85) was observed in males. In Bandama 2, each character exhibited the same growth type for combined sexes and male; positive allometry for three characters, negative allometry for six characters and isometry for four characters. As in Bandama 2, the shrimp specimens from Sassandra River exhibited the same growth type for each character in the two groups.

Regardless of the sampling site, the increase in weight of the shrimps occurred at a slower rate than did the increase in CL for combined sexes and males, b ranging from 2.02 (males from Bia) to 2.67 (males from Comoé).

Condition factor

The condition factor calculated for all samples of *M. macrobrachion* considered in the present investigation ranged from 0.35 to 0.89 with a mean value of 0.661±0.07 (Fig. 4).

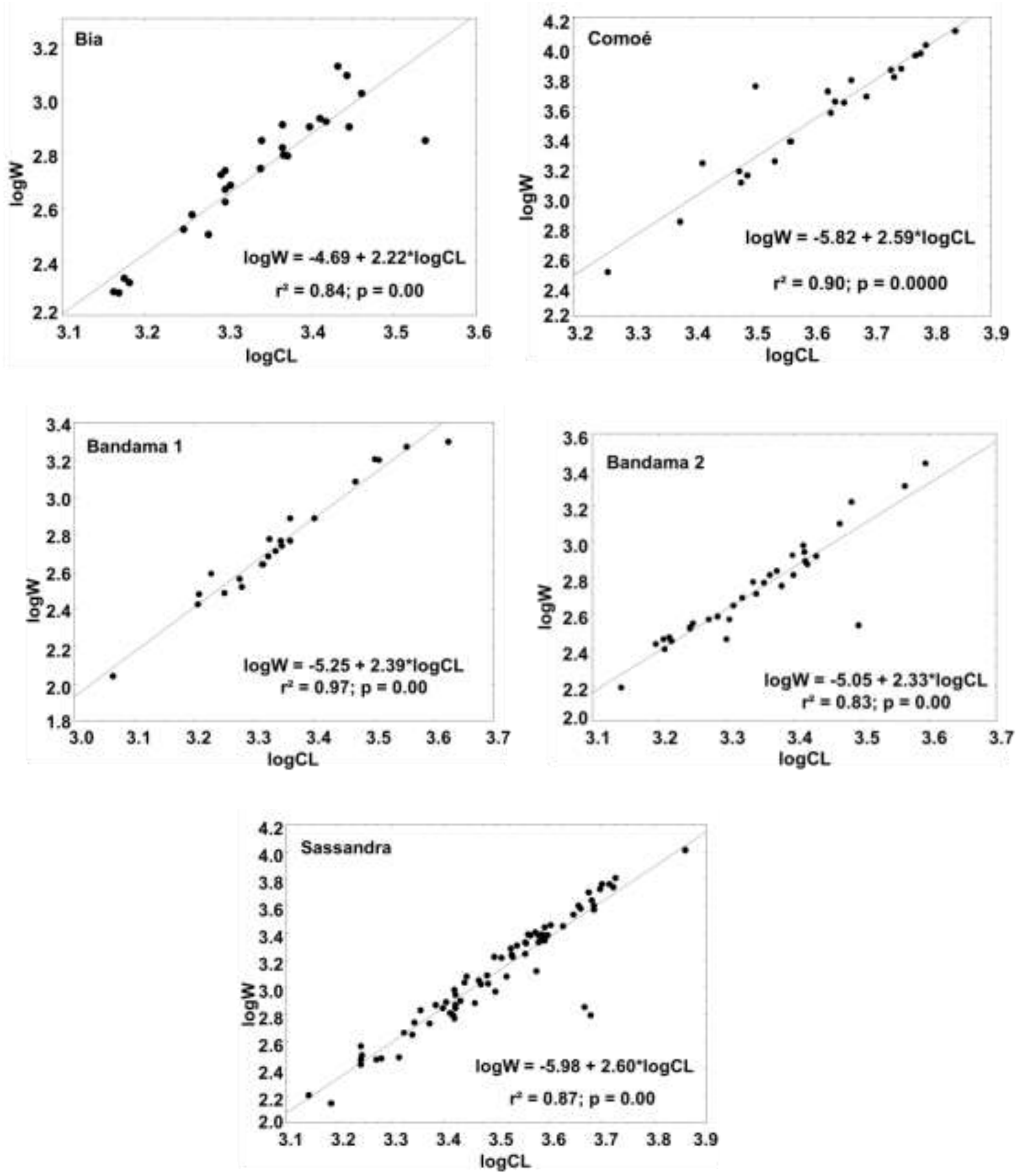

Figure 2: Scatter diagram showing length-weight relationships in combined populations of *Macrobrachium macrobrachion* from rivers of Côte d'Ivoire.

Minimum and maximum values for male and female populations were computed as 0.35–0.89 and 0.60 – 0.78, respectively. The mean value was 0.657±0.07 for males and 0.70±0.06 for females, suggesting that females were in better condition than males (Tukey's HSD test, p=0.031). A significant difference in condition factor was also observed between females and combined sexes (p=0.049).

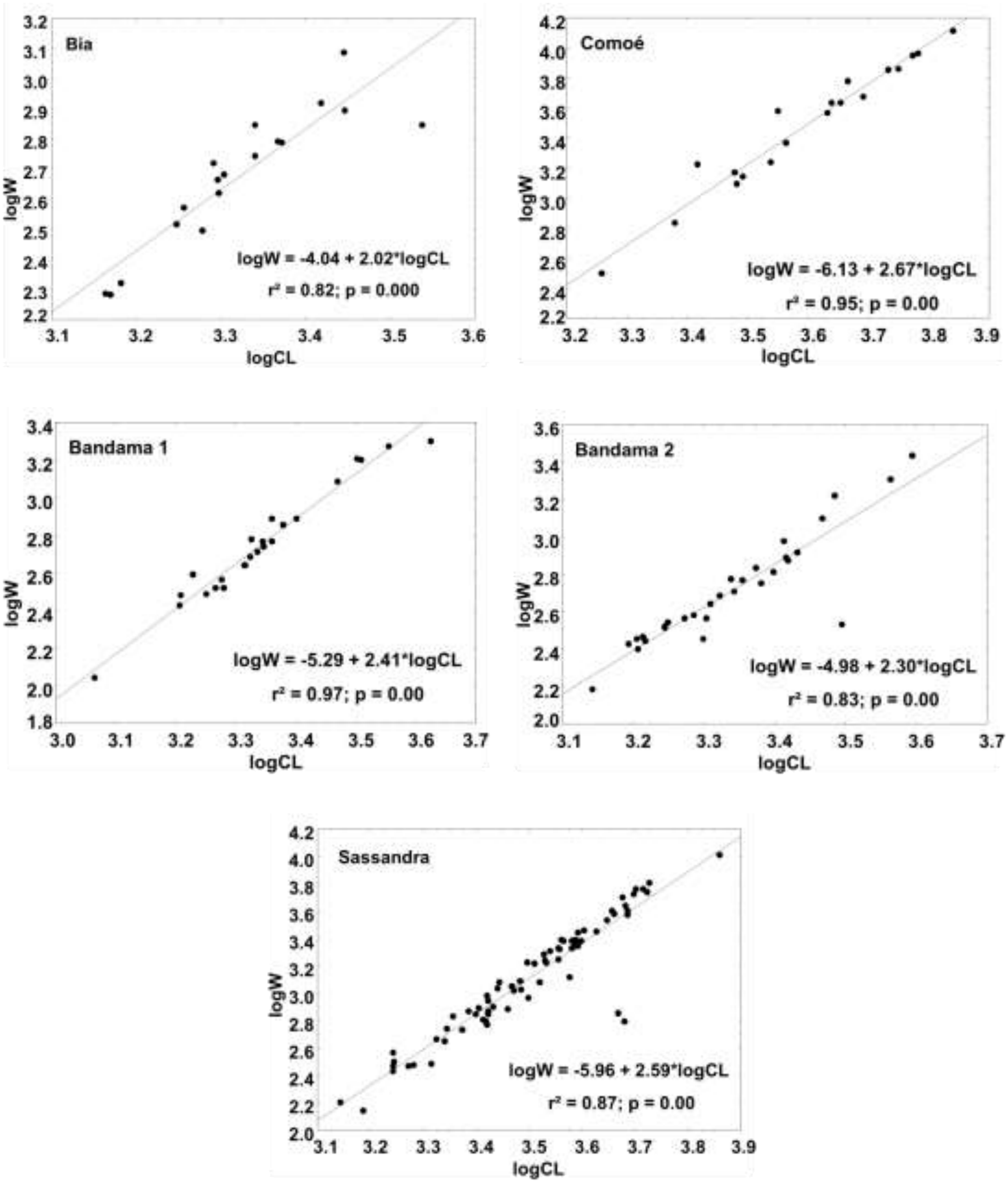

Figure 3: Scatter diagram showing length-weight relationships in male populations of *Macrobrachium macrobrachion* from rivers of Côte d'Ivoire.

Considering different populations, condition factor ranged between 0.63 (Sassandra) to 0.7 (Bia) and decreased from the eastern (Bia) to the western (Sassandra) zone. The one-way ANOVA showed that condition factor significantly varied among populations (F (4, 167)=6.62; p=0.00006)). The Tukey's honestly significant difference (HSD) test showed that condition factor was higher in Bia River (Eastern) than Sassandra River (Western) specimens.

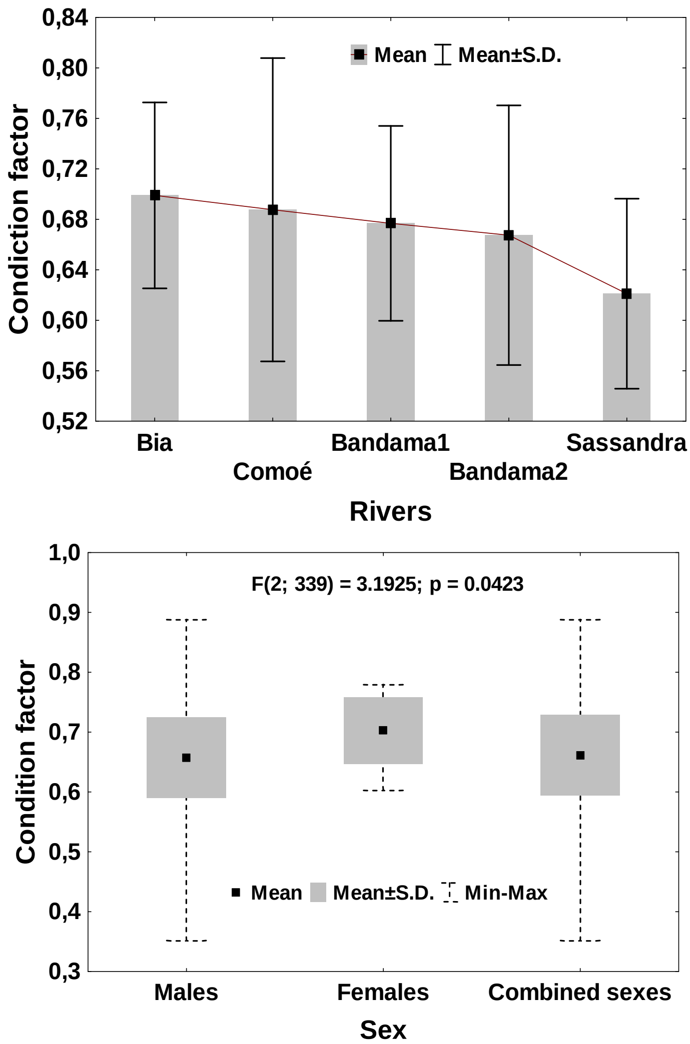

Figure 4: Diagram showing variation of condition factor between sampling sites and sexes of *Macrobrachium macrobrachion* from rivers of Côte d'Ivoire.

In males, even this trend of gradual decrease of the coefficient of condition is not observed along a geographical gradient east-west, the minimum (0.62±0.07) and maximum (0.69±0.08) mean values are recorded at the east (Bia) and the west (Sassandra) rivers, respectively (Fig. 4). The one-way ANOVA showed a significant difference in condition factor among Sassandra site, and Bia and the 2 sites of Bandama.

Discussion

Overall, the number of males is considerably higher than the number of females; 153 males against 22 females. This could be explained by the sampling period and areas. Indeed, the shrimp were sampled in the middle course of rivers and in the rainy season. During this period, the female *M. macrobrachion* are migrating to the river mouths to release larvae that need brackish water for their development (Udo, 2015).

Morphometric analysis and relative growth studies are widely used in decapods crustaceans (Hartnoll, 1978, 1982; Lovett and Felder, 1989) because of the possibility of changes related to sex, environmental conditions, food consumption, reproduction and genetics. Especially, in shrimps or prawns, several researches deal with morphometric analysis and allometric growth (e.g. Ragonese *et al.*, 1997; Mossolin and Bueno, 2003; Mariappan and Balasundaram, 2004; Deniz (Bök) *et al*., 2010, 2013; Konan *et al.*, 2010). In the present study, descriptive statistic values of characters for males and females of *M. macrobrachion* are presented separately. With the exception of the second pleura width (SWP), all morphometric traits showed no significant variation between sexes. These results indicated a great morphometric similarity between males and females of *M. macrobrachion*. Sexual dimorphism in this species is less obvious for most of the analyzed characters. Similar results have been observed in *M. macrobrachion* from the lower Taylor Creek (Niger Delta, Nigeria) by Kingdom *et al*. (2014). Therefore, *M. macrobrachium* belongs to *Macrobrachium* spp. in which sexual dimorphism is not pronounced in morphometrics, especially for the second pereiopod. In some species of this genus, e.g. in *Macrobrachium brasiliense* (Mantelatto and Barbosa, 2005), *Macrobrachium felicinum* (Kingdom *et al*., 2014), *Macrobrachium lar* (Sethi *et al.*, 2013), *M. vollenovenii* (Konan *et al*., 2008; Kingdom *et al*., 2014), mean size of parameters show higher values in males compared to females. In contrast, in some congeners as *M. amazonicum* (Hyad and Anger, 2013) males appear to have a more slender body shape than females, reaching thus lower weights at equal total length. SPW, the only analyzed character that significantly varied between sexes, was wider in females compared to males. In general, in decapods, the width of the second pleura included in abdomen length of the females is associated with reproductive features. Female crustaceans frequently exhibit an increase in abdomen width, thus providing a chamber where the egg mass attaches to the pleopods and is protected during incubation (Oh and Hartnoll, 1999; Kotb and Hartnoll, 2002). This result was consistent with the findings of other research carried out for some other decapods species, such as *M. vollenhovenii* (Konan *et al.*, 2014), *Uca rapax* (Castiglioni and Negreiros-Fransozo, 2004), *Uca thayeri* (Araújo *et al*., 2012a) and *Callinectes danae* (Araújo *et al*., 2012b).

Morphometric relationship study is a useful index to measure the variation in the growth of individual prawn or group of prawns (Jayachandran and Joseph, 1988). The high values of coefficient of determination (0.66 to 0.97) in all length-length and weight-length relationship explained the best predictor of body length and weight by reference measures used (carapace length and second pereiopod length). In the same species, Jimoh *et al*. (2012) reported r^2 values ranged between 0.55 and 0.88. Similar observations were made in other *Macrobrachium* species by other authors (Gabche and Hockey, 1995; Mariappan and Balasundaram, 2004; Moraes-Riodades and Valenti, 2004; Jimoh *et al*., 2012; Lalrinsanga *et al.*, 2012; Hyad and Anger, 2013).

Aregressive growth was observed for males (b=2.55) and isometric growth for females (b=2.78) in length-weight relationship. This result showed a pattern of allometric growth differential between sexes for *M. macrobrachion* as implemented by Hartnoll (1982) for crustaceans in general. In the present study, all individuals being mature, the puberty molts in females could explain the difference in pattern growth. According to Hartnoll (1982, 1985), the puberty molts involve a change in the level of allometry, an interval during which this phenomenon can take place and a mature morphology associated with reproduction. The same pattern growth was reported by Kingdom *et al*. (2014) in this species from lower Taylor Creek. Moreover, Adite *et al.* (2013) studying *M. macrobrachion* from Mono River (Benin) found similar values of b ranging from 2.71 to 2.80. In other *Macrobrachium* species (*M. amazonicum, M. nobilii, M. lar* and *M. vollenhovenii*), b values ranging between 2.51 and 2.92 were obtained (Mariappan and Balasundaram, 2004; Sethi *et al*., 2013; Hyad and Anger, 2013; Konan *et al*., 2014). On the other hand, a progressive allometry (b=3.10 to 3.50) was registered for some species such as *Macrobrachium acanthurus* (Albertoni *et al*., 2002), *M. brasiliense* (Mantelatto and Barbosa, 2005) and *Macrobrachium rosenbergii* (Lalrinsanga *et al*., 2012).

In length-length relationship, for growth in relation to carapace length, two types of allometry (negative and isometry) were observed for combined sexes, males and females. In addition, the three allometry types were obtained for growth in relation to the second pereiopod length. This variation of the growth between sexes and between different characters was explained by morphotypic variation (Cohen *et al*., 1981; Kuris *et al*., 1987; Moraes-Riodades and Valenti, 2004) and heterogeneous individual growth of the morphotypes in *Macrobrachium* (Ranjeet and Kurup, 2002). Moreover, Mantelatto and Barbosa (2005) showed that species of the genus *Macrobrachium* do not follow a typical growth pattern. Similar observations were reported by Mariappan and Balasundaram (2004) in *M. nobilii*, and Konan *et al*. (2014) in *M. vollenhovenii*.

It was observed in the present study that condition factor values were higher in females, suggesting that females were in better condition than males. These results are favourably comparable with condition factors of different *Macrobrachium* species investigated and reported by Albertoni *et al.* (2002), Deekae and Abowei (2010), Lalrinsanga *et al*. (2012), Olele *et al*. (2012), Soomro *et al*. (2012) and Konan *et al*. (2014). Conversely, *Macrobrachium dux* males generally appeared to have a higher mean condition factor than females (Arimoro and Meye, 2007). Considering sampling sites, condition factor decreased from the eastern (Bia) to the western (Sassandra) zones of Côte d'Ivoire. This observation was made by Konan *et al*. (2014) for *M. vollenhovenii* from the same sites. In addition, Konan *et al.* (2010), studying the morphometry of different male populations of *M. vollenhovenii* from the rivers of Côte d'Ivoire, reported this pattern of variation. A study, in which concurrently environmental parameters are measured and shrimp are collected, is necessary to further explain the causes for the observed variation. The results of this study do not allow for a direct comparison with other findings on *M. macrobrachion* because, in prior researches (Abohweyere and Williams, 2008; Lawal-Are and Owolabi, 2012; Adite *et al.*, 2013), total length was used as the reference dimension contrarily to carapace length in the present investigation. In fact, according to Grandjean *et al*. (1997) and Diaz *et al.* (2001), carapace length was used as a reference dimension for developing allometric relationships in shrimps because it was the easiest, fastest and the most reliable length measurement to obtain.

In conclusion, the results showed a high similarity in morphometry between males and females of *M. macrobrachion*. The relationships between the considered variables were significantly linear, r^2 ranging from 0.66 to 0.97. Overall, females of *M. macrobrachion* were in better condition than males. The three allometry types were obtained for growth in relation to the second pereiopod length. These results constituted a biological database on *M. macrobrachion* from the rivers of Côte d'Ivoire for further studies (ecology, reproductive biology, and aquaculture potentialities) and for fishery managers.

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