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Size structure, length-weight and length-length relationships and condition factor of the species *Ocypode africana* on the coast of Côte d'Ivoire

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Abstract

The present study describes the size structure, length-weight and length-length relationships and condition factor of the wild population of the crabs *Ocypode africana*, from the coast of Côte d'Ivoire (West Africa). Samples were randomly collected, in three localities, from August 2019 to August 2022. A total of 441 specimens were collected. The weight, length and other descriptors were determined on each specimen. The size obtained for the population varied from 8.70 mm to 64.36 mm, with an average of 34.94 ± 8.62 mm for females and 30.67 ± 7.48 mm for males. The sampled population had a modal class structure of [25.86 - 31.58 mm] for the males from Abidjan and Grand-Jacques and [31.58 - 37.30 mm] for the females and the males from Grand-Bassam. The study of the growth allometry of the Abidjan and Grand-Bassam populations showed a higher allometry coefficient for females ($b = 3.45$ and $b = 3.30$ respectively) and a lower one for males ($b = 2.64$ and $b = 2.24$ respectively). The allometry coefficient threshold is 3. However, the entire Grand Jacques population including the males and the females, had major allometry (Female: $b = 2.33$; Male: $b = 1.38$). The condition factor for the males differed significantly from that of the females. We inferred from those observations that crab populations in Grand-Jacques were overweight compared with those in Grand-Bassam and Abidjan. These results constituted an important biological database on *O. africana* of the coast of Côte d'Ivoire, and for further studies on the ecology and the reproductive biology of this species.

Keywords: *Ocypode africana*, growth allometry, condition factor, coastline, Ivory Coast, West Africa

Introduction

Ocypode africana (family Ocypodidae) is a crab found on many fine sand beaches in the eastern Atlantic Ocean, from Mauritania to Namibia (Sakai and Türkay, 2013) [20]. Crabs of the genus *Ocypode* are the main bioturbators of beaches and form a key ecological link in the food webs of these ecosystems (Lucrezi and Schlacher, 2014) [16]. They are known as bioindicators and allow rapid assessment of the impact of disturbance on beach habitats (Branco *et al.*, 2010; Noriega *et al.*, 2012; Jonah *et al.*, 2015) [17, 2, 13]. Despite its importance on the coast of Côte d'Ivoire, this species is under the influence of several pressures, generally of an anthropogenic nature, including the progressive and anarchic occupation of the coastline and pollution due to the accumulation of marine debris on the shore (Gül and Griffen, 2020) [11]. In addition to these anthropogenic pressures, these crab populations are also faced with natural processes such as climate change. These processes can modify the biodiversity and demography of riparian species (Defeo *et al.*, 2009) [5]. In addition, human disturbance in coastal regions can lead to a reduction in the abundance and distribution of population sizes and ages of certain bioindicator species (Cortes *et al.*, 2013; Siddig *et al.*, 2016) [3, 25]. In response to these pressures, some changes have been observed in the basic biology and physiology of these organisms, particularly in the species *O. africana*. However, to date, there have been no studies on the biology and ecology of this species in Côte d'Ivoire.

According to Rahman *et al.* (2004) [19], the study of the length-weight relationship and the condition factor is important for biological, physiological and ecological processes, as well as for assessment of the abundance and overweight of animal species.

It is also fundamental for morphological comparisons between different species or between populations from different habitats and/or regions (Gonçalves *et al.*, 1997). The aim of the present study was to estimate and compare the size structure, allometric growth and condition factor between different populations of crabs of the species *O. africana* of different sites in Côte d'Ivoire.

Materials and methods

Study sites

The samples were collected according to their accessibility, on the beaches (Table I) of Grand-Bassam, Abidjan and Grand-Jacques (Figure 1), from August 2019 to August 2022. The beaches of Grand-Bassam and Abidjan are subject to heavy anthropogenic pressure, unlike the beach at Grand-Jacques.

Table 1: geographical coordinates and characteristics of sampling sites

Sampling sites	geographical coordinates	site occupancy
Grand-Bassam	5°12'10.3"N; 3°46'52.6"W 5°11'39.7"N; 3°44'16.3"W	Hotels, swimming pool and Restaurants
Grand-Jacques	5°11'44.3"N; 4°28'02.2"W 5°11'57.5"N; 4°25'58.7"W	Village, Coco plantations
Abidjan	5,15'02.4"N; 3°57'32.5" W 5°14'33.9"N; 3°55'16.8"W	Domestic rubbish dump and fishing

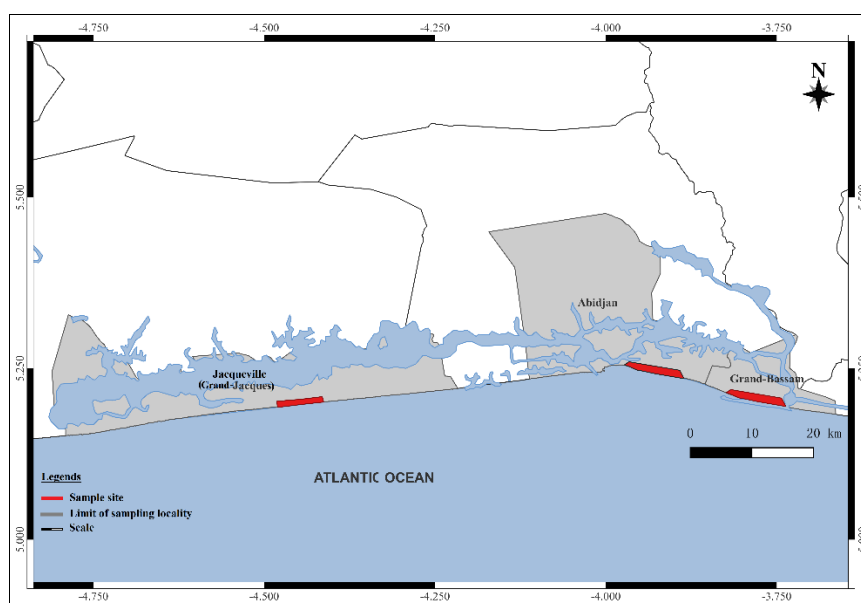


Fig 1: Sampling site

Sampling and data collection

Sampling was carried out between 19h and 00h. The crabs caught were kept in a cooler containing ice and transported to the laboratory for analysis. The crabs were separated according to sex in the laboratory and only intact specimens were considered for length-weight studies. A total of 441 specimens of the species *O. africana* were collected, including 261 males and 180 females (Table II). They were then weighed and measured using ImageJ software.

Table 2: Sample size of *O. africana* specimens collected per site

Samples site	Populations		
	Male	Female	Total
Abidjan	17	15	32
Grand-Bassam	12	15	27
Grand-Jacques	232	150	382
Total	261	180	441

The collected specimens were examined for morphometry. A total of seven descriptors, proposed by Kakou *et al.* (2017) [14] were used for this study. These descriptors are: carapace width (lc), carapace length (Lc), length of the right (LPD) and left (LPG) major chelipeds, length and width of the abdomen (La and la) and thoracic length (lth). The width of the carapace (lc) is the distance between the largest points of the

lateral extremities. It was taken as the reference measurement in this study.

Data analysis

The mean carapace weight and width of the populations were compared by site and sex using a one-factor ANOVA test at a significance level of 5% (Zar, 1999) using R software. The size frequency distribution was determined by interval class of the standard measure. It reflects an interaction between the rates of reproduction, recruitment, growth and mortality of the age groups present. According to Pauly (1983) [18], it can be used to identify problems such as growth deficit, low recruitment or excessive annual mortality. The size classes were defined on the basis of the Sturge rule (Scherrer, 1984) according to the following formula:

Where n is the total number of specimens. The class interval is also given by the following formula: $I = (L_{max} - L_{min}) / NC$, where L_{max} is the maximum carapace width, L_{min} is the minimum carapace width and NC is the number of classes. The length-weight and length-length relationships of all the samples collected were determined by the expression defined by Pauly (1983) [18] and given as follows:

$$Y = aL^b$$

Where Y denotes the derived weight (a), L denotes the length (mm) or width of the carapace, a is the intercept of the regression curve and b is the regression slope. The regression coefficients were estimated with a linear regression model, following the logarithmic transformation of the above expression:

$$\text{Log}(Y) = a' + b \log(L)$$

Carapace width (lc) was used as the independent variable, L. The dependent variables were the weight (P), the carapace length (Lc), the right claw length (LPD), the left claw length (LPG), the thoracic length (lth), the abdominal length (La) and the abdominal width (la). Also, several dependent characters were related: they were the length and width of the abdomen (La/la) and the lengths of the right and left chelipeds (LPD/LPG). The regression coefficients, a and b, were estimated with a linear regression model, where $\log(a) = a'$. Student's t-test was applied to check whether the regression slope b was significantly different from the allometry coefficient threshold which was 3. With respect to the regression slope b, the following three growth types were indicated: (1) when $b = 3$ or 1, the growth type was described as isometric; (2) when $b > 3$ or 1, the growth type was positive and (3) when $b < 3$ or 1, the growth type was negative (Spiegel, 1972). The Fulton condition factor (K) was calculated using the formula:

$$K = (P/lc^b) \times 10^3,$$

where P is the crab body mass, lc is the crab shell width (mm)

and b is the allometric constant.

Results

Size frequency distributions of *Ocypode africana*

The size frequency distribution of the species *O. africana* (Figure 1) showed that overall, the size of the specimens varied from 8.70 to 64.36 mm with a modal class represented by the interval [31.58 - 37.30 mm]. There were 124 specimens in this modal class. The minimum and maximum sizes of specimens depended on the locality. They were 21.00 and 34.25 mm at the Grand-Bassam site, 20.71 and 36.08 mm at Abidjan, and 8.70 and 64.36 mm at Grand-Jacques. The modal class of the Abidjan population was identical to that of Grand-Jacques and was [25.86 - 31.58 mm], with 13 and 99 specimens respectively. This class was smaller than that of the Grand-Bassam locality, [31.58 - 37.30 mm] with 18 specimens. The size frequencies recorded according to sex (Figure 2) varied from 8.70 to 64.36 mm for the males, with a modal class of [25.86 - 31.58 mm], comprising 92 specimens. For the females, the size varied from 10.18 to 58.20 mm with a modal class of [31.58 - 37.30 mm] and made up of 63 specimens. The same modal class was observed in the males of the different populations [25.86 - 31.58 mm] with the exception of the Grand-Bassam population, which had a modal class of [31.58 - 37.30 mm]. The numbers observed in each modal class are 8 for Abidjan, 81 for Grand-Jacques and 9 for Grand-Bassam. For the females, the modal class remained unchanged at all sites. This modal class was [31.58 - 37.30mm] and included 8 specimens for the Abidjan site, 10 specimens for the Grand-Bassam site and 45 specimens for the Grand-Jacques site.

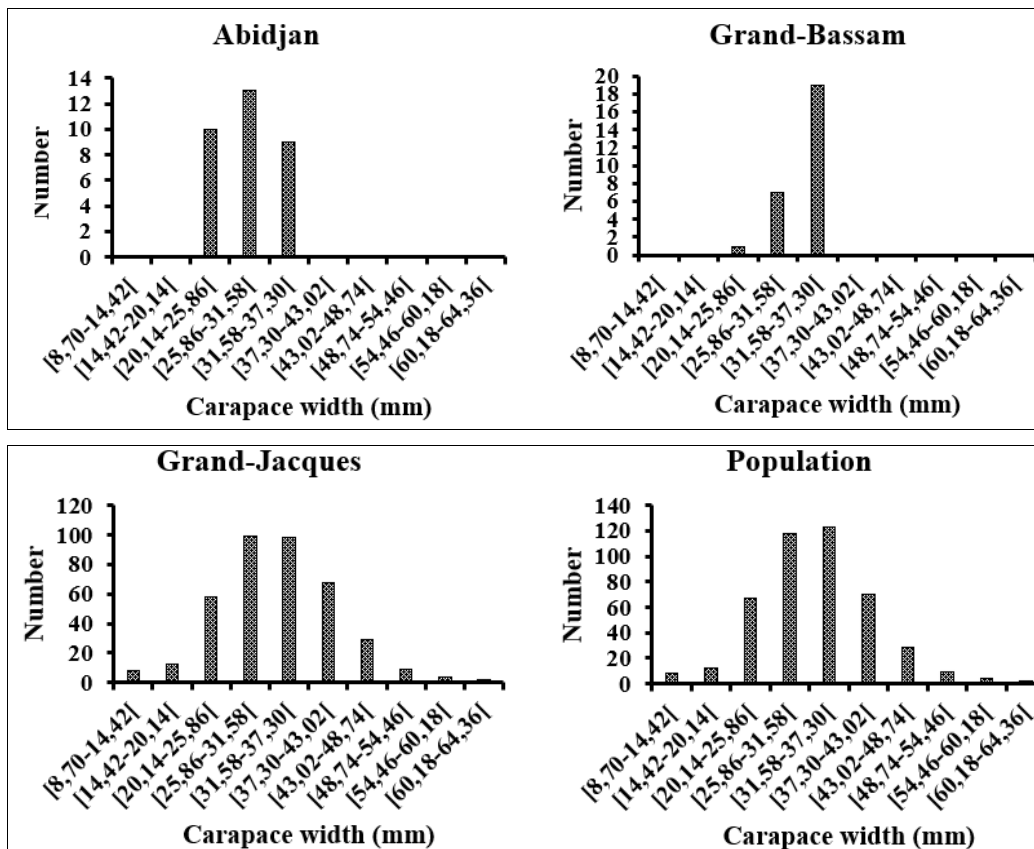


Fig 1: Size frequency distributions of *O. africana* according to locality

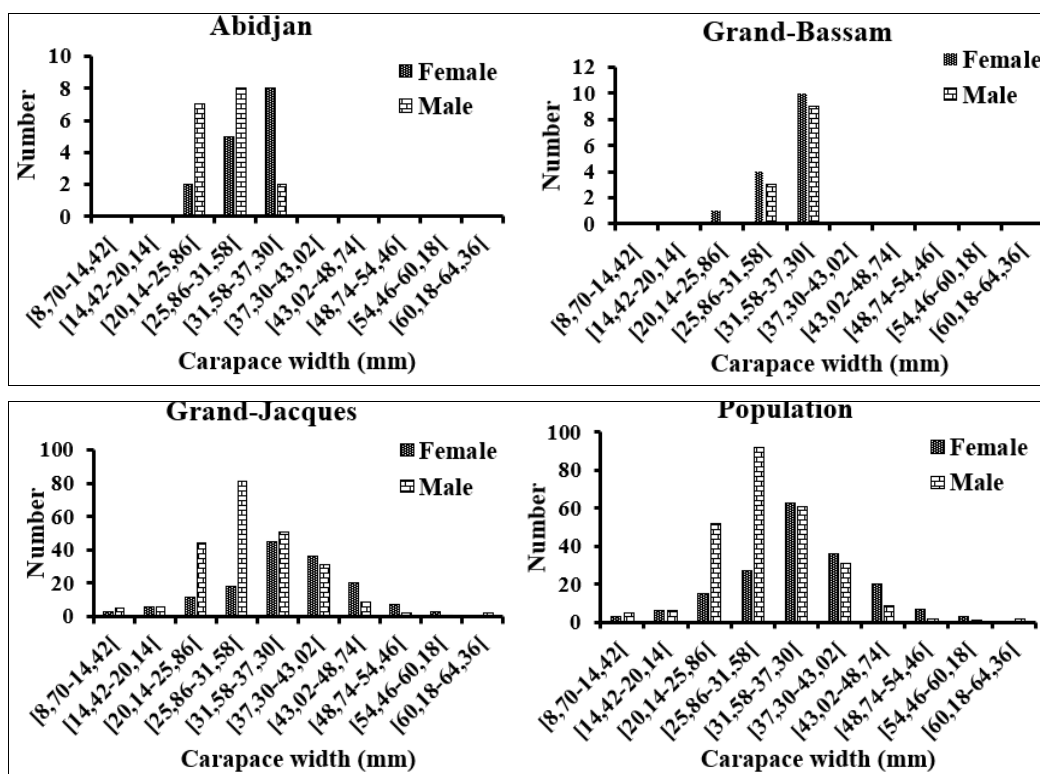


Fig 2: Size frequency distribution of *O. africana* males and females in each locality

Weight and size

Weight in all populations of the species *Ocypode africana* ranged from 0.23 g to 38.8 g (Table II) with a mean of 17.89 ± 7.39 g. Statistical analysis revealed a highly significant difference ($P < 0.001$) in weight according to site and sex. The average weights recorded for females were 14.41 ± 5.78 g (Abidjan) and 19.97 ± 9.00 g (Grand-Jacques), and were statistically higher than those of the males, with an average weight of 9.19 ± 4.87 g (Abidjan) and 18.37 ± 3.38 g (Grand-Bassam). With regard to carapace width, the values recorded in the whole population ranged from 8.70 mm to 64.36 mm,

with an average of 32.41 ± 8.23 mm. The computed mean values for females were 31.16 ± 4.12 mm, 30.95 ± 3.67 mm and 35.72 ± 9.10 mm for Abidjan, Grand-Bassam and Grand-Jacques, respectively. These averages were significantly different from those obtained for males, whose values were 26.74 ± 3.47 mm, 30.90 ± 7.79 mm and 31.78 ± 1.87 mm for Abidjan, Grand-Jacques and Grand-Bassam, respectively. These results showed that specimens from the Grand-Jacques and Grand-Bassam sites grew better in weight and size. In addition, in relation to sex, females generally showed better growth than males at all sites.

Table 3: Descriptive statistics for carapace weight and width of specimens (males, females and combined) of the species *Ocypode africana* at the three sites. Avg: mean, SD: standard deviation; min: minimum; max: maximum and Pop: female and male combined

Caractères	Gender	Grand-Bassam	Grand-Jacques	Abidjan	Population
		mean±sd	mean±sd	mean±sd	mean±sd
Carapace width (mm)	F	30.95±3.68 ^{aa}	35.72±9.10 ^{aa}	31.16±4.12 ^{aa}	34.94±8.62
		21.00 – 34.25	10.18 – 58.20	22.01 – 36.08	10.18 – 58.20
	M	31.78±1.87 ^{aa}	30.90±7.79 ^{ab}	26.74±3.47 ^{ab}	30.67±7.48
		28.25 – 34.15	8.70 – 64.36	20.71 – 33.88	8.70 – 64.36
	Pop	31.32±2.99 ^{ab}	32.79±8.65 ^b	28.81±4.34 ^a	32.41±8.23
		21.00 – 34.25	8.70 – 64.36	20.71 – 36.08	8.70 – 64.36
weight (g)	F	17.16±5.56 ^{abA}	19.97±9.00 ^{bA}	14.41±5.78 ^{aa}	19.27±8.68
		3.39 – 22.14	0.26 – 38.80	5.69 – 25.42	0.26 – 38.80
	M	18.37±3.38 ^{ba}	17.38±5.92 ^{bb}	9.19±4.87 ^{ab}	16.90±6.10
		12.49 – 22.28	0.23 – 34.30	3.17 – 16.97	0.23 – 34.30
	Pop	17.70±4.67 ^b	18.40±7.39 ^b	11.64±5.86 ^a	17.86±7.35
		3.39 – 22.28	0.23 – 38.80	3.17 – 25.42	0.23 – 38.80

Lower case letters in the same row indicate a comparison based on locality and upper-case letters in the same column indicate a comparison based on gender.

Carapace width-weight and length-length relationships in populations of crabs of the species *Ocypode africana*

The values of the coefficient of determination (r^2) for specimens of the species *O. africana* ranged from 0.35 (Grand-Jacques, males) to 0.75 (Grand-Bassam, females) and were highly significant ($P < 0.05$). The carapace width-weight

relationship for the Abidjan and Grand-Bassam populations indicated a major allometry with values of 3.12 and 3.18 respectively (Table III). In contrast, the carapace width-weight relationship for the Grand-Jacques population showed a minor allometry (1.72). In the males of the Abidjan and Grand-Bassam populations, the carapace width-weight

relationship indicated a minorizing allometry (-), whereas that of the females showed a majorizing allometry (+). Furthermore, the type of allometry obtained in the carapace width-weight relationship for males (1.38) and females (2.33) from the Grand-Jacques site is said to be in the minority. Consequently, specimens from the Grand-Jacques populations grew more in size than in weight, while those from the Abidjan and Grand-Bassam localities grew more in weight than in size. With regard to the length-length relationships

(Table IV), the recorded values of the coefficient of determination (r^2) varied between 0.12 (La/la, males) and 0.94 (lc/Lc, males) and were generally lower in the male populations of each locality. The allometric growth of the different relationships studied showed that the male and female populations of the Grand-Bassam locality generally had different allometric types compared to those of Abidjan and Grand-Jacques.

Table 4: Parameters of the allometric regression of weight against carapace width in males, females and the whole species of *Ocypode africana* from the different sites

Sites	Gender	a'	b	r ²	Equations	t	p	All.
Grand-Bassam	F	-3.71	3.30	0.75***	Log ₁₀ (P)=3.30 log ₁₀ (lc) - 3.71	15.75	2.65 10 ⁻¹⁰	+
	M	-2.21	2.24	0.47*	Log ₁₀ (P)=2.24 log ₁₀ (lc) - 2.21	-6.26	2.14 10 ¹⁵	-
	Pop	-3.52	3.18	0.72***	L og ₁₀ (P)=3.18 log ₁₀ (lc) - 3.52	14.76	3.73 10 ⁻¹⁴	+
Grand-Jacques	F	-2.38	2.33	0.57***	Log ₁₀ (P)=2.33 log ₁₀ (lc) - 2.38	-43.14	4.32 10 ⁻⁸⁶	-
	M	-0.85	1.38	0.35***	Log ₁₀ (P)=1.38 log ₁₀ (lc) - 0.85	-141.46	2.25 10 ⁻²²⁶	-
	Pop	-1.38	1.72	0.43**	Log ₁₀ (P)=1.72 log ₁₀ (lc) - 1.38	-131.39	2.01 10 ⁻³¹⁹	-
Abidjan	F	-4.01	3.45	0.63***	Log ₁₀ (P)=3.45 log ₁₀ (lc) - 4.01	-19.54	1.47 10 ⁻¹¹	+
	M	-2.82	2.64	0.70***	Log ₁₀ (P)=2.64 log ₁₀ (lc) - 2.82	17.37	8.30 10 ⁻¹²	-
	Pop	-3.53	3.12	0.72***	Log ₁₀ (P)=3.12 log ₁₀ (lc) - 3.53	7.3918	2.51 10 ⁻⁰⁸	+

r²: coefficient of determination; a: intercept; b: allometry coefficient. *** :P < 0.001; all: allometry; t: Student's t-test; F: female; M: male and Pop: population.

Table 5: Parameters of the allometric regression of weight against carapace width in males, females and the whole species of *Ocypode africana* from different sites.

Sites		lc/Lc		lc/LPD		lc/LPG		LPD/LPG		lc/lth		lc/La		lc/la		La/la	
		F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
Grand-Bassam	a'	-0.38	-0.27	0.01	-0.24	0.34	-0.68	-0.28	-0.01	-0.31	-0.96	-2.30	-2.11	0.53	0.73	-1.07	0.51
	b	1.20	1.12	1.05	1.21	0.85	1.50	1.13	0.94	1.06	1.49	2.38	2.11	0.69	0.53	1.83	0.43
	all	+	+	+	+	-	+	+	-	+	+	+	+	-	-	+	-
	r ²	0.78	0.94	0.50	0.57	0.44	0.39	0.76	0.15	0.67	0.38	0.82	0.49	0.65	0.13	0.81	0.12
Grand-Jacques	a'	-0.04	0.01	0.16	0.29	0.03	0.21	0.27	0.12	0.23	0.51	-0.06	0.34	-0.89	-0.12	-0.64	-0.18
	b	0.92	0.87	0.85	0.8	0.94	0.85	0.83	0.91	0.78	0.62	0.90	0.64	1.39	0.77	1.44	0.93
	all	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
	r ²	0.77	0.79	0.49	0.46	0.58	0.38	0.66	0.61	0.62	0.41	0.70	0.38	0.71	0.36	0.88	0.57
Abidjan	a'	-0.04	-0.08	0.53	0.35	0.67	0.69	0.92	0.99	0.002	0.11	-0.40	-0.22	-1.74	-1.66	-0.75	-0.32
	b	0.97	1	0.68	0.8	0.58	0.58	0.4	0.35	0.94	0.86	1.11	0.99	1.95	1.80	1.53	1.03
	all	-	0	-	-	-	-	-	-	-	-	+	0	+	+	+	0
	r ²	0.92	0.79	0.27	0.41	0.35	0.26	0.29	0.15	0.92	0.30	0.87	0.51	0.81	0.54	0.71	0.34

r²: coefficient of determination; a: intercept; b: allometry coefficient; all: allometry.

Condition factor

The mean values of the condition factor (K) recorded for males and females ranged from 0.46±0.15 (Abidjan) to 0.63±0.46 (Grand-Jacques) and showed no significant difference between sites (P > 0.05) (Table V). Furthermore, depending on sex, the mean values of the condition factor determined for females and males varied respectively from

0.46±0.11 (Abidjan) to 0.56±0.14 (Grand-Bassam) and from 0.45±0.19 (Abidjan) to 0.72±0.5 (Grand-Jacques). For males, the highest mean value was observed in Grand-Jacques (0.72±0.5) and for females in Grand-Bassam (0.56±0.14). In comparison, males recorded a higher condition factor (0.70±0.49) than females (0.48±0.33).

Table 6: Condition factor of males, females and both genders combined of the species *Ocypode africana* according to sites

Gender	Grand-Bassam	Grand -Jacques	Abidjan	Population	P
	Moy±Et	Moy±Et	Moy±Et	Moy±Et	
Females	Min - max	Min - max	Min - max	Min - max	0.4344
	0.56±0.14 ^{aA}	0.48±0.35 ^{aA}	0.46±0.11 ^{aA}	0.48±0.33 ^A	
Males	0.31 - 0.92	0.07 - 2.37	0.31 - 0.61	0.07 - 2.37	0.02913
	0.57±0.09 ^{abA}	0.72±0.5 ^{ab}	0.45±0.19 ^{bA}	0.70±0.49 ^B	
Gender combined	0.42 - 0.74	0.08 - 3.72	0.26 - 1.04	0.08 - 3.72	0.2178
	0.56 ± 0.12 ^a	0.63±0.46 ^a	0.46±0.15 ^a	0.61±0.44	
	0.31 - 0.92	0.07 - 3.72	0.26 - 1.04	0.07 - 3.72	

Discussion

The study of the variation in weight and size of the specimens showed that the females had a better growth performance than the males. In comparison, the maximum size (64.36 mm) obtained was greater than that reported by Schneider (1992) [23], who obtained a maximum size of 34 mm in *Ocypode africana*. In fact, this difference in size, observed mainly in

the Grand-Jacques locality, was due to the fact that this area was very sparsely populated. In addition, specimens of this species were more numerous and may be found in areas with plant cover extending more than 150 m from the beaches. According to Noriega *et al.* (2012) [17], ghost crabs were more abundant in areas with wider dunes that contain a large number of plant species and higher vegetation cover. In short,

the *O. africana* species appeared to be much more terrestrial. Furthermore, the size difference between females and males observed in this study is contrary to that reported by D'Almeida *et al.* (2014) ^[4], who stated that, in crustaceans, males tend to be larger than females. Indeed, males of marine brachyuran species generally reached a larger body size than females, which defines their competitive ability to access the marine environment of recipient females as well as to protect them during copulation (Hartnoll, 1969; Silva *et al.*, 2017) ^[12]. However, according to Williner and Collins (2013) ^[27], differences in growth between males and females could be linked to changes in feeding or reproductive options.

The allometric study of this species has made it possible to monitor changes in carapace width in relation to weight. In this study, the width-weight relationship equations (lc/P) showed that the weight of females (with the exception of those from the Grand-Jacques site) increased as carapace width increases, unlike that of males. This result is contrary to those of Din *et al.* (2017) and Shahriar and Rouf (2018), who carried out their study on crabs of the genus *Scylla*. According to these authors, the males of brachyuran crabs generally have a major allometric growth while the females have a minor growth. This observed difference in growth may be due to pollution, the destruction of their habitats and human disturbance. In fact, the beaches of Abidjan (particularly in the commune of Port-Bouët) and Grand-Bassam are subject to strong anthropic pressure and pollution due to the dumping of household waste. That observation is particularly true at the Abidjan site. According to Feary *et al.* (2009) ^[7], the reduction in habitat quality due to human disturbance can reduce the growth of individuals. In addition, according to Froese (2006) ^[8], the carapace width relationship can be affected by several factors, including habitat, area, seasonal effects, degree of fecundity, gonad maturity, sex, health, preservation techniques and differences in the observed length of specimens. It should also be pointed out that this species was very rarely found in Grand-Bassam and Abidjan, which could be due to the occupation of the beach for leisure purposes and, above all, to the fact that their habitat has been stripped of vegetation. The condition factor, higher in males than in females, was similar to those reported by Arimoro and Meye (2007) ^[11]. According to these authors, males generally appeared to have a higher condition factor than females. Furthermore, the high condition factor in the Grand-Jacques population as a whole, compared with other populations in more anthropised localities, indicates the well-being of the specimens in this locality. As Fulton (1904) ^[9] stated, a higher condition factor K expresses the 'well-being' of a population during the various stages of its life cycle. Furthermore, the low value of the condition factor of the species *O. africana* in the Abidjan locality could be due to the poor environmental conditions and the strong anthropic pressure exerted on this beach.

Conclusion

This study has shown that specimens from the Grand-Jacques locality, a site with little pollution and little anthropisation, showed good growth in size and weight. Also, the allometric coefficient in the Grand-Jacques locality was in the minority ($b < 3$) and differed from those of the Abidjan and Grand-Bassam populations, which were in the majority ($b > 3$). In addition, the condition factor as a function of sex showed that males had a better condition than females and as a function of site, showed that specimens from Abidjan were in

unfavorable conditions.

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