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Size class, density, and distribution of *Uca tangeri* (Eydoux, 1835; Decapoda: Ocypodidae) in the mangrove ecosystems of Senegal

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Abstract
This study focusing on the decapod brachyuran *Uca tangeri* is the first of its kind in Senegal. It was carried out in the mangroves of the Senegal River delta, the Saloum islands, and the Casamance estuary. The modal cephalothoracic length (L; mm) is between 24 and 25 mm in Saint-Louis, 18 and 19 mm in the Saloum, and 16 and 17 mm in Casamance. The modal cephalothoracic weight (Wei; mm) oscillates between 31 and 32 mm in Saint-Louis, 24 and 25 mm in the Saloum, and 25 and 26 mm in Casamance. Whether it is the relation Lc/We or that of the height/weight, the allome-tric growth of crabs is negative (b <3). Likewise, the correlation coefficient values revealed a strong relationship (R >0.8) among the biometric parameters. The average crab density in the mangrove is between 1.3 and 1.6 crabs per square meter. The strong presence and abundance of *Uca tangeri* suggest this species does not have a preferential spatial distribution.

Keywords: Mangrove, biometric parameters, density, repartition

1. Introduction

As a decapod brachyuran of the ocypodedae family [1], *Uca tangeri* crab is a species widely distributed in the tropics and subtropics [2]. With a distribution area extending from Morocco to southern Angola in the eastern-central Atlantic [3], this species is ubiquitous in West African mangroves [4]. Semi-terrestrial and mediolittoral, the crab lives in large colonies on the mud of mangroves in estuaries [5] and deltas and lagoons [4].

Crabs of this species exhibit a very pronounced sexual dimorphism [6]. Females have two small and equal chelipeds, but those of the males are assymetrical, one of which is small like the female and the other is very developed [3]. Being an integral part of the mangrove, like the other crabs closely associated with this ecosystem [7], they play their structural and functional role, thus earning them the name of "alien engineering species" [8].

Several carcinologic studies have been conducted. They have been considering the size class of *Uca arcuata* in Japan [9], *Uca rapax* in Brazil [10], *Portunus pelagicus* in Iran [11], *Goniopsis pelii* in Nigeria [12], *Callinectes amnicola* and *Cardisoma armatum* in Benin [13] [14]; the growth of *Uca tangeri* in Brazil; the density of Ocipodidae and Grapsidae in Mozambique [15], on the crab in general in French Polynesia [16] and Mayotte [17]; the distribution of *Panopeus pelagicus* in Iran [11], crabs in Cameroon [18], in Sri Lanka.

In Senegal, according to the literature, apart from studies of morphometry, growth, and distribution of crabs carried out by [20] [21], no other monograph on the crab *Uca tan* conductedger. From this perspective, the present study was carried out to contribute to this species knowledge.

Materials and Methods

Study Area

The present study was carried out in the three estuaries of Senegal, which are mangrove ecosystems. These are the estuaries of the Senegal river, Saloum and Casamance.

The Senegal river of 1700Km [22] (Figure 1) long has an unstable estuary [23] which covers an area of 4000 to 5000 Km2 [24]. It belongs exclusively to the semi-arid Sahelian domain.

The mangrove swamp of the river estuary is located at the northern limit, between 16°20 North latitude and 13°30 West longitude, and extends over 281.52 hectares [25]. This mangrove which borders the hydrological network, is currently residual [26]. The mangroves making up the Senegal River estuary are the *Rhizosphere racemosa* characterized by stilt roots and the Avicennia with aerial roots equipped with pneumatophores [25].

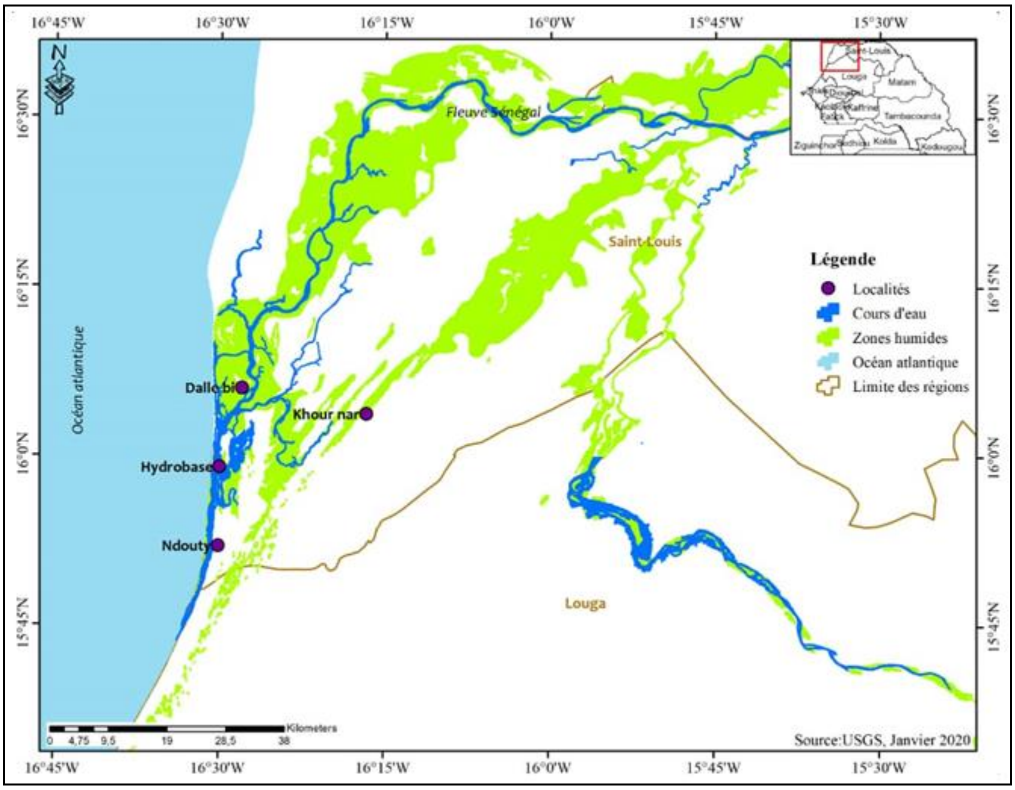

Fig 1: Senegal River Estuary

The estuary zone of Saloum covers an area of 8000 hectares [27]. It is divided by chains of islands, and its hydrological system is made up of three main branches: Saloum (110Km) to the North and Northeast, Bandiala (18Km) to the South, and Southeast, and Diombos (3Km) between the two [28] (Figure 2). From a functional point of view, the estuary is characterized by an inverse hypersalinity [29, 30, 31]. The mangrove is affected by climate change due to the increase in the salinity of the water following the rainfall deficit, the extension of tannes to the detriment of the visors, and the soil's acidification [32]. The climate is Sudanese. It is characterized by alternating a rainy season and a dry season.

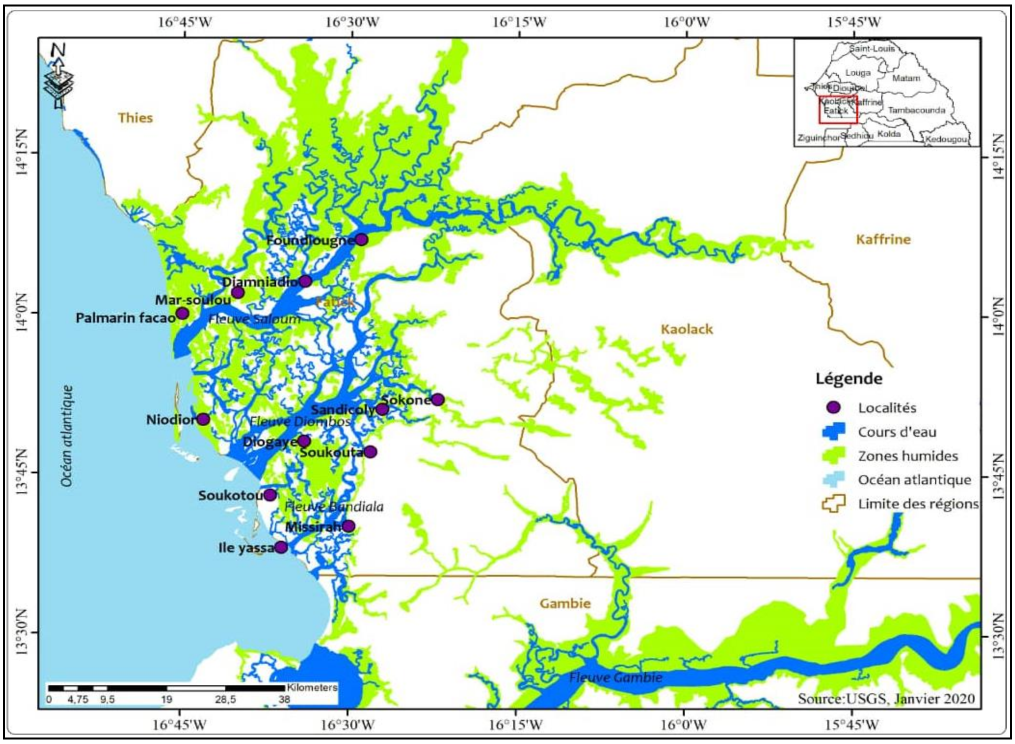

Fig 2: Saloum Estuary

The Casamance river covers a watershed of 20,150 Km2 [33] (Figure 3). Long of 350 Km, the Casamance river evolved into a typical estuary. However, several factors such as the hydrological deficit resulting from the drought of the 1970s and weakness of the slope are at the origin of the permanent intrusion of the sea into the estuary [34] hence the establishment of a hyperhaline with reverse estuary operation [35]. Casamance has a tropical subguinean climate characterized by alternating dry and wet seasons.

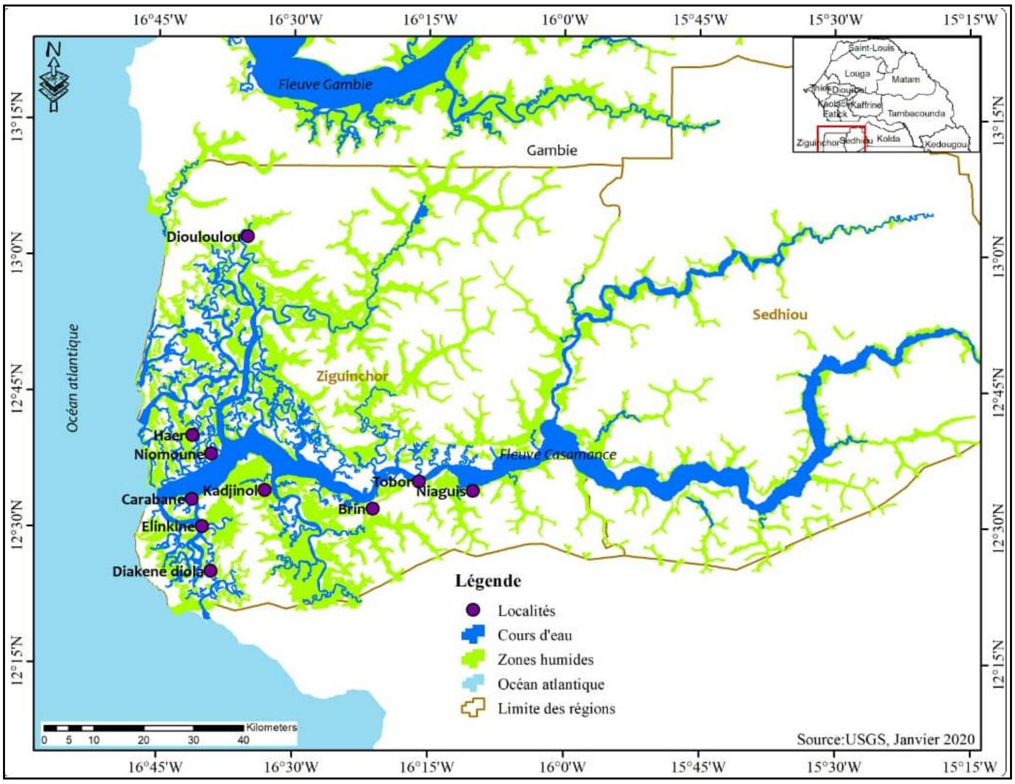

Fig 3: Casamance Estuary

The samples were collected from April to July 2019. Two capture methods have been adopted: square and sight capture. The capture by square consists in delimiting a square of 5 m side by stakes. The burrows of *Uca tangeri* internal to the quadrat were searched either by hand or with a trowel to dislodge residents, while sight capture was carried out by hand or with a dip net. A total of 27stations were sampled at the rate of 5 in Saint-Louis, 13 in the Saloum, and 9 in Casamance.

Study of biological parameters

Size frequency distribution

Size frequency distribution was established using cephalothoracic length. The size-frequency distribution allows a representation of the demographic structure of *Uca tangeri*. The individuals were grouped by size class of 1 mm intervals.

Biometric relationships

In the present study, the biometric relationships concerning *Uca tangeri* refer to the equation between cephalothoracic length (L) and width (Wi) on the one hand and the relationships between weight (We) and length (L). The relation which relates the length to the cephalothoracic width of *Uca tangeri* is described by the formula:

$$\log (L) = \log (a) + b*\log (Wi)$$

Where b= slopes of the regression lines; log (a)= y-interept; L= cephalothoracic length; Wi: cephalothoracic width.
The size-weight relationship is usually expressed by the equation We =a*Lb (We is the fresh weight in grams; L is the cephalothoracic length in millimeters; a is a constant and b an allometric coefficient). The log transformation can linearize the relation to reduce the variability and the two variables (We and L) [36]:

$$\ln We = \ln (a) + b*\ln (L).$$

The size-weight relationship reflects isometric growth when $b=3$ and allometric growth when $b \neq 3$. However, positive allometric growth is observed when $b>3$ and a negative when $b<3$ [37]. It expresses the morphology of the species. A coefficient b greater than 3 indicates more significant weight growth than length and vice versa [38].

Density

The density of each quadrat is calculated from this relation
D = number of individuals in each quadrat/quadrat surface
The average density (D) of each mangrove is obtained by applying this relation:
D= sum of densities (d)/Number of quadrats

Distribution

The distribution of species has been studied, considering its presence (+) or absence (-) in each site.
Statistical analysis
The statistical difference between the value of b determined and the isometric value was obtained using the following Student's t-test [39]:

$$tcal=(b-3)/ESb$$

Where tcal is the value of t-test of the Student, b the slope of the regression line and ESb the standard error of b. The

difference is significant if tcal is greater than three. The theoretical values at the threshold α= Regression statistics were calculated with Excel.
The correlation coefficient R made it possible to analyze the intensity and direction of the relationship between two quantitative variables. It is between $-1 \leq R \leq 1$. So if $|R| > 0.8$: the correlation is strong; if $0.5 < |R| < 0.8$: the correlation is medium and if $|R| < 0.5$: the correlation is weak.

Results

Distribution by size classes

The size-frequency frequency distribution indicated that the modal cephalothoracic length is between 24 and 25 mm in Saint-Louis (Figure 4), 18 and 19 mm in the Saloum (Figure 5), and 16 and 17 mm in the Casamance (Figure 6). Individuals of smaller sizes found in the Saloum were between 6 and 7 mm, followed by those sampled in the Casamance with 8 and 9 mm, and finally, the individual taken at Saint-Louis with 14 and 15 mm. The maximum values of this cephalothoracic length oscillated between 32 and 34 mm in the Saloum, 34 and 35 mm in Saint-Louis, and 28 and 29 mm in Casamance. The average cephalothoracic length was 24.5 mm in Saint-Louis, 19 mm in Casamance, and 18 mm in Saloum.
The modal cephalothoracic width was between 31 and 32 mm at Saint-Louis, 24 and 25 mm in the Saloum, and 25 and 26 mm in Casamance. The smallest value of this cephalothoracic width was between 11 and 12 mm in Casamance, 12 and 13 mm in the Saloum, and 21 and 23 mm in Saint-Louis. The largest cephalothoracic width was recorded in the Saloum; its measurement was from 44 to 45 mm, followed by Saint-Louis between 43 and 44 mm, and finally 41 and 42 mm in Casamance. The mean cephalothoracic width values were 33 mm in Saint-Louis, 27 mm in Casamance, and 25 mm in Saloum.

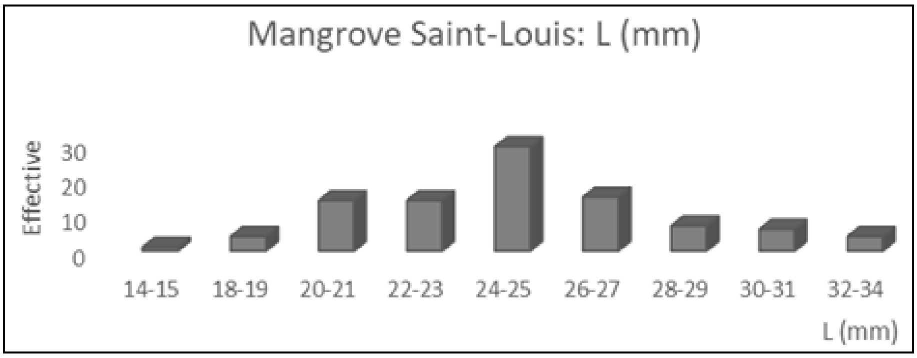

Fig 4: Cephalothoracic length L (mm) distribution of *Uca tangeri* in Saint-Louis

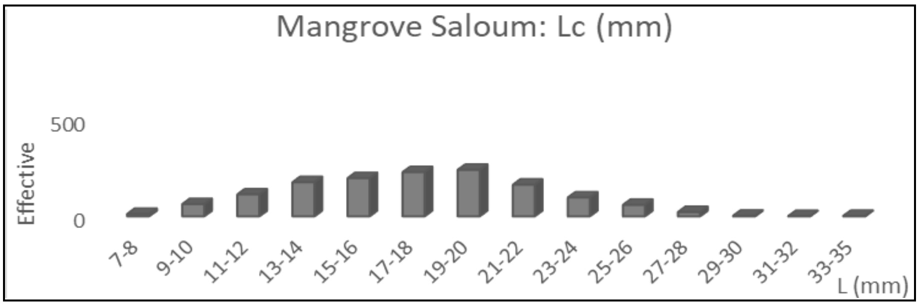

Fig 5: Cephalothoracic length L (mm) distribution of *Uca tangeri* in Saloum

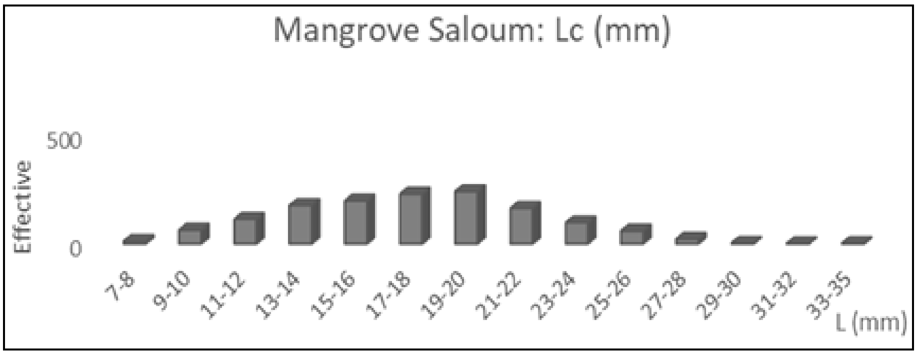

Fig 6: Cephalothoracic length L (mm) distribution of *Uca tangeri* in Casamance

Biometric and size/weight study

Relationship between cephalothoracic length and width (L/Wi)

For the L/Wi relationship (Table 1), $b < 3$ in the three ecosystems reveals negative allometric growth. Compared to the theoretical isometric value ($b=3$) at a threshold of α=5%, the difference is not significative in Saint-Louis (t.cal = 1.838 < 3) on the other hand it is significant in Saloum (t.cal=9.883 > 3), and Casamance (t.cal = 7.458 > 3). The relation between the cephalothoracic length and width is strong overall because the correlation coefficient $R > 0.8$

Table 1: Parameters relation cephalothoracic length (L) and width (Wi) *Uca tangeri*

Area	Variables	Number of individuels	Parameters			Equations
			a	b	R^2	
Saint-Louis	L/Wi	94	1.60	1.28	0.86	L=1.28*Wi + 1.60
Saloum	L/Wi	1376	4.04	1.22	0.89	L=1.22*Wi + 4.04
Casamance	L/Wi	609	2.48	1.31	0.92	L=1.31*Wi + 2.48

Size weight relationship

The size-weight relationship (Table 2), b < 3 in the three mangroves, indicates a negative allometric. The difference between the calculated and theoretical values is insignificant in Saint-Louis (t.cal = 0.565 < 3) at a threshold of 5%. This difference is however significant in Saloum (t.cal = 6.328 > 3) and Casamance (t.cal=4.019 > 3). The relationship between size and weight is strong because the correlation coefficient is strong at R > 0.8

Table 2: Parameters size-weight (L/We) relation *Uca tangeri*

Area	Variables	Number of individuals	Parameters			Equations
			a	b	R^2	
Saint-Louis	L/We	94	19.98	0.25	0.64	P=0.26*Lc+19.98
Saloum	L/We	1376	12.54	0.59	0.69	P=0.59*Lc+12.54
Casamance	L/We	609	13.56	0.53	0.78	P=0.53*Lc+13.56

Density and distribution of *Uca tangeri* crab

Density of *Uca tangeri* crab

In Saint-Louis, in the Gandiol at Ndouty, the average density was 1.28 individuals/m². Along the Saloum river from Palmarin facao to Diamniadio, the average density of *Uca tangeri* varied from 0.84 to 1.62 individuals/m²; two then decreased at Foundiougne with 0.74 individuals/m². In contrast, in the Diombos river, this average density gradually decreased from 2.94 individuals/m² at Soukôtou to 0.92 individuals/m² at Sokone. Along the Bandiala river, it fluctuated between 1.62 (at Iles Yassa) to 1.14 individuals/m² (at Soucouta). Along the Casamance river, the highest average density was noted at Carabane with 2.58 individuals/m², dropped at Niomoune with 0.82 individuals/m², then increased at Elinkine with 1.8 individuals/m².

Average density of *Uca tangeri* crab in the three mangroves

The average density of *Uca tangeri* crab was 1.3 individuals/m², 1.5 individuals/m² in Saloum, and 1.6 individuals/m² in Casamance (Figure 7). Therefore, this density increased from North to South in these three mangrove ecosystems.

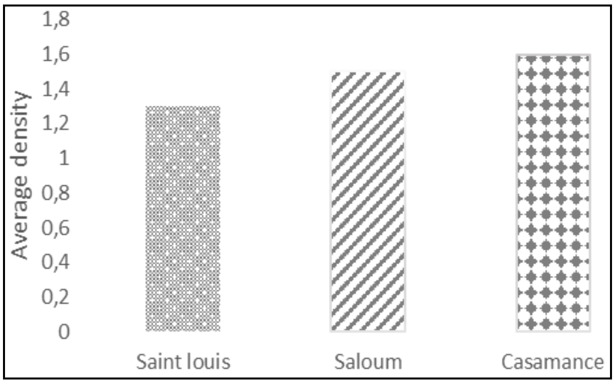

Fig 7: Average density of *Uca tangeri* crab in the three mangroves

Distribution of crab *Uca tangeri*

The distribution of the crab *Uca tangeri* in the three mangroves is shown in Table 3. This species is present in the sampled sites with some differences. Thus comparatively, the presence and abundance of this brachyuran were much more important in the mangrove of Saloum, followed by that of Casamance, and finally that of Saint-Louis.

Table 3: Distribution of crabs *Uca tangeri* in the three mangroves

		Sites	*U. tangeri*	% *Uca tangreri*	Distribution
Saint-Louis		Hydrobase	15	0.6	+
	Lagoon	Sanar	38	1.6	+
		Ndouty	26	1.1	+
		Khour-nar	00	0	-
	River	Dalle-bi	14	0.6	+
Saloum	Mouth	Niodior	197	8.2	++++
	Saloum River	Marsoulou	111	4.6	+++
		Palmarin facao	96	4	++
		Diamniadio	121	5	+++
		Foundiougne	51	2.1	++
	Diombos River	Soukôtou	186	7.7	++++
		Diogaye	197	8.2	++++
		Sandicoly	79	3.2	++
		Sokone	66	2.7	++
	Bandial a River	Ile Yassa	91	3.8	++
		Missirah	94	4	++
		Soukouta	111	4.6	+++
Casamance	Diouloul tributar	Diouloulou	18	0.8	+
		Haer	90	3.7	++
		Niomoune	40	1.7	+
	Mouth	Carabane	193	8	++++
	BolE-D	Elinkine	147	6.1	+++
		Diakène diola	147	6.1	+++
	Casamance River	Kadjinol	65	2.7	++

		Niaguis	34	1.4	+
		Tobor	97	4	++
		Brin	84	3.5	++

Discussion

The present study reveals that in the mangrove ecosystems of Senegal, the value of the maximum cephalothoracic width fluctuates between 41 and 45 mm. In the Atlantic-eastern zone [3] find that the most significant measure of the cephalothoracic width of *Uca tangeri* is 47 mm. In Nigeria, along the Abule-Agege mangrove stream forming part of the lagoon of Lagos [40], both sexes of *Uca tangeri* combined reported a cephalothoracic width of 38 mm. In the mangrove of the Island of Inhaca in Mozambique [41] found maximum values of the cephalothoracic width of 4 species of female grained crabs of the genus Uca: 12.71 mm for *U. annulipes*, 19.81 mm for *U. inversa*; 17.69 mm for *U. chlorophthalmus* et 23.5 mm for *U. vocans*. The climatic conditions in which these species evolve, especially the salinity, would justify these different results.

Concerning the size-weight relationship (L/We), the results study show negative allometric growth (b<3). This means that the growth in weight of the crab is less than that in size. Negative allometric growth was noted for the mangrove crab *Sesarma huzardi* [42], for female individuals of *Scylla serrata* [43], for *Uca tangeri*, for *Callinetes amnicola* [44].

In this study, the average density of the crab *Uca tangeri* varied between 1.3 and 1.6 individuals/m^2. [22] found a density of 1.8 individuals/m^2 at Dionewar and 1.6 individuals/m^2 at Sounil (Lagune de Fadiouth). These results are consistent with those of the present study. However, the difference in densities noted between the mangrove would be due to several factors; the regeneration of mangroves, especially Rhizophora, because of the high salinity negatively influencing their development [4546].

On the other hand [47] found in the Kema mangrove in the north of Sulawesi (Indonesia) an average density of 24.89 individuals/m^2 for species of genus Uca. [48], for the species *Uca annulipes*, gave average densities of 18.5 and 17.5 individuals/m^2 in spring tide and low tide of the Mida Stream (Kenya). On the one hand, this difference would be due to the method used, especially to the climatic conditions that conditioned the biology of crabs.

The investigations of this study show that crab *Uca tangeri* does not seem to have a preferential distribution. This species is found in all the localities surveyed: in sandy or muddy intertidal areas, strongly or weakly colonized by mangroves. Some low-density dig their galleries on bare tannes with a rigid substrate. Moreover [49] maintained that this wide distribution of this species is due to its adaptability, which allows it to occupy a vast set of microhabitats (visors, sandy and rocky beaches, areas beyond and below the line of high tide and mangroves) which are the equivalents of several distinct ecological niches occupied by several species of mangroves. According to [50], the fiddler crab *Uca tangeri* is a species characteristic of mangroves. However, it has specific requirements and tolerances concerning environmental factors. It is the euryhaline species adapted to ecological conditions. It is the most frequent and dominant. So whatever the state of the mangrove, the presence of this crab is always noted. It is regulated by the difference in sediment and vegetation as well as the degree of salinity, temperature, and time of exposure to drying [51].

Conclusion

The present study carried out in the three mangrove ecosystems of Senegal provides information on the size of *Uca tangeri* individuals, their density, biometric relationship, and their distribution. It provides an essential database for the management and understanding of these environments.

Acknowledgment

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