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Sizes at first sexual maturity and capture and demographic parameters of crabs *Callinectes amnicola* and *Cardisoma armatum* in the complex Nokoué Lake Porto-Novo lagoon in South Benin

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Abstract

Crabs *Callinectes amnicola* and *Cardisoma armatum* are intensively exploited in the complex Nokoué lake Porto-lagoon in South Benin. This study aims to evaluate the current exploitation level of these species based on the sizes at first sexual maturity and capture as well as on certain demographic parameters. For this, 1287 *Callinectes amnicola* crabs and 322 *Cardisoma armatum* crabs were collected, sexed and measured between May 2016 and April 2017. The study revealed that in both crab species, the calculated sex ratios were not different from the theoretical sex ratio ($p > 0.05$). In crab *Callinectes amnicola*, the size at first sexual maturity of females was lower than that of males whereas in *Cardisoma armatum*, males had a size at first sexual maturity inferior to females. The size at the first capture of *Callinectes amnicola* crab (4.60 cm) was greater than that of the *Cardisoma armatum* crab (4.41 cm). In both crab species, first-catch sizes were all smaller than first maturity sizes. The growth coefficient and the growth performance index in the crab *Cardisoma armatum* were superior to those of the crab *Callinectes amnicola*. The total mortality, natural mortality, and fishing mortality were higher in crab *Cardisoma armatum* than in crab *Callinectes amnicola*. In the complex Nokoué lake Porto-Novo lagoon in South Benin, crabs *Callinectes amnicola* and *Cardisoma armatum* are overexploited.

Keywords: sexual maturity, growth, mortality, exploitation, Benin

1. Introduction

In Benin, fishing is the main source of animal protein. This activity supplies nearly 86% of the country's fish production [1, 2]. In recent years, as a result of rapid population growth, the demand for fish and fish products has considerably increased. This situation has led to an overexploitation of aquatic resources, placing fish and crustacean stocks under high fishing pressure [3, 4].

In Benin's aquatic environments, as fishes and shrimps, crabs are an important source of protein and a fundamental component of culinary recipes in Benin [5]. In the fisheries of South Benin, particularly the Ahémé lake and the complex Nokoué lake Porto-Novo lagoon, which represent the two main fishing sectors [6, 7, 8], the exploitation of these species is intensifying from day to day and significant quantities are daily landed [5]. In order to conserve and rationally manage the stock of this resource, biological and demographic studies of the population of these species are needed. Among the important main features to the implementation of fisheries management programs, the knowledge of the onset sexual maturity and captures sizes occupies a choice place [4]. This approach is of a particular interest in order to evaluate the exploitation level and to determine the minimum sizes of catch and to regulate the meshes of fishing nets.

Contrary to the fish species which have been the subject of many bioecological studies in aquatic environments [4, 9, 10, 11, 12], work on the onset sexual maturity and capture sizes of the crab population is fragmentary. Indeed, studies and knowledge of crab species in aquatic environments in Benin are at their beginning. However, some works have been done on these species and mainly concerned their diversity [6], their exploitation and the different marketing channels [7, 8] and finally their domestication [5, 13]. The main objective of this work is to improve the scientific knowledge of the ecology and exploitation of crabs *Callinectes*

amicola and *Cardisoma armatum*, two principal species exploited in the water of South Benin, in particular the complex Nokoué lake Porto-Novo lagoon. Specifically, it is to:

- Determine the sizes at sexual maturity and at capture of these two species,
- Determine the growth and mortality parameters of these species,
- Evaluate the current exploitation level of these species in this ecosystem,

2. Materials and Methods

2.1 Study area

The present study was carried out in the complex Nokoué lake Porto-Novo lagoon. It is a complex located in the South East of Benin between the parallels 6° 25' and 6° 38' North latitude and 2° 27' and 2° 30' East longitude. The complex Nokoué

lake Porto-Novo lagoon is connected to the Atlantic Ocean by the Cotonou channel which has a length of 4.5 km. This complex covers an area of 180 km² and is the largest continental watercourse in Benin in terms of area, exploitation and productivity. The hydrological regime of the complex Nokoué lake Porto-Novo lagoon corresponds to a low water period (December to April), a high water period (May to June) and a flood period (September to November).

On this complex, six fishing habitats (including three for the crab *Callinectes amnicola* and three for the crab *Cardisoma armatum*) were selected for the study. Fishing habitats were selected based on the practice of crab fishing activity, the stations accessibility throughout the study period, and the collaboration of fishers from these habitats. These fishing habitats are: Ganvié, Zogbo, Hwlacomey for the water crab *Callinectes amnicola* and Kétonou, Agonsagbo, Denou for the land crab *Cardisoma armatum* (Figure 1).

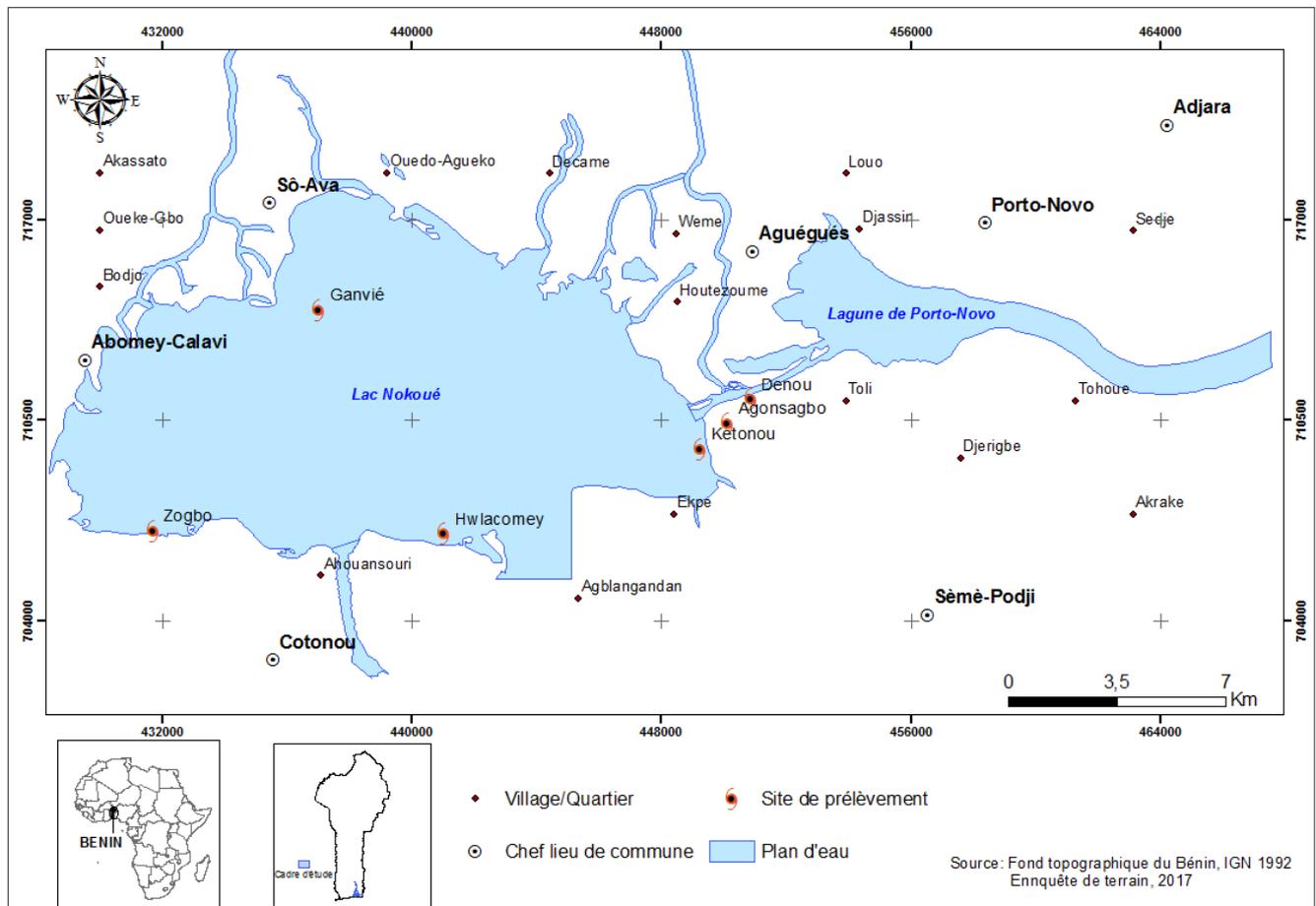


Fig 1: Location map of sampling sites

2.2 Methodology

2.2.1 Sampling

Samples of crabs *Callinectes amnicola* and *Cardisoma armatum* were collected very early in the morning in the identified fishing habitats in the complex Nokoué lake Porto-Novo lagoon through fishermen. The fishing gears or technics used to catch crabs are crab balances and traps for water crab *Callinectes amnicola* and traditional crab traps and manual catch for land crab *Cardisoma armatum*. The number of crabs collected varies according to the landings. On average, 70 to 100 crabs *Callinectes amnicola* and 40 to 50 crabs *Cardisoma armatum* of all sizes were collected per trip. The collected samples were immediately preserved in a 10% formalin

solution and transported to the Laboratory of Animal Biotechnology and Meat Technology of the Abomey-Calavi Polytechnic School of the University of Abomey-Calavi for the different measurements. Sampling was carried out monthly between May 2016 and April 2017.

2.2.2 Identification of specimens

In the laboratory, identification of specimens of the crabs *Callinectes amnicola* and *Cardisoma armatum* was performed using the identification keys West African Brachyuran Crabs Crustacea: Decapoda [14], the real crabs data sheet [15] and the Gulf of Guinea Commercial Marine Resources Guide [16].

2.2.3 Determination of sex

The sex determination was mainly based on the method used by Sankaré [17] and d’Almeida et al [18]. These methods of sex determination are mainly based on the aspect of the abdomen of the male and female. In the crab *Callinectes amnicola*, males have an upside down "T" shaped abdomen whereas in females the abdomen is triangular or semi-circular in shape. As for the crab *Cardisoma armatum*, males have a reversed "V" shaped abdomen, while the one of females is oval.

2.2.4 Determination of the stage of maturity

The stage of sexual maturity was determined using the sexual maturity scales of crabs proposed by Sankaré [17] and Lawal-Are [19]. Five stages of maturity have been proposed:

- Stage I: immature (no development of the gonads);
- Stage II: developing (partial development of the gonads);
- Stage III: beginning maturation (extension of the gonads in the carapace);
- Stage IV: advanced maturation (mature carapace filled of mature gonad materials);
- Stage V: Empty gonads.

2.2.5 Measurements

After the stage of sexing and grading of specimens according to the stage of maturity, each individual was weighed and measured. The measurements performed concern the carapace large width (cm), the carapace small width (cm), the carapace length (cm) and the weight (g). The linear dimensions were taken using a caliper and the weight was taken using an electronic balance of precision 0.1 g.

2.2.6 Data processing

2.2.6.1 Determination of the sex ratio

After identification of the sexes according to d’Almeida et al [18], the number of males and females collected for each species were recorded. The sex ratio is defined as the ratio of the total number of males to the total number of females.

2.2.6.2 Determination of size at first sexual maturity

For the determination of the sexual maturity percentages, females with "active" gonads are included as well as males at the same stages of sexual maturity [20]. According to this same author, the size at first maturity (L_{50}) (carapace large width) is the one reached by 50% of mature individuals of both sexes for the first time. The L_{50} will be determined from the

equation of the sigmoid curve of evolution of mature individuals’ percentages (stages two to five) according to the carapace large width (in cm).

This curve is obtained by logistic transformation according to Dagnelie [21] and is given by the formula:

$$P = \frac{x}{(1+x)}$$

with $x = e^{(a+bL)}$, a and b being the model’s parameters.

The logarithmic transformation of the equation has permitted to put it in the form:

$$\ln \frac{P}{(1-P)} = a + bL$$

and by replacing $P = 50\%$ in the equation, the L_{50} is obtained by

$$L_{50} = \frac{-a}{b}$$

This logistic model of the first maturity size is determined using the StatView software (version 5.0.1).

2.2.6.3 First capture size determination

The first capture size (L_{C50}) (carapace large width) is the one at which 50% of the crabs are caught by the fishery. It was determined using the general equation of Von Bertalanffy [22] incorporated in FISAT II software [9].

2.2.6.4 Determination of growth and demographic parameters

Growth parameters such as asymptotic carapace width (L_c), growth coefficient (K), growth performance coefficient (Rn), growth performance index (Φ') and demographic parameters like total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate were determined by the FISAT II software routines.

3. Results

3.1 Sex ratio

The Table 1 presents the calculated sex ratios of crabs *Callinectes amnicola* and *Cardisoma armatum* according to the maturity stages.

In the crab *Callinectes amnicola*, 1287 individuals were collected including 635 males and 652 females. The calculated sex ratios were not significantly different from the theoretical sex ratio (1: 1) at the different stages of maturity ($p > 0.05$).

In the crab *Cardisoma armatum* over the 322 individuals collected, 163 are males and 159 are females. The calculated sex ratios were not significantly different from the theoretical sex ratio (1: 1) at the different stages of maturity ($p > 0.05$).

Table 1: Calculated sex ratios according to the maturity stages in the two species

Species	Stage of maturity	Number of examined crabs		Sex ratio (M/F)	CChi-square (χ^2)	Significance test
		Males	Females			
<i>C. amnicola</i>	Immature	426	450	1/1.06	0.66	NS
	Mature	209	202	1/0.97	0.11	NS
	Immature + mature	635	652	1/1.03	0.22	NS
<i>C. armatum</i>	Immature	33	24	1/0.73	1.42	NS
	Mature	130	135	1/1.04	0.09	NS
	Immature + mature	163	159	1/0.97	0.048	NS

NS: Not Significant;

3.2 Sizes at first sexual maturity

The Figures 2 and 3 show the sizes at first sexual maturity respectively in crabs *Callinectes amnicola* and *Cardisoma armatum*. In crab *Callinectes amnicola*, 411 mature individuals (209 males and 202 females) were identified in

the samples. The minimum sizes at sexual maturity are 5.1 cm in the male and 5 cm in the female. The sizes at first sexual maturity L_{50} in the male and the female are respectively 7 cm and 6.8 cm.

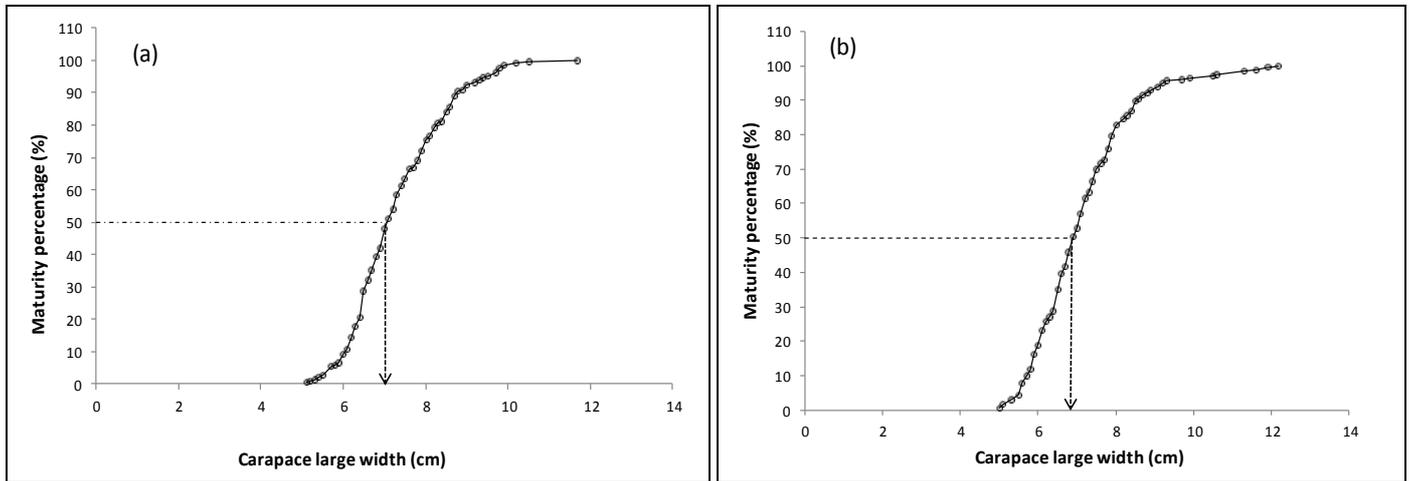


Fig 2: Sizes at first sexual maturity in (a) crab *Callinectes amnicola* male and (b) crab *Callinectes amnicola* female

In the crab *Cardisoma armatum*, on the other hand, 265 mature individuals (130 males and 135 females) were collected. In this species, the minimum sizes at sexual maturity in males and females were 4.6 cm and 5 cm,

respectively. In Crab *Cardisoma armatum*, the sizes at first sexual maturity were 5.8 cm in the male and 6 cm in the female.

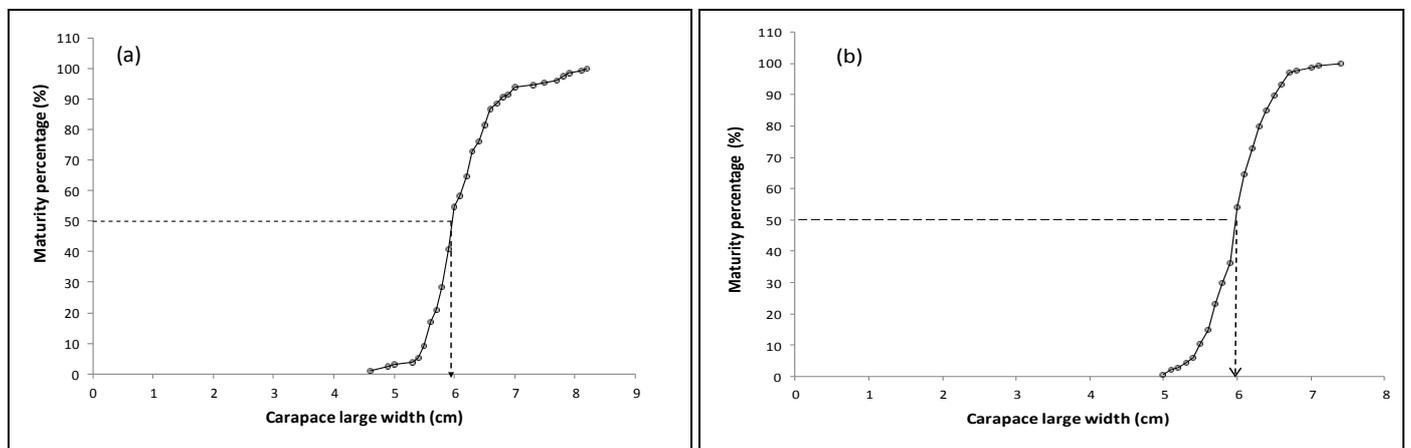


Fig 3: Sizes at first sexual maturity in (a) crab *Cardisoma armatum* male and (b) crab *Cardisoma armatum* female

3.3 Sizes at first capture

The first capture sizes L_{C50} (carapace large width) determined in crabs *Callinectes amnicola* and *Cardisoma armatum* are presented in Table 2.

In the crab *Callinectes amnicola*, 25%, 50% and 75% of the individuals were captured at 4.01 cm, 4.60 cm and 5.28 cm respectively.

On the other hand, 25%, 50% and 75% of the crab *Cardisoma armatum* were caught at 3.85 cm, 4.41 cm and 5.12 cm respectively (Table 2).

Table 2: Sizes at first capture in crabs *Callinectes amnicola* and *Cardisoma armatum* from the complex Nokoué lake Porto-Novo lagoon

Paramètres	<i>Callinectes amnicola</i>	<i>Cardisoma armatum</i>
L_{C25} (cm)	4.01	3.85
L_{C50} (cm)	4.60	4.41
L_{C75} (cm)	5.28	5.12

L_{C25} ; L_{C50} ; L_{C75} : respectively carapace width (cm) at which 25%, 50%, 75% of the crabs *Callinectes amnicola* and *Cardisoma armatum* are caught during fishing.

3.4 Growth parameters

The table 3 presents the parameter values describing the size growth (carapace large width) in crabs *Callinectes amnicola*

and *Cardisoma armatum*. These values expressing growth varied from one species to the other. *Cardisoma armatum* crabs had the best values of the growth coefficient K (1.5) and of the growth performance index Φ' (2.078). Regarding the value of the growth performance coefficient R_n , it was better in the crab *Callinectes amnicola* (0.262).

Table 3: Growth parameters in crabs *Callinectes amnicola* and *Cardisoma armatum* from the complex Nokoué lake Porto-Novo lagoon

Parameters	<i>Callinectes amnicola</i>	<i>Cardisoma armatum</i>
Asymptotic carapace width ($L_{C\infty}$ in cm)	12.60	8.93
Maximum carapace width (L_c in cm)	12.2	8.2
Growth Coefficient (K in an)	0.30	1.5
Growth performance coefficient (R_n)	0.262	0.249
Growth performance index (Φ')	1.678	2.078

3.5 Mortality parameters and exploitation level

The total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation level of crabs *Callinectes amnicola* and *Cardisoma armatum* in the complex Nokoué lake Porto-Novo lagoon were determined and presented in Table 4.

The values of the total mortality, natural mortality and fishing

mortality parameters were significantly higher in the crab *Cardisoma armatum* than in the crab *Callinectes amnicola*. The exploitation level was higher in *Callinectes amnicola* (81%) than in *Cardisoma armatum* (71%).

Table 4: Mortality parameters in crabs *Callinectes amnicola* and *Cardisoma armatum* from the complex Nokoué lake Porto-Novo lagoon

Parameters	<i>Callinectes amnicola</i>	<i>Cardisoma armatum</i>
Total mortality (Z)	5.39	11.54
Natural mortality (M)	1.04	3.39
Fishing mortality (F)	4.35	8.15
Exploitation level (E)	0.81	0.71

4. Discussion

4.1 Sex ratio

In the crab *Callinectes amnicola*, the calculated sex ratios were not different from the theoretical sex ratio at the different stages of maturity. In this species recruitment of juveniles is effected in an equal proportion of males and females. Dessouassi [8] observes on the same species at the Ahémé lake that the sex ratio is not different from the theoretical sex ratio. These observations confirm the results of this study. Arimoro and Idoro [23] report the same observations in the Warri River in Nigeria. Contrary to the results of this study, Guerrero and Arana [24] report in the *Chaceon chilensis* crab in the Juan Fernandez Archipelago in Chile, a difference between the calculated sex ratio and the theoretical sex ratio with a high proportion of male subjects (97.9%).

In the *Cardisoma armatum* crab, the same observations were also made on the sex ratio at the different stages of maturity. The male and female of this species are in equals proportions at the time of the recruitments of juvenile. In accordance with the results of the present study, Olalekan and Lawal-Are [25] report in Nigeria that the calculated sex-ratio in the crab *Cardisoma armatum* is not different from the theoretical sex-ratio (1 male for 0.8 female) but that the males are in high proportion. These observations made by these authors confirm the results of the present study. Some contrary observations have been reported by Vasquez and Ramirez [26] in the crab *Cardisoma crassum*.

4.2 Sizes at first sexual maturity

In the complex Nokoué lake Porto-Novo lagoon, the determined sizes at first sexual maturity (L_{50}) in the male and the female of crab *Callinectes amnicola* were respectively 7 cm and 6.8 cm. The L_{50} of the females was lower than that of the males. Thus, the females of the crab *Callinectes amnicola* reach sexual maturity faster than males. In this crab species, the determined sizes at first sexual maturity in male and female are very different from those reported in other Benin's rivers. The determined sizes in this study are lower than those reported by Dessouassi [8] on the same species in the Ahémé lake (9.16 cm for the male and 11.62 cm for the female). According to this author's observations, males reach sexual maturity sooner than females. The difference with our results can be related to several factors such as the food availability, the species condition in its environment and the high fishing pressure on its population.

In the Nigeria Lagos lagoon, lawal-Are [19] reports that crab *Callinectes amnicola* have onset maturity sizes (10.8 cm for males and 11.00 cm for females) much greater than those of the current study. Similarly, Udoh et al [27] report that male of

crab *Callinectes amnicola* have an onset sexual maturity size of 9.27 cm in the Imo River estuary in Nigeria. The same observations were also made on the L_{50} (10.9 cm) of the male of *Chaceon chilensis* crab in Chile. The difference with our results can also be related to these species condition in their environment and to the physico-chemical characteristics of fishing habitats.

In the crab *Cardisoma armatum*, on the other hand, the sizes at first sexual maturity were respectively 5.8 cm and 6 cm in both males and females. The L_{50} of males was lower than that of females in this species. Contrary to the crab *Callinectes amnicola*, mature males are smaller in size than females. The L_{50} of the male and of the female in the crab *Cardisoma armatum* are clearly superior to those reported in the crab *Carcinus aestuarii* (4.3 cm for the male and 3.4 for the female) in the North region of Sfax in Tunisia [28]. On the other hand, Fondo et al [29] report in crab *Scylla serrata* some L_{50} of male and female respectively of 7.5 cm and 7 cm. The difference with our results could be due to the same ecological factors such as the species condition, the lifestyle, the food availability and the physico-chemical characteristics of the environments.

The sizes at onset sexual maturity observed in crab *Cardisoma armatum* are lower than those of *Callinectes amnicola* crabs. The difference in L_{50} between the two species could be related to the genetic type and morphological characteristics of each species.

4.3 Sizes at first capture

The first capture sizes (L_{c50}) in crabs *Callinectes amnicola* and *Cardisoma armatum* were 4.60 cm and 4.41 cm, respectively. In both species, first-capture sizes were very below onset maturity sizes. This situation shows that the exploitation techniques of the two species in the complex Nokoué lake Porto-Novo lagoon affect the species fecundity so that the individuals often don't have the chance to reproduce at least once before being captured. There is therefore a high fishing pressure on the resource. The same observations were also made by Fondo et al [29], Dessouassi [8] respectively in crabs *Scylla serrata* and *Callinectes amnicola*.

4.4 Growth parameters

The growth study in aquatic species often takes into account the asymptotic length (L_{∞}), the rate or growth coefficient (K) and the growth performance index (Φ') [9]. The growth parameters (L_{∞} , K, Φ') determined in *Callinectes amnicola* and *Cardisoma armatum* crabs varied from one species to the other. Generally, growth in crab species occurs through successive moulting phases during which species evolve in size. Miserey [30], Delaporte [31] and Zouari [28] report that the growth rate of crab species varies according to the species, age, sex and the ecological conditions of the environment.

Data on crabs' growth in aquatic environments are rare or non-existent. Those obtained in the present study in crab *Callinectes amnicola* are lower than the reported values for the same species in the Ahémé lake (L_{∞} : 19.5 cm, K: 0.49, Φ' : 2.297) [8]. This difference with our results may be related to the fishing effort and to the environment's ecological conditions.

The growth rates determined in crabs *Callinectes amnicola* and *Cardisoma armatum* are higher than those reported for some fish species in some water courses in Benin and elsewhere [9, 32, 33].

4.5 Mortality parameters and exploitation level

The present study shows that total mortality (Z), natural mortality (M) and fishing mortality (F) were higher in crab *Cardisoma armatum* than in *Callinectes amnicola*. In fact, the determination of the mortality parameters depends closely on the obtained asymptotic length and on the growth coefficient K . Mortality and growth in aquatic organisms are two antagonistic phenomena [9]. The ratio that is often used to express the balance between mortality and growth in aquatic organisms is the Z/K ratio. In this study, the ratio of total mortality (Z) and growth coefficient (K) for crab *Callinectes amnicola* and *Cardisoma armatum* were 17.96 and 7.69, respectively. In both species, the Z/K ratio is higher than 1 and indicates that mortality predominates over growth.

In crab *Callinectes amnicola* and *Cardisoma armatum*, fishing mortalities are all higher than natural mortalities. These results mean that in the complex Nokoué lake Porto-Novo lagoon, *Callinectes amnicola* and *Cardisoma armatum* crabs are subject to a heavy exploitation. This situation follows the fish decline in this ecosystem leading then, fishermen to turn to previously under-exploited resources such as crabs [5-8, 34].

5. Conclusion

The study on the determination of the sizes at onset sexual maturity and capture in the crabs *Callinectes amnicola* and *Cardisoma armatum* shows that the females of the crab *Callinectes amnicola* mature faster than the males whereas in *Cardisoma armatum*, the males reach quickly their sexual maturity. In both crab species, most of individuals are often caught quickly before reaching their onset sexual maturity and often don't have the chance to reproduce.

The study of growth and mortality parameters in both species also shows that the crab *Cardisoma armatum* has better growth performances and is fished more than the crab *Callinectes amnicola*.

In the complex Nokoué lake Porto-Novo lagoon, the crab stock is overexploited. Fishing techniques and the current exploitation level of crabs represent a threat to the survival and to the perennity of species. Apart from fishing risk factors, other environmental and anthropogenic factors limit the production of these species in this ecosystem.

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