



Reproductive aspects of prawn *Desmocaris trispinosa* (Aurivillius, 1898) from a periurban stream of Abidjan (Banco stream, Côte d'Ivoire)

Aspectos reprodutivos do camarão *Desmocaris trispinosa* (Aurivillius, 1898) em um riacho suburbano de Abidjan (riacho Banco, Costa do Marfim)

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Abstract: Aim: Characterize habitats and determine the reproductive parameters of the prawn *Desmocaris trispinosa* (Aurivillius, 1898) from Banco stream, a periurban stream of Abidjan (Côte d'Ivoire, West Africa). **Methods:** Sampling was conducted monthly, from July 2020 to June 2021 at four stations. Environmental characteristics were measured before prawn sampling. The sampling was made with a dipnet during five-minute active fishing conducted by a single operator at each station. **Results:** According to environmental variables, sampling stations were divided into three groups: almost undamaged (B4), slightly disturbed (B1) and disturbed (B2 and B3). In total, 467 specimens of *D. trispinosa* were captured in which 127 males, 275 females and 65 juveniles. Overall, the sex ratio (1:2.1) was in favour of females. Considering stations, the sex ratio was also in favour of females. But, only in the almost undamaged station (B4), the difference was significant ($\chi^2 = 70.20$; $P < 0.001$). At this station, a variation of sex-ratio was observed in two seasons. In total, 116 ovigerous females were analysed on all stations. Fecundity varies from 5 to 16 oocytes with an average of 11.03 ± 2.18 . First maturity size was estimated at 4.82 mm carapace length for the combined data. Females from the station free from human activities (B4) reached sexual maturity (4.23 mm) before those of the other stations (4.97 in B1 and 5.70 mm in B2). *D. trispinosa* from Banco stream reproduces continuously year-round with two peaks in the rainy season. The oocyte volume was negatively influenced by temperature and positively by dissolved oxygen. **Conclusions:** *D. trispinosa* reproduces year-round in undisturbed stations and reaches sexual maturity faster at these stations compared to disturbed stations. The sex ratio was in favour of females. Consequently, this species would be naturally polygamous.

Keywords: reproduction parameters; *Desmocaris trispinosa*; West African; stream.

Resumo: Objetivo: Caracterizar habitats e determinar os parâmetros reprodutivos do camarão *Desmocaris trispinosa* (Aurivillius 1898) do riacho Banco, uma ribeira periurbana de Abidjan (Costa do Marfim, África Ocidental). **Métodos:** A amostragem foi realizada mensalmente, de julho de 2020 a junho de 2021 em quatro estações. As características ambientais foram mensuradas antes da amostragem do camarão. A amostragem foi feita com rede de mergulho durante cinco minutos de pesca ativa realizada por um único operador em cada estação. **Resultados:** De acordo com as variáveis ambientais, as estações de amostragem foram divididas em três grupos: quase intactas (B4), levemente perturbadas (B1) e perturbadas (B2 e B3). No total, foram capturados 467 exemplares de *D. trispinosa*, sendo 127 machos, 275 fêmeas e 65 juvenis. No geral, a razão sexual (1:2,1) foi a favor



do sexo feminino. Considerando as estações, a razão sexual também foi a favor do sexo feminino. Mas, apenas na estação quase intacta (B4), a diferença foi significativa ($\chi^2 = 70,20$; $P < 0,001$). Nesta estação, foi observada variação da razão sexual em duas estações. No total, 116 fêmeas ovígeras foram analisadas em todas as estações. A fecundidade varia de 5 a 16 oócitos com média de $11,03 \pm 2,18$. O tamanho da primeira maturidade foi estimado em 4,82 mm comprimento de carapaça para os dados combinados. As fêmeas da estação livre de atividades humanas (B4) atingiram a maturidade sexual (4,23 mm) antes das demais estações (4,97 em B1 e 5,70 mm em B2). *D. trispinosa* do córrego do Banco se reproduz continuamente durante todo o ano com dois picos na estação chuvosa. O volume oocitário foi influenciado negativamente pela temperatura e positivamente pelo oxigênio dissolvido. **Conclusões:** *D. trispinosa* reproduz-se durante todo o ano em estações não perturbadas e atinge a maturidade sexual mais rapidamente nestas estações em comparação com estações perturbadas. A razão de sexo foi a favor das fêmeas. Consequentemente, esta espécie seria naturalmente polígama.

Palavras-chave: parâmetros de reprodução; *Desmocarididae trispinosa*; África Ocidental; riacho.

1. Introduction

Prawn are essential species in river food webs because they serve as intermediate consumers, linking periphyton and detritus production to higher trophic groups (Browder et al., 1994; Frédéric & Spalding, 1994). Together with crabs, they constitute the majority of the macroinvertebrate's biomass in hydrosystems (Boulton & Lloyd, 1991; Sheldon & Walker, 1998). They are also an important food resource for carnivorous fish (Resende et al., 1996). Therefore, they are often considered key animals, especially in small streams (Pringle et al., 1993).

The Banco National Park (BNP) is located in the middle of Abidjan, the economic Côte d'Ivoire capital. This park plays an important role in the conservation of the forest ecosystem and biodiversity, the protection of underground waters and the micro climatic regulation for Abidjan (Lauginie, 2007). In this park, there is a stream (Banco) whose basin is almost entirely included within the limits of the National Park (Yao et al., 2019). This watercourse is subjected to anthropogenic disturbances due to the enormous quantities of runoff water from neighbouring municipalities at the BNP (Camara et al., 2012; Yao et al., 2019). This disturbance represents a menace for this river integrity and the aquatic communities. Several studies have been devoted to aquatic fauna of Banco (Daget & Iltis, 1965; Powell, 1980; Camara et al., 2009, 2012; Ouanko et al., 2019; Yao et al., 2019). Concerning prawn, the available studies dealt with the description of the prawn *Macrobrachium thysi* Powell, 1980, endemic to Côte d'Ivoire (Powell, 1980), and the ecology and diversity of prawn species (Camara et al., 2009). According to Camara et al. (2009), three prawn species are encountered in the Banco stream. Among them, the Desmocarididae *Desmocarididae trispinosa* (Aurivillius,

1898) was the largest distributed and the most abundant in the stream. It was sampled both in undisturbed and disturbed habitats. This small species seems to tolerate unfavourable conditions such as low dissolved oxygen and significant organic matter (Cumberlidge, 2006a). To our knowledge, with the exception of the research of Powell (1979) on the larval development of *D. trispinosa*, there is a lack of scientific data on the reproductive biology of this small prawn. However, reproduction is one of the important aspects in both ecology and biology of species (Zare et al., 2011). In addition, knowledge of reproductive biology characteristics of species is an essential tool that can provide relevant information for their conservation and their preservation (Lévêque & Paugy, 2006). The present study aims to examine the reproductive aspects of the prawn *D. trispinosa* in Banco stream. The specific objectives of this study are (i) to characterize the habitats of *D. trispinosa* through physico-chemical parameters and (ii) to determine the reproduction parameters (sex ratio, eggs diameter and volume, size at first sexual maturity), including the breeding period in the Banco stream basin. Results from this study constitutes preliminaries data on reproductive biology characteristics *D. trispinosa*.

2. Material and Methods

2.1. Study area and sampling sites

Banco National Park (BNP) is located between 5°21' and 5°25' N, and 4°01' and 4°05' W. It is a remnant of tropical forest (3000 hectares) located in the center of Abidjan city (Assemian et al., 2006; Lauginie, 2007). The Banco stream basin drains an area of approximately 38.48 km² (Figure 1). This stream crosses the entire park over 10.70 km of length with a depth average less than 1 m and flows into the Ebrié lagoon (Yao et al., 2019).

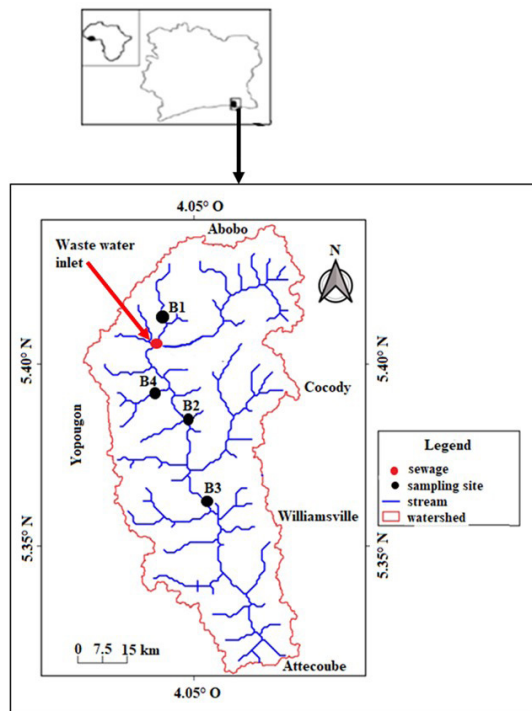


Figure 1. Location of sampling stations (B1 to B4) on the Banco stream.

Four stations were chosen on the stream; three stations (B1, B2 and B3) were located on the main channel, while station B4 was chosen on a tributary of the stream. Station B1, located upstream of the river, is characterized by relatively turbid water, and the presence of fragmented leaves, woody debris, riparian vegetation (*Turraenthus africanus*, *Petersianthus macrocarpus*, *Dacryodes klaineana* and *Thaumatococcus daniellii*), with a sandy substrate. It should also be noted that this station is partially disturbed probably due to the arrival of a small amount of runoff water causing silting of the bed. Station B2 is situated near the forestry school and is characterized by a turbid water, a muddy, sandy and clayey bottom with marginal grassy vegetation composed mainly of *Cyclosorus striatus* and *Nephrolepis biserrata*. This station is also the receptacle for wastewater from the forestry school and dwellings, and runoff water from Abobo city. As for station B3, it is located near the mouth of the river and is characterized by the presence of Indian bamboo trees debris with a clay and gravelly bottom. The station B4 is chosen on a permanent tributary of the Banco stream. At this site, the water is crystal clear and is free of any anthropogenic pollution. The substrate is mainly composed of mud and vegetal debris.

2.2. Data collection

Sampling was carried out monthly from July 2020 to June 2021, except for October 2020. Measurements of all environmental variables were made *in situ* prior to shrimp sampling. Electric conductivity ($\mu\text{S}\cdot\text{cm}^{-1}$), water temperature ($^{\circ}\text{C}$), dissolved oxygen ($\text{mg}\cdot\text{L}^{-1}$) and pH were measured using a multiparameter (HANNAH Hi 9828). The turbidity (NTU) was measured using a turbidimeter (AQUALYTIC CD 24). The depth (m) and width (m) of the water were measured (average of five trials) to the nearest centimeter using a tape measure.

The sampling of *D. trispinosa* was identical at all the stations on the stream. Shrimp were dip-net-caught during a five-minute active fishery by a single operator at each site. Within the framework of our study, the dip-net used has a metallic opening of 50 cm in diameter with a depth of 30 cm; the opening is fixed to a sleeve two (2) m long which allows to hold the material. After capture, ovigerous females (females carrying eggs) were placed in separate plastic jars to prevent loss of eggs during transport. These jars were labelled and contained 70% ethanol. In the laboratory, sexual differentiation was made through the observation of the endopodite morphology of the second pair of pleopods, as proposed by Ismael & New (2000). Prawn individuals were identified according to Monod (1966) and Cumberlandidge (2006b). All specimens clearly recognized as *D. trispinosa* were counted and then measured. The total body length (TL: measurement taken from the tip of the rostrum to the tip of the telson) and the carapace length (CL: measurement taken from the orbital hollow to the middle of the posterior end of the cephalothorax) were measured using a manual electron microscope (Celestrom 2.0). Shrimp weights were determined with a Baxtran electronic scale (model ANG200A1, capacity 200g) to the nearest 0.001g. Individuals with broken rostrum or another part of the body destroyed were discarded.

2.3. Determination of reproduction parameters

Size at first maturity was estimated by fitting the frequency of mature females to a logistic model (King, 2007): $y = \frac{1}{1 + e^{(-r(TL-Lm))}}$ where r is the slope, TL is the total length and Lm the size at first maturity ($Lm = \frac{a}{b}$).

The fecundity was obtained by direct counting of the eggs of 116 ovigerous females taking into

account the integrity of the eggs and the months of collection. The entire egg mass was removed from the abdomen, separated using forceps, and all eggs counted using an electron microscope (Celestrom 2.0). Egg development stages were classified according to the criteria proposed by Lara & Wehrtmann (2009): Stage I: Egg-bearing females with orange eggs, recently extruded egg, yellow uniform, no visible eye pigments; Stage II: Egg-bearing females with brown eggs, barely visible egg-eye pigments; Stage III: Egg-bearing females with grey eggs, clearly visible and fully developed eyes.

The sex ratio was obtained by identifying the number of males (M) and females (F) by station and by sampling season at each station using the formula: $SR = \frac{M}{F}$.

Oocyte diameters were measured in the middle (d1) and apical (d2) portions of the eggs using an electron microscope (Celestrom 2.0). Since the oocytes are ovoid, the diameter was calculated with the formula $d = \sqrt{d1 \times d2}$, where d1 represents the small diameter and d2 is the large diameter (Budi et al., 2020). The formula calculation of oocyte volume (V) is that proposed by Turner & Lawrence (1979) and used by several authors (e.g.: Cartaxana, 2003; Béguer et al., 2010): $V = \frac{\pi \times d1^2 \times d2}{6}$.

The reproductive period was determined through analysis of the relative frequency of ovigerous females monthly at each sampling site as implemented by Fransozo & Mantelatto (1998), and Hoffmann & Fransozo (2010).

2.4. Data analysis

A principal component analysis (PCA) was used for the ordination of the stations according to the physico-chemical characteristics. The Student t test was used for seasonal (dry and rainy) variation of oocyte diameter and oocyte volume. The one-way analysis of variance test (ANOVA I) was performed for spatial variation of fecundity (absolute and relative) and oocyte size (diameter and volume). Linear regressions were generated to describe the relationship between absolute fecundity and the size of ovigerous females; carapace length (CL) and absolute fecundity; fecundity and individual's weight. In addition, the linear regression was used describe the relationship between environmental variables and reproduction parameters. The chi-square test was used to compare the value of the sex ratio found with the theoretical sex ratio (1:1). The significance threshold for the probability value is $p < 0.05$. The R software was used to perform these two tests.

3. Results

3.1. Abiotic differentiation of sampling stations

Principal component analysis (PCA) made it possible to establish the abiotic typology of sampling stations (Figure 2). The first two axes expressed 55.13% of the total variance: 33.5% for axis1 and 21.63% for axis2 (Figure 2A). The correlation circle (Figure 2B) revealed that axis1 was strongly and negatively correlated by width, conductivity and depth. On the other hand, axis2 is strongly and positively correlated by the pH and the turbidity and to a lesser degree the temperature. The factorial map (Figure 2C) distinguishes three groups of stations. The first group is composed of samples from stations B2 and B3. In these stations, water was generally characterized by the high values of electric conductivity, wet bed width and water depth. The second and third groups were composed of sample from single station (B1 and B4 respectively). The samples from B1 were distinguished by high values of pH, turbidity and water temperature. In contrast, samples from B4 were mostly differentiated by low values of these environmental variables.

3.2. Spatial and season variations of the sex-ratio

In the present study, 467 specimens of *D. trispinosa* were captured in the four sampling stations (B1, B2, B3 and B4); 127 males, 275 females and 65 juveniles, resulting in a sex-ratio of 1:2.1 (male:female) in favour of females (Table 1). The results of the adjustment test (chi 2 test) showed that the observed sex-ratio was significantly different from the theoretical ratio of 1:1 ($\chi^2 = 54.48$, $P < 0.001$). On all the stations, the Chi 2 values showed that there is no difference from the theoretical ratio of 1:1, except for station B4 whose sex-ratio was 1:4 in favour of females ($\chi^2 = 70.20$; $P < 0.001$). Seasonal variations in the sex-ratio were in favour of females over the entire study period, except for station B3 in the dry season (Table 2). However, only station B4 recorded sex-ratios that were significantly different from the theoretical sex ratio between the two seasons sampling (1: 6.1; $\chi^2 = 2.48$, $P < 0.001$ in the rainy season and 1:1.7; $\chi^2 = 0.85$, $P < 0.05$ in the dry season).

3.3. Fecundity

Overall, fecundity varied from 5 to 16 oocytes with an average of 11.03 ± 2.18 . Extreme values were observed at station B4. The average fertility at B4 was 11 ± 2.29 oocytes for a total of 83 ovigerous

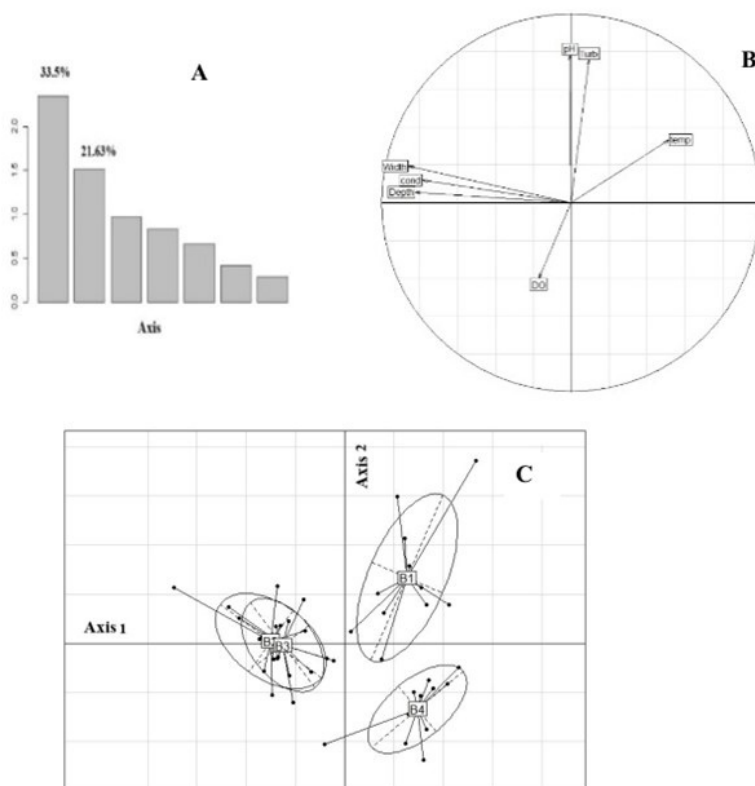


Figure 2. Ordination of the physico-chemical variables of the Banco stream sampling stations based on a Principal Component Analysis (A = histogram of eigenvalues; B = correlation circle; C = factorial map); temp = temperature; DO = dissolved oxygen; Width = width of the wet bed; Turb = turbidity; Cond = conductivity.

Table 1. Spatial variation of chi-square values for the sex-ratio of *Desmocariss trispinosa* from Banco stream.

Stations	Individuals number		Sex-ratio	χ^2	Significance level
	M	F	M:F		
B1	39	56	1:1.4	3.04	
B2	41	59	1:1.4	3.24	
B3	8	4	1:0.5	1.33	
B4	39	156	1:4	70.20	***
Total	127	275	1:2.1	54.48	***

*, ** or *** = significant ($p \leq 0.05, 0.01$ or 0.001). M: male; F: female.

Table 2. Seasonal variation of chi-square values for *Desmocariss trispinosa* sex-ratio Banco stream.

Stations	Seasons	Numbers		Sex-ratio	Significance level	
		M	F	M:F	χ^2	
B1	RS	24	32	1:1.33	1.14	-
	DS	15	24	1:1.6	2.07	-
B2	RS	23	35	1:1.5	2.48	-
	DS	18	24	1:1.33	0.85	-
B3	RS	3	3	1:1	2.48	-
	DS	5	1	1:0.2	0.85	-
B4	RS	20	122	1:6.1	2.48	***
	DS	19	34	1:1.7	0.85	*
Total	RS	70	192	1:2.7	73.28	***
	DR	57	83	1:1.4	59.28	-

*, ** or *** = significant ($p \leq 0.05$ ou 0.01 ou 0.001). M: male; F: female; RS: rainy season; DS: dry season.

females sampled. At station B1, 15 ovigerous females were collected. Absolute fecundity was between 9 and 13 with an average of 10.80 ± 1.32 . At station B2, 18 ovigerous females were captured, the minimum and maximum fecundity values being respectively 8 and 15 oocytes (mean = 11.39 ± 2.28). The calculated relative fecundity was 43.52 oocytes per gram of shrimp in all the stations. It was 48.37 ± 6.02 , 42.67 ± 8.14 and 42.82 ± 9.18 oocytes per gram at stations B1, B2 and B4, respectively. The analysis of variance did not indicate any significant spatial variation of the two fecundities ($p > 0.05$). There was a positive and significant relationship ($P < 0.05$) only between body weight and absolute fecundity (Figure 3C). The regression equations were $Y = 4.69 + 0.03X$,

and $r = 0.11$ (Figure 3B); $Y = 0.906 + 0.007 X$ and $r = 0.10$ (Figure 3A) and $Y = 4.95 + 22.88X$ and $r = 0.43$ for fecundity-total length, fecundity-carapace length and fecundity-weight of shrimp relationships, respectively. This means that the number of eggs increases only with increasing weight of the individuals.

3.4. First maturity size

The size at first maturity (L50) was estimated for females at each sampling station and in the stream as the standard length at which 50% of the shrimp were mature (Figure 4). For pooled data from all stations, the length at which 50% of females reached maturity was 4.82 mm CL (Figure 4A). The L50 estimated for females

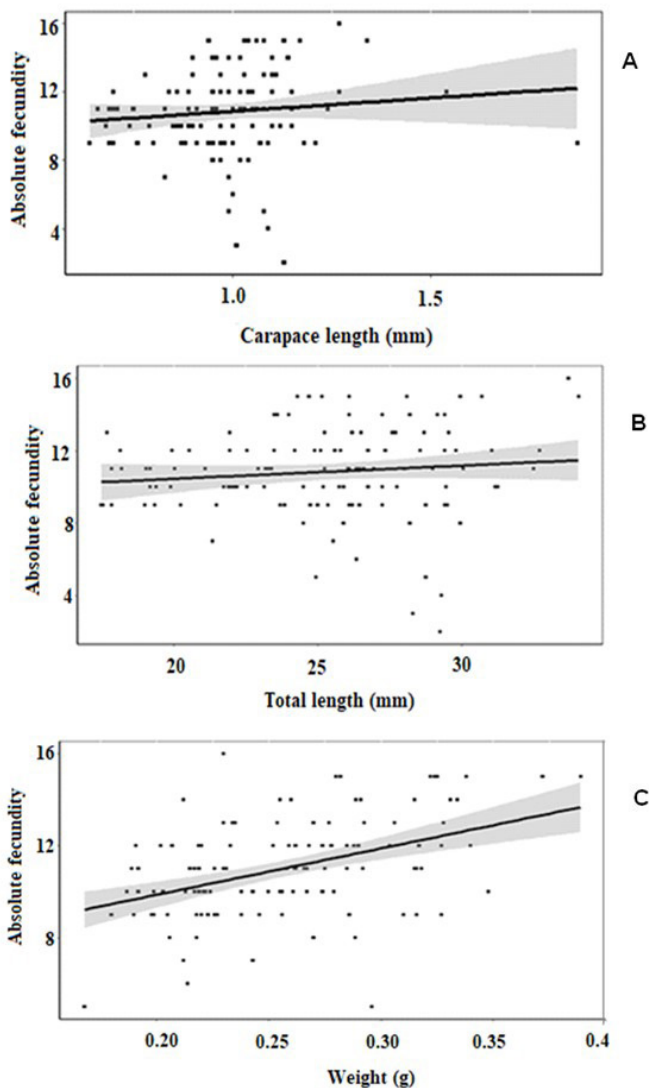


Figure 3. Relationships between absolute fecundity and carapace length (A), total length (B) and individual weight (C) in *Democaris trispinosa* from the Banco stream.

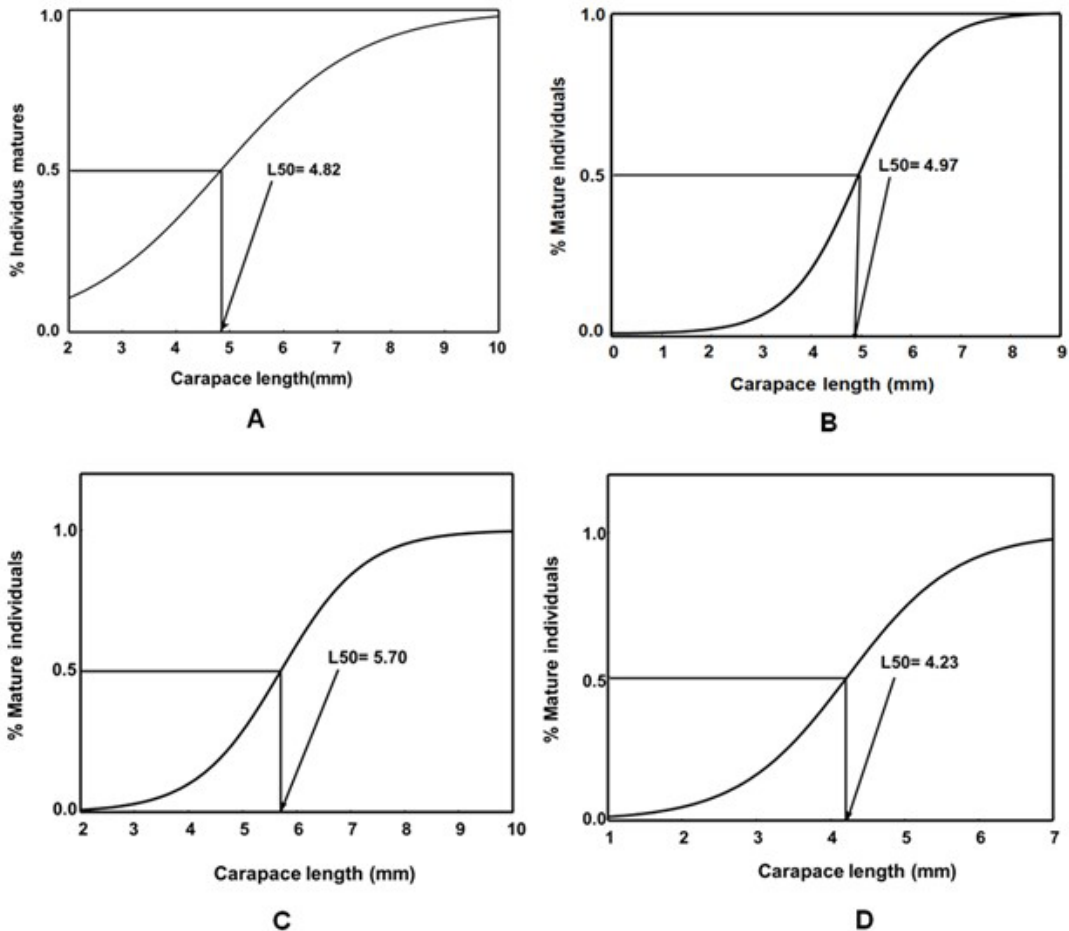


Figure 4. Logistic curve of estimated sexual maturity for *Desmocaris trispinosa* in Banco stream. Dashed line represents the class interval where the probability of being mature is 50%: (A) Combined populations; (B) Station B1; (C) Station B2; and (D) Station B4.

was 4.97, 5.70 and 4.23 mm LC at stations B1 (Figure 4B), B2 (Figure 4C) and B4 (Figure 4D), respectively. Female individuals from B4 reached sexual maturity before those from the other two stations (B1 and B2). From 10 mm CL, all females were mature (Figure 4).

3.5. Oocyte size (diameter and volume)

A total of 1289 eggs were measured. Of these, 526 eggs were stage I, 419 eggs stage II and 344 eggs stage III. The mean oocyte diameter increased from 1.08 ± 0.13 mm at stage I to 1.39 ± 0.20 mm at stage III. The ANOVA test showed a significant difference ($F = 33.71$, $p < 0.001$) in egg diameter between maturity stages. Concerning the spatial variation, the average value of the diameter of the oocytes was 1.20 ± 0.30 mm at B1, 1.29 ± 0.28 mm at B2 and 1.18 ± 0.15 mm at B4. As for the seasonal variation in oocyte diameter, the smallest value was obtained in the rainy season (1.19 ± 0.20 mm) and

the highest in the dry season (1.26 ± 0.18 mm). No significant variation was observed between stations (ANOVA: $F = 2.47$, $p = 0.089$) and between seasons (Student's t test: $t = -1.02$, $p = 0.714$). As for egg volume, it did not vary significantly between stations (ANOVA: $F = 2.14$, $p = 0.122$) and seasons (Student's t test: $t = -0.95$, $p = 0.52$). On the other hand, a significant difference was noted according to the stage of maturity (ANOVA: $F = 24.43$, $p < 0.001$). Oocyte volume was between 0.70 ± 0.25 mm³ (B4) and 0.85 ± 0.39 mm³ (B2), and between 0.73 ± 0.32 mm³ (rainy season) and 0.84 ± 0.36 mm³ (dry season). For the maturity stage, egg volume increased from stage I (0.55 ± 0.16 mm³) to stage III (1.00 ± 0.37 mm³).

3.6. Reproductive period

Overall, ovigerous females of *D. trispinosa* occurred throughout the year (Figure 5). From April to May and from November to December higher

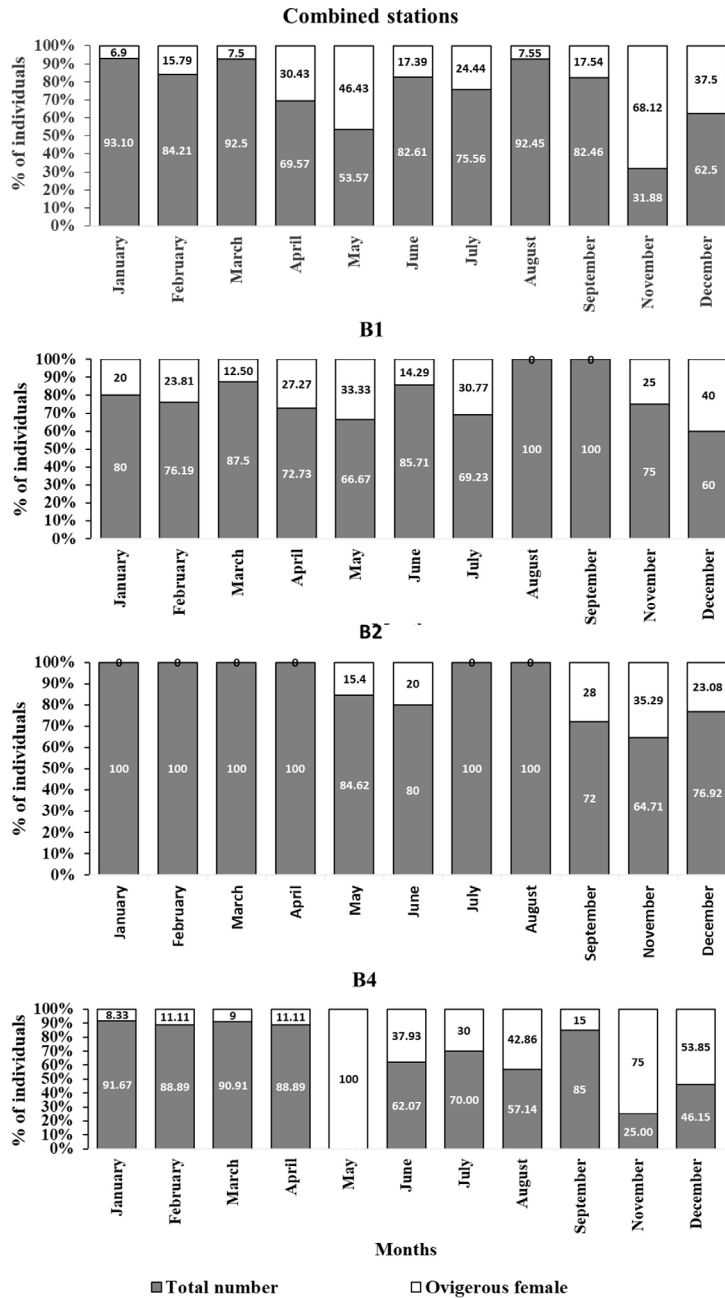


Figure 5. Monthly changes in percentage occurrence of ovigerous females of *Desmocaris trispinosa* in Banco stream during July 2021 to June 2022.

percentages (30.43 to 68.12%) of ovigerous females were observed, whereas during other months the percentages of ovigerous females were lower (6.9 to 24.44%). Considering stations, ovigerous females were also sampled every month at B4 (free from any human activity). At this station, the highest percentages of ovigerous females were obtained from May to December with peaks in May (100%) and November–December (75 to 53.85%). At B1, ovigerous females were encountered every month,

with the exception of August and September. The percentages were higher in May (33.33%), July (30.77%) and December (40%). Ovigerous females were only captured during five months (May, June, September, November and December) at station B2.

3.7. Relationships between environmental and reproductive parameters

The relationships established between environmental and biological variables indicated

that only oocyte volume was influenced by temperature and dissolved oxygen (Figure 6). A strong positive regression ($r = 0.53$, $P = 0.012$) was recorded between dissolved oxygen and oocyte volume (Figure 6A). This means that the oocyte volume of *D. trispinosa* increased with the dissolved oxygen rate of the water. In contrast, temperature had a negative influence ($r = -0.47$, $P = 0.025$) on oocyte volume of *D. trispinosa* in Banco stream (Figure 6B). The oocyte volume decreased with the increase of water temperature.

4. Discussion

Our study provides preliminaries data on them parameter of reproduction of prawn *D. trispinosa* from watercourse of West Africa. The species reproduction was studied for the first time, giving the opportunity to make useful comparisons with the other small prawn species. The results of this study showed that the spatial variations of the physico-chemical characteristics of waters were marked. Generally, quality water of Banco stream was better upstream than downstream. According to Camara et al. (2009), this could be attributable to several anthropogenic activities such as urban runoff to stream due to direct or unregulated discharges in the Banco stream of sewage water from neighbouring cities. These results w consistent with those of

Camara et al. (2012) and Yao et al. (2019) in same stream and those of those of Tchakonté et al. (2014) in five rivers of Douala (Cameroon). The pH values observed along the stream were acidic (5.45 to 6.54, respectively at B4 and B1). The acidity of the Banco stream water would be the consequence of the decomposition of plant organic matter in the water leading to a reduction in dissolved oxygen and an increase in CO_2 in the first layers of the soil. These results corroborate those of Camara et al. (2009) and Yao et al. (2019) in the Banco stream. The runoff water was responsible for the strong conductivities and high turbidity at stations (B2 and B3). The values of the wet bed width and the water depth were considerably higher in the upstream stations than in the downstream stations. Naturally, in a watercourse, these two characteristics generally follow a positive upstream-downstream gradient. These results agree with those of Camara et al. (2009, 2012) in the Banco stream.

Overall, the sex-ratio was in favour of females whether depending on the stations or the seasons. However, only at station B4, the difference in sex-ratio was significant. This demarcation of the sex-ratio of the balance proportion (1: 1) in favour of the females in habitats free from anthropogenic disturbances, could be due to the fact that this species would naturally be polygamous. Crustaceans exhibit a wide array of mating systems including polygamy (Palaoro & Beermann, 2020). This phenomenon is observed in other crustacean species such as the ectoparasitic crab *Dissodactylus primitivus* Bouvier, 1917 (Jossart et al., 2014) and the thalassinidean ghost shrimp (Bilodeau et al., 2005), *Callichirus islagrande* (Schmitt, 1935). Furthermore, among populations of the same species, the sex ratio can also be influenced by environmental conditions, geographical features and anthropogenic interference (Lima et al., 2014). Similar sex ratios have also been observed in Atyidae shrimp of small size (Yam & Dudgeon 2005) and related caridean families (Fransozo et al., 2004; Mantelatto & Barbosa, 2005). According to Rodrigues (1996), the predominance of females in a population, may represent a strategic response to compensate for the low fecundity of the species. *D. trispinosa* produces few eggs as shown by the results of this study. The absolute fecundity of *D. trispinosa* varied between 5 and 16 (mean = 11.03 ± 2.18). This fecundity is considered low, indicating that this species has a low reproductive potential. Fecundity is related directly to species life strategy (Oh & Hartnoll, 2004) and is of essential importance in order to estimate the reproductive

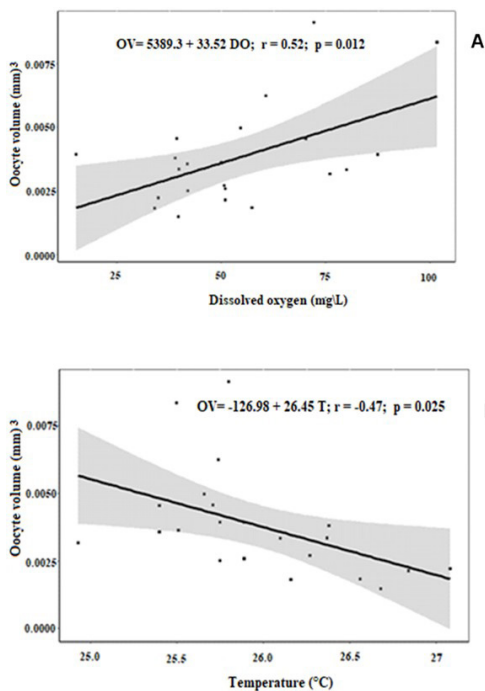


Figure 6. Relationships between oocyte volume and dissolved oxygen (A) and temperature (B) in *Desmocaris trispinosa* from the Banco stream.

potential (Figueiredo et al., 2008). In addition, fecundity is a phenotypic characteristic that is affected by numerous factors and intensities by specific features of different environments (Hines, 1991) and directly influenced by natural selection (Stearns, 1977). The maximum fecundity of *D. trispinosa* was much lower than that of other small shrimp species as *Caridina cantonensis* Yü, 1938, *Caridina fossarum* Heller, 1862, and *Caridina serrata* Stimpson, 1860. The results also showed that the increase in the mean egg number follows the increase in individual's weight. Therefore, the weight was an important biological factor which affects the potential fecundity of *D. trispinosa*. Lambert, (2008) reported that animal fecundity varies with body length or weight. Similar results were observed by Meireles et al. (2013) in *Macrobrachium amazonicum* from Santa Barbara region (Brasilia). (. No significant relationship was observed between the number of oocytes and the size of the shrimp (total length and carapace length), contrary to results observed in shrimp species such as *Caridina sakishimensis* (Fujino and Shokita, 1976) and *C. typus* (H. Millne Edwards, 1937) by Soomro et al. (2011), and *C. fossarum* by Zare et al. (2011).

The occurrence of ovigerous females in all monthly samples in station free from human activities indicates that the *D. trispinosa* population from Banco stream reproduces continuously year-round. The greater percentage of ovigerous females observed in April, may, November and December which are rainy season months in the study area, suggests that the reproductive cycle of *D. trispinosa* from Banco River was at its height during rainy periods. Because no partial spawnings were observed, it is assumed that spawnings in *D. trispinosa* are total. According to Galvão & Bueno (2000) and Mossolin & Bueno (2002), other caridean shrimps, such as the Atyidae *Atya scabra* (Leach, 1816) and the Palaemonidae *Macrobrachium olfersi* (Wiegmann, 1836) follow a similar reproductive pattern as that reported here for *D. trispinosa*. Regarding the breeding period, ovigerous females of *D. trispinosa* were obtained in all months of sampling. This means that this shrimp has a continuous reproductive period. Similar results have been found by Hoffmann & Fransozo (2010) in the Atyidae shrimp *Potimirim glabra* (Kingsley, 1878). The first maturity size obtained at stations B1, B2, and B4 was 4.97, 5.70 and 4.23 mm CL, respectively. Which clearly suggested that *D. trispinosa* quickly reach maturity in station free from anthropogenic disturbances (B4) compared

to stations that received them (B1 and B2). This could mean that habitat degradation is responsible for the delay in sexual maturity in this shrimp species. Oocyte size and oocyte volume increase during the incubation period in *D. trispinosa*. This phenomenon is a result of gradual water uptake during embryogenesis in decapods (Müller et al., 2004). According to Hernáez & Palma (2003), the swelling of the egg permits the development of the embryo which is probably controlled by the thickness and permeability of the egg membrane. Similar observations were made in caridean shrimps such as *Macrobrachium olfersi* by Mossolin & Bueno (2002), *M. potiuna* (Müller, 1880) by Nazari et al. (2003) and *M. carcinus* (Linnaeus, 1758) by Lara & Wehrtmann (2009).

The analysis of relationship between physical-chemical variables and reproductive parameters indicated that only temperature had a negative influence on oocyte volume compared to dissolved oxygen. This result suggested that conversion efficiency of yolk reserves in developing embryos in *D. trispinosa* was significantly reduced at elevated temperature as showed by Brillon et al. (2005) in the shrimp *Pandalus borealis* Krøyer, 1838. According to Brillon et al. (2005), ovigerous females at high temperature had a lower energetic condition than females at low temperature. At high temperature, ovigerous females accumulated less lipid reserves than ovigerous females at low temperatures. Lower lipid reserves could indicate that higher metabolic costs are associated with respiration and parental care in ovigerous females held at high temperature (Brillon et al. (2005).

In conclusion, the analysed environmental parameters highlighted two groups of habitats: disturbed and undisturbed. The shrimp *D. trispinosa* reproduces year-round in undisturbed stations and reaches sexual maturity faster at these stations compared to disturbed stations. The sex ratio was in favour of females. This species has a low fecundity (5-16 eggs).

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