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# COMPREHENSIVE STUDY OF THE FOOD ECOLOGY OF *MACROBRACHIUM MACROBRACHION* (HERKLOTS, 1851) IN COTE D'IVOIRE


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**ABSTRACT**

Expanding knowledges of the food ecology of *Macrobrachium macrobrachion* is the main purpose of this research. It permited to complete our knowledges of the distribution of this shrimp in natural habitats. These knowledges will also facilitate its reproduction in the breeding environment. Shrimps were caught monthly between September 2015 and august 2016. They come from an experimental dip net fishery. The study of the diet focused on 77 specimens. The results obtained revealed that this species consumes both animal and plant prey. The dietary index (FI) calculated in relation to the general food profile, has shown that his diet consists mainly of animal debris. This animal fraction was dominated by insects (%FI = 58.86). The study of the food ecology of this species taking into account space, sex and size classes gave the same results. *M. macrobrachion* is an omnivorous species that uses variable resources but with a preference for insects. This diet is less restrictive and is favorable for its breeding in an artificial environment.





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## INTRODUCTION

Freshwater shrimp species *Macrobrachium macrobrachion* is a giant shrimp and typical of Africa. It has been described for the first time by Herklots in 1851. In Côte d'Ivoire, this species is much appreciated on the culinary level. and commercialized. National production is artisanal and insufficient but supplies national and international markets (Gooré Bi, 1998; Mahyao *et al.,* 2010, 2014; Boghué, 2015). This species was often confused with *M. vollenhovenii* whom it formed a homogeneous entity with. Today, several studies about biology and systematics (Lévêque *et al.,* 1983; Gooré Bi, 1998; N'Zi, 2007; Konan, 2009; Boghué, 2015; Djirieoulou, 2017) permited to distinguish it in many rivers of the country. However, knowledges about the diet is brief and reported by Gooré Bi, 1998 and Gooré Bi *et al.,* 2001. Current trends aim to deepen the food ecology of this species in order to facilitate its reproduction in a controlled environment. This study was realised from the Cavally River for the first time in Côte d'Ivoire. It is part of a dynamic of the most exploited shrimp breeding and consists in achievements' strengthening of the food ecology of *M. macrobrachion*.


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## MATERIALS AND METHODS

**Study area:** Cavally is a River in West Africa running from north of Mont Nimba in Guinea at an altitude of 600 m, through Côte d'Ivoire, to Zwedru in Liberia, and back to the border with Côte d'Ivoire. It forms the southern two-thirds of the international boundary between Liberia and Côte d'Ivoire (Girard, 1974). Long of 700 km, it catchment area is 30 600 $km^2$. The Ivorian part of the Cavally River is 515 km long with a catchment area of 15000 $km^2$. Four sampling stations were selected on the Cavally River and its tributaries on both sides of the industrial and mining zone "Ity": one station Z1 (7°05´43.0´´N - 8°06´28.4´´) is an upstream; one station Z2 (6°52´33.52´´N - 8°06´29.21´´W) an intermediate stream and two stations [Z3 (6°50´30.12´´N - 8°06´59.03´´W) and Z4 (6°40´22.1´´N - 8°16´18.9´´W)] in downstream (Figure 1). The choice of stations were made to measure impact of the ''Ity'' gold mine operation on shrimps population and the environment of the area.

**Shrimp sampling and identification:** Shrimps were sampled monthly from September 2015 to august 2016 using a dip net (25 cm opening diameter and 2 mm mesh size). Fishing is done by one person according Djiriéoulou (2017). The dip net is immersed in water and then removed after a period of time sufficient to optimize shrimp capture.

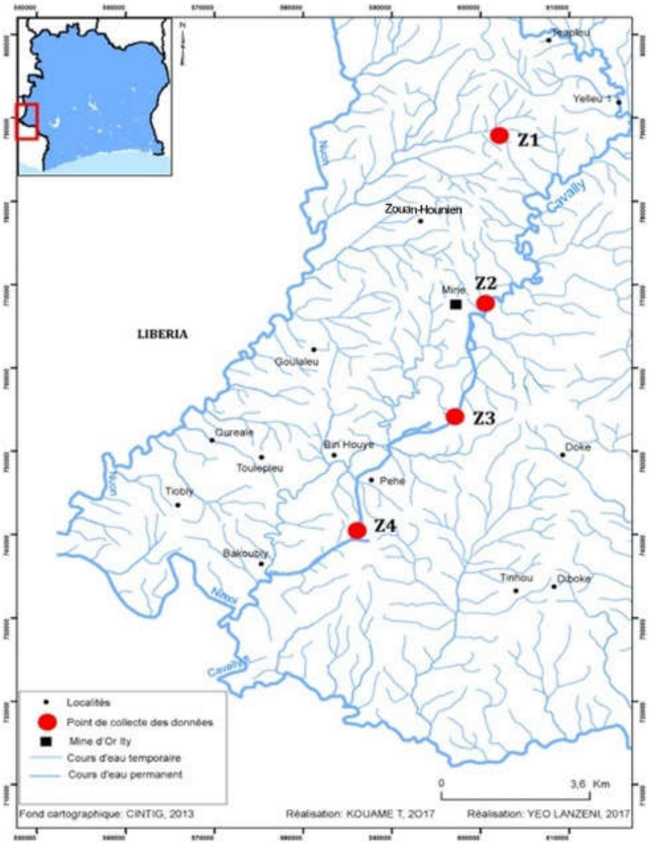


**Figure 1. Stations sampled (●) and mining zone "Ity" (■) in the upper Cavally River (Cote d'Ivoire) from september 2015 to august 2016**

At each site, the same catch effort (15 min of fishing) was applied. Shrimps captured were conserved into formaldehyde 10% and transported to the laboratory for identification and dissection. Shrimps were identified according Monod (1980), Powell (1982), Gooré Bi *et al.* (2002) and Konan (2009) identification keys.

**Stomach contents analysis:** In the laboratory, each specimen of *M. macrobrachion* was measured to the nearest cm for the standard length (LS) and weighed to the nearest 0.01 g using a top loading DENVER balance SI-4002 and dissected to remove the stomach. Each stomach was slit opened and its contents were sorted, counted under a binocular microscope Olympus CX21. All preys items were weighed to the nearest 0.001 g with Satorius balance (model TE153S) and identified to the lowest taxonomic according to Needham (1962), Brown (1994), Durand and Lévêque (1981) and Dejoux *et al.* (1981).

**Data analysis:** For this study, several methods and index were used to determine diet of *Macrobrachium macrobrachion*:

**Vacuity coefficient (CV)** to evaluate feeding intensity according to Hureau (1970) as follows: CV = (Nev / Nt) x 100; Where Nev = number of empty stomachs; Nt = total number of stomachs examined.

**Intestinal coefficient (IC)** according Paugy (1994) characterizes the different trophic groups: IC = Li/Ls; Where Li = length of the intestine; LS = standard length of the shrimp. Paugy (1994) defines the following limits: IC < 0.85 corresponds to the itchyophagous; 0.32 < IC < 2.18 = insectivorous; 0.8 < IC < 3.01 = omnivorous diet; 4.71 < IC < 6.78 = phytophagous; 10 < IC < 17 = limivorous

**Correct occurrence percentage (Fc)** (Rosecchi and Nouaze, 1987) defined as follows: $F_C = (Fi / \Sigma Fi) \times 100$ with Fi = Ni / Nt; where Ni = stomachs which contained prey i and Nt = total number of non-empty stomachs

**Point method coupled with the food index** according to Odum and Oradiwe (1996) is established as follows: FI = [(%Fc x %P) / TNS)] x 100; Where % Fc = percentage of occurrence; % P = percentage of points; TNS = Total number of stomachs. According to Lauzanne (1975), prey were classified as secondary prey when 0 < FI < 10%; important prey when 10% < FI < 25%; essential prey when 25% < FI < 50% and dominant prey when FI > 50%.

**Size class** (Scherrer, 1984) Class Number (NC) = 1+ (3.3 × $\log_{10}$N); where N = total number of specimens examined. Class interval (I) = (LS max – LS min) / NC; Where LS max = maximum standard length; LS min = minimum standard shrimp length. Spearman's correlation coefficient (Fritz, 1974) was used to analyze the relationship between standard shrimp length and gut length. All statistical analyses were performed with the software Statistica 7.1 version.

## RESULTS

**Relationship between standard length (LS) and intestine length (Li):** Figure 2 shows the relationship between standard length and intestine length. The linear regression line obtained has an ascending trend with a positive slope. The relationship between standard and intestine length was Log (Li) = 0.801 log (LS) + 0.191 with a significant correlation (r = 0.92, $p < 0.05$). Spearman's correlation test shows a significant correlation between LS and Li at p < 0.5 (p < 0.05). The mean value of intestinal coefficient (IC) of *M. macrobrachion* was 0.90 ± 0.02. It is ranged between 0.02 to 1 for specimen standard length ranged between 26.85 and 133.99 mm.

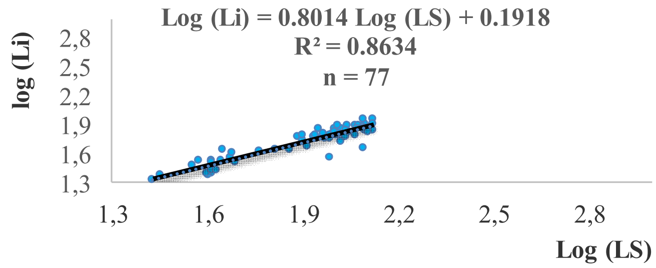


**Figure 2. Relationship between Standard length (Li) and intestine length (LS) in *Macrobrachium macrobrachion* caught in Cavally River between september 2015 and august 2016**

**General food profile of shrimps:** The qualitative analysis of the stomach contents of *M. macrobrachion* revealed some vegetable origin preys as fibers. There was also animal origin preys as insects, Fishes, molluscs and annelids. Quantitative analysis of stomach contents has respectively given values of feed index (FI) for each type of preys (Fibers: %FI = 27.8; insects: %FI = 58.86; fishes: %FI= 0.59; molluscs: %FI= 0.42 and annelids: %F= 0.58).

**Spatial study of the diet:** In *Macrobrachium macrobrachion* (Figure 3), fiber consumption is high in station Z1, Z2, Z4 and secondary in station Z3. The occurrence frequency values ranged from 0 to 33.33%. Those of the dietary indices oscillated between 0 and 25.30%. Regarding the animal fraction, insect consumption is dominant in all station Z2 except station Z3 where it is secondary. The frequencies of appearance varied between 0 and 35.56%. The food index values ranged from 0 to 74.07%. Fishes were important prey in station Z2 (%FI = 10.59) and were secondary in other stations (%FI = 0). The other components of this animal fraction (molluscs and annelids) are in a small proportion (0 ≤% FI ≤ 1.55).

**Diet variation according sex:** In *Macrobrachium macrobrachion* (Table 1), studies were focused on the stomach contents of 50 male and 21 female specimens. 28 male stomachs were empty, giving a vacuity rate of 56%. The number of stomachs of empty females was 9, giving a vacuity coefficient of 42.86%. Plant debris (fiber) is an essential food for males (% Fc = 32.3; %P = 18.99 and %FI = 28.05) but important for females (%Fc = 39.39; %P =19.39 and %FI= 21.46). Animal origin preys, however, were preferred and dominated in both sexes with males (%Fc = 38.47; %P = 71.52 and %FI = 59.27) and females (%Fc = 36.36; %P = 69.39 and %FI = 70.9). This animal fraction was dominated by insects in both sexes (males: %FI = 56.83 and females: %FI =: 70.9). Indeterminate prey was important foods for males (%FI = 12.68) and secondary foods for females (%FI = 7.64).

**Diet variation with size:** Diet was performed considering only the full state of the stomachs obtained. Thus, 40 stomachs were considered out of a total of 77 taken for this study. The maximum value of shrimp size measured was 133.99 mm standard length and the minimum value was 28.66 mm. ≤ 99 mm (N = 11) and size class 3 = 100 ≤ LS ≤ 135 value mm (N = 20) (Table 2).

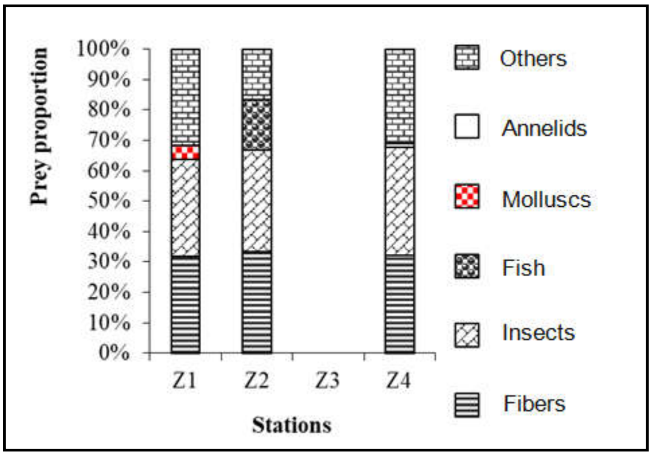


**Figure 3. Spatial composition of *Macrobrachium macrobrachion* diet**

In class of size 1, individuals of shrimps are small and immature. The dietary composition showed that the plant material represented exclusively by the fibers was an important choice in the diet of individuals in this class (N = 7; % Fc = 35; %P = 20.69 and %FI = 23.8). However, foods of animal origin were preferential preys (N = 8; %Fc = 40, %P = 72.41 and %FI = 70.53) compared to plant products. They are increased by the presence of insects in the dietary habits of this group (N = 7 %Fi = 35, %P = 59.48 and %FI = 68.41). There were lack of fishes and annelids.

**Table 1. Diet composition and prey classification in stomach contents of *Macrobrachium macrobrachion* by sex. Frequency of occurrence (Fc); Points Percentage (%P); Food index (FI); Food appreciation (FA); Secondary prey (PS); Important prey (PI); Essential prey (PE) and Dominant prey (PD)**

| Types of preys | (%) Fc | | %P | | (%) FI | | FA | |
|---|---|---|---|---|---|---|---|---|
| **Vegetable debris** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** |
| Fibers | 32.3 | 39.39 | 18.99 | 19.39 | 28.05 | 21.46 | PE | PI |
| **Animal debris** | | | | | | | | |
| Insects | 33.85 | 36.36 | 36.71 | 69.39 | 56.83 | 70.9 | PD | PD |
| Fishes | 1.54 | 0 | 12.66 | 0 | 0.89 | 0 | PS | PS |
| Molluscs | 1.54 | 0 | 9.49 | 0 | 0.66 | 0 | PS | PS |
| Annelids | 1.54 | 0 | 12.66 | 0 | 0.89 | 0 | PS | PS |
| OTHERS | 29.23 | 24.25 | 9.49 | 11.22 | 12.68 | 7.64 | PI | PS |
| **Total** | | | | | | | | |
| Vegetable debris | 32.3 | 39.39 | 18.99 | 19.39 | 28.05 | 21.46 | PE | PI |
| Animal debris | 38.47 | 36.36 | 71.52 | 69.39 | 59.27 | 70.9 | PD | PD |
| Others | 29.23 | 24.25 | 9.49 | 11.22 | 12.68 | 7.64 | PI | PS |

**Table 2. Diet composition and classification of prey recorded size of *Macrobrachium macrobrachion* according to size classes. N = stomachs which contained prey; Frequency of occurrence (Fc); Points Percentage (%P); Food index (FI);Food appreciation (FA); Secondary prey (PS); Important prey (PI) Essential prey (PE) and Dominant prey (PD)**

| | Class 1 : [28-63[ | | | | | Class 2 : [64-99[ | | | | | Class 3 : [100-135] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types of preys** | **N** | **%Fc** | **%P** | **%FI** | **FA** | **N** | **%Fc** | **%P** | **%FI** | **FA** | **N** | **%Fc** | **%P** | **%FI** | **FA** |
| **Vegetable debris** | | | | | | | | | | | | | | | |
| Fibers | 7 | 35 | 20.69 | 23.8 | PI | 9 | 31.04 | 26 | 24.03 | PI | 21 | 34.43 | 19.58 | 29.26 | PE |
| **Animal debris** | | | | | | | | | | | | | | | |
| Insects | 7 | 35 | 59.48 | 68.41 | PD | 10 | 34.48 | 66 | 67.76 | PD | 18 | 29.51 | 41.25 | 52.84 | PD |
| Fishes | 0 | 0 | 0 | 0 | PS | 0 | 0 | 0 | 0 | PS | 1 | 1.64 | 13.99 | 0.99 | PS |
| Molluscs | 1 | 5 | 12.93 | 2.12 | PS | 0 | 0 | 0 | 0 | PS | 0 | 0 | 0 | 0 | PS |
| Annelids | 0 | 0 | 0 | 0 | PS | 0 | 0 | 0 | 0 | PS | 1 | 1.64 | 13.99 | 0.99 | PS |
| Others | 5 | 25 | 6.9 | 5.67 | PS | 10 | 34.48 | 8 | 8.21 | PS | 20 | 32.78 | 11.19 | 15.92 | PI |
| **Total** | | | | | | | | | | | | | | | |
| Vegetable debris | 7 | 35 | 20.69 | 23.8 | PI | 9 | 31.04 | 26 | 24.03 | PI | 21 | 34.43 | 19.58 | 29.26 | PE |
| Animal debris | 8 | 40 | 72.41 | 70.53 | PD | 10 | 34.48 | 66 | 67.76 | PD | 20 | 32.79 | 69.23 | 54.82 | PD |
| Others | 5 | 25 | 6.9 | 5.67 | PS | 10 | 34.48 | 8 | 8.21 | PS | 20 | 32.78 | 11.19 | 15.92 | PI |

Indeterminated foods were a secondary component in the stomach contents of these shrimps (%FI = 5.67). In class of size 2, the individuals were mean size juveniles with substantially the same feeding behavior as those in the class 1. Plant material was represented exclusively by fibers and was important in the diets of individuals in this class (N = 9; % Fc = 31.04; %P = 26 and %FI = 24.03). Food of animal origin was predominant and more consumed (N = 10; %Fc = 34.48; %P = 66 and %FI = 67.76) compared to plant products. However, they were represented exclusively by the presence of insects in the stomach contents of this group. There were lack of fishes, annelids but also molluscs. Undetermined foods were a secondary component in the stomach contents of these shrimps (%FI = 8.21). In class of size 3, individuals were tall adults. These adults used the plant material, especially the fibers, which appear as an essential food in the environment (N = 21 % Fc = 34.43; %P = 19.58 and %FI = 48.2). The consumption of animal proteins, especially that of insects, predominated in this cohort (N = 20 %Fc = 32.79, %P = 69.23 and %FI = 54.82). Molluscs were absent in the animal fraction of the group. Undefined foods were an important parts of this group's food intake (%FI = 15.92).

## DISCUSSION

**Study of the intestinal coefficient of shrimps:** In the present study, examination of the relation of the length of the intestine to the standard length of *Macrobrachium macrobrachion* revealed a relatively high correlation and the characteristic correlation coefficient was 0.92. Spearman's correlation test has shown a significant difference between Li and LS at $p < 0.5$ for this relationship. Similar works previously realised by several authors have reported a positive correlation between the relative length of the intestine (Li / LS) and the diet of many species (Hofer, 1988; Kouamélan, 1992; Paugy, 1994; Kouamélan *et al.,* 1997 and N'Da, 2015) in fishes. For these shrimps, the calculated average intestinal coefficient (IC) was 0.90. This value tends to 1. This translates that the intestine of these animals is almost the same size with the whole body. These results are consistent with the works of Gooré Bi (1998) on Bia which obtained the intestinal ratio value (IC = 0.78) for *M. macrobrachion*. In addition, following Paugy (1994) classification, *M. macrobrachion* can be classified as insectivorous (0.32 < IC < 2.18) or omnivorous (0.8 < IC < 3.01). This prediction of the diet as defined by Paugy (1994) is therefore contrary to the results obtained in this study and does not apply to *M. macrobrachion* in this study. According to N'Da (2015), the information provided by the IC should therefore be confirmed by the analysis of stomach contents, which remains the best approach to characterize the diet.

**General food profile of shrimps:** In this study, the stomach contents of shrimps were analyzed for a total of 77 stomachs of *Macrobrachium macrobrachion.* This number is near that of Gooré Bi (1998) and higher than that of Kouton (2004) who worked respectively on a total of 80 and 50 shrimp stomachs. Indeed, the size of the sampling is a non-negligible factor that can influence the results of the analysis. The assertion of Madrid *et al.* (1997) and Petry *et al.* (2003) confirms our observations. According to these authors, the number of taxa identified in a sample is strongly dependent on the size of the sample or the sampling effort. The qualitative analysis has identified a relatively large number of preys classified into three categories according to whether they are some animals, plant or other origin. In *Macrobrachium macrobrachion*, the vegetable fraction consisted only of fibers. As for the animal fraction, it consisted of insects, fishes, molluscs and annelids. In view of the foregoing, it could certainly be said that *M. macrobrachion* has an omnivorous diet. The results of this work come from a first study. It was conducted on the Cavally River in Côte d'Ivoire but confirms and reinforces those of Odum and Oradiwe (1996) conducted in Ethiope River in Nigeria, those of Marioghae (1982) conducted in Lagos lagoon in Nigeria, those of Gooré Bi (1998) conducted on the Bia River in Côte d'Ivoire and those of Kouton (2004) conducted in the lower valley of Ouémé at Benin. This study has permited to inventory new types of prey consumed by shrimps specimens studied but not reported by previous authors. The absence of these types of preys in previous works may be due to the size of the sampling as noted by Madrid *et al.* (1997) and Petry *et al.* (2003), how to catch and conserve shrimp (Marioghae, 1982), the timing (night or day) of shrimp harvest (Gooré Bi, 1998; Kouton, 2004). But may also be due to habitat variability (Kouamélan *et al.,* 2003).

In *Macrobrachium macrobrachion*, food classification based on index percentages of the dietary index (FI) shows that plant debris represented by fibers (% FI = 27.8) were essentials for the species. Otherwise, animal debris represented by the insects (% FI = 58.86) are dominant preys for these shrimps. These results differ from those obtained by Gooré Bi (1998) on Bia. In the present study, the above values obtained from the feed index show that *M. macrobrachion* feeds certainly on a large quantity of vegetable materials but has a preference for preys of animal origin. This species is therefore omnivorous but with a carnivorous tendency feeding on more accessible prey such as insects.

**Diet variation according to sex:** In *Macrobrachium macrobrachion*, concerning the feeding by sex, plant debris (fiber) represents essential food for males (%FI = 28.05) but important for females (%FI = 21.46). Animal prey is preferred and dominates in both sexes with males (%FI = 59.27) and females (%FI = 70.9). This animal fraction is dominated by insects in both sexes (males: %FI = 56.83 and females: %FI= 70.9). Females are more voracious than males and prefer animal preys including insects that are more abundant and available in the environment. This polyphagia and this inclination towards meat products, observed generally in both sexes and in particular in females, could explain the cannibalism mentioned previously by Marioghae (1982) and Gooré Bi (1998).

**Diet variation by size class:** Based on the Sturge's rule, three size classes were defined in this study for this species. These classes are Class 1 (28 ≤ LS ≤ 63 mm) for immature shrimps; Class 2 (64 ≤ LS ≤ 99 mm) for juvenile and Class 3 (100 ≤ LS ≤ 135 mm) for adult individuals by observation of the size of ovigerous females and the size of the smallest individual mature of *Macrobrachium macrobrachion*. Concerning food diet, the plant material was consumed by immature individuals (%FI = 23.8) but foods of animal origin are preferential preys (%FI = 70.53). We noticed a lack of fishes and annelids in that group. Juveniles of this species have essentially the same feeding behavior as immature shrimps. The plant material was consumed by the individuals of this class (%FI = 24.03) but food of animal origin was predominant and more consumed (%FI = 67.76). There are a lack of fishes, annelids but also molluscs in that group. Adults use the plant material, especially the fibers that present themselves as an essential

food in the environment (%FI = 29.26). The consumption of animal proteins, especially that of insects, predominates in the group (%FI = 52.84). Molluscs are absent in the animal fraction. These results indicated a preference for animal debris over plant debris in all size classes and are contrary to those of Kouton (2004). In this study, preys observed are more diverse in adults than in immature and juvenile shrimps. These results are similar to those of (Hyslop, 1987). This author, in analyzing the stomach contents of a species of fish caught in the Sokoto-Rima River (Nigeria) observed that the importance of preys in the diet increases with the size of the specimens of this species. That could be due to the availability of the digestive organs at these individuals. This adaptation of the digestive system to the various types of preys had been evoked in previous studies by Kouamélan (1999) and Koné (2000). According to them, the digestive system evolves according to the classes of size and conditions the diet to certain species.
Then, the presence or absence of certain types of preys can be explained by their availability and their accessibility for shrimps in the environment. In addition, these two factors depend, according to Koné *et al.* (2014), on the living environment of individuals.

**Conclusion**

*Macrobrachium macrobrachion* diet study in the present study showed that the general food profile consists of plant and animal debris. The consumption of plant debris mainly rests on the fibers. The consumption of animal preys is greater and mainly consists of insects. This variety of food consumed made *Macrobrachium macrobrachion* an omnivorous animal but with carnivorous tendency. The results of the study of the diet according to space, sex and size classes confirmed the general food profile. In view of these results, it appears that the culturability of these shrimps is high in the rearing environment. This study confirms that *M. macrobrachion* is a potential breeding candidate for developing countries.

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