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Comparative study of the diet of three species of freshwater shrimp: *Macrobrachium vollenhovenii*, *M. macrobrachion* and *M. dux* (Crustacea, Palaemonidae) in Cavally River, Côte d'Ivoire

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Abstract

Freshwater Shrimps are important food resources consumed and very harvested in Côte d'Ivoire. The present study is the first one of the kind in Cavally River. It was conducted for understanding better the eating habits of breeding shrimps. It consists of studing the diet of three numerically majority species *Macrobrachuim vollenhovenii*, *M. macrobrachion* and *M. dux*. The harvests were realized monthly with dip nets. The study of the diet concerned 130 specimens of *Macrobrachium vollenhovenii*, 77 specimens of *Macrobrachium macrobrachion* and 133 specimens of *Macrobrachium dux*. Stomach content analysis revealed that the vacuity coefficient (CV) was weak. It value is 40 % for *M. vollenhovenii,* 48.05 % for *M. macrobrachion* and 41.35 % for *M. dux*. This situation could be explained by the availability of food resources in shrimp habitats. According to the feed index (FI), the diet of the three species consisted mainly of animal debris. This fraction was respectively dominated by insects with a feed index (%FI) of 65.85 %, 60.45 % and 45.98 % for these species. The present study confirms that these three species are omnivorous but from carnivorous tendency. They have variable resources but with a preference for insects. The differences observed between the present study and the previous authors one reveal that these species are opportunistic. Their adaptation to the environment could therefore promote their culturability in the breeding environment.

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Introduction

The breeding of Caridae has mainly concerned *Macrobrachium rosenbergii*, which is a giant commercial species. T the control of the breeding depends on a good knowledge of the biology and the ecology of the species of breeding. Several studies have been conducted in this direction in Africa and particularly in Côte d'Ivoire (Ville, 1970, 1971, 1972; Corredor, 1979; Powell, 1980, 1982; Lévèque *et al.*, 1983; Etim & Sankaré, 1998; Gooré Bi, 1992, 1998; Gooré Bi *et al.*, 2001, 2002, 2004; Kouton, 2004; N'Zi, 2007; N'Zi *et al.*, 2004, 2008; Konan, 2009; Djiriéoulou, 2017; Djiriéoulou *et al.*, 2014, 2017). The freshwater species *Macrobrachium vollenhovenii*, *Macrobrachium macrobrachion* and *Macrobrachium dux* are typical of West Africa. Breeding of the first two has been suggested by various authors (Odum & Oradiwe, 1996; Marioghae, 1982; Gooré Bi 1998; Kouton, 2004). However, their diet is not sufficiently known because of the variability of their prey observed in the literature at the mention of their feed ecology. Gooré Bi (1998) has focused mainly on the feeding habits of these species on the Bia River in Côte d'Ivoire. A more in-depth and diversified study taking into account other basins in Côte d'Ivoire such as Cavally would allow a better understanding of the feed ecology of these species.

This study, on the Cavally River, is a first in Côte d'Ivoire. It was conducted for understanding better the eating habits of breeding shrimps.

Materials and methods

Study area

The 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).

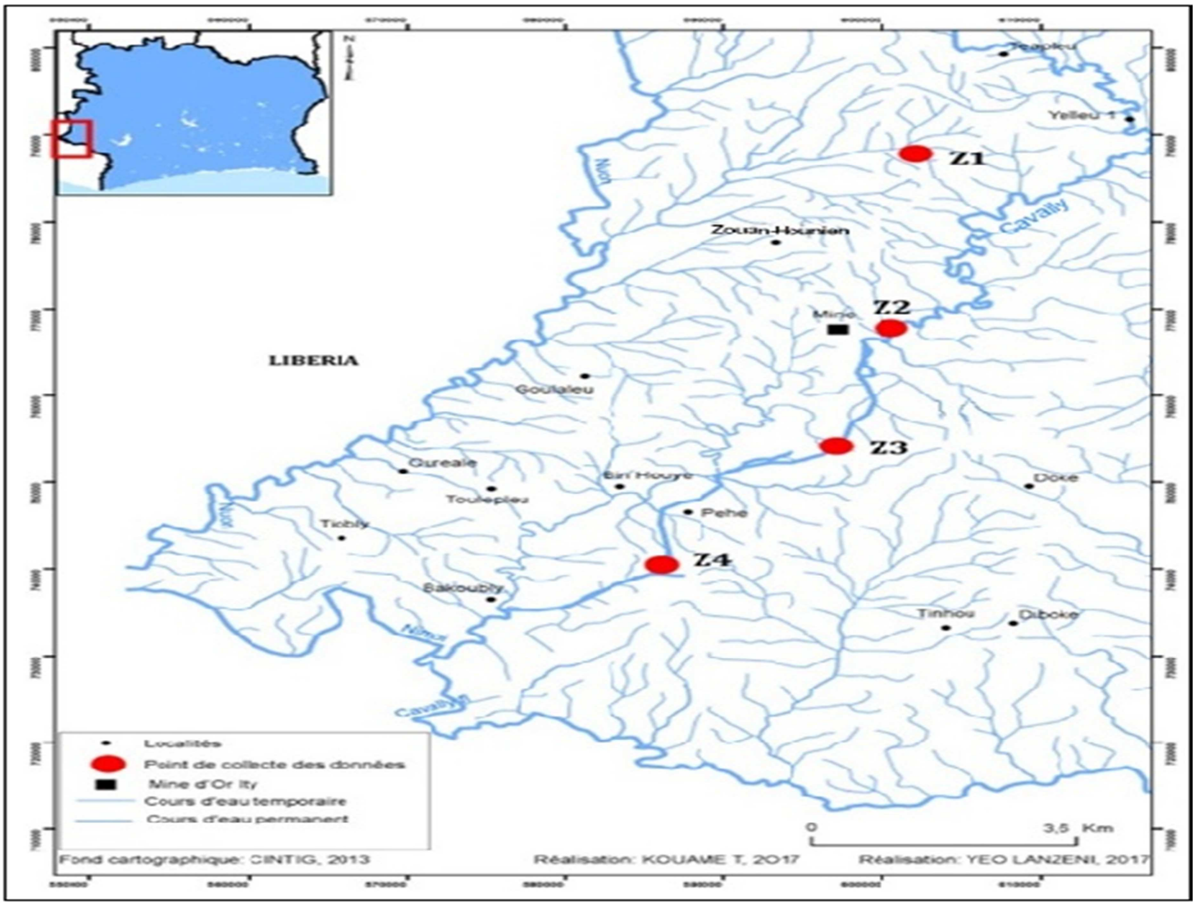

Fig. 1. Stations sampled (●) and mining zone "Ity" (■) in the upper Cavally River (Cote d'Ivoire) from September 2015 to August 2016.

Long of 700 km, it catchment area is 30 600 km². The Ivorian part of the Cavally River is 515 km long with a catchment area of 15000 km².

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 (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 (Fig.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. 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. vollenhovenii, M. macrobrachion and M. dux* 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 prey 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 Leveque (1981) and Dejoux *et al.* (1981).

Data analysis

For this study, several methods and index were used to determine diet of the shrimps. 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: Fc= (Fi / ∑Fi) x 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%.

The community index of Jaccard (Sj) (Douglas, 1984) is expressed as follows:

Sj = c/ (a+b-c) with: a: the total number of prey categories in the diet of species X; b: the total number of prey categories in the diet of species Y; c: the total number of prey categories common to species X and Y. Subsequently, according to Douglas (1984), similarity is observed when Sj > 0.7; it is average if 0.5 < Sj < 0.7 and is weak when Sj < 0.5.

Food similarity between *Macrobrachium vollenhovenii*, *M. macrobrachion* and *M. dux* species was evaluated by calculating the Jaccard community index (Sj) for these two-by-two species. The Mann-Whitney *U* test was used to compare the average intestinal coefficients of these three shrimp populations at p < 0.5.

Results and discussion

Food characterization of the three shrimp species

Three shrimp species are submitted to this study (Fig. 2). For these three species, the calculated values of the average intestinal coefficients (IC) are *Macrobrachium dux*, *M. macrobrachion* and *M. vollenhovenii* respectively of 0.95, 0.9 and 0.93. This translates that the gut of these animals is almost the same size with the whole body. In addition, the Mann-Whitney *U* test used to compare the IC of these three shrimp populations has not given significant difference at p < 0.5.

Table 1. Composition of the diet and classification of preys obtained in the stomach contents of *Macrobrachium vollenhovenii*. Number of stomachs (N) containing item i; Frequency of occurrence (Fc); Points Percentage (%P); Food index (FI); Food appreciation (FA); Secondary prey (PS); Essential prey (PE) and Dominant prey (PD).

Types of prey	N	%Fc	%P	%FI	FA
Vegetable debris					
Fibers	77	33	10.5	25.55	PE
Fibrils	1	0.4	4.04	0.12	PS
Phytoplankton	1	0.4	6.07	0.18	PS
Animal debris					
Insects	66	28.5	25.5	53.55	PD
Fishes	12	5	23.5	8.6	PS
Molluscs	1	0.4	2.02	0.06	PS
Annelids	7	3	10.9	2.39	PS
Plathyhelminthes	3	1.3	13.4	1.25	PS
Others	64	28	4.04	8.3	PS
Total					
Vegetable debris	79	34	20.6	25.85	PE
Animal debris	89	38	75.3	65.85	PD
Others	64	28	4.04	8.3	PS

These results are consistent with the works of Gooré Bi (1998) on Bia River, which respectively obtained the intestinal ratio values 0.77 for *Macrobrachium vollenhovenii* and 0.78 for *M. macrobrachion*. Besides, according to Paugy (1994) classification, these species can be classified as invertivores (0.32 < IC < 2.18) or omnivorous (0.8 < IC < 3.01).

This prediction of the diet as defined by Paugy (1994) is therefore different from the results obtained in this study and does not apply to the shrimp species studied.

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 for characterizing the diet of species. The qualitative analysis of stomach contents indicates that the food spectrum of these crustaceans consists in general of animal and plant organisms (Fig. 3). But we often distinguish the presence of a weak proportion of sand in their stomachs.

In *Macrobrachium vollenhovenii*, the vegetable fraction is consisted of plant debris subdivided into 3 types of prey. There are fibers, fibrils and phytoplankton.

The animal fraction is composed of 5 types of prey defined as: insects, fishes, molluscs, annelids and platyhelminths. In *Macrobrachium macrobrachion,* the vegetable fraction was observed and only consisted of fibers. As for the animal fraction, it was consisted of insects, fishes, molluscs and annelids.

Finally, for the *Macrobrachium dux* species, the analysis of the stomach contents also revealed the presence of 4 types of prey for the vegetable fraction. There are fibers, fibrils, fruits and phytoplanktons. Preys of animal origin are consisted of 5 items which are insects, scales, crustaceans, annelids and platyhelminths.

Table 2. Composition of the diet and classification of prey obtained in the stomach contents of *Macrobrachium macrobrachion*. Number of stomachs (N) containing item i; 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 prey	N	%Fc	%P	%FI	FA
Vegetable debris					
Fibers	37	34	17.62	27.8	PE
Animal debris					
Insects	35	32	39.62	58.86	PD
Fishes	1	1	12.58	0.59	PS
Molluscs	1	1	9.43	0.42	PS
Annelids	1	1	12.58	0.58	PS
Others	34	31	8.17	11.75	PI
Total					
Vegetable debris	37	34	17.62	27.8	PE
Animal debris	38	35	74.21	60.45	PD
Others	34	31	8.17	11.75	PI

Some representatives of these organisms could be identified until the species. For example, the species *Pila africana* (Physidae) and *Planorbis gibbonsis* (Planorbidae) have been identified in molluscs; *Calamyzas sp.* (Calamyzidae) is a polychete annelid; *Caobangia abbotti* (Caobangiidae) was found in insects. In addition, other prey organisms such as cysts and bacteria were observed but numerically very low in all three species. For these latter types of prey only the qualitative study was considered in this study. In view of the foregoing, it can undoubtedly be said that the shrimp species submitted to this study have an omnivorous diet.

Table 3. Composition of the diet and classification of prey obtained in the stomach contents of *Macrobrachium dux*. Number of stomachs (N) containing item i; 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 prey	N	%Fc	%P	%FI	FA
Vegetable debris					
Fibers	73	32	15.77	38.18	PE
Fibrils s	19	8	8.3	5.02	PS
Fruits	1	0.4	4.15	0.12	PS
Phytoplanktons	2	1	1.66	0.12	PS
Animal debris					
Insects	66	29	19.51	42.85	PE
Scales	2	0.8	14.52	0.83	PS
Crustaceans	1	0.4	6.22	0.18	PS
Annelids	5	2	12.03	1.77	PS
Plathyhelminthes	1	0.4	12.45	0.35	PS
OTHERS		26	5.39	10.58	PI
Total					
Vegetable debris	95	41.4	29.88	43.44	PE
Animal debris	75	32.6	64.73	45.98	PE
Others	58	26	5.39	10.58	PI

The results confirm those of Odum and Oradiwe (1996), Marioghae (1982), Gooré Bi (1998) and those of Kouton (2004). According to these authors, the simultaneous presence of animal and plant prey in the stomachs of these shrimps testifies to their belonging to animals having an omnivorous diet. Then, the absence of previous species in their works may be due to the size of the sampling as noted by Madrid *et al.* (1997) and Petry *et al.* (2003), the way to catch and conserve shrimps (Marioghae, 1982), the timing (night or day) of shrimps harvest (Gooré Bi, 1998; Kouton, 2004). But may also be due to habitat variability (Kouamélan *et al.*, 2003).

Fig. 2. Species of shrimp caught in the Cavally River for food ecology.

From a quantitative point of view, the value of the Jaccard community index for measuring food similarity between *Macrobrachium vollenhovenii* and *M. macrobrachion* is Sj = 0.88 > 0.7. This indicates that these two species have similar eating habits. This similarity of the diet was noted by Gooré Bi (1998) on the Bia River. According to this author, the two species, from the prey point of view, have the same diet.

The Jaccard community index for measuring food similarity between *Macrobrachium dux* and *M. vollenhovenii* on the one hand and between *M. dux* and *M. macrobrachion* on the other hand is respectively Sj = 0.58 > 0.5 and Sj = 0.45 < 0.5. These results show that the similarity is average for the first pair of species but weak for the second. In natural or controlled environments, apart from any phenomenon of predation or mutual cannibalism, these species may compete in the event of a scarcity of food resources. Such phenomena of cannibalism have been mentioned in previous studies by various authors including Marioghae (1982) and Gooré Bi (1998). In another sense, food similarity coupled with an omnivorous diet could facilitate the breeding of these species in controlled environments. The breeding possibilities of *M. vollenhovenii* and *M. macrobrachion* have been reported by Gooré Bi (1998), Kouton (2004) and Boghué (2015).

In general, the void coefficient (CV) calculated for all three species in this study is low. Its value is 40% for *Macrobrachium vollenhovenii*, 48.05 % for *Macrobrachium macrobrachion* and 41.35 % for *Macrobrachium dux*. These results reflect an increase in trophic activity generally in the study area. This situation could be explained by the availability of food resources at any time of the year related to a humid mountain climate of the study area. However, these values are relatively higher than those indicated by Gooré Bi (1998) which were 17 to 37 %. As the study environment is more and more anthropised, the increase in the value of the void coefficient may be due to the stress conditions that the animals are confronted. The same cases of stress conditions was reported by Kouamélan *et al.* (2003), Yao *et al.* (2005) and (Aboua, 2012) during their works. However, these values are relatively lower than those reported by Kouton (2004), which ranged from 48 to

72 % in adult shrimp. Furthermore, Gooré Bi (1998) and Kouton (2004) had shown that the trophic activity of these three shrimp species is more intense at night and weak during the day.

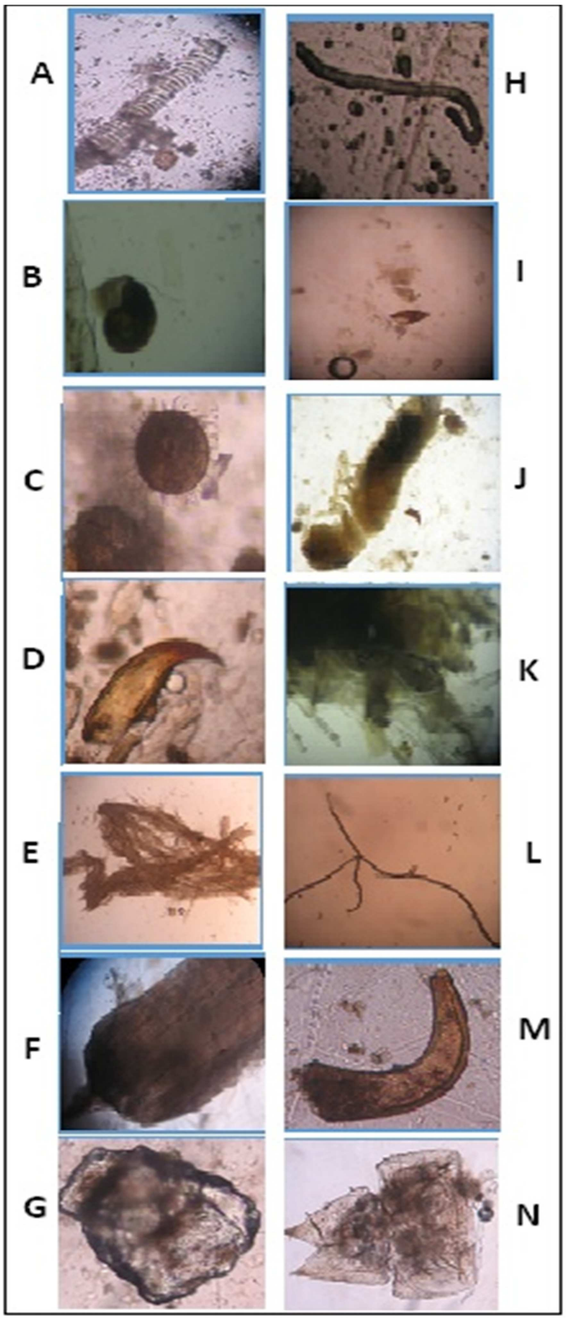

Fig. 3. Organisms prey collected in the stomach contents. A: Annelid; B: *Planorbis gibbonsis* (Planorbidae); C: proximochorate cyst; D: Crustacean debris; E: Fibers; F: microscopic fruit; G: sand crystal; H: Plathyhelminthe; I: *Pila africana* (Physidae); J: Beetle juvenile from the family of Brùchidae; K: fish skeleton; L: Fibrill; M: Piece of Phytoplankton of the genus *Closterium*; N: Indeterminated prey.

Concerning the quantitative analysis, the composition of the diet and the classification of preys observed in the stomach contents of *M. vollenhovenii* are shown (Table 1). The plant debris found in 79 stomachs have an occurrence frequency of 34 %. The percentage of relative points is 20.6 % and the resulting dietary index is 25.85 %. As a result, food classification based on index percentages of the feed index (IA) shows that fibers dominated by plant debris (N = 77, % Fc = 33, %P = 10.5 and % FI = 22.55) are essential foods for the species. As for animal debris, they were found in 89 stomachs and correspond to a percentage of occurrence of 38 %. The relative percentage of points is 75.3 % and the feed index is 65.85%. The food classification based on index percentages of the food index (IA) indicates that the animal fraction dominated by insects (N = 66, %, Fc = 28.5, %P = 25.5 and %FI = 53.55) is a dominant prey for the species. As far as foods are concerned whose identification was not possible, they were found in 64 stomachs with an occurrence frequency of 28 %. The corresponding percentage of points is 4.04 % and the food index is 8.3 %. That makes it possible to classify this unidentified fraction in secondary foods. These results differ from those obtained by Gooré Bi (1998) on Bia River.

According to the author, in this species, there are no important prey or dominant prey but essential prey and secondary. In the present study, the above values obtained from the feed index show that *Macrobrachium vollenhovenii* certainly feeds on a large quantity of plant material 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.

In *Macrobrachium macrobrachion*, the composition of the diet and the classification of prey observed in the stomach contents have been noted (Table 2). The plant debris was found in 37 stomachs, which allowed to estimate a frequency of appearance of 34%. The percentage of relative points is 17.62 % and the resulting dietary index is 27.8%. However, food classification based on index percentages of the feed index (IA) shows that the plant debris represented by the fibers (N = 37, % Fc = 34, %P = 17.62 and % FI = 27.8) are essential foods for the species.

Concerning animal debris, they were contained in 38 stomachs, which corresponds to 35 % occurrence. The relative percentage of points is 74.21 % and the feed index is 60.45 %. The food classification based on index percentages of the feed index (IA) indicates that the animal fraction dominated by insects (N = 35, % Fi = 32, %P = 39.62 % and % FI = 58.86) constitutes dominant preys for the species. For foods that could not be identified, they were stored in 34 stomachs with an occurrence rate of 31%. The corresponding percentage of points is 8.17 % and the feed index is 11.75 %. That makes it possible to classify this unidentified fraction in foods important for the species. These results once again place the animal fraction first in front of the vegetables one and confirm the food similarity between *M. vollenhovenii* and *M. macrobrachion*. These results are differents from those of Gooré Bi (1998) and Kouton (2004) according to which vegetable materials (plant debris and fibers) would be the most abundant constituents in the stomachs of these animals. In addition, the results of Gooré Bi (1998) showed that there are no important and preferential prey in *M. macrobrachion*, however, there are secondary preys and dominant preys. The results of this study show that there are dominant, essential, important and secondary preys in this species.

In *Macrobrachium dux*, the detection of plant debris in 95 stomachs has given the occurrence frequency of 41.4 %. The percentage of points awarded to this vegetable fraction is 29.88 % and the food index is 43.44 % (Table 3).

Thus, referring to the classification of foods based on the percentages of the feed index (FI), we have noted that the plant debris represented by the fibers (N = 73, % Fi = 32, %P = 15.77 and % FI = 38.18) constituted essential foods for the species. The animal debris, contained in the 75 stomachs, corresponds to a percentage of occurrences of 32.6 %.

The percentage of points is 64.73% and the food index is 45.98%. The food classification according to the percentages of the feed index (FI) indicates that the insects dominated animal fraction (N = 66, % Fc = 29, %P = 19.51 and % FI = 42.85) which constitutes essential prey for the species. Foods, whose nature was undefined, were kept in 58 stomachs, with a frequency of occurrence of 26 %. The corresponding percentage of points is 5.39 % and the food index is 10.58 %. That makes it possible to classify this unidentified fraction in important foods.

These results are differents from those of Kouton (2004) who showed that plant debris was the most abundant constituents in the stomachs of these shrimps. Discrepancies sometimes observed between the present study and previous studies could be explained by: the choice of equipment and the study methods used, the choice of the study environment (marked by the abiotic and biotic factors conditioning the food ecology).

Conclusion

The study of the diet was devoted to three numerically majority species. These are *Macrobrachium vollenhovenii, M. macrobrachion* and *M. dux*. In the present study, in addition to the ecological importance of these shrimps, *Macrobrachium vollenhovenii*, *M. macrobrachion* are of particular interest because they are giant species and have an economic interest. They have therefore been the subject of a careful study on Cavally River in order to expand the available data on the ecology of shrimps in Côte d'Ivoire. This study revealed that *Macrobrachium* species are omnivorous but have a carnivorous tendency. In view of these results, the culturability of these shrimps is high whereas they are omnivorous.

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