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Feeding Ecology of a Giant African Freshwater Shrimp *Macrobrachium vollenhovenii* Herklots, 1857 (Crustacea, Palaemonidae) in Cavally River, Côte D'ivoire

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ABSTRACT

Diet composition of the giant African shrimps *Macrobrachium vollenhovenii* were investigated from the experiment dip-net fishing during the period of September 2015 to August 2016 in the upper course of Cavally River. The stomach content were analysed in relation to sex, season and size. One hundred thirty five (130) specimens included 112 males and 18 females of *M. vollenhovenii* were examined. Stomach content analysis revealed that 49 stomachs *of M. vollenhovenii* were empty and 81 contained food with vacuity Index of 37.69 %. According to the Food Index (FI) combined to the point methods, this diet consisted mainly of animal debris. This animal fraction was dominated by insects (% FI = 65.85). Further study of the food ecology of this species taking into account sex, seasons and size classes gave the same results. According to the Food index calculated, *M. vollenhovenii* is an omnivorous species and feed on animals debris mainly dominated by insects (% FI = 53.55).

INTRODUCTION

All around the world, to meet the challenge of food self-sufficiency in animal proteins, shrimp farming has been undertaken. This domestication of shrimp began in the countries of South-East Asia, such as Indonesia with the extensive breeding of Penaeidae species. However, it is in 1933, under the impulse of Japanese researchers, that begins the modern history of the Penaeidae shrimp farms [30]. With regard to Caridae shrimps genus, their breeding has mainly started with *Macrobrachium rosenbergii*, which is a large commercial species. Therefore, for the control at all production stages, a solid knowledge of reproduction biology and feeding habits of species, were needed. Several studies have been conducted in this direction in Africa and particularly in Côte d'Ivoire [34]; [35]; [3]; [29]; [7]; [10]; [10; 12]; [19]; [24]; [15]; [5]. The freshwater species *Macrobrachium vollenhovenii* is very popular in Africa. Its breeding has been suggested by various authors such as [26], [21], [10] and [19]. But yet, its diet is not sufficiently known because of the variability of its prey observed in the literature at the mention of the study of its food ecology. The food diet study on this species were done by Abayomi *et al*. (2011) in Epe Lagoon of southwest Nigeria and were focused only on the general composition of diet. In Côte d'Ivoire, studies on this species are essentially focused on trophic activities in Bia River by [10] and their distribution in freshwater according to physicochemical parameters by [24]. Therefore, further study of the food ecology of *M. vollenhovenii* taking into account sex, seasons and size are necessary for the control of their feeding in a breeding environment.

This study, done on Cavally River, is the first of its kind and aims to provide further information on the food and feeding habits of these species.

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 [9]. 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 to [5]. 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 [22], [29], [11] and [15] identification keys.

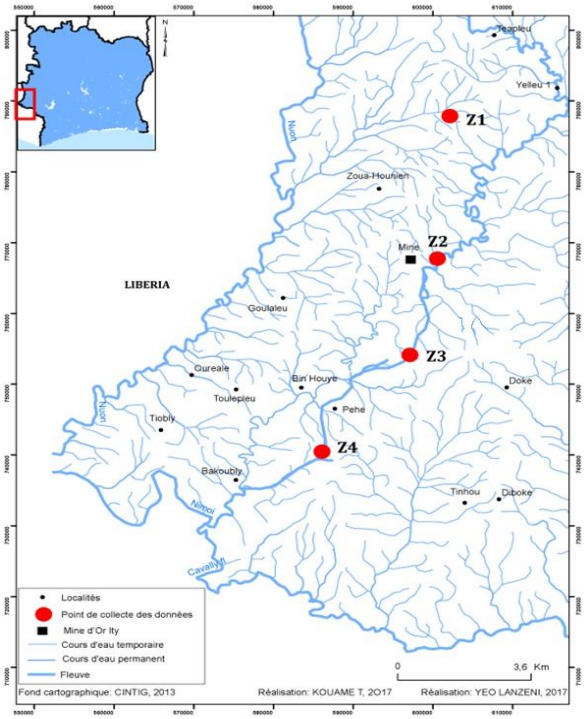

Figure 1: Stations sampled (●) and mining zone "Ity" (■) in the upper Cavally River (Cote d'Ivoire) from September 2015 to August 2016

Stomach contents analysis

In the laboratory, each specimen of *M. vollenhovenii* 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 balance model TE153S and identified to the lowest taxonomic according to [25], [2], [6] and [4].

DATA ANALYSIS

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

Vacuity coefficient **(CV)** to evaluate feeding intensity according to [13] as follows: CV = (Nev / Nt) x 100; Where Nev = number of empty stomachs; Nt = total number of stomachs examined

Intestinal coefficient **(IC)** according to [27] characterizes the different trophic groups: **IC =** Li/Ls; Where Li = length of the intestine; LS = standard length of the shrimp. [27] 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) [31] defined as follows: F_C = (Fi / ΣFi) 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 **(FI)** according [26] is established as follows: FI = [(%Fc x %P) / TNS)] x 100; Where, FI = percentage of Food Index; % 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 of [32]**.** 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.

Similarity index (α) of [33] was used to compare the diet of *Macrobrachium vollenhovenii* in different seasons (max probability retained *p*-level 0.06).

$$\alpha = 1 - 0{,}5 \text{ x} \sum_{i=1}^{n} \left| Pxi - Pyi \right|$$

With: Pxi = proportion of prey consumed by individuals at one season x; Pyi = proportion of prey consumed by individuals at another season y.

Spearman's correlation coefficient [8] 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 and intestine length

Figure 2 shows the relationship between intestine length (Li) and standard length (LS). The linear regression line obtained has an ascending trend with a positive slope. The relationship between intestine and standard length was Log (Li) = 0.849 log (LS) + 0.176 with a significant correlation (r = 0.74, $p < 0.05$). The Spearman correlation test shows a significant correlation between Li and LS at p < 0.5 (p < 0.05). The mean value of intestinal coefficient (IC) of *M. vollenovenii* was 0.93 ± 0.11. It is range between 0.11 to 1.03 for specimen standard length range between 48.34 and 164.47 mm.

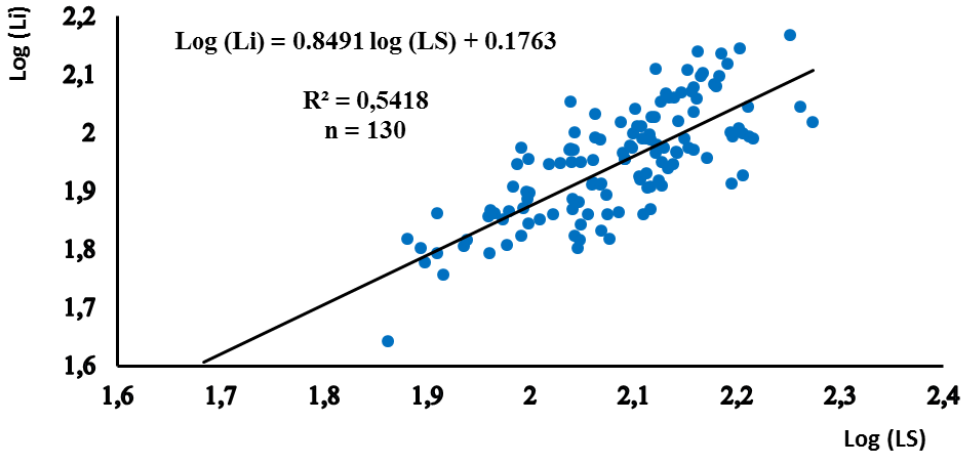

Figure 2: Relationship between gut length (Li) and Standard length (LS) in *Macrobrachium vollenhovenii* caught in the Cavally River between September 2015 and August 2016

General food composition

The qualitative analysis of the stomach contents of *M. vollenhovenii* revealed that diet of this specie was composed by fibers, fibrils, phytoplankton, insects, fishes, molluscs, annelids and

plathelminthes assigned into 8 taxonomic groups **(Table I)**. Among insects, *Caobangia abbotti* (Caobangiidae) was found. *Pila africana* (Physidae) and *Planorbis gibbonsis* (Planorbidae) have been identified in molluscs group. In annelid group, *Calamyzas sp*. (Calamyzidae) is into species stomach. Other groups such as cysts and bacteria were observed in gut content of *M. vollenhovenii*.

Quantitative analysis of stomach contents shows that animal debris (% FI = 65.85) mostly dominated by insects were an important or dominant prey (% FI = 53.55) eaten by *Macrobrachium vollenhovenii*. Secondary preys eaten by this species were composed by plant debris (% FI = 25.85) mostly dominated by filber (25.55). This fraction constitute and essential prey for *M. vollenhovenii* **(Table I).** Unidentified fraction composed of fragments of decomposing organic matter which could not be accurately identified due to their tiny size or poor physical condition with % FI = 8.3 constitute secondary prey or accessories prey for this species.

Table I: Composition of the general diet and classification of prey recorded in the stomach contents of *Macrobrachium vollenhovenii*. Number of stomachs (N) containing item i; Frequency of occurrence (Fi); 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

Foods variation according sex

In this study, 112 stomachs of males and 18 of females of *Macrobrachium vollenhovenii* were examined.

In males specimens, 39 stomachs were empty, giving a vacuity coefficient of 34.82%. Males eaten food are essentially composed by animals debris (%Fc = 39.15, % P = 77.96 and % FI = 65.42) manly dominated by insects (% Fc = 28.3, % P = 25.85 and % FI = 51.57). The secondary preys were plants (% FI = 25.48). Among them, fibers are the most eaten (% Fc = 32.55, % P = 11.02 and % FI = 25.27) **(Table II).**

In females specimens, the empty stomachs were 13 and the vacuity coefficient was 72.22%. The most eaten preys are constituted by animal debris manly dominated by insects (%Fc = 31.25, % P = 64.15 and % FI = 67.19). As secondary prey, females ate plants (% Fc = 28.07) manly dominated by Fibers (%Fc = 37.5, % P = 20.76 and % FI = 26.1) **(Table II).**

Table II: Diet composition and prey classification in stomach contents of *Macrobrachium vollenhovenii* by sex. Frequency of occurrence (Fi); Points Percentage (%P); Food index (FI); Food appreciation (FA); Secondary prey (PS); Essential prey (PE) and Dominant prey (PD)

Types of prey	**% Fc**		**%P**		**% FI**		**FA**	
VEGETABLE DEBRIS	Male	Female	Male	Female	Male	Female	Male	Female
Fibers	32.55	37.5	11.02	20.76	25.27	26.1	PE	PE
Fibrills	0	6.25	0	9.43	0	1.97	PS	PS
Phytoplankton	0.47	0	6.36	0	0.21	0	PS	PS
ANIMAL DEBRIS								
Insects	28.3	31.25	25.85	64.15	51.57	67.19	PD	PD
Fishes	5.66	0	24.58	0	9.78	0	PS	PS
Molluscs	0.47	0	2.11	0	0.05	0	PS	PS
Annelids	3.3	0	11.44	0	2.63	0	PS	PS
Platyhelminthes	1.42	0	13.98	0	1.39	0	PS	PS
OTHERS	27.83	25	4.66	5.66	9.1	4.74	PS	PS
TOTAL								
VEGETABLE DEBRIS	33.02	43.75	17.38	30.19	25.48	28.07	PE	PE
ANIMALS DEBRIS	39.15	31.25	77.96	64.15	65.42	67.19	PD	PD
OTHERS	27.83	25	4.66	5.66	9.1	4.74	PS	PS

Seasonal variation in diet composition

During the dry season, 40 shrimp stomachs of *Macrobrachium vollenhovenii* were collected. Nine (09) stomachs were empty hence a vacuity Index of 22.50%. According to sex, 36 stomachs of male shrimp were examined during dry season with 06 empty stomachs corresponding to vacuity coefficient (CV) of 16.66%. In the females, during the dry season, 4 stomachs were examined including 03 empty and a CV = 75%.

In the rainy season, 90 stomachs were examined including 43 empty ones. This corresponds to a CV of 47.77%. In this season, 76 male stomachs were analyzed including 33 voids, a CV = 43.42 %. In the rainy season, 14 female stomachs were scanned with 10 voids from where a CV = 71.42 %.

Regarding diet composition of *M. vollenhovenii* **(Table III)**, the results of the analysis of the stomach contents show a significant and essential consumption of plant debris in dry season and rainy season respectively (for dry season: % Fc = 34.09, %P = 8.59, % FI = 20.07 and for rainy season: % Fc = 34.41, %P = 25.23, % FI = 30.5). Ingesting dietary fiber is important and essential in dry season and rainy season respectively and occupies a prime position in the vegetarian shrimp diet (for dry season: % Fc = 34.09, %P = 8.59, % FI = 20.07 and for rainy season: % Fc = 33.01, %P = 13.76, % FI = 30). The animal component of the diet is predominant in dry season (% Fc = 37.5, %P = 87.98, % FI =73.25) and during rainy season (% Fc = 38.72, %P = 87.98 and % FI = 59.75). Insects are the most consumed prey in this animal fraction. Their ingestion predominates in the dry season (% Fc = 28.41, %P = 30.47 and % FI = 59.35) but is essential in the rainy season (% Fc = 28.17, %P = 25.69 and % FI = 47.8). The undetermined fraction is a food secondarily consumed by these shrimps at all seasons (% FI = 6.68 for dry season and % FI = 9.75 for rainy season). Also, the results of the food similarity study between dry and rainy seasons indicate that the similarity index of Schoener (α) is between 0.96 and 1 for any kind of prey. *Macrobrachium vollenhovenii* ate similar prey from season to season ($\alpha \geq 0.6$).

Table III: Diet composition and classification of prey ate by *Macrobrachium vollenhovenii* according to the seasons: Frequency of occurrence (Fi); Points Percentage (%P); Food index (FI); Food appreciation (FA); Secondary prey (PS); Essential prey (PE) and Dominant prey (PD); Rainy season (RS); Dry season (DS)

Types of prey	%Fc		%P		%FI		FA	
VEGETABLE DEBRIS	DS	RS	DS	RS	DS	RS	SS	SP
Fibers	34.09	33.01	8.59	13.76	20.07	30	PI	PE
Fibrills	0	0.7	0	4.59	0	0.19	PS	PS
Phytoplankton	0	0.7	0	6.88	0	0.31	PS	PS
ANIMAL DEBRIS								
Insects	28.41	28.17	30.47	25.69	59.35	47.8	PD	PE
Fishes	4.55	5.63	31.76	22.48	9.9	8.36	PS	PS
Molluscs	0	0.7	0	2.29	0	0.09	PS	PS
Annelids	2.27	3.52	6.44	14.22	1	3.3	PS	PS
Platyhelminthes	2.27	0.7	19.31	4.59	3	0.2	PS	PS
OTHERS	28.41	26.87	3.43	5.5	6.68	9.75	PS	PS
TOTAL								
VEGETABLE DEBRIS	34.09	34.41	8.59	25.23	20.07	30.5	PI	PE
ANIMALS DEBRIS	37.5	38.72	87.98	69.27	73.25	59.75	PD	PD
OTHERS	28.41	26.87	3.43	5.5	6.68	9.75	PS	PS

Diet variation with size

Diet of *Macrobrachium vollenhovenii* was performed considering only the full state of the stomachs obtained. Thus, 81 stomachs were considered out of a total of 130 taken for this study. The maximum value of shrimp size measured was 164.47 mm standard length and the minimum value was 48.34 mm. Based on the Sturge rule, three size classes have been defined: size class 1 = 48 ≤ LS ≤ 86 mm (N = 7); size class 2 = 87 ≤ LS ≤ 125 mm (N = 33) and size class 3 = 126 ≤ LS ≤ 165 mm (N = 41). Diet of the three size class was summarized in **Table IV.**

In class 1, individuals of *M. vollenhovenii* are small and immature. Animal debris were the dominated eaten preys (% Fc = 42.1, % P = 71.54 and % FI = 73.27) and insects were favourite prey (% Fc = 31.58, % P = 48.91 and % FI = 68.03). Secondary preys were composed by Plant (% Fc = 36.84, % P = 18.98 and % FI = 17.94). Fibers constitute the vegetable fraction most ingested by this shrimp cohort (% Fc = 31.58, % P = 11.68 and % FI = 16.25).

In class size 2, individuals of *M. vollenhovenii* are usually juveniles. Animal debris were the dominated eaten preys with% Fc = 39.56, % P = 85.24 and % FI = 67.68. Insects consumption predominates this fraction (% Fc = 26.37, % P = 28.7 and % FI = 51.64). Secondary preys were composed by Plant (% Fc = 34.07, % P = 10.97 and % FI = 25.5). Fibers constitute the vegetable fraction most ingested by shrimp in this class (% Fc = 34.07, % P = 10.97 and % FI = 25.5). Unidentified foods are consumed incidentally (% FI = 6.82) **(Table IV).**

In the size class 3, specimen were all mature. Animal debris were the dominated eaten preys (% Fc = 37.83, % P = 79.71 and % FI = 63.32). Insects were the most consumed in animal debris (% Fc = 29.73, % P = 22.18 and % FI = 50.11). Secondary preys were composed by Plant (% Fc = 36.04, % P = 16.16 and % FI = 28.48). Fibers constitute the vegetable fraction most ingested by this shrimp cohort (% Fc = 35.14, % P = 10.53 and % FI = 28.11) **(Table IV).**

Table IV: Diet composition and classification of prey recorded size of *Macrobrachium vollenhovenii* according to size classes. Frequency of occurrence (Fi); Points Percentage (%P); Food index (FI); Food appreciation (FA); Secondary prey (PS); Essential prey (PE); Significant prey (PI) and Dominant prey (PD)

	Class 1 : [48-86[				**Class 2 : [87-125[**				**Class 3 : [126-165]**			
Types of prey	%Fc	%P	%FI	FA	%Fc	%P	%FI	FA	%Fc	%P	%FI	FA
VEGETABLE DEBRIS												
Fibers	31.58	11.68	16.25	PI	34.07	10.97	25.5	PE	35.14	10.53	28.11	PE
Fibrills	5.26	7.3	1.69	PS	0	0	0	PS	0	0	0	PS
Phytoplankton	0	0	0	PS	0	0	0	PS	0.9	5.63	0.37	PS
ANIMAL DEBRIS												
Insects	31.58	48.91	68.03	PD	26.37	28.7	51.64	PD	29.73	22.18	50.11	PD
Fishes	5.26	21.9	5.07	PS	6.59	22.78	10.23	PI	4.5	26.32	8.97	PS
Molluscs	0	0	0	PS	1.1	2.11	0.15	PS	0	0	0	PS
Annelids	5.26	0.73	0.17	PS	3.3	12.66	2.83	PS	1.8	16.17	2.18	PS
Platyhelminthes	0	0	0	PS	2.2	18.99	2.83	PS	1.8	15.04	2.06	PS
OTHERS	21.06	9.48	8.79	PS	26.37	3.79	6.82	PS	26.13	4.13	8.2	PS
TOTAL												
VEGETABLE DEBRIS	36.84	18.98	17.94	PI	34.07	10.97	25.5	PE	36.04	16.16	28.48	PE
ANIMALS DEBRIS	42.1	71.54	73.27	PD	39.56	85.24	67.68	PD	37.83	79.71	63.32	PD
OTHERS	21.06	9.48	8.79	PS	26.37	3.79	6.82	PS	26.13	4.13	8.2	PS

DISCUSSION

Study of the intestinal coefficient of shrimps

In this study, relationship of intestine (Li) and standard length of *Macrobrachium vollenhovenii* revealed a hight correlation. This shows that the length of the intestines of individuals of this species grows proportionally to their size. Moreover, Spearman's correlation has shown a significant correlation between Li and LS ($r = 0.74$, $p < 0.05$). Similar work previously carried out on fish, reported a positive correlation between the relative length of the intestine (Li / LS) and the diet of many species [27]; [17]; [23]. In *M. vollenhovenii*, intestinal coefficient is 0.93. This high value of intestinal coefficient translates that the intestine of these shrimps is almost the same size with the whole body. This intestinal coefficient is high than those found by [10] (IC = 0.77) in Bia River. *M. vollenhovenii* obviously appears, on the basis of the intestinal coefficients found and, according to [27], as an omnivorous and insectivorous species.

General food profile of shrimps

Stomach contents of shrimp were analyzed for a total of 130 stomachs of *Macrobrachium vollenhovenii*. Our samples are higher than those of [10] and [19], who respectively studied on 80 and 50 shrimp stomachs. Indeed, the size of the sampling is a non-negligible factor that can influence the results of analysis. The assertion of [20] and [28] 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 of stomach content of *M. vollenhovenii* showed three categories of prey animal, plant or other origin. Plant fraction is constituted by fibers, fibrils and phytoplankton. The animal fraction is composed of insects, fish, molluscs, annelids and platyhelminths. In view of the foregoing considerations, and given of intestine coefficient according to [27] classification, *M. vollenhovenii* were an omnivorous diet with a invertivorous tendency. Our results-confirms and reinforces those of [26] in Ethiope River in Nigeria, [21] in Lagos lagoon in Nigeria, [10] on the Bia River in Côte d'Ivoire and [19] in the lower valley of Ouémé in Benin. This study made it possible to inventory new types of prey consumed by the shrimp specimens studied but not reported by previous authors. The absence of some types of prey in previous work may be due to the size of the sampling as noted by [20] and [28], in the mode of capture and conservation of shrimp [21], But may also be due to habitat variability [18]. In *Macrobrachium vollenhovenii*, analysis of stomach

contents showed that fiber-dominated plant debris (% FI = 25.85) is essential for the species. Also, animal debris constituted a dominated prey eaten by *M. vollenhovenii* (% FI = 65.85). These results differ to those obtained by [10] on Bia River. According to this author, in this species, there are no dominant prey but essential prey (plant debris, animal and fiber) and secondary (the rest of items). In the present study, the values of dietary index showed that *M. vollenhovenii* feeds on a large quantity of plant material but has a preference for animal preys. This species is therefore omnivorous but with a carnivorous tendency feeding on more accessible prey such as insects (% FI = 53.55). According to [19], *M. vollenhovenii* is the most carnivorous shrimp studied and the detritus present in the stomach consists of the bottom mud of inhabited shrimp environments.

Diet variation according sex

In *Macrobrachium vollenhovenii*, sex study required examination of stomach contents of 112 male and 18 female specimens. Thirty-nine (39) male stomachs were empty with a vacancy coefficient of 34.82 %. The number of empty female stomachs was 13 and an emptiness coefficient of 72.22%. When comparing the emptiness coefficient of both sexes, females emptiness coefficient is higher than males. This difference can be explained either by competition for food between the two sexes and by reproduction activity of females. These reproductive phenomena have been reported by [26], [11], [19] and [1]. As to consider feeding by sex, in *M. vollenhovenii*, plant debris dominated by fibers (% FI = 25.27) is essential for males and for females (% FI = 26.1). Animal debris is a dominant prey in males (% FI = 65.42) and in females (% FI: 67.19) and is mostly represented by insects. Females are more voracious than males and prefer animal flesh including insects. This polyphagia and this inclination towards meat products, observed generally in both sexes and in particular in females, could explain the cannibalism mentioned by [21] and [10].

Variation of the diet according to seasons

The results of the dietary similarity study between the dry and rainy seasons indicated that the Schoener similarity index [33] is $\alpha \geq 0.6$ regardless of the type of prey. Diet of *M. vollenhovenii* does not vary with the seasons. In the dry season, the vacancy coefficient of *M. vollenhovenii* is 22.50 % and in rainy season is 47.77%. According to the sexes, vacancy coefficient of males in dry season is 16.66 % and 43.42 % in the rainy season. In females, coefficient of vacuity is very high in both seasons. These reproductive phenomena have been noted in previous studies by [26], [10], [19] and [1]. In addition, the phenomena of recurring

stress noted above, can also explain this increase of vacuity coefficient. The rise observed in the dry season in females may be due to the scarcity of food resources often correlated with the phenomena of competitions in the environment.

Diet variation with size

Based on the Sturge's Rule, three diet size classes belonging immature, juvenile and adults were defined in this study. Immature individuals ($48 \leq LS \leq 86$ mm) of *M. vollenhovenii*, prefer animal protein (% FI = 73.27) mostly dominated by insect (% FI = 68.03). Fibers are the vegetable fraction most ingested by this shrimps (% FI = 16.25) as secondary prey. In juveniles ($87 \leq LS \leq 125$ mm), animal fraction is dominant (% FI = 67.68) and quite diversified, with insects (% FI = 51.64) followed by fish (% FI = 10.23) highly consumed. Plant debris with fiber (% FI = 25.5), secondary eaten, is essential food and are more consumed in the juveniles group than in immature.

In Adults, *M. vollenhovenii* feed on animal debris (% FI = 63.32) mainly dominated by insects (% FI = 50.11) followed by plant (% FI = 28.48). In this study, prey observed were more diverse in juveniles and adults than in immature shrimp. These results are similar with those of [14] for which the importance of prey in the diet increases with the size of the specimens. *Macrobrachium vollenhovenii* feed on plant debris but mainly preferred animal preys irrespective of the size. Our results are contrary to those of [19] and [16]. This difference could be due to the varieties of aquatic habitats prospected. The feeding habits of *M. vollenhovenii* therefore depend on the accessibility and availability of prey in its habitat. For [16], food change with size according anatomy of species and accessibility of prey in the predator environment.

The food similarity at the individuals of class of different size can give some explanation by 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 [16]. According to them, the digestive system evolves according to the classes of size and conditions the diet to certain species.

CONCLUSION

Macrobrachium vollenhovenii 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 flesh is greater and consists mainly of insects. This

variety of food consumed made *M. vollenhovenii* an omnivorous with carnivorous tendency. The results of the study of the diet according to sex, seasons and size classes confirmed the general food profile. This study confirms this finding and goes further by proposing that *M. vollenhovenii* be a potential candidate for breeding.

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