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Feeding Ecology of Small African Freshwater Shrimp *Macrobrachium dux* (Lenz, 1910) (Crustacea, Palaemonidae) in Cavally River, Côte d'Ivoire

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Abstract: ***The diet study included 133 specimens of Macrobrachium dux (56 males and 77 females) from the experimental dip net fishery. They were monthly harvested between September 2015 and August 2016. The results of Relationship between intestine length (Li) and standard length (LS) in Macrobrachium dux showed that the length of the intestine of individuals of this species is almost equal to standard length and grows proportionally to their size. Qualitative analysis showed that M. dux is an omnivorous species. It eats vegetable debris as fibers, fruits and phytoplanctons. It also eats animal debris such as insectes, crustaceans, annelids and plathyhelminthes. Concerning quantitative analysis, general food composition showed that this diet mainly consisted of animal debris. This animal fraction was dominated by insects (% FI = 42.85). Further study of the food ecology of this species taking into account sex, seasons and size classes gave the same results. M. dux is an omnivorous species that uses variable resources but with a preference for insects.***

Keywords: Feeding ecology, Freshwater Shrimps, Cavally River, Côte d'Ivoire, West Africa

1. Introduction

The species of fresh water *Macrobrachium dux* is generally neglected on the food plan by the public in Africa because of its small size nevertheless having an undeniable ecological role in the trophique network. Several works on the biology and the ecology of shrimps were led in Africa and particularly in Côte d'Ivoire [45, 46, 47, 48, 15, 16, 17, 27, 35, 36, 21, 6, 7, 8]. Some of these works among which those of [14], [34], [21] and [6] showed that this species is widely distributed in Côte d'Ivoire. It was found in most of the streams in Côte d'Ivoire. The previous studies where devoted to its systematics and to its distribution. In Africa, the studies concerning its diet are almost it not existing. [27] essentially centred its works on the food rhythm of this species in Benin. In Côte d'Ivoire, there are no research works on the food ecology of this species. An in-depth study of its food ecology taking into account the sex, the seasons and the classes of size remains. This study on Cavally River is the first one in Côte d'Ivoire. It was realized to define better the food habits of this shrimp and control its ecological role.

2. Materials and Methods

2.1 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 [12]. 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.

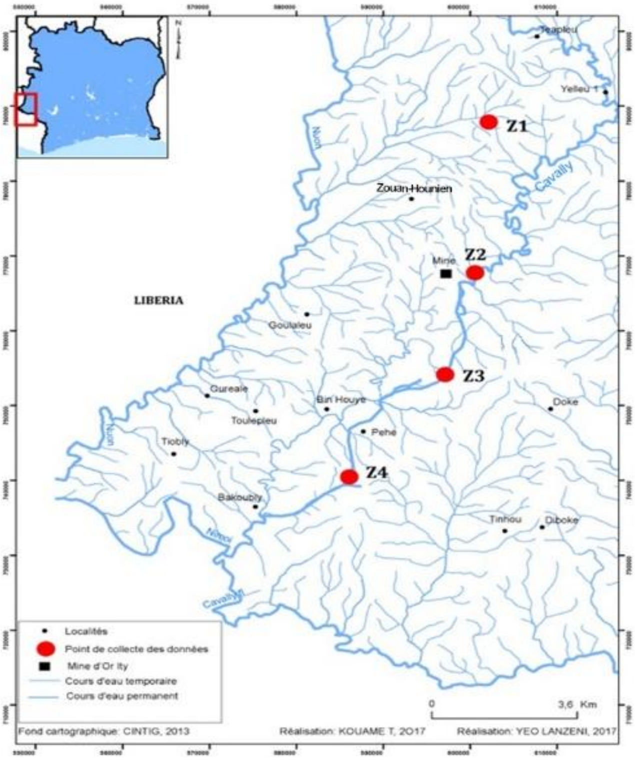

Figure 1: Stations sampled (●) and mining zone "Ity" (■) in the upper Cavally River (Côte d'Ivoire) from September 2015 to August 2016

2.2 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 [6]. 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 [31], [40], [16] and [21] identification keys.

2.3 Stomach contents analysis

In the laboratory, each specimen of *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 [32], [3], [9] and [5].

2.4 Data analysis

1) For this study, several methods and index were used to determine diet of *Macrobrachium dux*: **1) Vacuity coefficient (CV)** to evaluate feeding intensity according to [18] as follows: CV = (Nev / Nt) x 100; Where Nev = number of empty stomachs; Nt = total number of stomachs examined.
2) **Intestinal coefficient (IC)** according [38] characterizes the different trophic groups: IC = Li/Ls; Where Li = length of the intestine; LS = standard length of the shrimp. [38] 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
3) **Correct occurrence percentage (Fc)** [41] 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
4) **Point method coupled with the food index** according to [37] 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 [28], 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%.
5) **Size class** [42]**.** 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.
6) **Similarity index (α)** of [43] was used to compare the diet of *Macrobrachium dux* in different seasons (max probability retained *p*-level 0.06).

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

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 [11] 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.

3. Results and Discussion

3.1 Study of the intestinal coefficient of shrimps

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) = 0.760 log (LS) + 0.295 with a significant correlation (r = 0.87, $p < 0.05$).

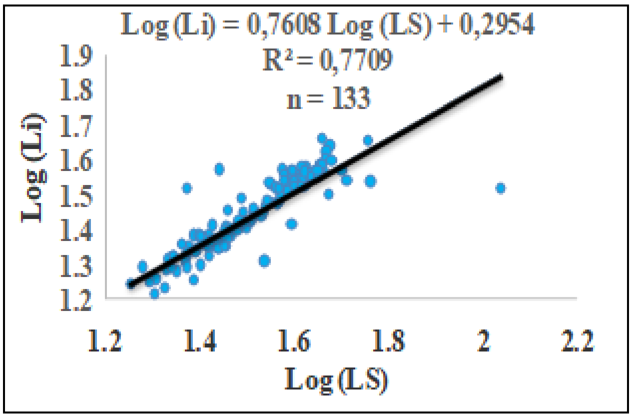

Figure 2: Relationship between intestine length (Li) and Standard length (LS) in *Macrobrachium dux* caught in the Cavally River between September 2015 and August 2016

The Spearman correlation test shows a significant correlation between Li and LS at p < 0.5 (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 [38, 25, 33].

The mean value of intestinal coefficient (IC) of *M. dux* was 0.95 ± 0.02. It is ranged between 0 to 1 for specimen standard length ranged between 18.02 and 47.77 mm. This high value of intestinal coefficient translates that the intestine of these shrimps is almost the same size with the whole body. *M. dux* obviously appears, on the basis of the intestinal coefficients found and, according to [38], as an omnivorous and insectivorous species.

3.2 General food profile of shrimps

Stomach contents of shrimp were analyzed for a total of 133 stomachs of *Macrobrachium dux.*

Quantitative analysis of stomach contents shows that animal debris (% FI = 45.98) mostly dominated by insects (% FI = 42.85) were dominant prey eaten by *Macrobrachium dux*. Secondary preys eaten by this species were composed by plant debris (% FI = 43.44) mostly dominated by filber (% FI = 38.18). This fraction constitute an essential prey for *M. dux*. These results are contrary to those of [27] who showed that plant debris was the most abundant constituents in the stomach of these shrimps.

3.3 Diet variation according sex

In *Macrobrachium dux*, 56 male stomachs were examined, of which 13 were empty. This corresponds to a vacuity coefficient of 23.21%. In females, 77 stomachs were examined, of which 28 were empty, giving a vacuity coefficient of 36.36%. When comparing the vacuity coefficient of both sexes, female's vacuity 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 [37], [17], [27] and [2].

Plant debris is a dominant prey item in males (%Fc = 52.44, %P = 40.88 and %FI = 50) but essential for females (% Fc = 34.89, %P = 25.23 and %FI= 37.76). The fibers are found predominantly in both sexes (males: %FI = 45.22 and females %FI = 32). The animal fraction is highly prized and is an essential prey for both sexes, male (%Fc = 39.03, %P = 49.06 and %FI = 46.38) and female (%Fc = 29.69, %P = 68.46 and %FI = 45.07).

Insects remain preferred prey for both sexes in this animal fraction (males: %FI = 43.27 and females %FI = 40.93). This polyphagia and this inclination towards meat products, observed generally in both sexes and in particular in females, could explain the cannibalism mentioned by [30] and [14].

Prey that could not be identified are secondary foods in males (%FI = 3.62) and important in females (%FI = 17.17) **(Table 1)**.

Table 1: Diet composition and prey classification in stomach contents of *Macrobrachium dux* 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 prey	**(%) Fc**		**%P**		**(%) FI**		**FA**	
VEGETABLE DEBRIS	Male	Female	Male	Female	Male	Female	Male	Female
Fibers	41.46	25.69	25.79	16.22	45.22	32	PE	PE
Fibrils	8.54	8.33	12.58	9.01	4.53	5.76	PS	PS
Fruits	0	0.87	0	0	0	0	PS	PS
Phytoplanktons	2.44	0	2.51	0	0.25	0	PS	PS
ANIMAL DEBRIS								
Insects	35.37	25.17	28.93	21.17	43.27	40.93	PE	PE
Scales	0	1.39	0	15.76	0	1.66	PS	PS
Crustaceans	0	0.87	0	6.76	0	0.45	PS	PS
Annelids	3.66	1.39	20.13	11.26	3.11	1.17	PS	PS
Plathyhelminthes	0	0.87	0	13.51	0	0.86	PS	PS
OTHERS	8.53	35.42	10.06	6.31	3.62	17.17	PS	PI
TOTAL								
VEGETABLE DEBRIS	52.44	34.89	40.88	25.23	50	37.76	PD	PE
ANIMAL DEBRIS	39.03	29.69	49.06	68.46	46.38	45.07	PE	PE
OTHERS	8.53	35.42	10.06	6.31	3.62	17.17	PS	PI

3.4 Seasonal variation in diet composition

During the dry season, 113 shrimp stomachs of *Macrobrachium dux* were collected and examined. 36 of them were empty with a vacuity coefficient (CV) of 31.85%. According to sex, 47 male shrimp stomachs harvested were thoroughly examined. Ten (10) stomachs were empty corresponding to a vacuity coefficient of 21.27%. In females, 66 stomachs were examined. Twenty six (26) were empty corresponding to a CV of 39.39%.

In the rainy season, 20 stomachs were obtained and examined including 05 empty. This corresponds to a vacuity coefficient (CV) of 25%. According to sex, out of a total of 09 analyzed male stomachs, 03 were empty giving a CV of 33.33%. In females, 11 stomachs were scanned with 02 empty giving a CV of 18.18%.

In both sex, coefficient of vacuity is relatively high in the dry season. The rise observed in the dry season may be due to the scarcity of food resources often correlated with the phenomena of competitions in the environment. In addition, the phenomena of recurring stress noted above, can also explain this increase of vacuity coefficient. Cases of similar stress conditions were mentioned by [26], [50], [36] and [1] during their works.

Regarding the composition of the diet of *Macrobrachium dux* (Table 3), the results of the stomach contents analysis revealed a high consumption of plant debris in the dry seasons (% Fc = 42.09, %P = 24.74 and %FI = 43.16). This consumption is more weak but essential in the rainy season with % Fc = 34.78; %P = 42 and %FI = 42.27. Plant debris were dominated by fibers. Ingestion of dietary fibers is essential in the dry season (%Fc = 31.19, %P = 13.06 and %FI = 37.13) and in the rainy season (%Fc = 34.78, %P = 42 and %FI = 42.27). The animal component of the diet is also essential for this species during periods of recession (% Fc = 33.18, %P = 70.45 and %FI = 46.03) but dominant during floods (% Fc = 34.78, P% = 53 and %FI = 53.33). Insects are also the most consumed prey in this animal fraction.

Their ingestion is essential in the dry season (%Fc = 28.71, %P = 15.81 and %FI = 41.33) but dominant during the rainy season (% Fc = 34.78, %P = 53 and %FI = 53.33). The indeterminate fraction is an important food consumed by these shrimp during dry season (%FI = 10.81) but ingested secondarily during rainy periods (%FI = 4.4) **(Table 2)**. These previous results are consistent with those of [44], [49] and [20] who have shown that in tropical environments, depending on flood and recession periods, fish's accessible food varies considerably, increasing in quantity and variety during high water and decreasing sharply during low water.

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 type of prey. *Macrobrachium dux* ate similar prey from season to season (α ≥ 0.6).

Table 2: Diet composition and classification of prey ate by *Macrobrachium dux* according to the seasons. 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); Rainy season (RS); Dry season (DS)

Types of prey	*(%) Fc*		*%P*		*(%) FI*		*FA*	
Vegetable Debris	DS	RS	DS	RS	DS	RS	DS	RS
Fibers	31.19	34.78	13.06	42	37.13	42.27	PE	PE
Fibrils	9.41	0	6.87	0	5.82	0	PS	PS
Fruits	0.5	0	3.44	0	0.14	0	PS	PS
Phytoplanktons	0.99	0	1.37	0	0.07	0	PS	PS
Animal Debris								
Insects	28.71	34.78	15.81	53	41.33	53.33	PE	PD
Scales	0.99	0	12.03	0	1.05	0	PS	PS
Crustaceans	0.5	0	18.9	0	0.84	0	PS	PS
Annelids	2.48	0	9.97	0	2.25	0	PS	PS
Plathyhelminthes	0.5	0	13.74	0	0.56	0	PS	PS
Others	24.73	30.44	4.81	5	10.81	4.4	PI	PS
Total								
Vegetable Debris	42.09	34.78	24.74	42	43.16	42.27	PE	PE
Animal Debris	33.18	34.78	70.45	53	46.03	53.33	PE	PD
Others	24.73	30.44	4.81	5	10.81	4.4	PI	PS

3.5 Diet variation with size

The study *of Macrobrachium dux* diet was performed considering only the full state of the stomachs obtained. Thus, 78 stomachs were considered out of a total of 133 taken for this study. The maximum value of shrimp size measured in this lot was noted and is 47.77 mm standard length. The minimum value obtained was 18.02 mm. Based on the Sturge rule, three size classes have been defined. These are: D1 = 18 ≤ LS ≤ 28 mm (N = 22); D2 = 29 ≤ LS ≤ 39 mm (N = 22) and D3 = 40 ≤ LS ≤ 50 mm (N = 34). Diet of the three size class was summarized in **Table 3.**

In the class 1, individuals are of small size and probably immature. The results of the study of the food composition of this group show an essential consumption of vegetable material (N = 25, %Fc = 40.99, %P = 41.76 and %FI = 45.48). Fiber consumption is higher than other components ranged among the plant fraction (%FI = 38.79). There is an absence of fruit in the group's diet. Food of animal origin is consumed essentially (N = 20, % Fc = 32.79, %P = 48.83 and %FI = 41.99). Insects are the most ingested prey among other animal components (%FI = 40.03). There is no ingestion of scales, crustaceans and platyhelminths. Unidentified food consumption is important in this class (%FI = 12.53).

In Class 2, shrimps are juveniles and relatively mediocre to small size. Their dietary pattern is almost identical to that of class D1 shrimps. Their consumption of organic material of vegetable origin is essential (N = 25, %Fc = 40.32, %P = 42.44 and %FI = 45.01) and consisting mainly of fibers (%FI = 39.35). There was an absence of phytoplankton consumption contrary to the results of class 1. Foods of animal origin are essential too (N = 21, %Fc = 33.87, %P = 49.42 and %FI = 43.96) and more softly weaker than those of plant origin. Ingesting insects accounts for the majority (%FI = 41.71) of all other animal components and there is an absence of consumption of scales and platyhelminths. Unidentified foods are also ingested significantly (%FI = 11.03).

In class 3, there were mature (adults) shrimps which were relatively larger size than those of the previous classes. Based on the index classification of the dietary index, foods of plant origin with N = 41, %Fc = 41, %P = 25.72 and %FI = 40.3 are classified as essential foods consumed by this group. Vegetable foods are represented mainly by fibers (%FI =35.9). There was an absence of fruit in plant foods. Animal prey with N = 33; Fc = 33, %P = 69.52 and %FI = 51.37 was dominant. In animal foods, insects are at the top of the list (%FI = 45.77) and there was no evidence of platyhelminths.

Table 3: Diet composition and classification of prey recorded size of *Macrobrachium dux* according to size classes. Frequency of occurrence (Fi); Points Percentage (%P); Food index (FI); Food appreciation (FA); Secondary prey (PS); Essential prey (PE); Important prey (PI) and Dominant prey (PD)

	Class 1 : [18-28[					**Class 2 : [29-39[**					**Class 3 : [40-50]**				
Types of prey	N	%Fc	%P	%FI	FA	N	%Fc	%P	%FI	FA	N	%Fc	%P	%FI	FA
Vegetable Debris															
Fibers	18	29.51	25.88	38.79	PE	19	30.65	24.42	39.35	PE	32	32	16.67	35.9	PE
Fibrils	6	9.84	12.94	6.46	PS	5	8.06	12.21	5.17	PS	8	8	8.1	4.35	PS
Fruits	0	0	0	0	PS	1	1.61	5.81	0.49	PS	0	0	0	0	PS
Phytoplanktons	1	1.64	2.94	0.23	PS	0	0	0	0	PS	1	1	0.95	0.05	PS
Animal Debris															
Insects	19	31.15	25.3	40.03	PE	18	29.03	27.33	41.71	PE	28	28	24.28	45.77	PE
Scales	0	0	0	0	PS	0	0	0	0	PS	2	2	16.67	2.24	PS
Crustaceans	0	0	0	0	PS	0	0	0	0	PS	1	1	7.14	0.48	PS
Annelids	1	1.64	23.53	1.96	PS	2	3.23	4.65	0.79	PS	2	2	21.43	2.88	PS
Plathyhelminthes	0	0	0	0	PS	1	1.61	17.44	1.46	PS	0	0	0	0	PS

Others	16	26.22	9.41	12.53	PI	16	25.81	8.14	11.03	PI	26	26	4.76	8.33	PS
Total															
Vegetable Debris	25	40.99	41.76	45.48	PE	25	40.32	42.44	45.01	PE	41	41	25.72	40.3	PE
Animal Debris	20	32.79	48.83	41.99	PE	21	33.87	49.42	43.96	PE	33	33	69.52	51.37	PD
Others	16	26.22	9.41	12.53	PI	16	25.81	8.14	11.03	PI	26	26	4.76	8.33	PS

Indeterminate foods are consumed secondarily by representatives of this group (% FI = 8.33). In this study, prey observed were more diverse in adults than in immature and juvenile shrimps. These results are similar with those of [19] for which the importance of prey in the diet increases with the size of the specimens. *Macrobrachium dux* feed on plant debris but mainly preferred animal preys irrespective of the size. Our results are contrary to those of [27]. This difference could be due to the varieties of aquatic habitats prospected. The feeding habits of *M.dux* therefore depend on the accessibility and availability of prey in its habitat. For [23] and [22], 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 [24] and [23]. According to them, the digestive system evolves according to the classes of size and conditions the diet to certain species.

4. Conclusion

The study of diet in *Macrobrachium dux*, in this 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 meat products is greater and consists mainly of insects. This variety of food consumed makes *M. dux* an omnivorous but carnivorous animal. The results of the study of the diet according to sex, seasons and size classes confirmed those of the general food profile. In view of these results, it appears that the culturability of these shrimps is high in the rearing environment. These results show that *M. dux*, despite its small size, is a potential breeding candidate for developing countries.

References

[1] Aboua, B. R. D. (2012). Développement d'un indice d'intégrité biotique piscicole pour la préservation de la biodiversité du fleuve Bandama. Thèse de Doctorat, Université Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire. 227 p.
[2] Boguhé, H. (2015). Biologie de la reproduction et exploitation de deux espèces de crevette du Genre *Macrobrachium*: *M. vollenhovenii* (Herklots, 1857) et *M. macrobrachion* (Herklots, 1851) du fleuve Bandama (Côte D'Ivoire). Thèse de doctorat de l'Université Félix Houphouët-Boigny de Cocody. Abidjan, Côte d'Ivoire. 216 p.
[3] Brown, D. S. (1994). Freshwater snails of Africa and their medical importance. Taylor and Francis Ltd, London. 608 p.
[4] Corredor, L. (1979). Identification, distribution et aperçus écologiques des crevettes d'eau douce de Côte d'Ivoire. Rapport DEA Océanographie Biologique, Paris, 6: 37 p.
[5] Dejoux, C.; Elouard, J. M.; Forge, P. and Maslin, J. L. (1981). Catalogue iconographique des insectes aquatiques de Côte d'Ivoire. Rapport ORSTOM, 42: 178 p.
[6] Djiriéoulou, K. C. (2017). Peuplements des crevettes des hydrosystèmes de marais et fluvio-lagunaires du Sud-Est de la Côte d'Ivoire: diversité, structure et croissance des populations. Thèse de Doctorat, Université Félix Houphouët-Boigny de Cocody, Abidjan, Côte d'Ivoire. 196 p.
[7] Djiriéoulou, K. C.; Bamba, M.; Konan, K. M.; N'Zi, K. G.; Gooré Bi, G. and Koné, T. (2017). Peuplement de la faune de crevettes de la Forêt des Marais Tanoé-Ehy (Sud-Est de la Côte d'Ivoire). Journal of Applied Biosciences, 112: 11100-11110.
[8] Djiriéoulou, K. C.; Konan, K. M.; Koné, T.; Bamba, M.; Gooré Bi, G. and Koné, I. (2014). Shrimp Assemblages in Relation to Environmental Characteristics of Four Shallow Rivers in South East Côte d'Ivoire. Turkish Journal of Fisheries and Aquatic Sciences, 14: 651-658.
[9] Durand, J. R. and Lévêque, C. (1981). Flore et faune aquatiques de l'Afrique sahelo soudanienne. Tome 2. ORSTOM, Paris. pp 391-873.
[10] Etim, L. and Sankare, Y. (1998). Growth and mortality, recruitment and yield of freshwater shrimp, *Macrobrachium vollenhovenii* Herklots, 1857 (Crustacea, Palaemonidae) in the Faye reservoir, Côte d'Ivoire, West Africa. Fisheries Research, 38: 211-223.
[11] Fritz, E. S. (1974). Total diet comparison in fishes by Spearman rank correlation coefficients. Copeïa, 1: 210-214.
[12] Girard, G. (1974). Données fragmentaires sur les régimes hydrologiques en Côte d'Ivoire. 22 p.
[13] Gooré, Bi G. (1992). Contribution à l'étude de l'écologie des crevettes du genre *Macrobrachium* (Décapode, Palaemonidae) des cours d'eau de Côte d'Ivoire. DEA, Université Nationale de Côte d'Ivoire. 50 p.
[14] Gooré Bi, G (1998). Contribution à l'étude des crevettes d'eau douce de Côte d'Ivoire: systématique, biologie et analyse socioéconomique de la pêche de *Macrobrachium vollenhovenii* (Herklots 1857) et de *M. macrobrachion* (Herklots 1851) (Crustacea Decapoda, Palaemonidae) du bassin de la Bia. Thèse de Doctorat 3e cycle, Université de Cocody-Abidjan, Côte d'Ivoire. 145 p.
[15] Gooré Bi, G.; Gourène, G.; N'douba,V. and N'Guessan, K. J. (2001). Rythme d'activité et rythme alimentaire de deux espèces de crevettes d'eau douce ouest africains: cas de la rivière Bia (Côte d'Ivoire). Sciences et Technonologie, Sciences naturelles et agronomie, 25 (2): 17- 24.

[16] Gooré Bi, G.; Kouassi, N. J. and Thys Van Den Audenaerde, F. E. D. (2002). Critères pratiques d'identification et peuplement des crevettes (Caridae) de la rivière Bia (Côte d'Ivoire). Bulletin de l'Institut fondamental d'Afrique noire Cheikh Anta Diop, Dakar, Sénégal. pp. 163-186.
[17] Gooré Bi, G.; Gourène, G.; N'Douba V. and N'Guessan, K. J. (2004). Stratégie de reproduction de deux espèces de crevettes d'eau douce *Macrobrachium vollenhovenii* (Herklots 1857) et de *M. macrobrachion* (Herklots 1851) de la rivière Bia (Côte d'Ivoire). Revue Internationale Sciences de la vie et de la terre, (4):116-127.
[18] Hureau, J. C. (1970). Biologie comparée de quelques poissons antarctiques (Nototheniidae). Bulletin de l'Institut Océanographique de Monaco, 68: 1-244.
[19] Hyslop, E. J. (1987). The growth and feeding habits of C. anguillaris during their first season in the foodplain pools of the Sokoto Ŕ Rima river basin, Nigeria. Journal of Fish Biology, 30: 183-192.
[20] King, R. P. (1989). Distribution, abundance, size and feeding habitat of Brienomyrus brachyistius (Gill, 1862) (Teleostei : Mormyridae) in a Nigerian rain forest stream. Cybium 13, 25-36.
[21] Konan, K. M. (2009). Diversité morphologique et génétique des crevettes des genres *Atya* Leach, 1816 et *Macrobrachium* Bate, 1868 de Côte d'Ivoire. Thèse de doctorat de l'Université d'Abobo-Adjamé, Côte d'Ivoire. 189 p.
[22] Koné, A.; Agnissan, A. J. P.; Kouassi, K. S. and N'Da, K. (2014). Régime alimentaire de deux requins : Sphyrna zygeana (Linnaeus, 1758) et Isurus oxyrinchus (Rafinesque, 1809) des côtes ivoiriennes. International Journal of Innovation and Applied Studies, 8: 1173-1186.
[23] Koné, T. (2000). Régime alimentaire et reproduction d'un tilapia lagunaire (Sarotherodon melanotheron Rüpell, 1852) dans la rivière Bia et le lac de barrage d'Ayamé (Côte d'Ivoire). Thèse de Doctorat. Katholieke Universiteit Leuven, Belgique. 253 p.
[24] Kouamélan, E. P. (1999). L'effet du lac de barrage d'Ayamé (Côte d'Ivoire) sur la distribution et écologie alimentaire des poissons Mormyridae (Teleostei, Osteglossiformes). Thèse de doctorat. Katholieke Universiteit Leuven, Belgique. 221 p.
[25] Kouamélan, E. P.; Gourène, G.; Teugels, G. G. and Thys van den Audenaerde, D. F. E. (1997). Diversité morphologique du tube digestif chez 39 espèces de poissons africains et relation avec la classification ichtyologique. Journal of African Zoology, 111: 109-119.
[26] Kouamélan, E. P.; Teugels, G. G.; N'Douba V.; Gooré Bi, G. and Koné, T. (2003). Fish diversity and its relationships with environmental variables in a West Africanbasin. Hydrobiologia, 505: 139-146.
[27] Kouton, M. D. (2004). Diversité, Ecologie et Exploitation des crevettes d'eau douce dans la basse vallée de l'Ouémé: cas de la commune d'Adjohoun au Bénin. Thèse pour l'obtention du Diplôme d'Ingénieur Agronome. Université D'Abomey-Calavi, Benin. 111 p.
[28] Lauzane, L. (1975). Régime alimentaire d' *hydrocynus forskalii* (Pisces, Characidae) dans le lac Tchad et ses tributaires. Cahiers ORSTOM Série Hydrobiologie, 9 (2): 105-121.
[29] Lévêque, C.; Dejoux, C. and Iltis, A. (1983). Limnologie du fleuve Bandama, Côte d'Ivoire. Hydrobiologia, 100: 113-141.
[30] Marioghae, I. E. (1982). Notes on biology and distribution of *Macrobrachium vollenhovenii* and *Macrobrachium macrobrachion*in the Lagos lagoon (Crutacean, Decapoda, Palaemonidae). Nigeria institute of oceanography and marine Research, Lagos, 96 (3): 507 p.
[31] Monod, T. (1980). Décapodes. *In* : DURAND J. R. & LEVEQUE, C. (éds.). Flore et faune aquatiques de l'Afrique sahélo-soudanienne. ORSTOM, Paris, Tome I, 44: 369-389.
[32] Needham, R. (1962). A guide to study of freshwater biology. San-Francisco Holden Day, Inc. 105 p.
[33] N'Da, A. S. (2015). Biodiversité, structure du peuplement ichtyologique et relations trophiques d'un bassin du Nord de la Côte d'Ivoire: cas de la rivière Bagoé. Thèse de Doctorat, Université Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire. 198 p.
[34] N'Zi, K. G. (2007). Diversité biologique des peuplements de crevettes d'eaux douces de Côte d'Ivoire en relations avec les variables environnementales du milieu. Thèse de Doctorat, Université de Cocody-Abidjan, Côte d'Ivoire. 178 p.
[35] N'Zi, K. G.; Gooré Bi, G.; N'Douba, V.; Koné, T.; Kouamélan, E. P. and Ollevier, F. (2004). Diversité biologique des crevettes d'un petit bassin côtier ouest africain, rivière Mé, Côte d'Ivoire en relation avec les variables environnementales, Sciences et Techniques, Sciences naturelles et agronomie, 27 (1 et 2): 17-27.
[36] N'Zi, K. G., Gooré Bi., G.; Kouamélan, E. P.; Koné, T.; N'Douba, V. and Ollevier, F. (2008). Influence des facteurs environnementaux sur la répartition spatiale des crevettes dans un petit bassin ouest africain: rivière Boubo (Côte d'Ivoire). Tropicultura, 26 (1): 17-23.
[37] Odum, O. and Oradiwe, U. (1996). Some aspects the biology of *Macrobrachium macrobrachion* (Herklots, 1851) in the Ethiope River, Nigeria (Crustacea: Decapoda Palaemonidae) Journal African Zoology: 53-60.
[38] Paugy, D. (1994). Ecologie des poissons tropicaux d'un cours d'eau temporaire (Baoulé, haut bassin du Sénégal au Mali): adaptation au milieu et plasticité du régime alimentaire. Revue Hydrobiogie tropical, 27: 157-172.
[39] Powell, C. B. (1980). The genus *Macrobrachium* in West Africa. I: *M. thysi*, a new large Egged species from Ivory Coast (Crustacea Decapoda Palaemonidae). Revue de Zoologie africaine, 94: 317-326.
[40] Powell, C. B. (1982). Fresh and brackish water shrimps of economic important in the Niger Delta. University of Port Harcourt. Present to the second conference of the fisheries society of Nigeria held at Calabar, 24-27 January: 1-45.
[41] Rosecchi, E and Nouaze Y. (1987). Comparaison de cinq indices utilisés dans l'analyse des contenus stomacaux. Revue des Travaux de l'Institut des Pêches Maritimes, 49: 111-123.
[42] Scherrer, B. (1984). Présentation des données. *In*: Biostatistique (Morin G., ed). Boucherville, Canada. pp 103-126.

[43] Schoener, T. W. (1970). Non-synchronous spatial overlap of lizards in patchy habitats. Ecology, 51: 408-418.

[44] Stout, R. J. (1982). Effects of a harsh environment on the life history of patterns of two species of tropical aquatic Hemiptera (Family: Naucoridae). Ecology, 63: 75-83.

[45] Troadec, J. P.; Garcia, S. and Petit, P. (1969). La crevette. In Les productions Animales. Le Guide de l'agriculteur en Côte d'ivoire (PAPE Akassey Raymond). Volume IV. 247 p.

[46] Ville, J. P. (1970). Recherches sur la reproduction des *Macrobrachium* des lagunes ivoiriennes. I: la fécondité précoce chez les *Macrobrachium* de Côte d'Ivoire. Annales de l'Université d'Abidjan, série. E, (Ecologie), 3 (1): 253-262.

[47] Ville, J. P. (1971). Ecologie des *Macrobrachium* de Côte d'Ivoire. Rôle de la température et de la salinité. Annales de l'Université d'Abidjan, série. E, (Ecologie), 4 : 317-324.

[48] Ville, J. P. (1972). Cycle ovarien saisonnier chez *Macrobrachium vollenhovenii* (Herklots1857), Décapode, Palaemonidae, en Côte d'Ivoire. Annales de l'Université d'Abidjan, série. E, (Ecologie), 5 (1): 561-576.

[49] Welcomme, R. L. (1985). River fisheries. FAO fisheries technical paper 262. Rome. 330 pp.

[50] Yao, S. S.; Kouamélan, E. P.; Koné, T.; N'Douba, V.; Gooré Bi, G.; Ollevier, F. and Thys Van Den Audenaerde, D. F. E. (2005). Fish communities along environmental gradients within the Comoé River basin, Côte d'Ivoire. African Journal of Aquatic Science, 30 (2): 185-194.