

Diet of *Hepsetus akawo* from the Tanoé-Ehy Marsh Forest TEMF (Côte d'Ivoire)

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ABSTRACT

The diet of *Hepsetus akawo* (Bolch, 1794) was studied in the 12,000 hectare large Tanoé-Ehy (TEMF) Côte d'Ivoire marsh forest. This study was carried out between October 2018 and September 2019, on a sample of 292 digestive tracts of *Hepsetus akawo*. The sizes of fish whose digestive tracts have been examined vary between 110 and 320 mm of standard length. These fish were caught each month using gillnets, nerve nets, hawks and hooks. Of these 292 tubes, 187 stomachs contained prey and 105 were empty, which corresponds to an emptiness coefficient of 35.96%. The general diet of *H. akawo* is composed of 9 items grouped into 5 categories of prey: Cyprinidae, Clupeidae, Cichlidae, Macrophytes, plants, and remains of insects. *H. akawo* feeds mainly on Cyprinidae which constitute the major part of its diet compared to small fish of the Cichlidae family including *Hemichromis bimaculatus* and Clupeidae including *Pellonula leonensis*.

Keywords: Diet, *Hepsetus akawo*, Tanoé-Ehy, Marsh Forest

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1. Introduction

Knowing how fish are fed in a natural environment is an essential step in understanding their biology and ecology. The study of the diet of *Hepsetus akawo* from the Tanoé-Ehy marsh forest (TEMF) gives indications on the presence, abundance and availability of prey but also on the trophic potential of the environment [1]. The foraging strategies, the variations in the diet of a species of fish from one environment to another and / or from one season to another, provide information on the adaptive capacities of this fish in the face of constraints of the environment [2]. Knowledge of the prey ingested as well as the feeding habits of *Hepsetus akawo* from the Tanoé-Ehy Marsh Forest (TEMF) is essential to understanding the feeding ecology of this species. Determining one's diet can help explain variations in growth, certain aspects of reproduction, migration, and foraging behavior [1]. Indeed, *Hepsetus akawo* is the new species described within the genus *Hepsetus* in eastern West Africa. It is mainly distinguished from *Hepsetus odoe* by a smaller number of lateral line scales and shallower head depth along the length of the head. *Hepsetus akawo* differs mainly from the recently rehabilitated *Hepsetus cuvieri* by: a higher number of gill gills and a lower number of scales between the dorsal fin and the lateral line [3]. In West Africa, the range of the new species is limited to the Sassandra River (Côte d'Ivoire) in the west to the Cross River (Cameroon) in the east. The species is entirely allopatric with *H. odoe*, which has a much more restricted distribution than previously thought and occurs from the Senegal River (Senegal) in the west to the Cavally River (Côte d'Ivoire) in east [3].

The objectives of this work are to examine the foraging habits of *Hepsetus akawo* captured in the Tanoé-Ehy Marsh Forest (TEMF) as a function of habitat, season, and size in relation to

the foraging habits of this species.

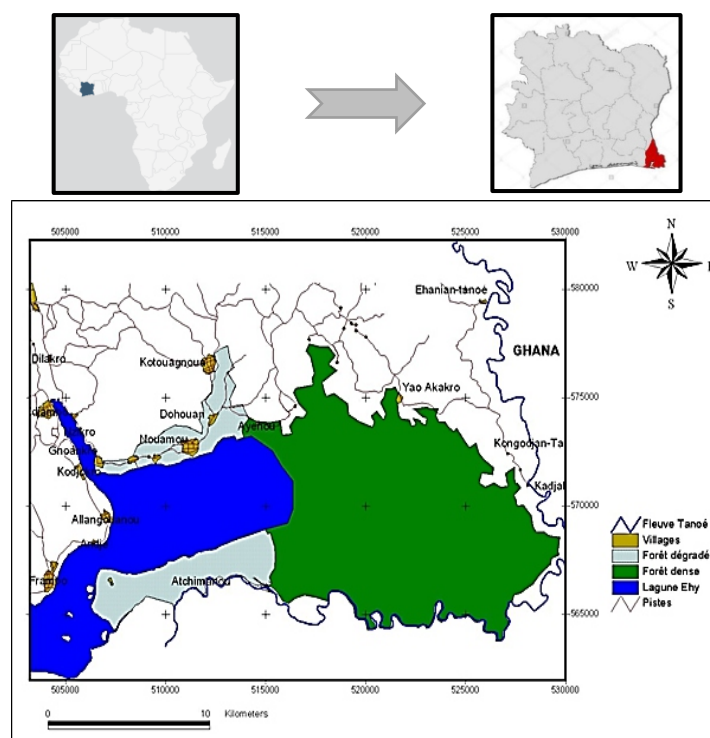


Figure 1: Geographical location of the Tanoé-Ehy Marsh Forest (TEMF)

2. Material and Methods

2.1. Study environment

The present study was carried out in the Tanoé-Ehy Marsh Forest (TEMF) (Ivory Coast). The Tanoé-Ehy Marsh Forest (TEMF) with an area of 12,000 hectares, is located at the

interface of several villages in the Department of Tiapoum and in the sub-prefectures of Noé, Nouamou and Tiapoum. Located in the Tanoé-Ehy area at the interface of the Tanoé River and the Ehy lagoon in the South-East of Côte d'Ivoire, the Tanoé-Ehy Marsh Forest (TEMF) is an unprotected forest heritage of the rural domain (figure 1).

2.2. Sampling of fish and data processing

The fish were caught through monthly campaigns between October 2018 and September 2019 using gillnets, nerve nets, sparrow hawks and hooks, measured and dissected then their stomach contents were fixed in a solution of 10% formalin. The nets were set in the evening between 6 p.m. and 7 p.m. and visited the next day at 8 a.m. and then at 12 p.m.

In the laboratory, each stomach was weighed, before and after incision, and the weight of the stomach contents was then determined. The empty stomachs were counted and the emptiness coefficient (Cv) which expresses the percentage of empty stomachs was calculated by the formula: $Cv = (N_v / N_t) \times 100$

where N_v is the number of empty stomachs and N_t is the total number of stomachs.

For stomachs containing food, their contents were washed through a series of 1000 μm , 500 μm , 250 μm , and 100 μm mesh sieves. The stomach contents are diluted through these sieves. The different solutions obtained are examined with a binocular magnifying glass. For the identification of phytoplankton taxa, observations are made under an optical microscope [4]. To determine the number of assemblies to be observed, the mixture is stirred and 1 ml is mounted between slide and coverslip. The experiment is repeated several times and with each assembly, the appearance of new species is noted, as well as the number of prey items already identified at each assembly. The number of prey items identified from the 3 ml is compared to 10 ml for a sample of 1 g of stomach contents. The total number of prey items present in the stomach contents is then determined by the rule of proportionality. They are then identified under a binocular magnifying glass down to the lowest taxonomic level possible, then grouped by species or family, counted, and weighed using electronic balances such as Ohaus (precision 0.01 g) and Sartorius (precision 0.001 g). The identification of phytoplankton taxa is made according to the keys of Komarek and Anagnostidis [5].

The relative importance index (IRI) which takes into account the percentages of occurrence (F), numerical (N), and weight (P), was used to characterize the trophic level of the species. Its formula is as follows:

$IRI = F(N+P)$.

The predominance index (I_p) has been used to determine the contribution of each food in the food regiment of *Hepsetus akawo* Tanoé-Ehy Marsh Forest TEMF, according to the formulae of Nataraja and Jhingran [6]. modified by Amundsen [7]:

$$I_p = \frac{F_c \times P}{\sum (F_c \times P)} \times 100$$

$$\text{With } F_c = \left(\frac{F_i}{\sum F_i} \right) \times 100 \text{ et } F_i = \frac{N_i}{N_t}$$

with F_i = frequency of prey i ; n_i = the number of stomachs containing a prey i and N_t = total number of studied full stomachs.

The weight percentage (P) has been determined according to Hyslop [8]:

$$P = \left(\frac{P_i}{P_t} \right)$$

Where P_i = weight of the item i and P_t = total weight of all the items.

Analysis of similarity ANOSIM has all the same been realized so as to compare the effects of seasons and the contribution of each category of prey in the dissimilarity between seasons.

2.3. Results

General composition of food regiment

In total, 292 digestive tubes of *Hepsetus akawo* whose sizes vary between 110 and 320 mm of standard length have been studied, 187 stomachs contained preys and 105 were empty, which correspond to a coefficient of vacuity of 35,96%. The general food regiment of *Hepsetus akawo* is recorded in Table I. it is made up of different types of foods, in majority constituted of fish (86,56 % of I_p). The whole is made of 3 items, divided into 3 orders: Cypriniformes, Clupeiformes and Perciformes. According to percentages of weight index, Cyprinidae (*Enteromius ablabes*, *Enteromius tripilos*, and *Enteromius eburneensis*) constitutes the principal preys followed by Clupeidae (*Pellonula leonensis*) in the category of important prey and others within prey accessories.

Variation of diet according to sites

Of the 187 full stomachs examined, 86 came from the Ehy lagoon, 60 from the Tanoé river and 41 came from fish caught in rivers, backwaters and marshes.

The list of the different taxa recorded at the different stations and their preponderance index are given in Table I. In total, 9 taxa were identified and found at all three stations. Based on the main food index, small fish appear as the main prey of *Hepsetus akawo* at all the sampling sites of the Tanoé-Ehy Marsh Forest (TEMF). Macrophytes composed of fruits and plant debris constitute the secondary prey on all items. In terms of fish, *Pellonula leonensis* is the most consumed prey in the three stations with 87.1%. The preponderance indices are 15.6%, 26.3%, and 25.1% respectively in the Ehy lagoon, the Tanoé River, and the river-backwater-marsh complex. *Enteromius ablabes* is considered to be secondary prey in fish with dominance in the area of the river-backwater-marsh complex (34.1%).

Table 1: Quantitative composition of the diet of *Hepsetus akawo* captured in the Tanoé-Ehy Marsh Forest TEMF. (% N = numerical percentage) depending on the sampling sites.

Taxons	Total	Stations		
		Lagoon Ehy	River Tanoé	Complex (river, marigots and marshland)
Fish	(% N)	(% N)	(% N)	(% N)
Cyprinidae				
<i>Enteromius ablabes</i>	23,1	33,6	18,1	34,1
<i>Enteromius tripilos</i>	26,7	20,9	26,9	20,7
<i>Enteromius eburneensis</i>	21,8	10,3	18,7	15,2
Clupeidae				
<i>Pellonula leonensis</i>	20,1	15,6	26,23	25,1
Cichlidae				
<i>Hemichromis bimaculatus</i>	5,4	18,31	8,3	1,4
Macrophytes				
Fruits	0,8	0,09	0,7	0,03
Plant Crumb	0,5	0,7	0,63	0,2
Unidentified				
Larvae	0,7	0,4	0,6	0,9
Insect remains				
	0,9	0,1	0,4	1,97
TOTAL				
Fish	97,1	98,71	98,23	96,5
Macrophytes	1,3	0,79	1,33	0,23
Others	1,6	0,5	0,44	3,27

Seasonal variations in diet

The taxonomic composition was analyzed taking into account two hydrological seasons (dry season and rainy season).

The comparative analysis of the composition of stomach contents shows that fish are dominant in the diet of *Hepsetus akawo* regardless of the season considered. *Pellonula leonensis* and *Enteromius ablabes* are the dominant prey at all sampling stations. Nevertheless, all five (5) fish taxa recorded on the three stations considered, appeared in the dry season and the rainy season. Similarity analysis (ANOSIM) calculated significant differences between prey assemblages from one season to another, regardless of the location of the sampling sites ($R = 0.185$, $p = 0.2$). This similarity analysis (ANOSIM) for the season indicates an average similarity in the rainy season of 60.26% while that of the dry season is 60.78% on all three sites. All similar taxa in the three sites considered have a cumulative contribution of 91.35% in the rainy season and those of the dry season have a cumulative contribution of 90.74%.

Table 2: Seasonal variations in the diet of *Hepsetus akawo* captured in the Marsh Forest of Tanoé-Ehy TEMF (% N = numerical percentage) depending on the sampling sites and the seasons.

Taxon	Total	Stations					
		Ehy lagoon		River Tanoé		Complex (rivers, marigots, and marshland)	
		Ss	sp	Ss	sp	Ss	sp
Fish	(% N)	(% N)	(% N)	(% N)	(% N)	(% N)	(% N)
Cyprinidae							
<i>Enteromius ablabes</i>	33,6	36,8	34,8	45,2	20,2	41,1	28,41
<i>Enteromius triples</i>	12,41	23,5	22,1	30,9	20,10	10,7	30,21
<i>Enteromius eburneensis</i>	29,31	11,01	12,5	11,54	9,28	18,36	10,33
Clupeidae							
<i>Pellonula leonensis</i>	11,9	16,99	18,9	6,3	36,15	27,0	25,1
Cichlidae							
<i>Hemichromis bimaculatus</i>	9,2	8,21	8,57	5,5	6,8	1,4	2,4
Macrophytes							
Fruits	1,2	0,98	0,98	0,56	5,3	0,03	0,9
Plant Crumb	0,7	0,59	0,5	-	0,9	0,2	0,8
Unidentified							
Larvae	0,78	0,94	0,95	-	0,4	0,9	0,6
Insect remains	0,9	0,98	0,7	-	1,0	0,22	1,25
TOTAL							
Fish	96,42	96,51	96,87	99,44	92,36	98,65	96,45
Macrophytes	1,9	1,57	1,48	0,56	6,20	0,23	1,7
Others	1,68	1,92	1,65	-	1,44	1,12	1,85

Study of diet according to the sex of individuals

Analysis of the diet of *H. akawo* by sex identified three groups of items in both males and females (Table 3). In both sexes, the prey is divided into three taxa (fish, macrophytes, and insects). The relative abundance of food revealed that fish are the main prey for males and females with values of 61.89% and 52.80%, respectively. In the general diet, macrophytes (IRI = 26.27%) and insects (IRI = 20.93%) are secondary items in the diet of females. On the other hand, insects (IRI = 27.62%) represent the secondary prey in the diet of males. The Spearman correlation coefficient calculated from the relative abundance of items indicates that the diets of males and females are not significantly different ($N = 3$; $R = 0.7$; $p = 0.2$).

Table 3: Variations in the diet of *Hepsetus akawo* captured in the Marsh Forest of Tanoé-Ehy TEMF according to the sex of the individuals (% N = numerical percentage, % P = weight percentage, % F = percentage of occurrence, IRI = relative importance of items)

Items	Males				Females			
	% O	%N	%P	IRI	% O	%N	%P	%IRI
Fish	76,69	63,56	64,11	61,89	78,05	47,44	66,97	52,80
<i>Enteromius ablabes</i>	24,2	18,28	19,3	22,2	30,2	11,3	19,4	13,6
<i>Enteromius tripilos</i>	29,2	21,1	21,2	13,5	13,1	9,66	10,6	20,3
<i>Enteromius eburneensis</i>	9,5	11,1	8,51	13,62	15,69	9,78	21,6	5,12
<i>Pellonula leonensis</i>	10,2	10,2	9,66	11,1	5,89	13,2	11,66	6,17
<i>Hemichromis bimaculatus</i>	3,59	2,88	5,44	1,47	13,26	3,5	3,71	12,73
Macrophytes	20,33	18,02	19,42	10,49	19,33	29,50	23,76	26,27
Fruits	15,3	13,11	15,77	5,36	10,62	15,3	11,14	11,29
Plant crumb	5,03	4,91	3,65	5,13	8,71	14,2	12,62	14,98
Unidentified	2,98	18,42	16,47	27,62	2,62	23,06	9,27	20,93
Larvae	1,1	10,3	9,88	8,45	1,3	12,36	2,66	9,65
Insect Remains	1,88	8,12	6,59	6,64	1,32	10,7	6,61	11,28
TOTAL	100	100	100	100	100	100	100	100

Study of the diet according to the size of individuals

The analysis of stomach contents as a function of the size of the fish is shown in Figure 1. Of all the prey listed in *H. akawo* captured in the Tanoé-Ehy Marsh Forest (TEMF), three categories of prey (fish, insects, and macrophytes) are represented both in individuals of group I ($LS \leq 120$ mm) and in individuals of group II ($LS > 120$ mm). Based on materiality (RRI), fish are the primary prey in the two defined groups of individuals. They constitute 56.85% and 75.81% of the diet of *H. akawo* respectively in group I (juveniles) and in group II (adults). Insects and macrophytes represent a significant part of the diet of individuals of group I ($LS \leq 120$ mm) and constitute secondary prey with respective proportions of 18.66% and 20.30%. In group II, insects (IRI = 15.30%) and macrophytes (ARI = 8.89%) constitute the secondary prey. The comparative analysis of the diet according to size revealed a difference between the diets of the specimens of group I and those of group II ($N = 3$, $R = 0.80$, and $p = 0.03 < 0.05$).

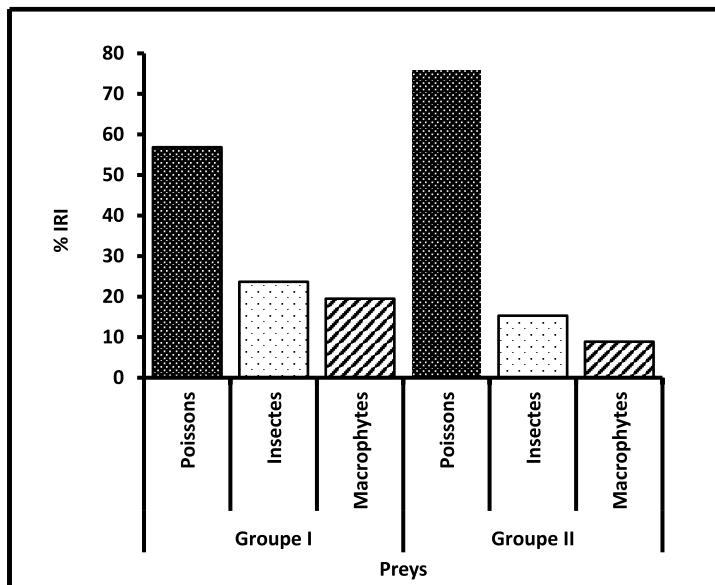


Figure 2: Diet of *Hepsetus akawo* from the Marsh Forest of Tanoé-Ehy TEMF according to the standard length of individuals (IRI: Relative Importance of Items, Group I: $LS \leq 120$ mm, Group II: $LS > 120$ mm)

Discussion

The general diet profile of *Hepsetus akawo* from the Tanoé-Ehy Marsh Forest (TEMF) confirms that this species is an ichthyophagous predator. The qualitative analysis of stomach contents identified seven items in the diet of *H. akawo* in the swamp forest. This food spectrum seems restricted. However, it is made up of prey including fish, insects and macrophytes. Quantitatively, the diet has shown that this species preferentially eats small fish, mainly *E. Ablas* and *E. Tripilos*. The abundance of these prey in the diet of *H. akawo* is explained by the fact that this species has a piscivorous diet [9]. The diet of *H. akawo* is almost identical to that of *H. odoe*, *P. obscura*, and *M. electricus*, which also consume almost exclusively fish. These results are similar to those of the work carried out in the Ogun River where *H. Odoe*, in addition to fish as main prey, consumes aquatic insects, shrimps, and zooplankton [10]; [11]. The presence of macrophytes in the stomachs of *H. akawo* could be explained by the decrease in live prey in the living environment of this species. The low rate of the vacuity coefficient of *H. akawo* captured in the Tanoé-Ehy Marsh Forest (TEMF) is thought to be because this species feeds continuously.

Analysis of the *H. akawo* diet as a function of space shows that fish are the main prey at all stations.

This could be explained by its presence throughout the Tanoé-Ehy marsh forest area TEMF [12]. In addition, the presence of terrestrial insects would be linked to runoff water which brings to aquatic environments a significant amount of organic matter (which may include plant matter and/or insects) and nutrients of terrestrial origin which enrich these environments. [13]. In addition to this nutrient supply, insects and other terrestrial organisms, fruits and plant debris could also possibly fall into the water under the effect of wind and rain and thus serve as prey for fish [14].

Based on the Materiality Index (RRI), fish represent the preferred prey of both males and females of *H. akawo*. The diet of *H. akawo* according to season and space does not vary significantly. This species feeds mainly on fish all year round. However, small fish from the Cyprinidae family make up most of its diet, ahead of small fish from the Cichlidae family including *Hemichromis bimaculatus*, and Clupeidae including *Pellonula leonensis*.

Indeed *H. akawo* is a fish with a long muzzle, a large mouth, and jaws furnished with conical teeth arranged in three rows: an external row of strong teeth, a row of impacted teeth lying in a gutter under the functional series, and an inner row of smaller teeth. The study of the *H. akawo* diet according to the size of the individuals shows that the diet spectrum specializes since juvenile age. All types of prey are eaten in both small individuals (group 1) and large individuals (group II) in the three stations. This similarity in the diet of juveniles and adults is due on the one hand to the search for energy for growth in the former and for reproduction in the latter. According to Ikhwanuddin [15], fish select foods that can provide them with the maximum energy to perform growth and reproduction functions [16].

Conclusion

This study shows that *H. akawo* has a very restricted food spectrum which gives it the status of ichthyophagous fish with a piscivorous tendency. Almost 70% of its diet consists of fish and consists of small fish from the Cyprinidae and Cichlidae families. The eating habits of *H. akawo* captured in the Tanoé-Ehy Marsh Forest (TEMF) do not change according to the seasons, the sex, and the size of the individuals. The hydrographic regimen of the Marsh Forest would be an asset for this species.

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