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Feeding habits of *Synodontis nummifer*, 1899 (Siluriformes: Mockokidae), from lower course of Tsiémé River (tributary of right bank of Congo River)

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Abstract

This study is a contribution for knowledge of feeding habits of Synodontis nummifer from the lower course of Tsiémé River, captured monthly using cast nets. The analysis of 460 stomach contents has been conducted from January 2013 to December 2014, according to class size, sampling season and sex. The size of specimens were between 32.25 and 101.71mm, for an average of 63.73 ± 13.46mm; the vacuity coefficient was 13%. The food spectrum of S. nummifer consists mainly of sand (Ip= 51.83%) and unidentified prey (Ip= 20.18%). The change in diet is observed depending on the size, with a tendency to entomophagy for small specimens. The diet varies also with the seasons, sand is the main prey during the dry season and insects became main prey during the rainy season. There is no difference between the sexes. The food composition and the intestinal coefficient revealed that Synodontis nummifer is an omnivorous species.

Keywords: Tsiémé River, *Synodontis nummifer*, Diet, Intestinal coefficient, Omnivorous, Congo Brazzaville.

Introduction

The family of Mockokidae which includes fish of the genus Synodontis are commonly referred to as squeakers or upside-down catfishes. Their distribution extends from the Nile basin, Chad, Niger and West African regions. The genus Synodontis is the richest in species of the African ichthyofauna. This genus is in fact the most diversified, after that of the Barbus[1]. Currently, it includes 119 described species[2], which are commercially important[3]. Studieson the genus Synodontis has been conducted in many African rivers : *S. bastiani*[4]; *S. schall*[5,6]; *S. nigrita*[5]; *S. resupinatus*[6]; *S. koensis*[7]; *S. membraneceus*[8]; *S. victoriae*[9-11]; *S. afrofischeri*[10] and *S. schoutedeni*[12] *Synodontis nummifer* is an endemic species from the Congo Basin[13], distributed along the Congo River in the Republic of Congo, the Democratic Republic of Congo and Cameroon[1,14,15].

Analysis of fish diet in the natural environment is necessary for understanding their biology, ecology, ethology and physiology[16-18]. Fish diet studies must also precede the implementation of a conservation or management policy for fish populations[19]. *Synodontis nummifer* like all species of Mochokidae, is a very appreciated by local population. Despite its ecological and socio-economic importance, there are no diet studies onthis species; except for the one qualitative study carried out in Tumba Lake and Ikela region in Democratic Republic of Congo[20]. Thus, the present study provides qualitative and quantitative informations on *S. nummifer* diet flower course of Tsiémé River, according to the size, the season and the sex.

Materials and Methods

The Tsiémé River, tributary of the right bank of the Congo River which crosses Brazzaville, is located between 4°09' and 4°16' south latitude and 15°12' and 15°18' east longitude[21]. The source of this river is located in Djiri district under the hills of the Massengo district. It flows north-west then south-east and flows into the Congo River upstream from Yoro port in Talangaï district (Figure-1).

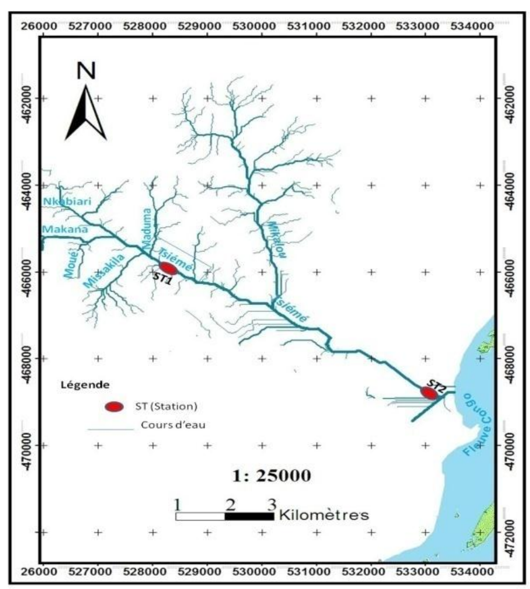

Figure-1: Location of the sampling site on the Tsiémé River.

Sampling and analysis of stomach contents: The monthly samples of *Synodontis nummifer* were taken at the Station 2 of the lower Tsiémé River, from January 2013 to December 2014. The cast nets were used for capturing specimens, which were stored in formalin 10%. In the laboratory, the fixed fish were immersed in a large volume of water in order to remove the formalin. The standard length was measured to the nearest millimeter. After dissection of the specimens, the digestive tract was highlighted in order to take pictures. The intestine were measured, the stomach contents are extracted, examined and sorted under a binocular magnifier before being weighed to the nearest mg; prey identification were done by several authors[22-26]. The qualitative and quantitative diet analysis has been carried using following indices.

Intestinal coefficient (IC): The intestinal coefficient makes it possible to predict the diet of the species studied; it is calculated by the following formula[27]:

$$IC = \frac{IL}{SL}$$

Where: IL is intestinal length; SL is standard length.

Vacuity coefficient (V): It is the ratio in percentage between the empty stomachs number (Ev) and examined stomachs number (N). This report makes it possible to specify the existence of trophic rhythms and to assess the availability of resources in the fish life environment[28].

$$V = \frac{E_v}{N} x100$$

Where V is the vacuity percentage; Ev is the empty stomachs number; N is the examined stomachs number,

Percentage of occurrence (%OC): It is the degree of presence of a prey or a prey category in relation to the examined stomachs.

$$\%OC = \frac{E_p}{E_e} x100$$

Where: Ep is the number of stomachs containing a category of prey; Eeis the total number of examined stomachs. This method provides information on prey items frequently consumed by fish. However, itdoes not provide any quantitative indication on the importance of different prey[29,30].

Weight percentage: It is the percentage ratio of a prey weight or a prey category (Pi) to the consumed prey total weight (Pt).

$$P = \frac{P_i}{P_t} x100$$

Where: Pi is the individuals total weight of the same species i ; Pt is the preytotal weight.

Preponderance index: Preponderance index (Ip) is a mixed index having the advantage of integrating the percentages of occurrence and weight, allowing a much more real interpretation of the diet, by minimizing the biases caused by each of these percentages[31,32]. Each percentage used alone would possibly lead to bias in the diet assessment. The prey are classified according to the value of this preponderance index, the formula is as follows[33]:

$$I_p = \frac{\%Oc \text{ x } \%P}{\sum(\%Oc \text{ x}\%P)} x100$$

Where: Ip is the preponderance index; % Oc is the occurrence percentage; P %is the weight percentage.

The value of the preponderance index makes it possible to classify the different prey[34]: the prey is accessory if Ip is less than 10; the prey is considered secondary when Ip is between 25 and 10. It is important if it is between 50 and 25 and the prey is main when Ip is greater than 50.

Horn's dietary overlap index: This index makes it possible to assess the degree of food overlap of specimens between seasons, sexes and size classes. It is given by the following formula[34]:

$$C\lambda = \frac{2\sum_{i=1}^{s} xi.yi}{\sum_{i=1}^{s} xi^2 + \sum_{i=1}^{s} yi^2}$$

Where: S is the food items total number; xi is the proportion of prey i consumed by specimens during a season x;yi is the proportion of a prey consumed by specimens during a season y. The overlap index (Cλ) varies between 0 and 1. The samples are completely separate when Cλ is equal to 0 and the samples are identical when it is equal to 1. Diets are significantly overlapping when the Cλ value is greater than or equal to 0.6.[36]
Sturges' rule was used to determine the size class[37]:

$$IC = \frac{LS \text{ maxi } - LS \text{ min}}{NC}$$

$$NC = 1 + (3{,}3 \text{ Log } N)$$

Where: CI is the class interval; LS maxi is the maximum standard length; LS min is the minimum standard length; NC is the classes number and N is the specimens number.

Data analysis: The ascending hierarchical classification analysis carried out from the matrix “preponderance index of different foods/size class samples” was used to show the degree of dietary similarity between the different size classes.

Results and Discussion

Description of the external morphology of the digestive tract: The structure study of the digestive tract of *Synodontis nummifer* has highlighted the different parts of this organ. The esophagus is short, followed by a thick U-shaped stomach, not surrounded by the pyloric coeca. The relatively short intestine ventrally surrounds the stomach and then continues forming a loopin the rectum (Figure-2).

Vacuity coefficient: Of the 460 stomachs of examined *S. nummifer*, 400 contained food and 60 were empty, the emptiness coefficient was equal to 13%.

Intestinal coefficient: A sample of 460 specimens of *S. nummifer* collected from the lower Tsiémé was examined. The determination coefficient r^2 was equal to 0.60, the correlation coefficient r is equal to 0.78. The intestinal coefficient was between 0,40 and 2,04mm, the average is equal to 0,92 ± 0,2 mm, which indicates that *S. nummifer* intestine is relatively short. It is predictive of an omnivorous diet (Figure-3).

General composition of trophic structures: Fourteen types of food items divided into four groups have been identified in the stomachs and intestines of *S. nummifer*: invertebrates (insects, arachnids and molluscs) vertebrates (fish); plants (plants debris and algae) and other prey consisting of in prey and sand (Table-1). This study were done according to the specimens size, the season and the sex. The general composition of the trophic structures of *S. nummifer* shows that sand is the main prey of *S. nummifer* with 53.81% of the preponderance index; the prey neither constitute the secondary prey with 20.18% and the rest of the prey (plant debris, nematodes, diptera, algae, annelids, unidentified insects, ephemeroptera, hymenoptera, beetles, molluscs, fish and arachnids) are accessory prey with preponderance index lower than 5%. This result was highlighted by other authors[20,38,39], indeed, they showed that *S. nummifer* isa species which exploites benthic invertebrates, various plants and animals, especially insect larvae and molluscs, but also oligochaetes, ostracods, terrestrial insects and scales. On the left bank of Pool Malebo (Congo River), the study of diet of seven species of Synodontis (S. *angelicus*, S. *acanthomias*, S. *alberti*, S. *congicus*, S. *decorus*, S. *greshoffi* and S. *notatus*) concluded that these fish have an omnivorous benthophage diet[39]. Another study carried out on the rigth bank of Pool Malebo, showed that *S. schoutedeni* of Tsieme River is omnivorous[12].

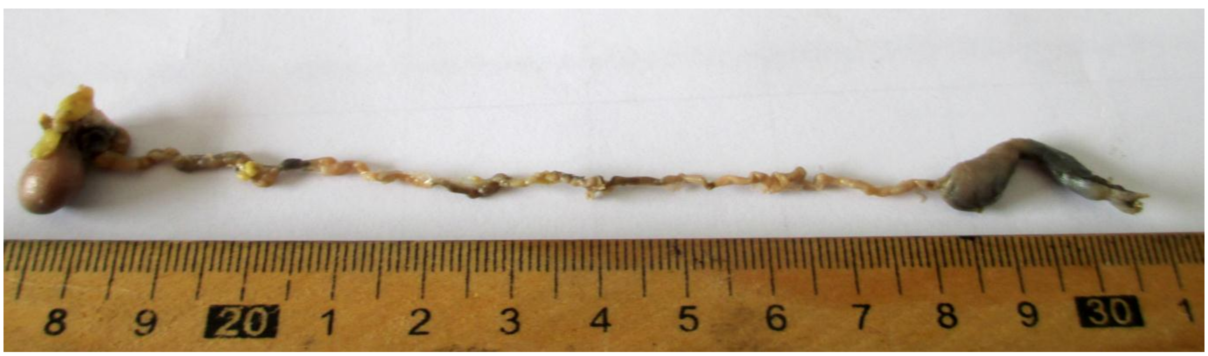

Figure-2: Unrolled digestive tract of *Synodontis nummifer*.

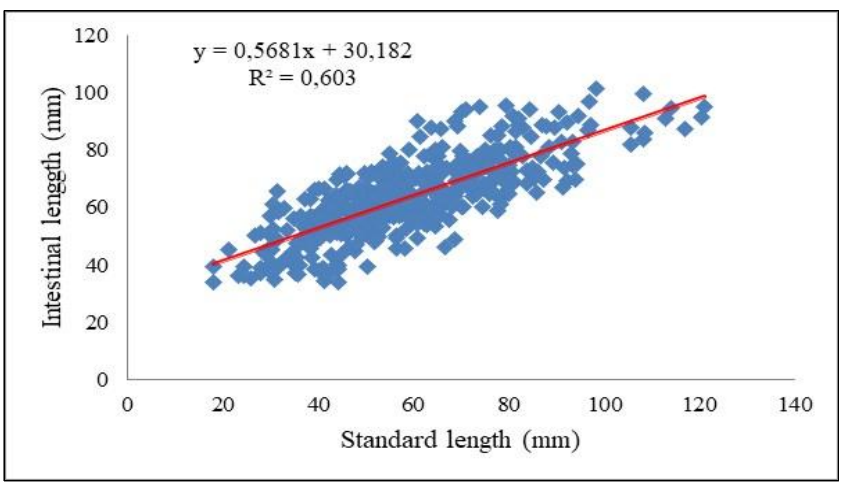

Figure-3: Evolution of intestine length according to standard length of *S. nummifer*.

Variation in diet according to the size class: The analysis of the diet of *S. nummifer* by size class shows that the consumption of sand increases with the size of the specimens. Sand represents the main prey consumed in classes 5, 6, 7, 8 and 9-10 with the respective preponderance indices of 69.45%, 67.80%, 73.54%; 77.94% and 63.82%. The consumption of insects decreases while the size of the specimens increases, the insects which are secondary prey in classes 3,4,5, become accessory prey in classes 6,7,8,9-10. Nematodes are secondary prey in class1 and 2, they are accessory prey for the rest of the classes. Plants and annelids are accessory prey in all classes with preponderance index less than 10 (Figure-5).

The ascending hierarchical classification analysis carried out on the basis of the preponderance index of the different food items calculated in each size class makes it possible to consider four groups of size classes (Figure-6). Group 1 is made up only of specimens of class 1 and group 2 is 2 is made up of specimens of class 2. Group 3 is made up of specimens of size classes 4 and 3. Group 4 is made up of specimens of classes 5, 6, 7, 8 and 9-10. The diet between the different size classes of *Synodontis nummifer* shows that specimens of classes 1 and 2 consume more insects. However, specimens from classes 3 to class 9-10 consume more sand. This variation in diet depending on the size of the specimens may be linked to the ability to find the preferred food and its digestibility. This dietary change may be linked to changes in certain anatomical and morphological structures of the food system[40,41].

Table-1: General profile of the diet of *S. nummifer.*

Prey		% OC	% P	I_p
Invertebrates	Nematodes	11.98	5.67	5.41
	Annelids	8.12	5.37	3.47
	Coleoptera	0.60	0.30	0.01
	Diptera	11.98	4.55	4.34
	Ephemeroptera	2.60	1.37	0.28
	Hymenoptera	2.13	0.76	0.13
	Unidentifiedpreys	7.99	3.10	1.97
	Molluscs	0.33	0.16	0.00
	Arachnids	0.13	0.02	0.00
Vertebrates	Fishes	0.87	0.16	0.01
Plants debris	Algaes	8.26	1.87	1.23
	Plants debris	12.38	9.28	9.15
Otherprey	Sand	12.32	54.89	53.81
	Unidentifiedprey	20.31	12.49	20.18

% Oc: occurrence percentage; % P: weight percentage; IP: weight index; ni: not identified.

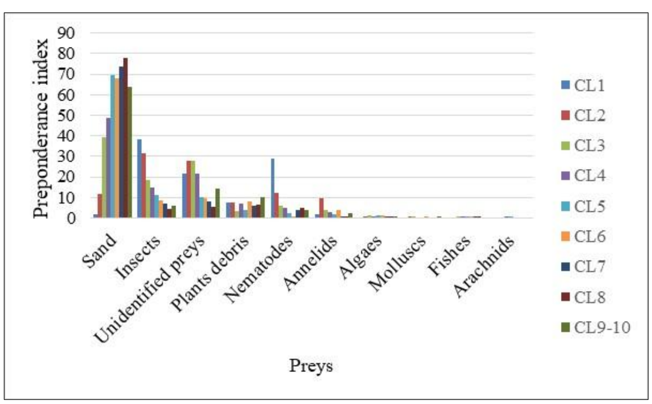

Figure-4: Diet composition of S. *nummifer* according to the size class.

Variation in diet according to the hydrological season: The diet composition of the *Synodontis nummifer* indicates a seasonal variation. In the rainy season, insect constitute the important prey of *S. nummifer* with a preponderance index equal to 38,94%; nematodes and unidentified prey constitute secondary prey with respective preponderance indices of 24.37% and 24.29%. Sand, plant debris, annelids, fish and molluscs are accessory prey with indices less than or equal to 7%. In the dry season, sand is the main prey with a preponderance index equal to 66.67%; unidentified prey forms secondary prey. The rest of the prey (insects, nematodes, plant debris, annelids, fish, arachnids, algae and molluscs) constitute the accessory prey (Figure-7). The difference in *S. nummifer*'s diet between the two seasons is significant, since the overlap index Cλ is less than 0.60 and equal to 0.25[42]. The same observations were made for *S. schall* of the central delta of the Niger and *Synodontis batiani* of the fluvio-lacustrine complex of the Bia (Ivoiry Coast), where a seasonal difference was observed in the relative importance of food[4,40]. This indicates that in tropical environments, the quantity and quality of available food can vary considerably according to the season.

Variation in diet according to the sex: The analysis of diet according to sex of *Synodontis nummifer* showed that the preponderance of sand is higher in both sexes, respectively 55.04% in males and 62.57% in females, respectively. Plant debris, nematodes, annelids, algae, fish, molluscs and arachnids are accessory prey with preponderance index less than or equal to 7% (Figure-8). *Synodontis nummifer*'s diet According to sex show no significant difference between males and females because the index of food overlap between the two sexes is equal to 0.99. These results can be explained by the availability of resources in the environment. The ingestion of sand is considerable and represents in males (Ip = 55.05%) as in females (Ip = 62.57%) the main food. The other prey consumed the most consumed group of prey in males (Ip = 72.20%) as in females (Ip = 75.47%). The same observations were made in *Synodontis koensis*, where there was no significant difference in the consumption of prey in males as in females[7].

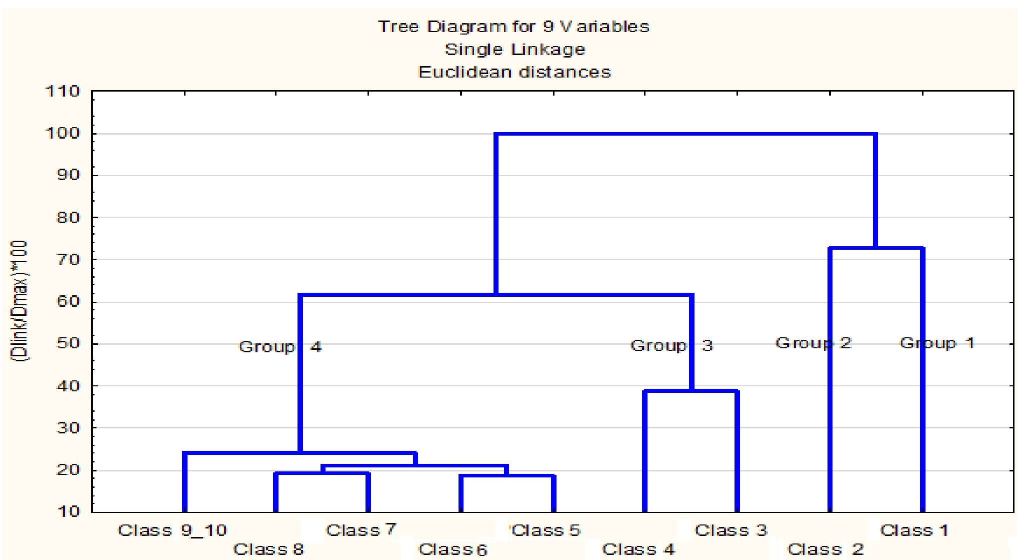

Figure-5: Dendrogram showing dietary similarities between different size classes of S. *nummifer.*

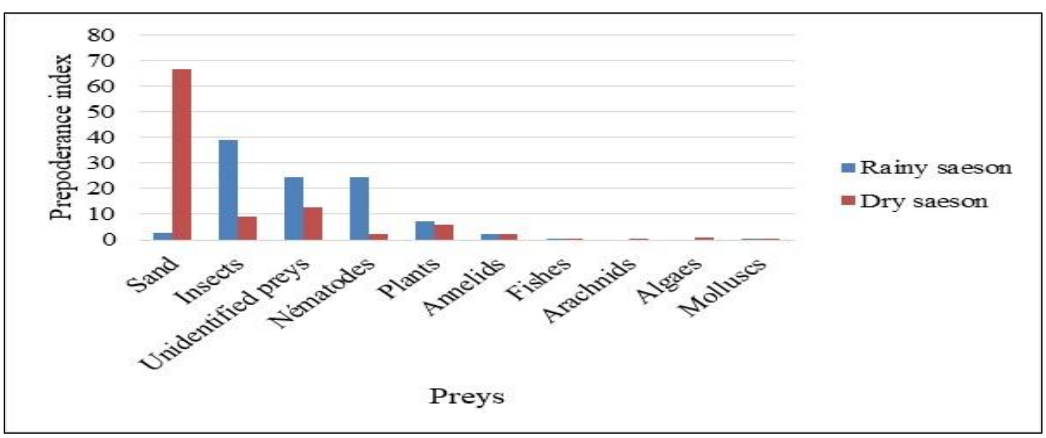

Figure-6: Diet composition of *S. nummifer* according to the season.

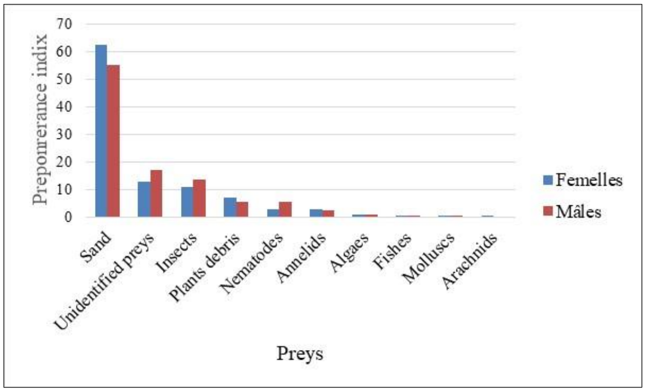

Figure-7: Diet composition of *S. nummifer* according to the sex.

Conclusion

A study of the trophic ecology of *Synodontis nummifer* has shown that this species has a thick-walled stomach and a relatively short intestine and an omnivorous type diet. The trophic spectrum differs according to size class, so that class 1-2 is mainly entomophagous. The entomophagy decreases as specimen size increases. On the other hand, the consumption of sand is higher in tall individuals. Analysis of the stomach contents according to the season showed a significant difference in the prey absorbed by the fish. The diet of S. *nummifer* does not vary according to the sex.

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