Scientific Research Publishing

Journal of Environmental Protection, 2020, 11, 954-976
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

Diet and Food Consumption of the African Catfish, *Chrysichthys nigrodigitatus* Lacépède (1803) (Siluriformes: Claroteidae), from the Hydrosystem Lake Togo-Lagoon of Aného (South of Togo)

Kamilou Ouro-Sama[1*], Komlan Mawuli Afiademanyo[2], Hodabalo Dheoulaba Solitoke[1], Gnon Tanouayi[1], Tchaa Esso-Essinam Badassan[1], Housséni Ahoudi[1], Kissao Gnandi[1]

[1]Laboratoire de Gestion, Traitement et Valorisation des Déchets (GTVD), Faculté des Sciences, Université de Lomé, Lomé, Togo
[2]Laboratoire d'Ecologie Animale et d'Ecotoxicologie, Département de Zoologie et Biologie Animale, Faculté des Sciences, Université de Lomé, Lomé, Togo
Email: *ouro_kamilou@yahoo.fr

How to cite this paper: Ouro-Sama, K., Afiademanyo, K.M., Solitoke, H.D., Tanouayi, G., Badassan, T.E.-E., Ahoudi, H. and Gnandi, K. (2020) Diet and Food Consumption of the African Catfish, *Chrysichthys nigrodigitatus* Lacépède (1803) (Siluriformes: Claroteidae), from the Hydrosystem Lake Togo-Lagoon of Aného (South of Togo). *Journal of Environmental Protection*, **11**, 954-976.
https://doi.org/10.4236/jep.2020.1111060

Received: October 10, 2020
Accepted: November 14, 2020
Published: November 17, 2020

Abstract

Catfishes belonging to the genus *Chrysichthys* are generally important fish species in inland water bodies of Africa because of their high commercial value. Among them, *C. nigrodigitatus* could represent, at certain periods of the year the highest biomass of the littoral ichthyofauna, accounting for 17 to 43.8% of total catches. In this paper, its diet in the hydrosystem Lake Togo-Lagoon of Aného was investigated focusing on how differences in diet and food consumption are related to size, season and sexual maturity. A total of 195 males and 137 females were sampled from January to December 2017. The digestive tract of each individual was dissected and its content was analyzed, using indexes of stomach contents analysis method. Diet variability in relation to season and biometric parameters was also studied. About 99 stomachs were empty with an overall vacuity index of 29.82%. However, vacuity index was found to vary in relation to fish size and months. The fish has been found to be omnivorous with a carnivorous tendency consuming a wide range of prey items (H = 3.34). Juvenile and adult freshwater clams (*Galatea paradoxa*) were the numerical dominant preys (%N = 44%) while the penaeid shrimps (*Farfantepenaeus notialis*) with an annual frequency of occurrence (Fo) of 49.36% and all species confused of fish (33.91%) were the most preferred preys. The index of relative importance (IRI) reveals that freshwater clam (40.49%), penaeid shrimps (35.85%) and all species confused of fish

(14.58%) were the most important preys of *C. nigrodigitatus*. The dominance of Malacostraca and Mollusca in the diet of *C. nigrodigitatus* in the hydrosystem Lake Togo-Lagoon of Aného is likely one of the more important considerations for future management plans.

Keywords

Chrysichthys nigrodigitatus, Food Item, Feeding Ecology, Lake Togo, Lagoon of Aného

1. Introduction

Fish and seafood are highly valued and play an important role in human diet because of their content of high quality protein and essential amino acids, polyunsaturated fatty acids and micronutrients [1]. In 2017, according to FAO estimates, fish provided at least 50% of the total animal protein intake of humans in several West African countries including Togo [2]. In these countries, artisanal catches could represent the bulk (60%) of the domestic fisheries catches [3]. Unfortunately, catches are not expected to maintain their current growth rate in the next decade. The region is expected to become more dependent on imports to satisfy demand, reaching 41% of consumption in 2026 [4]. In Togo, in the last decade, the production of most species by artisanal fisheries was stable, or fluctuating around the average without a real tendency to increase [5]. More worrying, total catches of many valued food fishes (silver catfish, blackchin tilapia…) have decreased because of overfishing, drought and watershed degradation [3] [6]. It was therefore, strongly recommended that the necessary efforts be made to achieve a rational management of the stock and to find ways of improving the level of productivity of coastal lagoons and estuaries [5].

The study of the food and feeding habits of fish is a subject of continuous research, because it plays an integral part in the development of a successful fisheries management program on fish capture and culture [7] [8]. Indeed, feeding behavior based on the analysis of stomach contents is widely used in fish ecology as an important tool for understanding the role of fishes in aquatic ecosystems since they indicate relationships based on feeding resources and indirectly indicate community energy flux [9]. From a practical standpoint, information on quantity and quality of food consumed and the feeding behavior pattern is needed to understand the predicted changes that might result from any natural or anthropogenic intervention. In addition, knowledge of the feeding ecology of commercial as well as non-commercial fish species is essential for implementing a multispecies approach to lagoon and estuary fisheries management [10].

The bagrid catfish species, notably *Chrysichthys nigrodigitatus* Lacépède, 1803 and *C. auratus* Geoffroy Saint-Hilaire, 1809 are important members of fresh and brackish water fish highly sought after for their flavor and chemical composition [11]. They have been reported from practically all the river and lagoon systems of Africa within latitudes 25˚N and 25˚S and from Tanzania in the east to Senegal in the west [12] [13]. Bagrid catfish species have great commercial and economic value in West African countries [14] [15] and ensure food security and the livelihoods of local populations. Studies on the fauna in inshore habitats revealed that *Chrysichthys spp* could represent, at certain periods of the year, the highest biomass of the littoral ichthyofauna, accounting for 17% to 43.8% of total catches [5] [16] [17]. The most recent works on feeding ecology come mostly from the lagoons and rivers of Ghana [18] and Nigeria [15] [19] [20] [21]. In Togo, studies on the bioecology of fish, which have mostly been limited to the description of fisheries, are very rare and old [14]. Accordingly, very little information is available on diet of brackish and freshwater fishes in the country. The present study aims to characterize the diet of *C. nigrodigitatus* from the hydrosystem Lake Togo-Lagoon of Aného through a qualitative and quantitative description of the stomach contents and its temporal and ontogenetic variation.

2. Materials and Methods

2.1. Study Area

The Lake Togo-Lagoon of Aného complex is part of a lagoon system set in south-eastern Togo located between latitudes 6˚14'38" and 6˚17'37" North and longitudes 1˚23'33" and 1˚37'38" East. It stretches from the villages of Dékpo and Sévatonou in the north-west to of Aného in the south-east. It covers 64 km^2 and includes the Lake Togo (46 km^2), the Lagoon of Togoville which is a channel of 13 km length parallel to the coast with a width varying between 150 and 900 m, the Lake Zowla (6.55 km^2) and the Lagoon of Aného in the South-East. It communicates with the ocean at Aného. In addition, the Lagoon of Aného communicates with the Mono river in the East via the Gbaga channel. The Zio and Hahorivers are the main tributaries of the hydrosystem [22]. The Lake Togo watershed enjoys a subequatorial or Guinean climate with two rainy seasons composed of a large one (mid-March to mid-July) and a small one (mid-September to mid-November) alternated by two dry seasons composed of a large one (mid-November to mid-March) and a small one (mid-September to mid-November). The most popular economic activities around the lagoon system are fishing, agriculture and livestock. Phosphorite mining takes place in this watershed with discharge of all kinds of mining waste. **Figure 1** shows the location of the study area and sampling points.

2.2. Sample Collection and Determination of Stomach Contents

A total of 332 fishes were collected monthly at two landing stations over an annual cycle, from January to December 2017, in collaboration with professional fishermen of the lagoon complex [15] [23] [24]. The gear types often used by fishermen include drag net, hook and line, bottom-set gillnet and bottom-set traps. They were set the day before between 07:00 and 08:00 am; then raised and the fish collected the next day between 05:00 and 06:00 am. Samples were immediately

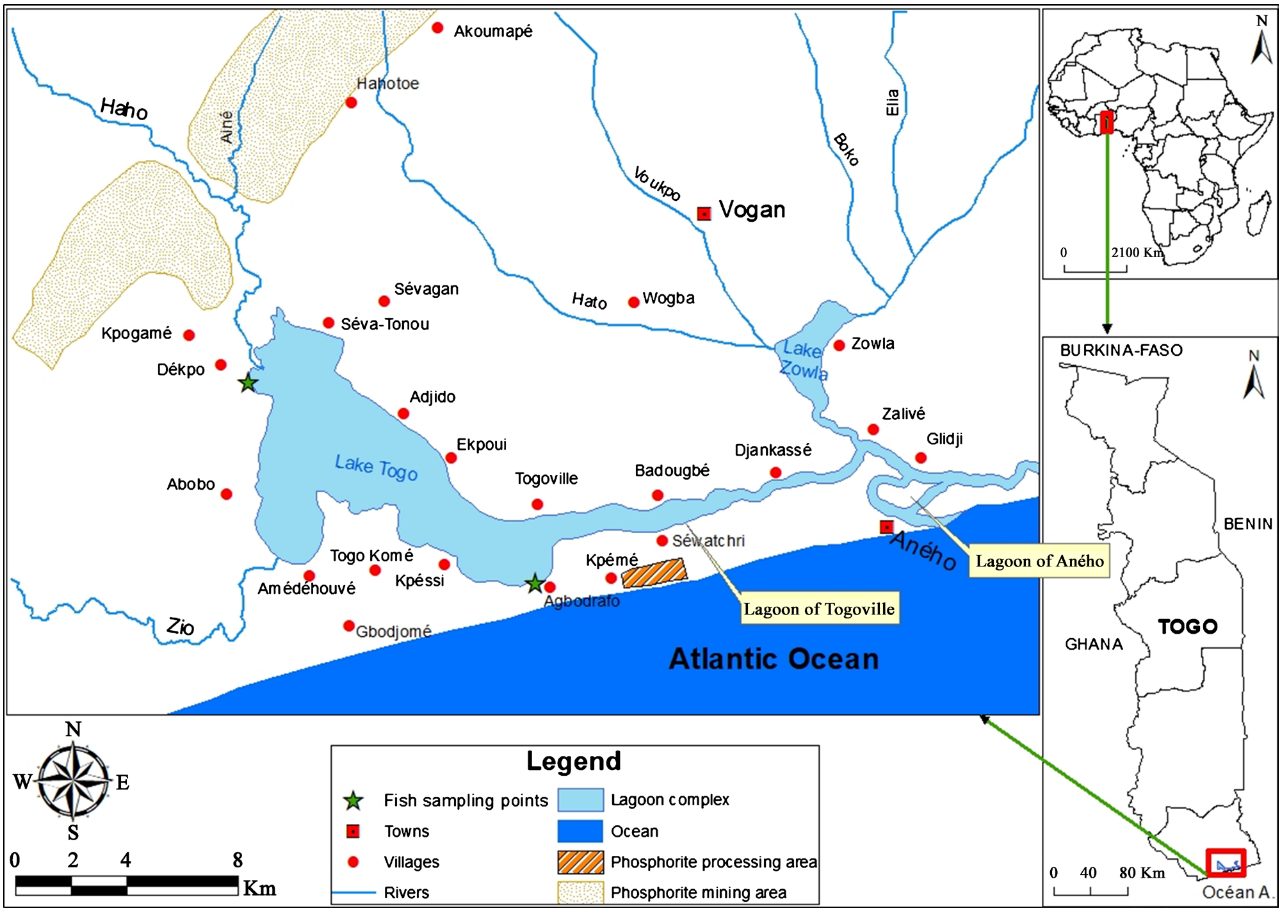


Figure 1. Location map of the study area showing the sampling points.

packaged in a cooler containing ice and transported to the Laboratory of Animal Ecology and Ecotoxicology of the University of Lomé. After identification according to Lévêque *et al.* [25] and Stiassny *et al.* [26], each specimen was measured to the nearest millimeter (total length), then weighed (total weight) using a KERN type balance with an accuracy of 0.01 g. The fishes were then dissected using stainless dissection materials. The entire gastrointestinal tract was removed and stored in 5% formalin to stop decomposition and consolidate the preys until their contents analysis [15] [23] [24] [27].

The digestive tracts were opened longitudinally and their contents were emptied into petri dishes. The decomposed preys were counted based on the number of heads, eyes, legs etc. Recognizable preys were identified to the lowest possible taxon under a stereomicroscope OPTIKA LAB-20 with a magnification range of 7 to 45 times. For identification of food items, the standard literature on the systematics of aquatic invertebrates such as Grassé *et al.* [28], Durand and Lévêque [29] and Bouchard [30] was referred to.

2.3. Sex Ratio

Fish sexes were determined by macroscopic observation of the gonads after dissection. The sex ratio (SR) was calculated using the Equation (1) [15] [31] [32]:

$$\mathrm{SR} = \frac{\mathrm{Male}}{\mathrm{Female}} \quad (1)$$

2.4. Data Analysis of *C. nigrodigitatus* Stomach Contents

Numerous food indexes have been described and used to analyze and quantify the importance of different prey items in the diets of aquatic species [7] [33]. Some of them were used in the present study:

1) The vacuity index (VI) was calculated using the Equation (2):

$$\mathrm{VI} = \left(N_{es}/N_{ts}\right)\times 100 \quad (2)$$

where N_{es} is the number of empty stomachs and N_{ts} is the total number of stomachs examined.

2) Frequency of occurrence (%Fo). It was expressed according to the Equation (3):

$$\%\mathrm{Fo} = \left(N_s/N_t\right)\times 100 \quad (3)$$

where, N_s is the number of stomach containing a given prey and N_t is the number of non-empty stomach. This index was interpreted according to the scale of Pillay [34] as modified by Gning [35] as follows: Fo > 30%, the prey consumed is considered preferential prey, 10% < Fo < 30%: the prey is qualified to be secondary and Fo < 10%: the prey can be considered to be accidental.

3) The numerical abundance index (%N). It was calculated using the Equation (4)

$$\%\mathrm{N} = \left(N_i/N_t\right)\times 100 \quad (4)$$

where N_i is the number of a given prey in the stomach and N_t is the total number of preys ingested.

4) The gravimetric abundance index (%W). The following equation allowed its calculation

$$\%\mathrm{W} = \left(W_i/W_t\right)\times 100 \quad (5)$$

with W_i is the weight of a given prey in the stomach and W_t is the total weight of preys ingested.

5) The index of relative importance (IRI) was used to assess the relative importance of a prey category in the diet by minimizing bias caused by each food index [36]. It was calculated as follow:

$$\mathrm{IRI} = \left(\%\mathrm{N} + \%\mathrm{W}\right)\times \%\mathrm{Fo} \quad (6)$$

where, %N is the numerical abundance index, %W is the gravimetric abundance index and %Fo is the frequency of occurrence [23] [37].

2.5. Statistical Analysis

The Chi-square test (χ^2) was used to compare the observed sex-ratios to the theoretical sex-ratio of 1:1 [15] [38]. The importance of the food spectrum was determined using the Shannon-Wiener diversity index (H). A value of $H = 0.5$

indicates a very low diversity:

$$H = -\sum_{i=1}^{n} P_i \log_2 P_i \quad (7)$$

where, P_i is the numerical abundance of the prey "*i*" [15] [39]. The specific richness of ingested prey was determined using the Margalef index (*d*). This value ranges between 1 et 4.5:

$$d = \frac{S-1}{\log N} \quad (8)$$

where S is the number of species and N is the number of individual preys [15] [40] [41]. The degrees of similarity of diets or dietary overlap between sexes, size classes and states of sexual maturity were determined using the Schoener index (SI):

$$\mathrm{SI} = 1 - 0.5\left(\sum_{i=1}^{n} \left|P_{xi} - P_{yi}\right|\right) \quad (9)$$

where, P_{xi} = the numerical abundance of the prey "*i*" in the diet of fish group x and y [42]. This index varies from 0 to 1. The diets are considered to be significantly similar when SI value is superior or equal to 0.6 (SI ≥ 0.6) [43] [44] [45].

The ontogenetic variation in diet was highlighted by the Cluster Analysis (CA) of size classes on the basis of numerical abundance of the prey items. The temporal variation of the diet was assessed by principal component analysis (PCA) on the basis of the numerical abundance of the prey items [23] [35]. The CA and PCA were performed using STATISTICA 6.1 software.

3. Results

3.1. Biometric Parameters of *C. nigrodigitatus*

3.1.1. Sexratio and Proportions of Sexes

The overall result of the monthly sex ratio shows that of the 332 fishes examined 195 (58.73%) were males and 137 (41.27%) were females giving a sex ratio (M/F) of 1.42 or 1:0.70. A chi-square analysis of the result shows that this sex ratio is significantly different from the theoretical one (1:1). Thus, the number of males was significantly higher than females in the population of *C. nigrodigitatus* examined ($\chi^2 = 10.13$; p = 0.0014).

3.1.2. Variation of Morphometric Parameters

The largest *C. nigrodigitatus* caught during the study was a ripe male. It measured 53.50 cm and weighed 1.660 kg. The total lengths, all sexes combined varied between 7.95 and 53.50 cm (average size 25.10 ± 7.66 cm) while the total weights ranged from 13.29 to 1660.50 g (average size 171.73 ± 178.41 g). A perusal of the result indicates similar morphometric parameters in both sexes with total length and weight averages respectively 24.25 ± 8.01 cm and 167.69 ± 207.17 g for males and 26.32 ± 7 cm and 177.48 ± 127.23 g for females (**Table 1**).

Table 1. Morphometric parameters of *C. nigrodigitatus* from Lake Togo-Lagoon of Aného.

Morphometric parameters	Statistics	Males (N = 195)	Females (N = 137)	Combined sexes (N = 332)
Total length (cm)	Min-Max	7.95 - 53.50	8.20 - 46.50	7.95 - 53.50
	Avg ± SD	24.25 ± 8.01	26.32 ± 7.00	25.10 ± 7.66
Total weight (g)	Min-Max	13.29 - 1660.50	14.68 - 1015.10	13.29 - 1660.50
	Avg ± SD	167.69 ± 207.17	177.48 ± 127.23	171.73 ± 178.41

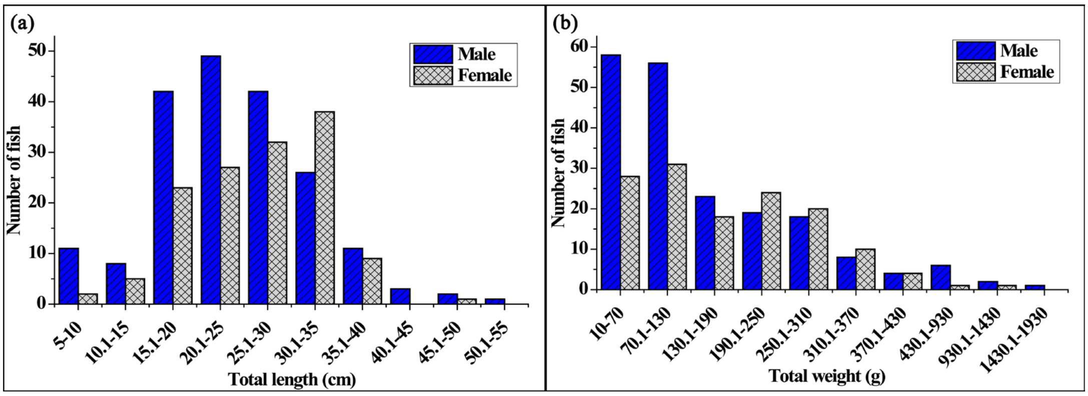


Figure 2. Frequency of lengths (a) and weights (b) in *C. nigrodigitatus* individuals.

However, large and small individuals are poorly represented in the samples. The population exhibited a unimodal distribution skewed towards middle sizes, with fishes measuring 15 to 35 cm and weighing between 10 to 130 g dominating the catch the two sexes (Figure 2). These fish are composed of juveniles, pre-adults (young individuals) and adults.

3.2. Diet Composition

3.2.1. Vacuity Index

Of the 332 stomachs examined, 99 were empty corresponding to an overall vacuity index (VI) of 29.82%. The vacuity index varied according to sex with 34.36% for males and 23.36% for females.

The lowest vacuity indexes were observed in January (20.59%), February (16.33%), March (22.22%) and August (21.74%) (Figure 3). These periods correspond to the dry season in accordance with the climatic calendar of the coastal zone of Togo.

In general, for both sexes, the vacuity index values increase with the size of the fish (Figure 4). The lowest values were recorded in young individuals belonging to 7 - 14 cm size class (24%) while the highest was observed in adults measuring between 49 and 56 cm (75%).

3.2.2. Overall Composition of the Food Items

Analysis of the contents of 233 full stomachs yielded a food spectrum comprised of 23 types of preys that can be divided into 7 major groups: fish, molluscs,

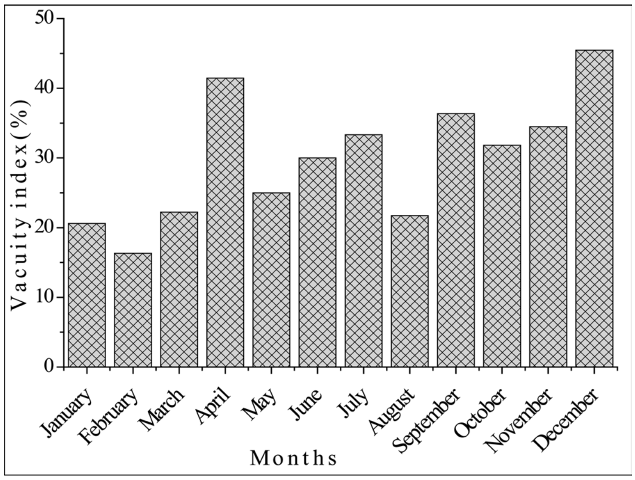


Figure 3. Temporal variation of the vacuity indexes.

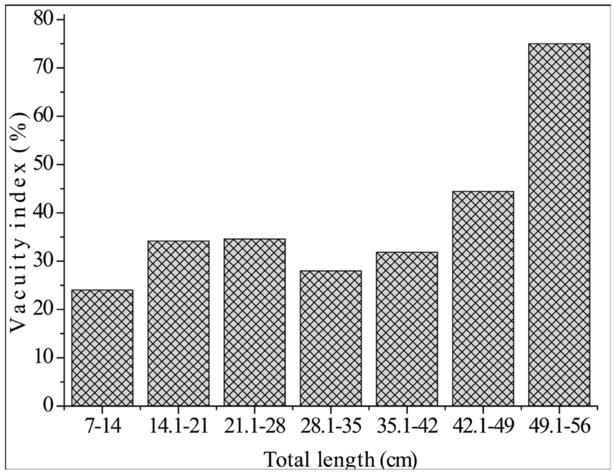


Figure 4. Variation of the vacuity index according to fish sizes.

crustaceans, insects, annelids, vegetables and sediments. Qualitatively, Table 2 indicates that *C. nigrodigitatus* of the lagoon complex has a wide range of prey. Indeed, the frequency of occurrence (%Fo) indicated that, shrimps (*Farfantepenaeus notialis*) with a frequency of occurrence of 49.36% and unidentified fish (33.91%) were the most preferred food items consumed by the silver catfish. While the secondary prey consists of clams (*Galactea paradoxa*) (29.61%), mud (22.32%), fish (*Ethmalosa fimbriata*) (20.6 %), the decapod crustacean (*Callinectes amnicola*) (12.88%), the gastropod mollusc (*Pachymelania fusca*) (12.45%) and vegetable debris (16.74%). The other preys were accidental in the diet with frequencies of occurrence less than 10%.

Based on the numerical abundance (%N), the food spectrum was numerically dominated by juvenile and adult clams (44%) and shrimps (13.62%). They are followed by the unidentified fish (6.94%), *E. fimbriata* (6.24%), vegetable debris (5.28%) and gastropod mollusk *P. fusca* (4.06%). In term of gravimetric abundance (% W), the clam *G. Paradoxa* (40.17%), the shrimp *F. notialis* (26%) and the fish *E. fimbriata* (10.27%) were the most abundant prey. The decapod crustacean

Table 2. Prey found in *C. nigrodigitatus* stomachs from Lake Togo-Lagoon of Anécho.

Preys	Codes	Qualitative and quantitative indexes			
		%N	%W	%Fo	%IRI
Fish		**15.88**	**19.34**	**33.91**	**14.58**
Ethmalosa fimbriata	Et.f	6.24	10.27	20.60	6.24
Eucinostomus melanopterus	Eu.m	0.44	0.71	2.15	0.05
Caranx hippos	Ca.h	0.52	1.01	3.00	0.08
Tilapia zillii	Til.z	0.52	1.19	3.00	0.09
Fish fry	FiFry	1.22	0.21	4.29	0.11
Unidentified fish	UidFi	6.94	5.95	33.91	8.01
Molluscs		**51.77**	**47.44**	**29.61**	**44.30**
Pachymelania fusca	Pa.f	4.06	3.99	12.45	1.84
Juvenile gastropods	JvGas	0.26	0.03	0.43	0.00
Galatea paradoxa	Ga.p	34.40	40.17	29.61	40.49
Juvenile *G. paradoxa*	JvGa.p	9.60	1.14	5.58	1.10
Mytilus perna	My.p	3.45	2.11	8.58	0.87
Crustaceans		**19.86**	**32.75**	**49.36**	**38.38**
Ostracods	Ostr	2.01	0.01	6.87	0.25
Amphipods	Amp	1.22	0.00	4.72	0.11
Farfantepenaeus notialis.	Fa.no	13.62	26.00	49.36	35.85
Calinectes amnicola	Ca.am	2.53	6.57	12.88	2.15
Pagurus sp.	Pag.sp.	0.48	0.17	1.29	0.02
Insects		**3.28**	**0.03**	**8.58**	**0.46**
Chironomid larvae	ChiroLv	2.36	0.02	8.58	0.37
Chaoboid larvae	ChaoLv	0.92	0.01	5.15	0.09
Annelids		**3.67**	**0.08**	**8.58**	**0.53**
Polychaetes	PolyAn	2.71	0.06	8.58	0.44
Oligochaetes	OligAn	0.96	0.02	4.72	0.09
Vegetables		**5.54**	**0.21**	**16.74**	**1.68**
Vegetable Debris	VegDe	5.28	0.21	16.74	1.68
Filamentous Algae	FilAlg	0.26	0.00	0.86	0.00
Sediments			**0.15**	**22.32**	**0.06**
Mud/Sand	Ma/Sa		0.15	**22.32**	0.06

Note: %N: = numerical abundance, %W = gravimetric abundance, %Fo = frequency of occurrence, %IRI: index of relative importance.

C. amnicola, the unidentified fish, the gastropod mollusk *P. fuscatus* and the bivalve mollusk *M. perna* followed by respective gravimetric abundances (%W) of 6.57%, 5.95%, 3.99% and 2.11%.

The relative importance (IRI) of the different food items in the stomachs of the silver catfish based on numerical abundance (%N), gravimetric abundance (%W) and frequency of occurrence (%Fo) indexes is given in **Table 2**. The results indicated that clams *G. paradoxa* (40.49%) and shrimps *F. notialis* (35.85%) which together make up 76.34% of the IRI are the most important and preferred preys of *C. nigrodigitatus*. Unidentified fish (8.08%), *E. fimbriata* (6.24%), the decapod crustacean *C. amnicola* (2.15%), the gastropod mollusk *P. fusca* (1.83%), vegetable debris (1.68%) and juvenile clams (1.10%) represented the secondary prey of the species in the lagoon complex with a total of 21.02% of the IRI. The others prey with a total IRI of 2.64% are in the accidental prey category. The Shannon-Wiener diversity index (H) calculated on prey showed that the overall food spectrum of *C. nigrodigitatus* is very diverse (H = 3.34). In addition, the Margalef index (d) indicated that this spectrum has a high specific richness (d = 5.36).

3.3. Variation of Diet According to Sex

The collected fish are sorted by sex, based on the numerical abundance (%N) of their prey. **Figure 5** indicates that the most abundant preys are clams (*G. paradoxa*) and penaeid shrimps (*F. notialis*) with respectively %N = 33.58% and 16.10% in females and %N = 34.75% and 11.99% in males. Data shows that males consumed many more clams (% N = 12.57%) than females (% N = 5.07%). Furthermore, juvenile gastropods are very poorly represented in males and absent in females. However, the Schoener dietary overlap index (C) calculated for male and female preys yielded a significant result (C = 0.85 > 0.6) indicating similarity between the diets of both sexes.

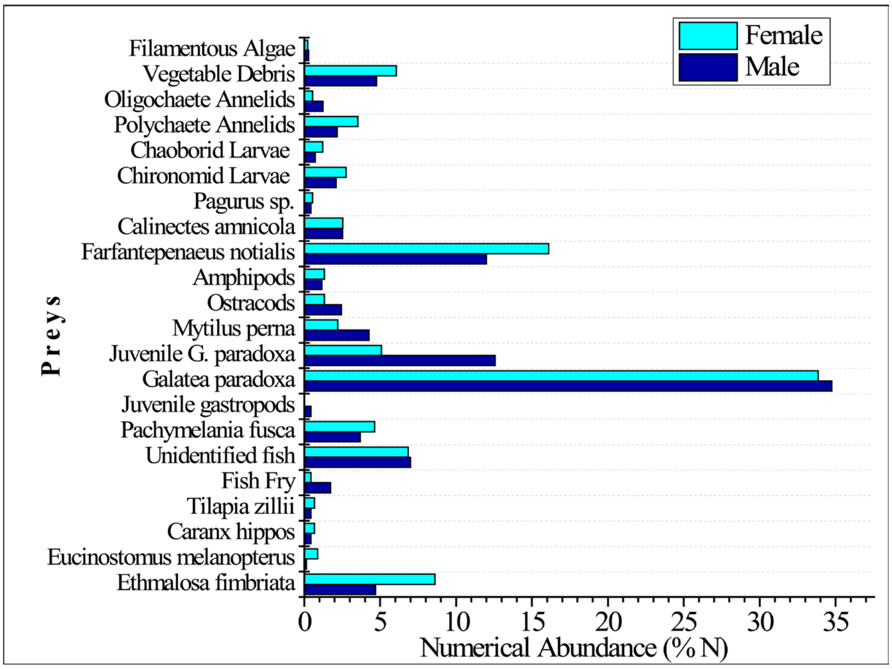


Figure 5. Variation of diet according to sex in *C. nigrodigitatus.*

3.4. Ontogenetic Variation of Diet

3.4.1. Variation According to Fish Size

According to the dendrogram obtained from the cluster analysis (**Figure 6**) two main clusters are identified: one composed of four isolated size classes (a, b, c and d) which are respectively 7 - 14 cm, 35.1 - 42 cm, 42.1 - 49 cm and 49.1 - 56 cm and the other (Group A) grouping three size classes (14.1 - 21 cm, 21.1 - 28 cm and 28.1 - 35 cm). This suggests that there is a significant ontogenetic change in the diet of the silver catfish in the hydrosystem Lake Togo-Lagoon of Aného. The Schoener indexes calculated between the different size classes (**Table 3**) shows that this change in the diet composition of the species according to size classes occurs gradually. Indeed, there is no significant similarity (C < 0.6) between the isolated classes a, b, c and d which represent the smallest sizes (a, b) and the largest sizes (c, d) of *C. nigrodigitatus* in the lagoon complex. However, the intermediate size classes belonging to group A are significantly similar to each other (C = 0.64 to 0.79). Furthermore, the difference between the largest class of the smallest sizes (14.1 - 21 cm) and the smallest class of intermediate sizes of group A (21.1 - 28 cm) is small (C = 0.59), suggesting that the first two

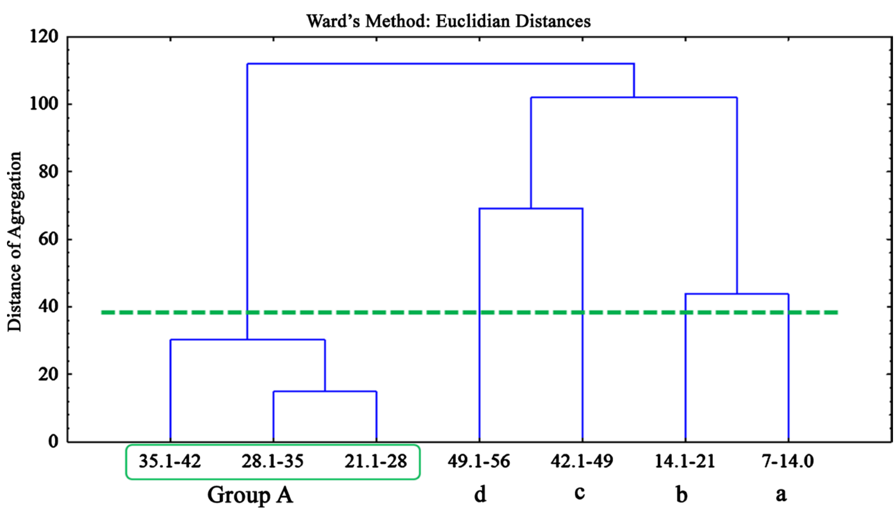


Figure 6. Dendrogram of cluster analysis of the size classes of *C. nigrodigitatus* according to the numerical abundances of the prey (size in cm).

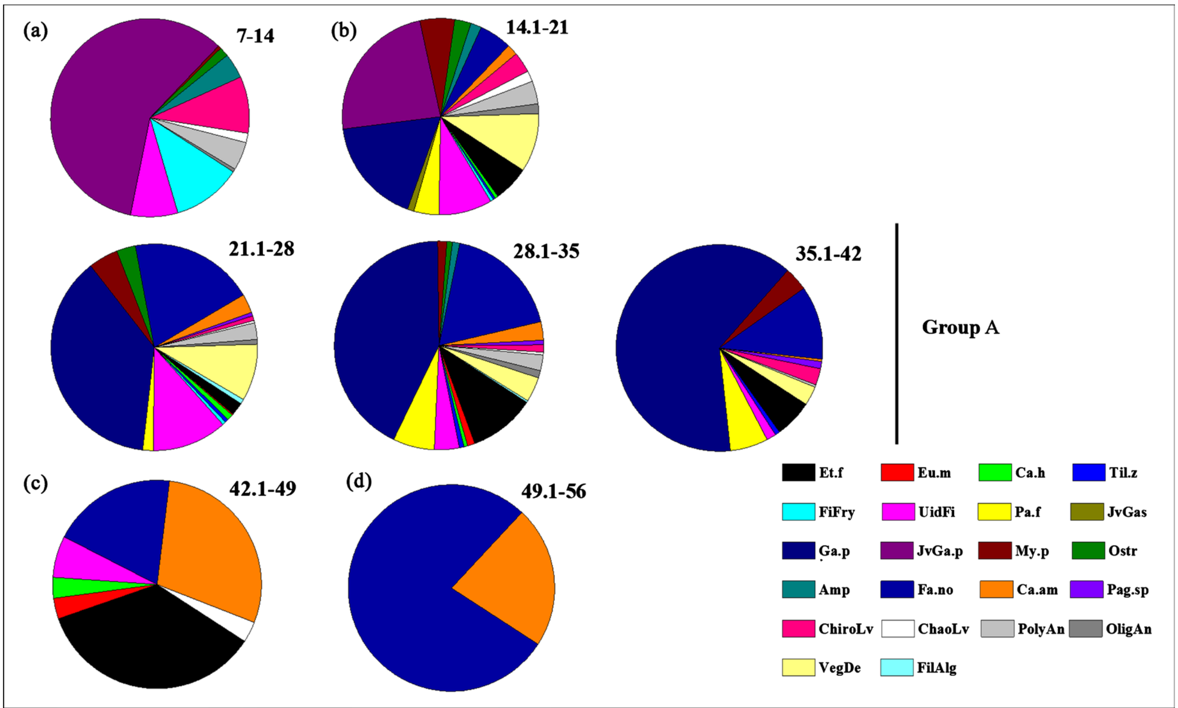
Table 3. Schoener similarity indexes between size classes of *C. nigrodigitatus*.

	7 - 14.0	14.1 - 21	21.1 - 28	28.1 - 35	35.1 - 42	42.1 - 49	49.1 - 56
7 - 14.0							
14.1 - 21	0.45						
21.1 - 28	0.15	0.59					
28.1 - 35	0.11	0.52	**0.79**				
35.1 - 42	0.05	0.45	**0.64**	**0.75**			
42.1 - 49	0.08	0.22	0.32	0.37	0.19		
49.1 - 56	0.00	0.07	0.22	0.21	0.12	0.42	

classes of group A are closer to the smaller class sizes.

Figure 7 shows that the diet of fishes of size 7 - 17 cm is largely dominated by juveniles of *G. paradoxa* (58.97%) followed by fry, chironomid larvae and unidentified fish with 11.28%, 9.23% and 7.69% respectively. This diet was different from that of the next class (14.1 - 21 cm) where the food items are largely dominated by juvenile (23.61%) and adult (17.53%) clam *G. paradoxa.* They were followed by vegetable debris (9.66%), unidentified fish (8.77%) *E. fimbriata* (5.90%), *M. perna* (5.72%) and *F. notialis* (5.37%). Then, the data shows a gradual decrease of juvenile clams *G. paradoxa* from 58.97% for sizes 7 - 14 cm to 23.61% for sizes 14.1 - 21 cm. The diet changed from juvenile clam-dominated to adult clam-dominated. The latter appears in the di*et al*ong with *E. fimbriata*, *C. hippos*, *T. zillii*, *P. fusca*., juvenile gastropods, *F. notialis*, *C. amnicola* and vegetable debris. In addition, the numerical proportions of fry have significantly decreased from sizes 7 - 14 cm (11.28%) to sizes 14.1 - 21 cm (0.54%).

The food spectra of the size classes of group A are similar in that they contain almost the same preys. Indeed, *G. paradoxa* and *F. notialis* are the most abundant preys of the three size classes with respective proportions of 37.66% and 19.48% for sizes 21.1 - 28 cm, 42.65 % and 18.11% for the sizes 28.1 - 35 cm and 63.20% and 11.52% for the size class 35.1 - 42 cm. However, a gradual disappearance of some preys such as fry, amphipods, ostracods, chaoborid larvae, oligochaete annelids and filamentous algae were noted. Therefore, this group can constitute a transition between individuals of medium sizes and those of large sizes. On the other hand, the diet of individuals of sizes 42.1 - 49 cm is



Note: Preys codes are defined in Table 2.

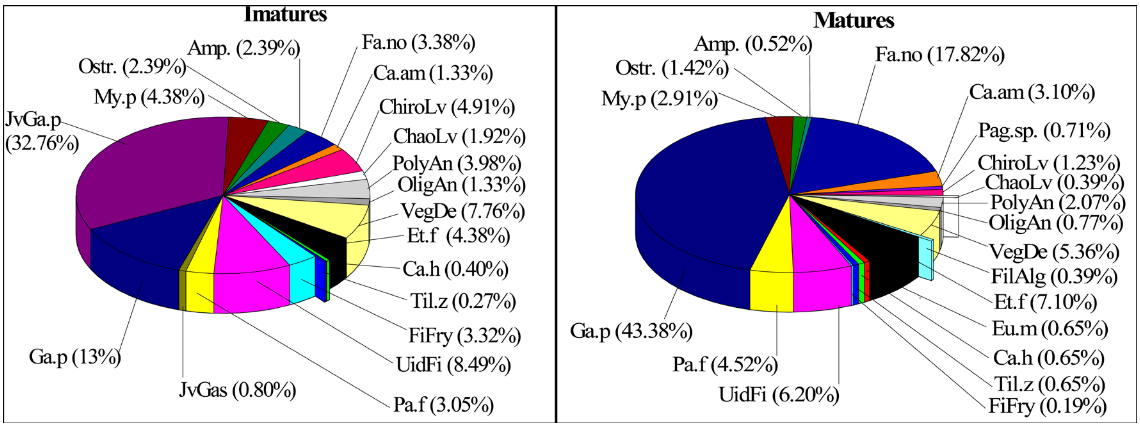
Figure 7. Numerical abundances of prey for each size class of *C. nigrodigitatus.*

dominated by fish in particular *E. fimbriata* (35.48%), crabs *C. amnicola* (29.03%) and shrimps *F. notialis* while those of 49.1 - 56 cm consisted only of crustaceans, with a notorious dominance of shrimp *F. notialis* (77.78%). In addition, the data shows a decreasing trend in predation intensity as *C. nigrodigitatus* grew. It can therefore be concluded that up to 14 cm, *C. nigrodigitatus*, has a diet based mainly on juvenile clams (*G. paradoxa*). Then, the diet changes with the integration of a wide variety of preys when the catfish measure between 14.1 and 42 cm and before stabilizing around fish (*E. fimbriata*), shrimps (*F. notialis*) and crabs (*C. amnicola*).

3.4.2. Variation According to Sexual Maturity

Individuals of *C. nigrodigitatus* have been grouped into two categories namely immature and mature on the basis of their average size at first sexual maturity which is approximately 21 cm. Figure 8 shows that immature individuals have a diet dominated by juvenile clams (32.76%), diverse fish species (16.86%) and adult clams (13%). While, adult clams (43.38%), shrimps (17.82%) and various species of fish (15.44%) were the most abundant prey in the dietary spectrum of mature individuals. A comparative analysis of the two food spectra indicates that the observed difference is due to the disappearance of juvenile clams and the appearance of shrimps. This difference was confirmed by the Schoener dietary overlap index which revealed a significant difference between the diets of immature and mature individuals ($C = 0.47 < 0.6$).

The Shannon-Wiener diversity index (H) showed that immature individuals have a more diverse food spectrum ($H = 3.41$) than mature individuals ($H = 2.86$). However, the Margalef index (d) showed a slight increase in the specific richness of prey ingested by mature individuals ($d = 5.64$) compared to those consumed by immature individuals ($d = 5.21$).



Note: Preys codes are defined in Table 2.

Figure 8. Variation of diet according to the sexual maturity of the fish.

3.4.3. Temporal Variation in Diet

Temporal variation in diet was carried out by principal component analysis applied to the numerical abundances of prey. Results in Table 4 indicated that the first two factor axes (Fact 1 and Fact 2) explain 74.35% of the total variance, suggesting that the factorial plan Fact 1 × Fact 2 can restore most of the information contained in the data.

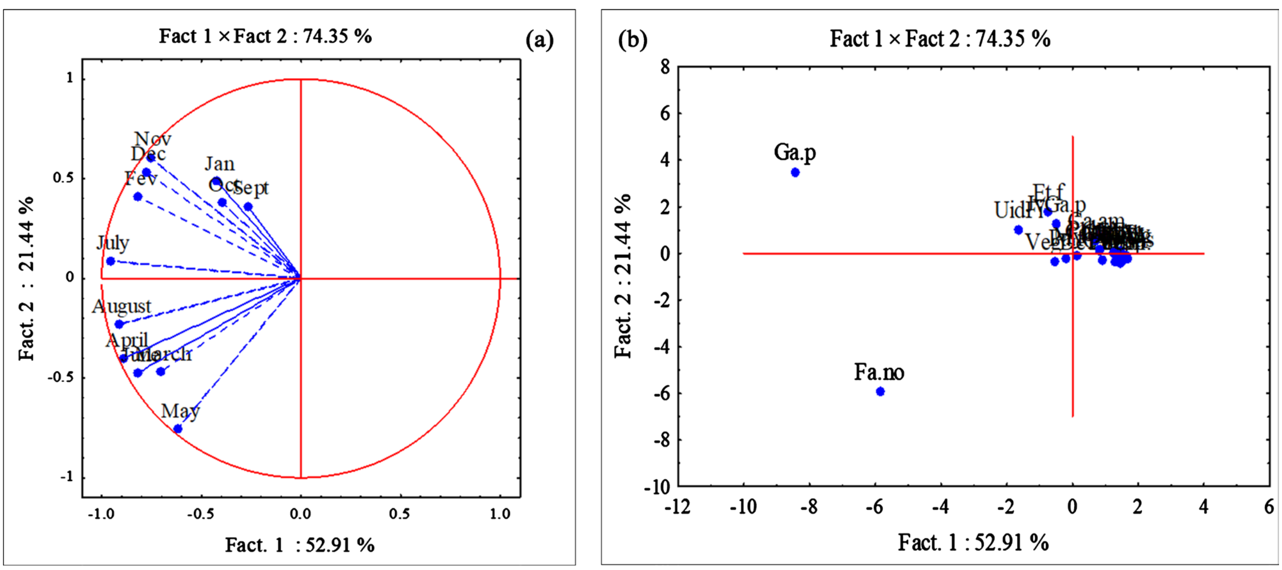
The projection of months in the factorial plane (Fact 1 × Fact 2) shown in Figure 9(a) indicates a slight temporal variation in the food items of *C. nigrodigitatus*. It is evident from this Figure that the twelve months of the year form four groups: 1) March to August 2) November, December and February, 3) September and October, and 4) January. The projection of the preys in the same plane is presented in Figure 9(b). This figure, compared to that of the months indicates that the months of the first group are characterized by a high abundance of shrimps in the food spectrum. The second group is mostly dominated by clams. The unidentified fish were abundant during September and October while juvenile clams dominated the food spectrum in January.

The detailed presentation of the monthly food spectrum of the species (Figure 10) shows that this variation in diet is mainly due to temporal variation in the abundance of shrimps in the ecosystem. Indeed, the first appearance of shrimps (*F. notialis*) in the diet of *C. nigrodigitatus* was noted in December at the beginning of the dry season. The predation on shrimps (*F. notialis*) increased gradually to a maximum reached in May before decreasing until it is canceled from

Table 4. Eigenvalues, total variances explained and cumulative variances.

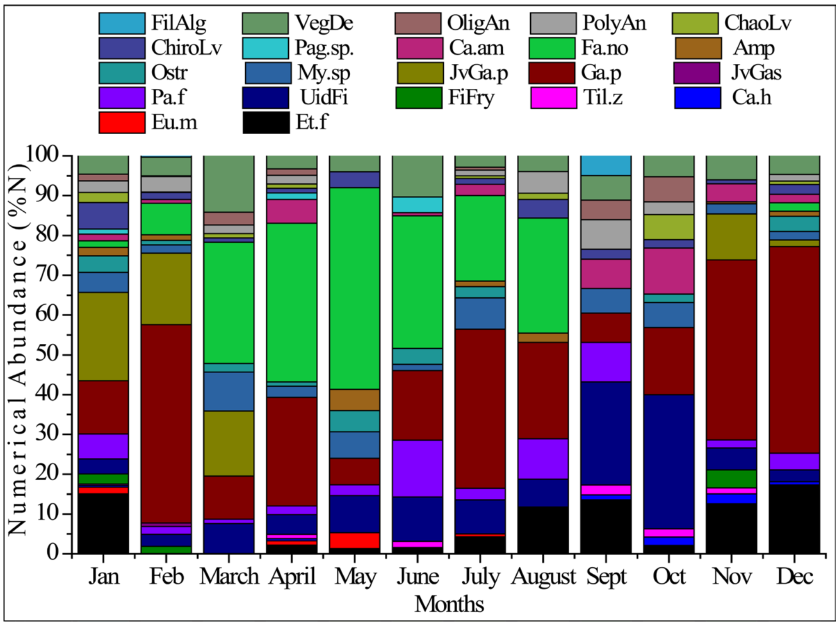
	Fact 1	Fact 2	Fact 3
Eugenvalues	6.35	2.57	1.56
% Total variance	52.91	21.44	12.99
% Cumulated Variance	52.91	74.35	87.35

Note: The prey codes in the legend are defined in Table 2.



Note: Preys codes are defined in Table 2.

Figure 9. Projection of months (a) and preys (b) in the factorial plane Fact 1 × Fact 2.



Note: Preys codes in the legend are defined in Table 2.

Figure 10. Monthly numerical abundances of different prey.

September to November. This variation seems to be inversely proportional to those of clams and fishes.

4. Discussion

Sex ratio and size structure constitute the basic information for assessing reproductive potential and estimating the stock size of populations [46]. Analysis of the sex ratio of *C. nigrodigitatus* in Lake Togo-Lagoon of Aného showed that the number of males was significantly higher than that of females. It can be explained by the fact that the fishing gear was not installed near the breeding grounds [19]. These results are similar to those obtained for the same species in some aquatic ecosystems in Nigeria [19] [31] [47]. However, they differ from those reported by Vanderpuye [17] in Volta Lake. These apparently contradictory results could be attributed to partial segregation of mature forms through habitat preferences and migration or behavioral differences between sexes rendering one sex more easily caught than the other [46]. According to Offem *et al.* [19], males migrate more frequently from breeding grounds to feeding areas located in shallow parts of the water body where they become vulnerable to be captured. Also, they suggest that females could take more shelter for incubation and protection of their offspring. Likewise, some samples obtained by Vanderpuye [17] suggest that females of *Chrysichthys spp* aggregate during certain periods of the year. Nevertheless, sex ratio divergence might also be explained by food availability and changes in environmental conditions. Nikolsky [48] observed that when food is limited, males predominate, with the situation reversing in regions where food is abundant.

The length frequency distribution of silver catfish collected in Epe Lagoon in

Nigeria showed a triple mode suggesting that the species were made of three age groups during the study period [31]. On the contrary, in the present study, there was no evidence of more than one mode in the size structure which might suggest spawning periods. Similar results were obtained by Vanderpuye [17] in Volta Lake (Ghana). These findings conform to the assertion of year-round recruitment and breeding which is common in tropical species because of the relatively stable and elevated water temperatures in the tropics [49] [50]. The maximum total lengths and total weights recorded during this study (Lt = 53.50 cm and Wt = 1660.50 g) are similar to those observed by Idodo-Umeh [51] in the Ase River in Nigeria (Lt = 57.5 cm, Wt = 1500 g). However, these values are much higher than those recorded in *C. nigrodigitatus* from Epe Lagoon in Nigeria (24.30 cm and 178.87 g) by Lawal *et al.* [31] and from the Aiba Reservoir in Nigeria (25.6 cm and 288.7 g) by Atobatele and Ugwumba [15]. The variations of size (length and weight) in fishes may be due to a number of factors including season, habitat, genetic and environmental factors [37] [52]. In addition, these variations can be affected by gonad maturity, sex, diet and stomach fullness, health and preservation techniques [53].

The vacuity indexes obtained during this study appear to be relatively high (16.33% to 45.45%) and variable. The obtained vacuity indexes could be attributed to regurgitation during capture in fixed gillnets [54] and/or to excessively long fishing periods during which digestion continues [55]. The monthly variations in the vacuity indexes recorded in the present study (**Figure 3**) indicate the existence of a seasonal rhythm in the feeding activity of *C. nigrodigitatus* in Lake Togo-Lagoon of Aného [7] [24]. The periods of intense feeding activity probably correspond to those of the availability of preferred prey in the environment [56]. Thus, the rhythm of feeding activity in fishes is conditioned by temporal variations in the availability of food in the environment [57] and environmental factors such as the transparency of the water [58]. The increase of the vacuity index with size of the species (**Figure 4**) could be explained by the fact that young individuals appear to be more agile than adults in finding and capturing active prey [56].

Analysis of the stomach contents revealed that *C. nigrodigitatus* in Lake Togo-Lagoon of Aného complex fed on a wide range of food items notably bivalves and gastropods (mainly *G. paradoxa* and *P. fusca*), decapod crustaceans (*F. notialis* and *C. amnicola*) and various fish species. In addition, vegetables, amphipods, ostracods, insect larvae, annelids and mud were present but in very small quantities. These results in agreement with the findings of Lalèyè *et al.* [59] in the Lake Nokoué-Porto Novo Lagoon complex in Benin and those of Lawal *et al.* [31] in the EpeLagoon in Nigeria. However, *C. nigrodigitatus* has been reported to feed mainly ongastropod mollusc and ostracod crustaceans in Lekki Lagoon in Nigeria [60]. On the other hand, Oronsaye and Nakpodia [61] and Esenowo *et al.* [21] found that the diets of the silver catfish respectively from the Ethiope and Nwaniba Rivers (Nigeria) were dominated by detritus, plant matters, insects and fish remains. Atobatele and Ugwumba [15] reported that in the Aiba reservoir, the diet of *C. nigrodigitatus* is dominated by crustaceans (copepods, ostracods) and various species of insects. Overall, it emerges from these studies that *C. nigrodigitatus* has a very eclectic diet based mainly on benthic food resources, molluscs, aquatic larvae of insects, shrimps and crabs but also copepods, ostracods, filamentous algae and small fishes. These food categories can be found in the diet either in greater or lesser numerical importance depending on the biotopes and the hydrological season. Based on these results, *C. nigrodigitatus* is an omnivorous species with a carnivorous tendency. This omnivorous character of the species was reported by other studies in tropical aquatic ecosystems [19] [20] [31] [59] [61]. Furthermore, according to the classification established by Lauzanne [62], the species can be considered a secondary consumer consuming mainly benthic invertebrates, zooplankton and zooperiphyton. Thus, although *C. nigrodigitatus* has a morphology suitable for feeding on the bottom of water bodies, a wide variety of prey has been found in its stomach. This suggests the ability of this species to move to different aquatic habitats to capture different kinds of prey. The plasticity of their diets gives the silver catfish the power to adapt to various biotopes, to very different geographic and climatic conditions. In the different ecological conditions in which they may live, they will find food that suits them [19] [62] [63]. The presence of mud and sand in the stomachs of these fish could be due to accidental ingestion along with other foods [64].

The dietary spectra of the male and female are found to be similar in the present study according to the Schoener Overlap Index. This lack of variation in utilization of resources between sexes indicates that resource sharing or potential competition might exist between males and females. This finding defers from the results of Lauzanne [62] in which the males of *C. nigrodigitatus* fed more on planktonic crustaceans while the females fed more on benthic insect larvae in Aiba reservoir (Nigeria). According to these authors, this suggests a strategy for reducing intraspecific competition. The sex based differences in food consumption by mature individuals could be related to gender asymmetry in the energy invested in the development of primary and secondary sexual characters [65].

The variation in diet composition according to fish sizes was observed in the present study. This ontogenetic variation has also been reported by many studies in diet of *C. nigrodigitatus* and other fish species [15] [24] [45] [56] [59] [66] [67]. These changes in diet spectra may be an adaptation to reduce intraspecific competition between individuals belonging to different size classes [68]. However, this can be due to the opportunistic nature of the species in the environment or its ability to search for the preferred foods [45]. It is generally known that fishes preferentially consume the most abundant preys in the environment [62]. Nikolsky [48] had suggested that variation in the composition of food with age and size is a substantial adaptation towards increasing the range of food supply of their population by enabling the species to assimilate a variety of foods. Diet changes are often linked to anatomical changes in fish, allowing them to have a preference for large preys [24]. These large preys provide them with maximum energy for growth and reproductive functions [69].

The temporal variations observed in the diet are mostly dependent on the presence or absence of penaeidshrimps (*F. notialis*) in the hydrosystem. In fact, shrimps are completely absent from the diet of the catfish during September, October and November. This is due to the fact that these months correspond to a high water period in the hydrosystem via freshwater discharge leading to a considerable decrease of water salinity. Indeed, average salinity values in the hydrosystem dropped quickly from its maximum value of 14.8 g/l in March to 2.19 g/l in October [70]. This decrease in salinity triggers the return of shrimps to the ocean leading to their absence in the food spectrum of *C. nigrodigitatus*. Shrimpsre-appear in small quantities in December, corresponding to the start of the decrease in water level and the intrusion of marine waters into the lagoon. It is noted that in the absence of shrimps, the species feeds mainly on fish and bivalve molluscs (**Figure 10**). Some previous studies on silver catfish food habits also demonstrated a shift in diet depending on prey availability. Dada and Araoye [71] reported that plant materials were high in the months that coincide with rainy season. Choaborus and chironomid insects commonly found in the stomachs of the species also coincide with reproduction period of insect, especially dipterans. Similar observations were made by Atobatele and Ugwumba [15]. Thus, the present study may conclude that the occurrence of different types of food items in stomach and gut contents of *C. nigrodigitatus* in different months depend on their availability rather than selection by the catfish. The species is a non-migratory fish and remains in a specific habitat throughout its life and has to adapt the food available in the habitat during all seasons of the year.

5. Conclusion

The present study gives the first information on the food and feeding habits of *C. nigrodigitatus* in the Lake Togo-Lagoon of Aného complex. The findings confirmed that *C. nigrodigitatus* is an eclectic omnivore consuming mainly benthic invertebrates. Its diet varies depending on the size of individuals, their sexual maturity and time (months). However, no significant differences were observed between the sexes in terms of food preference. The dominance of Malacostraca and Mollusca in the diet is likely to be one of the more important considerations for future management plans. In this study, freshwater clams (juveniles and adults) constitute a considerable portion of the diet (44%), suggesting that the recent declining trend in *G. paradoxa* populations in the Mono River, in the Lake Togo and Lagoon of Anéhoas a result of habitat alteration and overfishing could have a negative effect on the catfish fisheries. Future studies should therefore focus on the macro-invertebrate fauna and its spatial and temporal distributions in the hydrosystem.

Acknowledgements

This study was co-funded by the International Foundation for Science (IFS) in

Sweden and the organization for the prohibition of chemical weapons (OPCW) in Netherland (IFS Scholarship: I-2-A-6056-1). We also wish to express our gratitude to the Laboratory of Management, Treatment and Valorization of Waste (*Laboratoire Gestion, Traitement et Valorisation des Déchets*) of the University of Lomé (Togo).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Alune, E. and Andrew, G. (1996) Fishes. Cambridge University Press, London.

[2] FAO (2020) La situation mondiale des pêches et de l'aquaculture 2020. La durabilité en action. Rome. https://doi.org/10.4060/ca9229fr

[3] Belhabib, D., Kutoub, V. and Pauly, D. (2015) The Marine Fisheries of Togo, the "Heart of West Africa", 1950 to 2010. In: Belhabib, D. and Pauly, D., Eds., *Fisheries Catch Reconstructions: West Africa, Part II*, Vol. 23, Fisheries Centre Research Reports Fisheries Centre, University of British Columbia, Vancouver, 37-50.

[4] OCDE/FAO (2019) Perspectives agricoles de l'OCDE et de la FAO 2019-2028. Éditions OCDE, Paris.

[5] Läe, R. (1994) Evolution des peuplements (poissons et crustacés) dans une lagune tropicale, le lac Togo, soumise à un régime alternatif de fermeture et d'ouverture du cordon lagunaire. *Aquatic Living Resources*, **7**, 165-179. https://doi.org/10.1051/alr:1994019

[6] Laë, R., Williams, S., Morand, P. and Mikolasek, O. (2004) Review of the Present State of the Environment, Fish Stocks and Fisheries of the River Niger (West Africa). In: Welcomme, R. and Petr, T., Eds., *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining Livelihoods and Biodiversity in the New Millennium*, Vol. I, FAO, Rome, 199-277.

[7] Hyslop, E.J. (1980) Stomach Contents Analysis: A Review of Methods and Their Application. *Journal of Fish Biology*, **17**, 411-429. https://doi.org/10.1111/j.1095-8649.1980.tb02775.x

[8] Sarkar, U.K. and Deepak, P.K. (2009) The Diet of Clown Knife Fish *Chitala chitala* (Hamilton-Buchanan) an Endangered Notopterid from Wild (India). *Electronic Journal of Ichthyology*, **1**, 11-20.

[9] Hajisamae, S., Chou, L.M. and Ibrahim, S. (2003) Feeding Habits and Trophic Organization of the Fish Community in Shallow Waters of an Impacted Tropical Habitat. *Estuary Coast Shellfish Science*, **58**, 89-98. https://doi.org/10.1016/S0272-7714(03)00062-3

[10] Henderson, H.F., Ryder, R.A. and Khudhongania, A.W. (1973) Assessing Fishery Potential of Lakes and Reservoirs. *Journal of Fishery Resource Board Canada*, **30**, 2000-2009. https://doi.org/10.1139/f73-324

[11] Saliu, J.K. (2008) Effect of Smoking and Frozen Storage on the Nutrient Composition of Some African Fish. *Advances in Natural and Applied Sciences*, **2**, 16-20.

[12] Rish, L.M. (1992) Bagridae. In: Lévêque, C., Paugy, D. and Teugels, G.G., Eds., *Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest*, Tome II, ORSTOM Edition, Editions ORSTOM, Paris, 395-431.

[13] Geerinckx, T., Risch, L., Vreven, E.J., Adriaens, D. and Teugels, G.G. (2007) Claroteidae. In: Stiassny, M.L.J., Teugels, G.G. and Hopkins, C.D., Eds., *Poissons d'eaux douces et saumâtres de basse Guinée*, *Ouest de l'Afrique centrale*, Volume 1, Edition IRD, Collection Faune et Flore tropicales 42, 586-629.

[14] Laë, R. (1992) Les pêcheries artisanales lagunaires ouest-africaines: Echantillonnage et dynamique de la ressource et de l'exploitation. Edition ORSTOM, Collection Etudes et Thèses, Paris.

[15] Atobatele, O.E. and Ugwumba, A.O. (2011) Condition Factor and Diet of *Chrysichthys nigrodigitatus* and *Chrysichthys auratus* (Siluriformes: Bagridae) from Aiba Reservoir, Iwo, Nigeria. *Journal of Tropical Biology*, **59**, 1233-1244.

[16] Lavoie, I., Hamilton, P.B., Campeau, S., Grenier, M. and Dillon, P.J. (2008) Guide d'identification des diatomées des rivières de l'Est du Canada. Presse de l'Université du Québec, Québec. https://doi.org/10.2307/j.ctv18ph4tz

[17] Vanderpuye, C.J. (1979) Life History of *Chrysichthys* Catfish in Volta Lake, Ghana. Iowa State University, Ames.

[18] Okyere, I. and Boahemaa Kobil, E.E. (2020) Occurence and Food Habits of Bagrid Catfish in the Pra River Estuary. *Journal of Fisheries and Coastal Management*, **2**, 29-34.

[19] Offem, B.O., Akegbejo-Samsons, Y. and Omoniyi, I.T. (2008) Diet, Size and Reproductive Biology of the Silver Catfish, *Chrysichthys nigrodigitatus* (Siluriformes: Bagridae) in the Cross River, Nigeria. *Revue de Biologie Tropicale* (*International Journal of Tropical Biology*), **56**, 1785-1799. https://doi.org/10.15517/rbt.v56i4.5759

[20] Yem, I.Y., Bankole, N.O., Ogunfowora, O. and Ibrahim, B. (2009) Food Habit of the Catfish *Chrysichthys nigrodigitatus* (Geoffrey Saint Hilaire, 1808) in Kainji Lake, Nigeria. *Nature and Sciences*, **7**, 17-22.

[21] Esenowo, I.K., Ugwumba, A.A., Umoh, I.I. and Andem, A.B. (2017) Aspects of the Biology of Silver Catfish (*Chrysichthys nigrodigitatus*) in Nwaniba River, Southeast Nigeria. *Asian Journal of Biology*, **3**, 1-9. https://doi.org/10.9734/AJOB/2017/34408

[22] Millet, B. (1986) Hydrologie et hydrochimie d'un milieu lagunaire tropical: Le lac Togo. Edition ORSTOM, Collection Etudes et Thèses, Paris.

[23] Koné, T., Kouamélan, E.P., Ouattara, N.I. and Kicho, A.V. (2007) Régime alimentaire de *Pomadasys jubelini* (Pisces, Haemulidae) dans une lagune Ouest africaine (lagune Ebrié, Côte d'Ivoire). *Sciences & Nature*, **4**, 65-73. https://doi.org/10.4314/scinat.v4i1.42131

[24] Ouattara, S., Ouattara, N.G., Soro, D. and Fantodji, A. (2014) Régime alimentaire de *Engraulis encrasicolus* (Linneaus, 1758) du littoral de la Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, **8**, 916-924. https://doi.org/10.4314/ijbcs.v8i3.8

[25] Lévêque, C., Paugy, D. and Teugels, G.G. (1992) Faune des poissons d'eaux douces et saumâtres d'Afrique de l'Ouest. Tome 2. Edition ORSTOM et MRAC, Collection Faune tropicale no 28.

[26] Stiassny, M.L.J., Teugels, G.G. and Hopkins, C.D. (2007) Poissons d'eaux douces et saumâtres de basse Guinée, Ouest de l'Afrique centrale. Volume 1. Edition IRD, Collection Faune et Flore tropicales 42.

[27] Uwem, G.U., Ekanem, A.P. and Eni, G. (2013) Food and Feeding Habits of *Ophiocephalus obscura* (African Snakehead) in the Cross River Estuary, Cross River State, Nigeria. *International Journal of Agricultural Extension and Rural Development*, **1**, 94-100.

[28] Grassé, P.-P., Poisson, R.A. and Tuzet, O. (1970) Précis de Zoologie. Tome 1: In-

vertébrés, Précis de Sciences Biologiques. 2è édition edn. Masson et Cie Editeurs, Paris.

[29] Durand, J.-R. and Lévêque, C. (1980) Flore et faune aquatiques de l'Afrique Sahelo-Soudanienne. Tome 1. Edition ORSTOM, Collection Initiations-Documentations Techniques n° 44, Paris.

[30] Bouchard, R.W. (2004) Guide to Aquatic Macroinvertebrates of the Upper Midwest. Water Ressources Center, University of Minnesota, St. Paul.

[31] Lawal, M.O., Sangoleye, O.J. and Seriki, B.M. (2010) Morphometry and Diet of *Chrysichthys nigrodigitatus* (Lacépède) in Epe Lagoon, Nigeria. *African Journal of Biotechnology*, **9**, 7955-7960. https://doi.org/10.5897/AJB09.1514

[32] Belhoucine, F. (2012) Etude de la biologie de la croissance et de la reproduction d'un poisson téléostéen le merlu (*Merluccius merluccius* L., 1758) et son utilisation comme indicateur biologique de la pollution par les métaux lourds (Zinc, Plomb et Cadmium) dans la baie d'Oran (Algerie). Thèse de Doctorat, Université d'Oran, Algérie.

[33] Hynes, H.B.N. (1950) The Food of Freshwater Sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a Review of Methods Used in Studies of the Food of Fishes. *Journal of Animal Ecology*, **19**, 36-58. https://doi.org/10.2307/1570

[34] Pillay, T.V.R. (1952) A Critique of the Methods of Study of Food of Fishes. *Journal of the Zoological Society of India*, **4**, 185-200.

[35] Gning, N. (2008) Écologie trophique des juvéniles de quatre espèces de poissons dans l'estuaire inverse du Sine-Saloum (Sénégal): Influence des conditions de salinité contrastées. Thèse de Doctorat, Université Montpellier II, France.

[36] Pinkas, L., Oliphant, M.S. and Iverson, I.L.K. (1971) Food Habits of Albacore, Blue Fin Tuna and Bonito in Californian Waters. California Department of Fish and Game, 152, 1-105.

[37] Irom, O., Offem, B.O. and Keremah, R.I. (2017) Length-Weight Relationship, Condition Factor and Gut Content of *Chrysichthys Furcatus* Gunther, 1864 (Bagridae) from Cross River at Ahaha. *Fisheries and Aquaculture Journal*, **8**, 4. https://doi.org/10.4172/2150-3508.1000228

[38] Bodji, I.M., Kouadio, J.K., Alla, Y.L., Ouattara, N.I. and Atsé, B.C. (2013) Reproductive Biology of the Sompat Grunt, *Pomadasys jubelini* (Cuvier, 1830) in Côte d'Ivoire Lagoons Complex (West Africa). *Journal of Applied Biosciences*, **72**, 5855-5868. https://doi.org/10.4314/jab.v72i1.99673

[39] Berg, J. (1979) Discussion of Methods of Investigating the Food of Fishes with Reference to a Prelimnary Study of the Prey *Gobiusculus flavescens* (Gobiidae). *Marine Biology*, **50**, 263-273. https://doi.org/10.1007/BF00394208

[40] Pielou, E.C. (1969) An Introduction to Mathematical Ecology. Wiley-Interscience, New York.

[41] Brower, J.E. and Zar, J.H. (1984) Field and Laboratory Methods for General Ecology. 2nd Edition, E.C. Wm. C. Brown, Dubuque.

[42] Schoener, T.W. (1970) Non-Synchronous Spatial Overlap of Lizards in Patchy Habitat. *Journal of Ecology*, **51**, 408-418. https://doi.org/10.2307/1935376

[43] Werner, E.E. and Hall, D.J. (1977) Competition and Habitat Shift in Two Sunfishes (Centrarchidae). *Ecology Letters*, **58**, 869-976. https://doi.org/10.2307/1936222

[44] Wallace, H. and Ramsay, J.S. (1983) Reliability in Measuring Diet Overlap. *Canadian Journal of Fisheries and aquatic Sciences*, **40**, 347-351. https://doi.org/10.1139/f83-050

[45] Liwouwou, J.F., Montcho, S.A., Chikou, A., Adandedjan, D., Mbega, J.D. and Laleye, A.P. (2013) Le régime alimentaire de *Schilbe multitaeniatus* (Pellegrin, 1913) (Siluriforme, Schilbeidae) de la rivière Rembo Bongo au Gabon (Afrique Centrale). *International Journal of Biological and Chemical Sciences*, **7**, 1853-1865. https://doi.org/10.4314/ijbcs.v7i5.6

[46] Vazzoler, A.E.A.M. (1996) Biologia da reprodução de peixes teleósteos: Teoria e prática/Apresentação de Paulo de Tarso da Cunha Chaves. EDUEM São Paulo, Maringá.

[47] Fagade, S.O. and Adebisi, A.A. (1979) On the Fecundity of *Chrysichthys nigrodigitatus* (Lacépède, 1803) of Asejire dam, Oyo State, Nigeria. *Nigerian Journal of Natural Sciences*, **1**, 127-131.

[48] Nikolsky, G.V. (1963) The Ecology of Fishes. 6th Edition, Academic Press, London.

[49] Pauly, D. (1979) Gill Size and Temperature as Governing Factors in Fish Growth: A Generalization of von Bertalanffy's Growth Formula. Berichte Institut Für Meereskunde.

[50] Dash, G., Sen, S., Koya, K.M., Sreenath, K.R., Mojjada, S.K., Zala, M.S. and Pradeep, S. (2013) Fishery and Stock Assessment of the Three-Spot Swimming Crab *Portunus sanguinolentus* (Herbst, 1783) of Veraval, Gujarat. *Indian Journal of Fisheries*, **60**, 17-25.

[51] Idodo-Umeh, G. (2002) The Feeding Ecology of Bagrid Species in River Ase, Niger Delta, Southern Nigeria. *Tropical Freshwater Biology*, **11**, 47-68. https://doi.org/10.4314/tfb.v11i1.20868

[52] King, R.P. (1996) Length-Weight Relationship of Nigeria Freshwater Fishes. *Naga, the ICLARM Quarterly*, **19**, 49-53.

[53] Kazemi, K., Seyed, Y., Paighambari, S.Y. and Naderi, R.A. (2013) Length-Weight and Length-Length Relationships, Condition Factors and Optimal Length of Some Fish Species from the Persian Gulf and Oman Sea. *International Journal of Aquatic Biology*, **1**, 167-174.

[54] Johnson, J.H., Dropkin, D., Warkentine, S., Barbara, E., Rachlin, J.W. and Adrews, W.D. (1997) Food Habitat of Atlantic Sturgeon of the Central New Jersey Coast. *Transactions of the American Fisheries Society*, **126**, 166-170. https://doi.org/10.1577/1548-8659(1997)126<0166:FHOASO>2.3.CO;2

[55] Dadswell, M.J. (1979) Biology and Population Characteristics of the Shortnose Sturgeon, *Acipenser brevirostrum* Lesueur, 1818 (Osteichthyes: Acipenseridae), in the Saint John River Estuary, New Brunswick. *Canadian Journal of Zoology*, **57**, 2186-2210. https://doi.org/10.1139/z79-287

[56] Mukabo, O.G., Cikwanine, K.D.-d., Micha, J.-C., Nshombo, M.V., Rwakana, R.O., Bizuru, N.P., Muhirwa, B.G., Mboboci, S.D.E. and Mudimbe, K.P. (2017) Ecologie alimentaire de *Labeobarbus altianalis* (Boulenger, 1900) du Bassin de la rivière Luhoho, en territoire de Kalehe (Sud-Kivu, R.D. Congo). *International Journal of Biological and Chemical Sciences*, **11**, 208-227. https://doi.org/10.4314/ijbcs.v11i1.17

[57] Sanchez-Vazquez, F.J., Martinez, M., Zamora, S. and Madrid, J.A. (1994) Design and Performance of an Accurate Demand Feeder for the Study of Feeding Behavior in Sea Bass, *Dicentrarchus labrax* L. *Physiology & Behavior*, **56**, 789-794. https://doi.org/10.1016/0031-9384(94)90244-5

[58] Ponton, D. and Stroffek, S. (1987) Régime alimentaire des alevins de Gardon (*Rutilus rutilus* (L.)) dans un port du lac Léman. Comparaison avec la nourriture disponible. *Swiss Journal of Hydrology*, **49**, 329-342. https://doi.org/10.1007/BF02538293

[59] Lalèyè, A.P., Baras, E. and Philippart, J.-C. (1995) Variations du régime alimentaire de *Chrysichthys nigrodigitatus* et *C. auratus* (Claroteidae) dans les lagunes du Sud-Bénin. *Aquatic Living Resources*, **8**, 365-372. https://doi.org/10.1051/alr:1995041

[60] Ikusemiju, K. and Olaniyan, C.I.O. (1977) The Food and Feeding Habits of the Catfishes: *Chrysichthys walkeri* (Günther), *Chrysichthys filamentosus* (Boulenger) and *Chrysichthys nigrodigitatus* (Lacépède) in the Lekki Lagoon, Nigeria. *Journal of Fish Biology*, **10**, 105-112. https://doi.org/10.1111/j.1095-8649.1977.tb04047.x

[61] Oronsaye, C.G. and Nakpodia, F.A. (2005) A Comparative Study of the Food and Feeding Habits of *Chrysichthys nigrodigitatus* and *Brycinus nurse* in a Tropical River. *Pakistan Journal of Science and Industrial Resources*, **48**, 118-121.

[62] Lauzanne, L. (1988) Les habitudes alimentaires des poissons d'eau douce africains. In: Lévêque, C., Bruton, M.N. and Sentongo, G.W., Eds., *Biologie et Écologie des Poissons d'Eau Douce Africains*, ORSTOM Edition, Editions ORSTOM, Paris, 221-242.

[63] Warren, W.G. (1993) Changes in the Within-Survey Spatial Temporal Structure of the Northern Cod (*Gadus morhua*) Population. *Canadian Journal of Fisheries and aquatic Sciences*, **54**, 139-148. https://doi.org/10.1139/cjfas-54-S1-139

[64] Fagbenro, O., Adedire, C.O., Ayotunde, E.O. and Faminu, E.O. (2000) Haematological Profile, Food Composition and Digestive Enzyme Assay in the Gut of the African Bony Tongue, *Heterotis* (*Clupisudis*) *niloticus* (Cuvier, 1829) (Osteoglossidae). *Tropical Zoology*, **13**, 1-9. https://doi.org/10.1080/03946975.2000.10531125

[65] Bastos, R.F., Condini, M.V., Varela Junior, A.S. and Garcia, A.M. (2011) Diet and Food Consumption the *Geophagus brasiliensis* (Teleostei: Cichlidae): Relationships with Gender and Sexual Maturity. *Neotropical Ichthyology*, **9**, 825-830. https://doi.org/10.1590/S1679-62252011005000049

[66] Adite, A., Winemiller, K.O. and Fiogbé, E.D. (2005) Ontogenetic, Seasonal, and Spatial Variation in the Diet of *Heterotis niloticus* (Osteoglossiformes: Osteoglossidae) in the Sô River and Lake Hlan, Bénin, West Africa. *Environnmental Biology of Fishes*, **73**, 367-378. https://doi.org/10.1007/s10641-004-5563-9

[67] Ajah, P.O., Georgewill, M.N. and Ajah, M.O. (2006) The Food and Feeding Habits of Five Freshwater and Brackish Water Fish Species in Nigeria. *African Journal of Aquatic Sciences*, **31**, 313-318. https://doi.org/10.2989/16085910609503901

[68] Mbadu, Z. (2011) Biologie des espèces du genre Distichodus Muller et Troschel, 1845 (Distichodontidae) du pool Malebo (Fleuve Congo) en rapport avec les mécanismes d'exploitation de leurs niches trophiques. Thèse de Doctorat, Faculté notre Dame de la Paix de Namur, Belgique.

[69] Derbal, F. and Kara, M.H. (2007) Régime alimentaire du Corb *Sciaena umbra* (Sciaenidae) des côtes de l'est algérien. *Cybium*, **31**, 189-197.

[70] Ouro-Sama, K., Tanouayi, G., Solitoke, H.D., Badassan, T.E.-E., Ahoudi, H., Nyametso, A.Y. and Gnandi, K. (2018) Seasonal Variation, Quality and Typology of Waters' Abiotic Parameters of a Tropical Lagoon: The Hydrosystem Lake Togo-Lagoon of Aného (South-East of Togo). *International Journal of Innovation and Applied Studies*, **24**, 656-673.

[71] Dada, J.O. and Araoye, P.A. (2008) Some Aspects of the Biology of *Chrysichthys nigrodigitatus* (Pisces: Siluroidae) in Asa Lake, Ilorin, Nigeria. *Nigerian Journal of Fisheries*, **5**, 73-84. https://doi.org/10.4314/njf.v5i1.41971