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Microalgae, zooplankton and macroinvertebrate food components of *Oreochromis niloticus* (Piscis: Cichlidae) in liberty reservoir, Jos, Nigeria

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Abstract
The food of *Oreochromis niloticus* (Linnaeus, 1758) in Liberty Reservoir, Jos, Nigeria was studied based on the characterization of microalgae, zooplankton and macroinvertebrates present in the stomach of the cichlid. A total of 55 adult *O. niloticus* (Total length range 82-259 mm) were procured on the 10th of October 2014 from one of the fishermen who set fish traps in the reservoir and taken to the laboratory for stomach contents analysis. The percent frequency of occurrence and the numerical percentage methods were used to analyse the stomach contents of the fish samples. Only 56.36% of the fish had food in their stomach. A total of 98 taxa of prey items (made up of 17 genera of cyanobacteria, 27 genera of diatoms, 25 genera of chlorophytes, 15 genera of charophytes, two genera each of dinoflagellates and euglenophytes, one genus each of cryptophytes, heterokontophytes, chrysophytes and rhodophytes, and three zooplankton and two macroinvertebrate taxa) were found in the examined stomachs. Microalgae, primarily diatoms, constituted 99% of the diet with zooplankton and macroinvertebrates making up the residual 1%, showing *O. niloticus* in the Liberty Reservoir to be predominantly algivorous.

Keywords: Stomach contents analysis, *Oreochromis niloticus*, Liberty Reservoir, Jos, Nigeria, macroinvertebrates, microalgae, zooplankton

1. Introduction
Liberty Reservoir is a man-made lentic ecosystem located in the Lamingo village (09°53' N 08°55' E; elevation 1280 m) in Jos North Local Government Area of Plateau state, Nigeria [1]. The reservoir was created for the main purpose of supplying Jos town and its environs with portable pipe-borne water. The reservoir, having accumulated from a natural stream at the foot of the Shere Hills in Lamingo village, was populated by some clariid, cyprinid and tilapiine species, but *Oreochromis niloticus* (Linnaeus, 1758) was not part of the tilapiine community. The latter species was introduced into the reservoir in the early 2000s by one of the local fishermen. The population of *O. niloticus* in this reservoir has since then increased tremendously, probably due to the early maturation of individuals. The size at first maturation of this species has been observed to be 130 mm [2]. Although recreational and fishing activities are prohibited in the reservoir, a few locals, nevertheless, fish clandestinely in it. The daily landings of the fishermen reveal that *O. niloticus* is an important fishery species in the reservoir and needs to be effectively managed.
Cichlids, generally, have been reported to have a wide food spectrum [3, 4], and *Oreochromis niloticus* is recognized as an omnivorous, but largely algivorous, cichlid [4, 5]. It is an important fish species in aquaculture operations, especially in the tropics and subtropical areas [4, 6] because it grows to "table size" within a relatively short farming period in well-managed fish farms. This work focussed only on algae, zooplankton and macroinvertebrates as food of *O. niloticus* in the Liberty Reservoir, Jos. Detritus, though often present in the stomach of fish, was not considered in the present study because some authors consider detritus as incidental (or even accidental) pick-ups with minimal nutritional value [4, 7, 8]. It has also been reported that *Tilapia* does not feed preferentially on detritus [9], and that detritus does not support good growth of the cichlid *Sarotherodon mossambicus* [10]. It is the nutritional constraints imposed by low protein levels in detrital aggregate that account for the paucity of exclusively detritivorous fish species [10]. It is also important to note that the fisherman used dead organic matter of plant origin as bait in the fish traps.

The smell of the fermented bait attracted fish into the traps. Fish, so attracted, may gorge their stomach with such a matter, and any analysis of stomach contents that includes detritus that originated from ingesting the bait matter may erroneously indicate that the fish feeds preferentially on detritus.

Although the food and feeding habits *O. niloticus* have been studied in many parts of the world by different workers [e.g. 4,5,6], the food and/or feeding habits of this species in Liberty Reservoir, Jos, Nigeria have not been reported in the literature. This study was conducted to fill this gap, and, hence, contribute to the global efforts being made by aquatic scientists towards the understanding of the biology and ecology of the Nile tilapia. The study might also be useful in the management of *O. niloticus* fishery in the reservoir.

2. Materials and Methods

Oreochromis niloticus specimens (n = 55) were procured on 10 October 2014 from one of the local fishermen who set fish traps in the reservoir. In order to prevent spoilage, the specimens were transported to the laboratory in a cooler box with ice cubes. In the laboratory, the sex of each specimen was determined. The total length and weight of each fish was also determined. The stomach of each fish was obtained after slitting open the abdominal region of the fish. Each stomach was noted as empty or not empty. Each stomach with food was then stored separately in an appropriately labelled specimen tube containing 10% formalin.

For the analysis of microalgae, zooplankton and macroinvertebrate food components, the contents of each stomach were first emptied into a petri dish, a measured volume of deionized water added (depending on the concentration of particles), and observed under the dissecting microscope for macroinvertebrate identification. After all macroinvertebrates, when present, were sorted and identified, the rest of the material in the dish was transferred into an appropriately labelled sample tube, and a small amount of 4% formalin added. The so-treated samples were stored pending the analyses of microalgae and zooplankton prey items. Before the analysis of microalgae and zooplankton, the contents of each tube was further diluted with deionized water to enable ready identification of the organisms under the light microscope. The final volume of each stomach contents, following the dilution, was noted and used to calculate the numerical strength (number per ml that was subsequently converted to numerical percentage) of each identified taxon in the sample [11, 12]. Fifty microliters (50 µl) of subsample was drawn from the well mixed material in a sample tube and dropped on a plane glass slide and covered with a coverslip. The slide was then transferred unto the stage of the light microscope and the organisms viewed, identified and counted under 400x magnification. In identifying the organisms, several guides [13, 14, 15, 16] on freshwater algae, zooplankton and macroinvertebrates were consulted. Organisms were identified to the lowest possible taxon.

The two-sample t-test, which assumes unequal variances, was used to compare the mean total length (mm) and the mean body weight (g) between the female and male *Oreochromis niloticus* samples at $\alpha = 0.05$. Two methods of stomach contents analysis (the percent frequency of occurrence and the numerical percentage methods) were employed during this study [17]. On the one hand, the percent frequency of occurrence methods gives the percentage of stomachs containing a particular food item out of the total stomachs with food. On the other hand, the numerical percentage method gives the percentage of a specific prey item within a food component in all the stomachs by considering the importance of the prey in relation to the total counts for that component – for example, the numerical percentage of the prey item *Aphanizomenon* in the food component cyanobacteria was obtained by dividing the total counts (N) for *Aphanizomenon* by the sum (S) of all the cyanobacteria present in the analysed stomach, and the result multiplied by 100. The relative importance of each food component was also determined.

3. Results

Out of the 55 specimens of *O. niloticus* 39 were males and 16 females. Almost all the females were carrying eggs, which were at various stages of maturation. Data on total length and weight of the fish are presented in Table 1. There was a highly significant difference ($t(53) = 5.92$; two-tail $p = 0.00000024$) in mean total length between the male fish (mean total length = 178 mm and the Confidence Interval (C.I.) on true mean = 164, 192) and the female fish (mean total length = 228 mm and the C.I. on true mean = 218, 238). There was equally a highly significant difference ($t(53) = 5.48$; two-tail $p = 0.00000156$) in mean weight between the male fish (mean weight = 124 g and the C.I. on true mean = 98, 150) and the female fish (mean weight 219 g and the C.I. on true mean = 195, 243).

Only 56.36% of the fish had food in their stomach. Among the 43.64% of fish with an empty stomach, 38.19% were males. Thus, only a small percentage (5.45%) of female fish had an empty stomach. The microalgal, zooplankton and macroinvertebrate prey items observed in the stomachs of the fish specimens are given in Table 2. A total of 97 taxa were recorded. These included 17 genera of cyanobacteria, 27 genera of diatoms, 25 genera of chlorophytes, 15 genera of charophytes, 1 genus each among the cryptophytes, heterokontophytes, chrysophytes and rhodophytes, and 2 genera each among the dinoflagellates and euglenophytes. Others are 3 taxa of zooplankton and two taxa of macroinvertebrates.

The frequency of occurrence (%) and numerical percentage (%#) of the prey items in the stomachs are presented in Tables 3 and 4. Among the algae, representatives of Bacillariophyta, Charophyta, Chlorophyta, Cyanobacteria, and Dinophyta were present in all the stomachs with food. In the Division Bacillariophyta the following genera *Amphora, Cymbella, Fragilaria, Gomphonema, Melosira, Navicula* and *Synedra* were seen in all stomachs with food (100% occurrence); *Diatoma, Pinnularia* and *Tabellaria* occurred each in 80% of the stomachs. Among the charophytes *Staurastrum* (100% occurrence), *Closterium* and *Staurodesmus* (80% occurrence each) were the most important food items. The most important chlorophytes were *Oedogonium* which occurred in all the stomachs with food (100% occurrence), and *Oocystis* which occurred in 80% of the stomachs. *Microcystis* (100% occurrence) and *Synechocystis* (80% occurrence) were the most important food items among the cyanobacteria food component. Among the dinoflagellate food component, *Peridinium* occurred in all the stomachs with food (100% occurrence), while *Gymnodinium* occurred in 80% of the stomachs.

In terms of numerical percentage, *Microcystis* had the highest numerical percentage (74.6%) among the cyanobacteria food component. Each of the other cyanobacteria prey items had a numerical percentage that was less than 10%. Among the diatoms, *Cymbella* had the highest numerical percentage (53%) followed by *Gomphonema* (12.6%). Each of the other prey items belonging to the diatom food component had a numerical percentage that was less than 10%. Among the chlorophytes *Oedogonium* had the highest numerical percentage (41.2%). The other prey items in the chlorophyte food component had a numerical percentage that was less than 10%. Among the charophytes, *Staurastrum* (21.8%) and *Spirogyra* (21.3%) had the highest numerical percentage followed by *Mougeotia* (12.6%) – each of the remaining prey items in the charophyte food component had a numerical percentage that was less than 10%. Among the other algal groups (listed under other algae) *Peridinium* had the highest numerical percentage (71%) followed by *Dinobryon* that scored 11% (Table 3).

Among the zooplankton food component, copepods occurred in all the stomachs with food (100% occurrence), while rotifers and cladocerans occurred in 60 and 40%, respectively of the stomachs. Copepods also had the highest numerical percentage value (67%), followed by the rotifers (20%), and then the cladocerans that scored 13%. Among the macroinvertebrate food component, chironomids and odonates occurred each in 20% of the stomachs, and each had a 50% numerical percentage score (Table 4). Nevertheless, 99% of the prey items observed in the stomachs belonged to microalgae (Figure 1), and the majority (51%) of the microalgal prey were diatoms (Bacillariophyta). Cyanobacteria contributed 24% of the microalgal prey items, while Chlorophyta contributed 14%, and the charophytes 7%. The 'other algae' group (the cryptophytes, dinophytes, euglenophytes, heterokontophytes, chrysophytes and rhodophytes) contributed just 4% of the total microalgal prey items in the stomachs of *O. niloticus* (Figure 2).

4. Discussion

The average weight of the female fish was higher than that of the males. One possible reason for this is the fact that almost all of the female fish samples were bearing eggs. Another possible reason is the fact that most of the male fish had no food in their stomach. Out of the 43.64% of fish with an empty stomach, 38.19% were males.

When considering the total percentage of fish with an empty stomach, the 43.64% recorded during this study could be viewed as a high percentage. However, some other workers reported even a higher percentage of fish with empty stomachs. For example, Assefa and Getahun [18] observed that 65% of *O. niloticus* sampled in Lake Hayq, Ethiopia had empty stomachs. In aquaculture operations, non-feeders are often observed, especially in hatchery aquaria, and such observations are often attributed to stress factors (such as too high or too low water temperature, low dissolved oxygen level, patchy food concentration, and high stocking density, among others) that affect the fish [19]. But why do individuals of wild *O. niloticus* have an empty stomach in the midst of plenty of food, and favourable environmental conditions? The environmental conditions of Liberty Reservoir, Jos are optimal for aquatic biotas inhabiting the ecosystem [1]. Moreover, food resources are not limiting for cichlids (in natural environments) that show high levels of efficiency in habitat use [20]. One possible reason for the empty stomachs observed in this study may include the fact that *O. niloticus* feeds mainly during the daylight hours [4, 6, 21], and as such it is possible that most of the stomachs evacuated overnight. It should be noted, too, that the fishermen set fish traps during the night, and harvest their catch by 06:00 hrs the next day.

Adults of *O. niloticus* in Liberty Reservoir fed preferentially on microalgae, and scarcely on zooplankton and macroinvertebrates. However, this apparent food preference by the fish needs to be further studied via a monthly survey of stomach contents during, at least, a one year period. Bowen [8] suggested that in order to characterise the diet of tilapias, it is important to know the food components that occur consistently in different stomachs over a long period. The different seasons of the year have the potential to influence prey availability in a given water body, and, hence, the feeding habit of *O. niloticus* [22]. Nevertheless, the findings of the present study are in agreement with the findings of other workers. For example, Moriarty and Moriarty [23], Yada [24], Ajuzie and Nwokorie [4], Teferi *et al*. [21] and Abdel-Tawwab and El-Marakby [25] all reported that adults of *O. niloticus* are largely algivores that sparingly feed on zooplankton and other faunal components. Abdel-Tawwab and El-Marakby [25] even reported that in the stomachs of adult *O. niloticus* captured in ponds in Egypt, faunal components did not exceed 1% of the total food components, and that microalgae were the most dominated food eaten by this fish.

Among the microalgae, diatoms appeared to be the most preferred prey. Although it has been suggested that the algal cell wall cannot be lysed by the digestive enzyme of fish [26], diatoms are an exception. This is because the structure of their valves permits a connection between the protoplasm of the cells and the external milieu, which makes it possible for the organic contents of the cells to be digested by the cichlids [6, 27, 28, 29]. In view of the fore mentioned, Ajuzie and Nwokorie [4] suggested that diatoms are the most important source of nutrients for *O. niloticus*. This is in agreement with the findings of Fryer and Iles [3], Fish [27], Bowen [26, 30] and De Moor *et al*. [31]. For example, Fish [27] reported that there was a high yield of tilapia in the areas of Lake Albert, Uganda dominated by diatoms.

Cichlids can modulate their feeding habits from pelagic filter-feeding to substrate feeding [32, 33]. The microalgae recorded in the stomachs of *O. niloticus* in Liberty Reservoir, Jos can be found among the plankton, benthos, and periphytes. Some of the microalgae are unicellular (e.g. *Peridinium*); others colonial (e.g. *Dinobryon*) or filamentous (e.g. *Spirogyra*). Therefore, *O. niloticus* in Liberty Reservoir, Jos may be described as a filter-feeder, a benthic grazer, and a browser of microalgae. This gives the fish a wide feeding range, permitting it to consume microalgae in different niches. With reference to the benthos, it appears this fish feeds mostly on epibenthic microalgae, and does not dig deep into the bottom. According to Jones [34], whereas browsers bite and tear off bits of attached or free floating filamentous algae, grazers scrape or glean microalgae off the substratum, or as suction feeders [35], which suck prey from the epibenthos directly into the buccal cavity. Benthic macroinvertebrates, for example, are typically infaunae that bury themselves deep into the bottom. This behaviour and the epibenthic feeding behaviour of *O. niloticus* must be partly responsible for the low frequency of occurrence of macroinvertebrates in the diet of the cichlids. Another possible reason why the animal components were scarce in the stomachs of *O. niloticus* is the fact that the animals have the ability to make a relatively quick escape. Mallin [32] is of the opinion that prey items with poor evasive abilities are vulnerable to tilapia predation. It should also be noted that fish more readily digest faunal prey than algae.

Since Liberty Reservoir is primarily used for the distribution of treated pipe-borne water to inhabitants of the city, and since *O. niloticus* feeds extensively on microalgae in this reservoir, this cichlid could be very helpful in the control of microalgal blooms that negatively affect water quality. Mallin [32] reported that tilapia has the ability to control nuisance microalgal blooms due to their feeding preference for microalgae. And in Lake Kinneret, Israel, because the cichlid *S. galilaeus* feeds extensively on the predominant phytoplankton *Peridinium gatunense* [36, 37] that usually forms monospecific blooms in the waterbody, *S. galilaeus* was considered beneficial to maintaining good water quality in the lake [38, 39]. In view of this, it would be proper for local authorities to manage *O. niloticus* fishery in the reservoir by, among others, officially recognizing the fishermen who now fish clandestinely in the waterbody. This will help put in place measures that will limit fishing efforts and the size of fish to be retained by the fishermen. At the moment, the fishermen fish intensively in the reservoir, and many smaller fish are landed by them. This is evidenced in the records of total lengths and weights of the samples bought from one of the fishermen for this study.

This study also suggests that microalgae could be effectively utilized for the successful farming of *O. niloticus*. In view of this, readily consumed microalgae could be isolated from the wild and intensively cultured for the farming of this fish. By so-doing the high energy and nutrients contained in the algae [40] will be efficiently transformed into animal protein. This practice will significantly lower the cost of rearing tilapia, making room for great harvests and, hence, a profitable fish farming business.

Table 1: Comparison of the size and weight of male and female *O. niloticus* specimens from Liberty Reservoir, Jos.

Parameter	**Sex**	
	Male (n = 39)	Female (n = 16)
Total length (mm)		
Maximum	244	250
Minimum	82	194
Median	178	234
Mean	178	228
Confidence Limit on true mean (p = 0.05)	14	10
Confidence Interval (C.I.) on true mean (p = 0.05)	(164, 192)	(218, 238)
Weight (g)		
Maximum	289	296
Minimum	10	156
Median	107	213
Mean	124	219
Confidence Limit on true mean (p = 0.05)	26	24
Confidence Interval (C.I.) on true mean (p = 0.05)	(98, 150)	(195, 243)

Table 2: Prey items in the stomachs of *Oreochromis niloticus* from Liberty Reservoir, Jos, Nigeria

Cyanobacteria	**Diatom**	**Chlorophyta**	**Charophyta**	**Other algae**	**Zooplankton**	**Macroinvertebrate**
Aphanizomenon	*Achnanthes*	*Botryococcus*	*Chara*	(Cryptophyta)	Cladocera	Chironomidae
Aphanotheca	*Amphora*	*Chlamydomonas*	*Closterium*	*Cryptomonas*	Copepoda	Odonata
Chamaesiphon	*Asterionella*	*Chlorella*	*Cosmarium*		Rotifera	
Chroococcus	*Caloneis*	*Chlorococcum*	*Euastrum*	(Dinophyta)		
Coelosphaerium	*Coscinodiscus*	*Cladophora*	*Gonatozygon*	*Gymnodinium*		
Hydrococcus	*Cyclotella*	*Coelastrum*	*Micrasterias*	*Peridinium*		
Lyngbya	*Cymatopleura*	*Crucigenia*	*Mougeotia*			
Merismopedia	*Cymbella*	*Dictyosphaerium*	*Penium*	(Euglenophyta)		
Microcoleus	*Diatoma*	*Enteromorpha*	*Pleurotaenium*	*Euglena*		
Microcystis	*Epithemia*	*Eudorina*	*Spirogyra*	*Phacus*		
Oscillatoria	*Eunotia*	*Geminella*	*Spondylosium*			
Plectonema	*Fragilaria*	*Hydrodictyon*	*Staurastrum*	(Heterokontophyta)		
Pseudanabaena	*Frustulia*	*Microspora*	*Staurodesmus*	*Tribonema*		
Raphidiopsis	*Gomphonema*	*Oedogonium*	*Xanthidium*			
Schizothrix	*Grammatophora*	*Oocystis*	*Zygnema*	(Chrysophyta)		
Synechococcus	*Hantzschia*	*Pandorina*		*Dinobryon*		
Synechocystis	*Licmophora*	*Pediastrum*				
	Melosira	*Pithophora*		(Rhodophyta)		
	Meridion	*Pseudosphaerocystis*		*Lemanea*		
	Navicula	*Roya*				
	Neidium	*Scenedesmus*				
	Nitzschia	*Sphaerocystis*				
	Pinnularia	*Tetraedron*				
	Rhizosolenia	*Trentepohlia*				
	Surirella	*Ulothrix*				
	Synedra					
	Tabellaria					

Table 3: Frequency of occurrence (%) and numerical percentage (%#) of microalgae in the stomachs of *O. Niloticus* from Liberty Reservoir, Jos

Cyanobacteria	%	%#	Bacillariophyta	%	%#	Chlorophyta	%	%#	Charophyta	%	%#	Other algae	%	%#
Aphanizomenon	20	0,2	*Achnanthes*	20	0,1	*Botryococcus*	20	0,3	*Chara*	20	0,5	Cryptophyta		
Aphanotheca	20	0,2	*Amphora*	100	5	*Chlamydomonas*	20	0,3	*Closterium*	80	5,2	*Cryptomonas*	20	1,1
Chamaesiphon	40	1,7	*Asterionella*	40	0,2	*Chlorella*	20	0,6	*Cosmarium*	60	7,5			
Chroococcus	20	0,4	*Caloneis*	20	0,4	*Chlorococcum*	20	1,7	*Euastrum*	40	3	Dinophyta		
Coelosphaerium	20	0,2	*Coscinodiscus*	20	0,1	*Cladophora*	20	0,3	*Gonatozygon*	20	0,5	*Gymnodinium*	80	8,7
Hydrococcus	20	3,5	*Cyclotella*	60	0,2	*Coelastrum*	40	3,5	*Micrasterias*	20	0,5	*Peridinium*	100	71
Lyngbya	20	0,2	*Cymatopleura*	20	0,1	*Crucigenia*	20	0,9	*Mougeotia*	20	13			
Merismopedia	20	7	*Cymbella*	100	53	*Dictyosphaerium*	20	2,6	*Penium*	20	0,5	Euglenophyta		
Microcoleus	20	0,2	*Diatoma*	80	0,2	*Enteromorpha*	20	0,3	*Pleurotaenium*	20	4	*Euglena*	40	2,2
Microcystis	100	75	*Epithemia*	20	0,1	*Eudorina*	20	0,3	*Spirogyra*	60	21	*Phacus*	20	1,1
Oscillatoria	40	0,4	*Eunotia*	60	1	*Geminella*	20	0,3	*Spondylosium*	20	1,7			
Plectonema	20	0,2	*Fragilaria*	100	2,2	*Hydrodictyon*	60	2,3	*Staurastrum*	100	22	Heterokontophyta		
Pseudanabaena	40	5	*Frustulia*	20	0,1	*Microspora*	60	31	*Staurodesmus*	80	7,5	*Tribonema*	20	3,3
Raphidiopsis	20	0,2	*Gomphonema*	100	13	*Oedogonium*	100	41	*Xanthidium*	20	0,5			
Schizothrix	20	0,2	*Grammatophora*	20	0,1	*Oocystis*	80	2,6	*Zygnema*	40	13	Chrysophyta		
Synechococcus	20	0,4	*Hantzschia*	20	0,1	*Pandorina*	20	1,2				*Dinobryon*	60	11
Synechocystis	80	5	*Licmophora*	40	0,2	*Pediastrum*	40	0,6						
			Melosira	100	11	*Pithophora*	20	0,3				Rhodophyta		
			Meridion	20	0,1	*Pseudosphaerocystis*	20	1,2				*Lemanea*	40	2,1
			Navicula	100	6	*Roya*	20	0,3						
			Neidium	40	0,2	*Scenedesmus*	40	1,2						
			Nitzschia	40	0,2	*Sphaerocystis*	20	0,3						
			Pinnularia	80	0,7	*Tetraedron*	20	0,3						
			Rhizosolenia	20	0,1	*Trentepohlia*	20	0,9						
			Surirella	60	0,5	*Ulothrix*	40	6						
			Synedra	100	4,4									
			Tabellaria	80	0,7									

Table 4: Frequency of occurrence (%) and numerical percentage (%#) of zooplankton and macroinvertebrates in the stomachs of *O. niloticus* from Liberty Reservoir, Jos

Zooplankton	%	% #	Macroinvertebrate	%	% #
Cladocera	40	13	Chironomidae	20	50
Copepoda	100	67	Odonata	20	50
Rotifera	60	20			

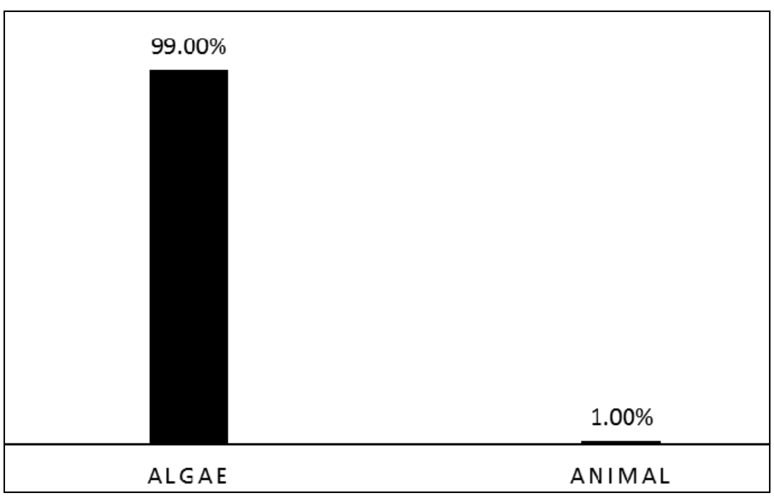

Fig 1: Percentage composition of microalgal (algae) and animal (macroinvertebrates and zooplankton) components in the stomach of *Oreochromis niloticus* from Liberty Reservoir, Jos

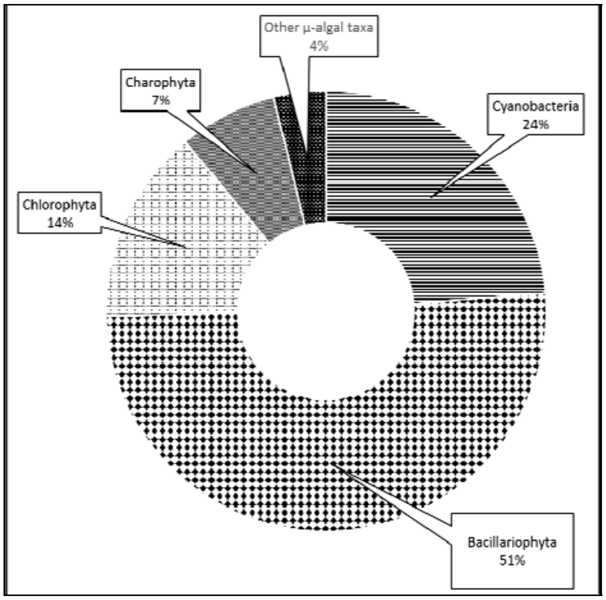

Fig 2: Diatoms formed the majority of the microalgae prey of *O. niloticus* from Liberty Reservoir, Jos

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