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Seasonal and Spatial Variations in Feeding on the Plankton Patterns for the Nile Tilapia, *Oreochromis niloticus*, (Linnaeus, 1758) off the Nile Course in Aswan, Egypt

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ABSTRACT

The importance of plankton as the main food for the Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758**)** has been widely addressed. However, the composition of the Nile tilapia diet may vary in a wide range of seasonal and spatial conditions, fish size and maturity. Therefore, this study aimed to compare the plankton patterns fed by the Nile tilapia in the southern parts of the Nile in Egypt (Lake Nasser, Aswan Reservoir and the Nile River). These areas differ in their morphological and hydrological characteristics due to the presence of the High Dam and the Aswan Low Dam. In addition, the study focused on the effect of the flood seasons on the feeding behavior of the Nile tilapia since the flood directly affects the ecosystem of the study areas and subsequently the composition of its natural food. In addition, the feeding behavior according to different sex and size was studied. A total of 454 samples of *O. niloticus* were collected from commercial fishing by fishermen using the common trammel gill nets. The frequency of occurrence method was utilized to assess the diet composition of *O. niloticus*. No significant differences were detected in stomach contents during the different flood seasons and regions for Bacillariophyceae and Cyanophyta. Nevertheless, there were significant differences in stomach contents in the different flood seasons and regions for the other planktonic food items. The results indicated that the feeding behavior of *O. niloticus* was not related to sex. Stomach analysis of *O. niloticus* in different length groups at each region revealed that some of the phytoplankton items (Bacillariophyceae and Cyanobacteria) had the same frequency, while the feeding behavior did not show a distinctive pattern for other phytoplankton items. Furthermore, there were significant differences in stomach contents for zooplankton items, with the variation of length groups. The study concluded that the composition of the Nile tilapia diet (except Bacillariophyceae and Cyanophyceae) varied according to region and season based on the previously reported food availability.

INTRODUCTION

Tilapia is a freshwater fish group that inhabits rivers, lakes, shallow streams and ponds, and is found less commonly in brackish waters. Tilapia is one of the most known members of tropical and subtropical fishes. It is recommended by the (FAO) as a culture fish species because of its importance in aquaculture and its capability in contributing to the increased production of animal protein in the world. Therefore, it is now globally distributed and has become very popular through the advances in cultivation techniques **(Prabu *et al.*, 2019)**. The Nile tilapia (*Oreochromis niloticus*) is the most common species of tilapia in tropical and subtropical freshwater and has always been the basis of commercial fisheries in many African countries. It is also a common target fish in small-scale artisanal fisheries **(Mohamed & Uraguchi, 2013)**. Its high tolerance to environmental conditions and the ability to accept formulated and natural feeds make it economically viable **(Adeyemi *et al.*, 2009)**. This fish is characterized by its extreme endurance; it can withstand a wide range of environmental changes with high growth and reproductive rate **(Adeyemi *et al.*, 2009)**. Thus, the Nile tilapia has become one of the most important farmed fish in Africa. In Egypt, tilapia fishes represent the main fish production of freshwater fisheries, accounting for about 41.4% of the total production of freshwater fisheries, 79.5% of the total production of Lake Nasser and 30.9% of the Nile. Moreover, it ranks first in the productivity of farmed fish, accounting for about 65.5% of the productivity of fish farms **(GAFRD, 2019)**.

Food is the main source of energy for all living organisms including fish and is a major factor in determining their condition, growth rate and population levels **(Begum *et al.*, 2008)**. Information about the feeding habits and diet of fish provides a critical understanding of their biology, physiology and behavior. Moreover, analyzing the contents of fish stomachs provides information about the whole ecosystem. The stomach content of organisms is a valuable source for obtaining data on the community structure of fauna and flora in a certain area and for determining the demographics of species that cannot be determined by other methods **(Ibrahim *et al.*, 2003)**. There are many key factors to the success of fisheries management as well as aquaculture, one of which is an understanding of some biological fundamentals, particularly feeding behaviors **(Shalloof & Khalifa, 2009; Shalloof *et al.*, 2020)**.

The Nile tilapia is characterized by a diverse feeding behavior characterized by generalized and opportunistic feeding behavior **(Canonico *et al.*, 2005)**. Several studies have reported the importance of plankton as the main food for the Nile tilapia **(Tadesse, 1999; Prabu, 2008; Shalloof & Khalifa, 2009; Shalloof *et al.*, 2009; Shalloof *et al.*, 2020)**. In this respect, **Tsegay *et al.* (2016)** postulated that, phytoplankton species are the most food items consumed by the Nile tilapia, and still zooplankton species are also widely consumed **(Hollihan *et al.*, 2001)**. The composition of the Nile tilapia diet may vary in a wide range of seasonal and spatial conditions of environments **(Hollihan *et al.*, 2001**). Food composition may also vary depending on fish size, maturity, environmental condition, and habitat types (**Kamal *et al.*, 2010**).

Several studies have focused on the feeding modes of Nile tilapia in Egyptian water bodies. For example, **Al-Zahaby *et al.* (2004**) studied the feeding habit of Tilapia spp. from the River Nile in the Cairo region. **Shalloof and Khalifa (2009**) investigated the stomach contents of *O. niloticus* from Abu- Zabal Lakes. Also, **Shalloof *et al.* (2009)** studied the food and feeding habits of three cichlid species namely *O. niloticus*, *C. zillii*, and *S. galilaeus* inhabiting the Damietta branch of the River Nile. **Shalloof *et al.*** (**2020**) studied the feeding behavior of *O. niloticus*, *Sarotherodon galilaeus*, *and Coptodon zillii* in Lake Nasser. However, the available data about the feeding behaviors of *O. niloticus* at the southern parts of the Nile course in Egypt are still scarce. Furthermore, these areas are different in their hydrological and morphological characteristics as a result of the presence of two dams (the High Dam and the Aswan Low Dam) in addition to the effect of the flooding seasons. Where both dams and flooding play hydrological effects that directly affect the ecosystem dynamics, hence the composition of natural food items (**Godlewska *et al.*, 2003; Xie *et al.*, 2015; Srivastava *et al.*, 2020; Hegab *et al.*, 2021; Zaher and Aly, 2021**). Therefore, this study aims to investigate the feeding modes of O. *niloticus* in the southern parts of the Nile based on seasonal and spatial, sexual, and size variations.

MATERIALS AND METHODS

Site description

Samples were collected from three regions [Lake Nasser (Khor El-Ramla), Aswan Reservoir and the mainstream of the River Nile] in the southern course of the River Nile in Egypt in Aswan Governorate (Fig. 1). Khor El-Ramla is among many embayments (khors) in Lake Nasser. It is located to the north of Lake Nasser with a surface area of about 101.20km^2, a length of 25.72 km and a mean depth of 14.2m during the dry season and 19.5m during the flood season **(Wahab *et al.*, 2018; Kassem *et al.*, 2020)**. Aswan Reservoir is a small artificial lake formed as a result of Aswan Low Dam built in the period between 1898 and 1902 on the Aswan Waterfall. Aswan Reservoir is located between the High Dam (Lake Nasser) and the beginning of the mainstream of the Nile (Aswan Low Dam). It has a length of about 7km, a mean depth of 18m and a mean width of 1.5km **(Iskaros & El- Otify, 2013)**. The mainstream area of the Nile is represented by the region downstream of Aswan Low Dam. This area is characterized by depths ranging from 8 to 11 and a mean width of 2.8km.

Sampling and examination

Sampling was carried out in July 2019 (pre-flood season), October 2019 (flood season) and January 2020 (post-flood season). A total of 454 samples of *O. niloticus* were collected from commercial fishing by fishermen using the common trammel and gill nets. Fishes were divided into three length groups (small, medium and large), depending on the length range in each sampling site, with an interval of (L_{max}-L_{min})/3. Additionally, fish were divided into two groups (males and females) in each sampling site. The stomach contents were stored and examined using a binocular research microscope. The food organisms were identified as species level as possible according to **Evans and Prescott (1956)**, **Pontin (1978)**, **Streble and Krauter (1978)**, **Shiel and Koste (1979)** and **Komärek and Fott (1983)**.

Data analysis

The frequency of occurrence method was utilized to assess the diet composition of *O. niloticus*. The occurrence of food items was expressed as the percentage of the total number of stomachs containing food. This method demonstrated what organism uses qualitatively rather than quantitively **(Hyslop, 1980)**.

Variations in the occurrence of plankton items according to different regions, seasons, sex and sizes were analyzed with one-way analysis of variance (ANOVA) with Tukey's honestly significant difference (HSD) post hoc tests using XLSTAT 2016 software.

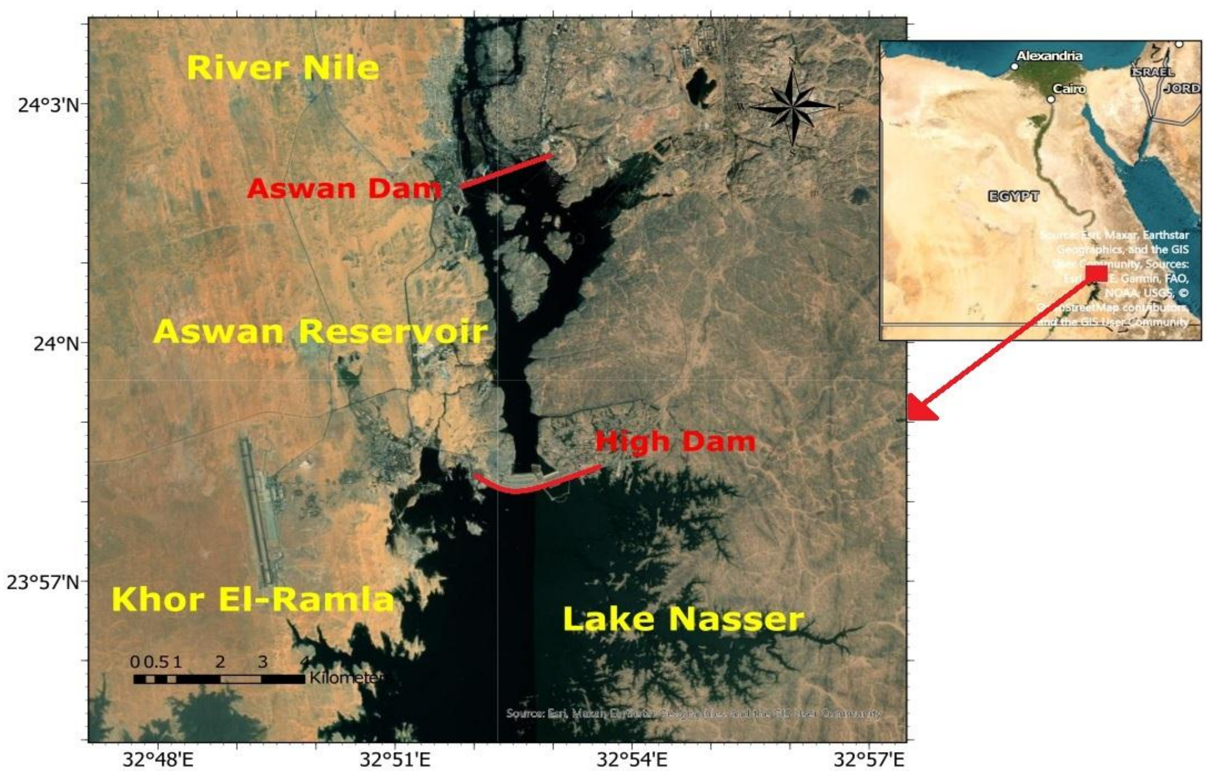

Fig. 1. Maps showing the location of the study area and sampling locations (River Nile, Aswan Reservoir and Khor El-Ramla).

RESULTS AND DISCUSSION

The planktons identified in the stomach of *O. niloticus*

The phytoplankton in *O. niloticus* is represented mainly by Cyanophyta (*Microcyst* spp., *Merismopedia* spp. and *Oscillatoria* spp.), Bacillariophyceae (*Synedra* spp., *Cyclotella* spp., *Melosira* spp. and *Navicula* spp.), Cholorphyta (*Scendesmus spp., Ankistrodesmus* spp., *Pediastrum* spp. and *Planktospherium* spp.), Dinophyceae (*Ceratium* spp.), Charophyceae and Ochrophyta.

While, zooplankton is represented by Rotifera (*Brachionus* spp., *Keratella* spp., *Lecan* spp., *Monostylla* spp., *Tricocerca* spp., *Philodina* sp., *Conchilus* sp., *Chlorella* sp., *Cephalodella* sp., *Asphlanchna* sp., *Epiphanes* sp., and *Anuraeopsis* sp.), Copepoda, (*Mesocyclops ogunnus*, *Thermocyclops neglectus*, *Thermodiaptomus galebi,* in addition to Copepodit stages and Nauplius larvae), Cladocera (*Alona quadrangularis*, *Bosmina longirostris*, *Ceriodaphnia dubia*, *Chydorus sphaericus*, and *Daphnia longispina*) and Protozoa (*Centropyxis aculeata*, *Vorticella campanula* and *Epistylis* sp.).

Feeding modes of *O. niloticus* based on different localities and seasons

The seasonal and spatial variations in the frequency of occurrence of phytoplankton and zooplankton groups in the stomach of *O. niloticus* are shown in Table (1). The investigation of phytoplankton food items showed that Bacillariophyceae and Cyanophyta were recorded in all the examined samples (100%) in the three regions under study during different seasons. Moreover, the ANOVA analysis showed that there were no significant differences in stomach contents in different seasons and regions for these two food items. Nevertheless, there were significant differences in stomach contents in the different flood seasons and regions for the least frequent food item of phytoplankton (Chlorophyta, Charophyta, Ochrophyta, Euglinophyta and Dinoflagellate) (Table 1). Similarly, zooplankton items varied in the different flood seasons and regions. Rotifers were the most frequented group in the examined stomachs. They accounted for about 93, 78, and 100% in Lake Nasser; 80, 100, and 73% in the Aswan reservoir, and 78, 54, and 100% in the Nile during pre-flood, flood and post-flood seasons, respectively. Cladocera was the second most frequented group, and it was extensively recorded in Lake Nasser in the post-flood season and flood season with about 60 and 67%, while it decreased to 14% in the pre-flood season. On the other hand, Cladocera occurred in low percentages of the examined stomachs in the Nile River and the reservoir (Table 1). Protozoa occurred in slightly high percentages of 28, 56 and 40% in Lake Nasser during pre-flood, flood and post-flood seasons, respectively. In contrast, during flood season, it attained 27 and 31% in the reservoir and Nile River, respectively. Moreover, it was not recorded in the post-flood season and pre-flood season in the Nile and the reservoir. Copepods were rarely recorded in the reservoir and the Nile, but they increased slightly in Lake Nasser, especially in flood season (67%).

From the previous results, a discrepancy was detected in the food items according to the region and season. This can be attributed to the nature of the Nile tilapia depending on the availability of food, which changes according to the region throughout the year due to the seasonality of the available foods **(Ballesteros *et al.*, 2009; Hussian *et al.*,**

2019). In addition, the hydrological characteristics differ in the three regions studied due to the presence of the High Dam and Aswan Low Dam. Dams affect the aquatic ecosystem by altering the physical, chemical and environmental states causing changes in species composition, ecosystem structure as well as biodiversity **(Srivastava *et al.*, 2020)**. Furthermore, flood seasonality plays a major role in the ecological state and plankton structure in these regions **(Hussian *et al.*, 2019; Goher *et al.*, 2021; Hegab *et al.*, 2021; Zaher & Aly, 2021)**. **Abdel-Aziz and Gharib (2007**) mentioned that, the number of food items and their diversity varied from one season to another indicating the adaptability of fish to change their diet according to the food types available in the environment. **Njiru *et al.* (2004**) found that, the change in the diet of *O. niloticus* could be due to ecological and environmental changes in Lake Victoria. On the other hand, the present results showed the importance of phytoplankton (Cyanophyta and Bacillariophyceae) all over the year in the different regions, which can be attributed to the dominance of these groups in the study area **(Farghl & Samer, 2015; Goher *et al.*, 2021)**. Regarding zooplankton, Rotifera was the most abundant food for *O. niloticus* in the Nile, the reservoir and Lake Nasser during different seasons. This is consistent with the fact that Rotifera is the dominant group in the Nile throughout the year **(Hegab & Khalifa, 2021)**. Nevertheless, copepods represented the main group in Lake Nasser **(Goher *et al.*, 2021; Hegab *et al.*, 2021)**, and this can be explained by the fact that copepods are larger and have more developed movement organs as well as they swim quickly, thus they can escape from predators more than other zooplankton groups.

Feeding modes of *O. niloticus* based on sex variation

Stomach analysis of *O. niloticus* in terms of different sex at each region revealed that some of the food items (Bacillariophyceae and Cyanobacteria) were nearly the same. Nevertheless, differences were recorded in the other groups (e.g., Protozoa), either in one of the study regions or in the three regions such as Charophyceae (Table 2). Whereas, Bacillariophyceae and Cyanophyta were frequently recorded (100%) in all examined stomachs of males and females in the three regions. Rotifera was the most zooplankton group and it frequented between 71 to 94 & 80 to 89 % of males and females in the three regions, respectively. On the other hand, no significant differences were detected in the occurrence of Protozoa in the stomachs of males and females in the Nile and the reservoir. Nevertheless, in Lake Nasser, Protozoa were recorded more in females' stomachs (56%) than in males' stomachs (27%). Chlorophyta occurred in higher percentages in females (100 and 80%) than in males (93 and 53%) in both Lake Nasser and the reservoir. However, a slight difference between males and females (59 and 58% respectively) was noticed between males and females in the Nile River. Charophyta occurred with higher percentages in females (100, 58, and 90%) than males (87, 12, and 53%) in Lake Nasser, the River Nile and the reservoir, respectively.

Table1. The occurrence of plankton groups (%) in the stomach of *O. niloticus* in the three studied regions during different flood seasons

Food item	Pre- flood				Flood				Post-flood			
	Lake Nasser	Aswan Reservoir	Nile River	Pr > F	Lake Nasser	Aswan Reservoir	Nile River	Pr > F	Lake Nasser	Aswan Reservoir	The Nile River	Pr > F
Protozoa	28^{b}	0	0	0.00	56^{a}	27^{b}	31^{b}	0.01	40^{a}	0	0	0.00
Rotifera	93^{a}	80^{b}	78^{b}	0.001	78^{b}	100^{a}	54^{c}	0.0001	100^{a}	73^{b}	100^{a}	0.001
Cladocera	14^{d}	20^{c}	22^{c}	0.01	67^{a}	18^{cd}	31^{b}	0.0001	60^{a}	9^{d}	22^{c}	0.0001
Copepoda	21^{b}	0	0	0.00	67^{a}	9^{c}	8^{c}	0.001	20^{b}	0	0	0.00
Bacillariophyceae (Diatoms)	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0
Cyanophyceae (Blue-green algae)	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0
Chlorophy~~ta~~ceae(green algae)	100^{a}	70^{b}	33^{cd}	0.01	100^{a}	91^{a}	54^{c}	0.001	80^{b}	27^{d}	100^{a}	0.0001
Charophyceae	86^{b}	10^{a}	22^{d}	0.0001	100^{a}	55^{c}	92^{a}	0.001	80^{bc}	18^{d}	89^{b}	0.001
Ochrophyta	36^{a}	20^{bc}	0	0.01	11^{c}	9^{c}	23^{b}	0.01	40^{a}	9^{c}	44^{a}	0.001
Euglenophyceae	21^{bc}	50^{a}	11^{c}	0.001	0	9^{c}	8^{c}	0.001	40^{ab}	9^{c}	$11b^{c}$	0.001
Dinoflagellates (Dinophyceae)	14^{b}	0	11^{b}	0.00	0	0	0	0.00	60^{a}	0	0	0.00

a–d: Different letters in the same raw indicate statistically significant differences ($P < 0.05$, Tukey's test)

Pr > F: The *P*-value is associated with the *F*-statistic of a given effect and test statistic.

The previous results indicated that the feeding pattern of the investigated fish species does not relate to the sex, as there were no significant differences for some food items between the sexes in the three regions. On the other hand, there were significant differences in the other items from one region to another. Thus, the current study can propose that the variation in the feeding pattern of the Nile tilapia depends mainly on the availability of food and is not related to the difference in fish sex. Yet, several studies reported that the feeding behavior of fish depends on the difference in sex **(Offem *et al.*, 2007; Ayoade *et al.*, 2008)**.

Table 2. The occurrence of different food items (%) in the stomach of *O. niloticus* s considering different sex types in the three studied regions

Food item		Lake Nasser			Aswan Reservoir			The Nile River		
		Male	Female	Pr > F	Male	Female	Pr > F	Male	Female	Pr > F
Zooplankton	Protozoa	27^{b}	56^{a}	0.001	18^{a}	10^{a}	0.12	12^{a}	8^{a}	0.18
	Rotifera	87^{a}	89^{a}	0.53	71^{a}	80^{a}	0.18	94^{a}	83^{a}	0.16
	Cladocera	27^{b}	67^{a}	0.0001	24^{a}	20^{b}	0.026	0	42^{a}	0.000
	Copepoda	40^{a}	33^{b}	0.01	6^{a}	0	0.006	6^{a}	0	0.006
Phytoplankton	Bacillariophyceae (Diatoms)	100^{a}	100^{a}	1.0	100^{a}	100^{a}	1.0	100^{a}	100^{a}	1.0
	Cyanophyceae (Blue-green algae)	100^{a}	100^{a}	1.0	100^{a}	100^{a}	1.0	100^{a}	100^{a}	1.0
	Chlorophyceae (green algae)	93^{b}	100^{a}	0.03	53^{b}	80^{a}	0.003	59^{a}	58^{a}	0.55
	Charophyceae	87^{b}	100^{a}	0.01	53^{b}	90^{a}	0.001	12^{b}	58^{a}	0.001
	Ochrophyta	33^{a}	22^{b}	0.016	24^{ab}	30^{a}	0.06	0	17^{a}	0.003
	Euglenophytaceae	7^{a}	11^{a}	0.1	6^{b}	20^{a}	0.01	24^{a}	8^{b}	0.008
	Dinoflagellates (Dinophyceae)	33^{a}	0	0.000	0	0	--	0	0	--

a–b: Different letters in the same raw of each region indicate statistically significant differences ($P < 0.05$, Tukey's test)

Pr > F: The *P*-value is associated with the *F*-statistic of a given effect and test statistic

Feeding modes of *O. niloticus* based on the different sizes

Stomach analysis of *O. niloticus* according to different length groups at each region revealed that some of the food items showed no variation in their frequency (e.g., Bacillariophyceae and Cyanophyceae); nevertheless, there were variations in the other phytoplankton groups (Table 3). Bacillariophyceae and Cyanophyta were frequently recorded (100%) in all examined stomachs of males and females in the three regions, while the feeding pattern of fish of the other phytoplankton groups was not depending on the different sizes in the different regions. These results may indicate that the Nile tilapia prefer feeding on phytoplankton during their different growth stages. It also depends for its nutrition on the availability of different phytoplankton groups **(Hussian *et al.*, 2019)**. Several studies agree with our results. **Tsegay *et al.* (2016)** indicated that phytoplankton species are the most food items consumed by *O. niloticus*. Additionally, **El-Naggar *et al.* (2019**) mentioned that, the green algae are the main dominant food items in the stomachs of O. *niloticus* in the River Nile. **Teferra and Fernando (1989**) reported that, phytoplankton (blue-green algae, diatoms, and green algae) were the principal food of both adult and young *O. niloticus* in Lake Awassa, Ethiopia. Likewise, **Teferra (1993**) found that adult *O. niloticus* in Lake Chamo, Ethiopia mainly feeds on phytoplankton.

Regarding zooplankton groups, there were significant differences in the stomach contents of the different fish sizes in the three regions. Zooplankton groups were more frequent in the stomachs of large fish samples in the three regions (Table 3). According to **Otino *et al.* (2014)**, fish are fed on the more digestible food items fitting their mouth openings. This is because the digestive system of the fish develops as the fish grows, and thus the absolute rate of food consumed increases **(Wakil *et al.*, 2014)**. Furthermore, the increase in zooplankton in large fish can be explained on the basis that the increase in the fish length is accompanied by an increase in the size of its intestines, thus increasing the quantity and variety of food.

Table 3. The occurrence of different food items (%) in the stomach of *O. niloticus* s associated with different lengths in the three studied regions

Food item		Lake Nasser				Aswan Reservoir				The Nile River			
		Small	Medium	Large	Pr > F	Small	Medium	Large	Pr > F	Small	Medium	Large	Pr > F
Zooplankton	Protozoa	0	38^{b}	45^{a}	0.0001	13^{b}	6^{b}	33^{a}	0.001	0	0	17^{a}	0000
	Rotifera	91^{b}	88^{b}	100^{a}	0.007	75^{a}	50^{b}	82^{a}	0.0001	67^{c}	89^{b}	100^{a}	0.000
	Cladocera	45^{b}	31^{c}	100^{a}	0.001	38^{b}	6^{c}	50^{a}	0.0001	20^{a}	11^{b}	23^{a}	0.009
	Copepoda	10^{c}	25^{b}	45^{a}	0.001	0	0	17^{a}	0.000	0	6^{a}	0	0.000
Phytoplankton	Bacillariophyceae (Diatoms)	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0
	Cyanophyceae (Blue-green algae)	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0	100^{a}	100^{a}	100^{a}	1.0
	Chlorophyceae (green algae)	100^{a}	94^{b}	100^{a}	0.03	63^{a}	67^{a}	33^{b}	0.000	56^{b}	67^{a}	60^{a}	0.01
	Charophyceae	91^{b}	88^{b}	100^{a}	0.007	88^{a}	61^{c}	67^{b}	0.001	33^{a}	28^{b}	20^{c}	0.006
	Ochrophyta	27^{a}	31^{a}	0	0.000	25^{b}	17^{c}	33^{a}	0.003	22^{a}	11^{b}	0	0.000
	Euglenophy~~ta~~ceae	9^{b}	25^{a}	0	0.000	13^{a}	11^{a}	0	0.000	33^{a}	22^{b}	0	0.000
	Dinoflagellates (Dinophyceae)	0	25^{b}	100^{a}	0.000	13^{a}	0	0	0.000	0	0	0	

a–c: Different letters in the same raw of each region indicate statistically significant differences ($P < 0.05$, Tukey's test)

Pr > F: The *P*-value is associated with the *F*-statistic of a given effect and test statistic.

CONCLUSION

The study concluded that the composition of the Nile tilapia diet varied according to region and season based on the availability of food. In addition, the difference in the feeding on the plankton pattern for the Nile tilapia depends mainly on the availability of food and not on the difference in fish sex. There were significant differences in stomach contents according to sizes for zooplankton, while the feeding pattern on phytoplankton items was not varying.

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