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Assessment of the Impact of the Nile Flood on Food Chain in Lake Nasser—Egypt, with Special Reference to Turbidity

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Abstract

This study aimed to assess the impact of the Nile flood with special reference to turbidity on the food chain in Lake Nasser water as one of the largest man-made lakes in Africa before the flood (BF) and after the flood (AF) seasons. To achieve that aim, subsurface water samples were collected from 11 sampling stations along the lake before and after the flood for analyzing the water turbidity, total suspended solids, and total phosphorus, as well as chlorophyll-*a* and zooplankton to represent the food chain in the lake. Results showed an increase in water turbidity after the flood than that before the flood. Total suspended solids concentration displayed a similar trend as water turbidity. Chlorophyll-*a* concentration increased in AF all over the lake except at the entrance of the lake, as compared to the BF season. Zooplankton count was represented by copepods, cladocerans, and rotifers with the dominance of copepods in AF and rotifers in BF. The density of zooplankton was higher in the AF than the BF season. The negative impact of flood turbidity had appeared on crustacean organisms.

Keywords

Lake Nasser, Flood, Turbidity, Phytoplankton, Chlorophyll-*a*, Zooplankton

1. Introduction

Lake Nasser provides an important source of water for humans, livestock, agriculture, the generation of hydro-power, fish production, and eco-tourism. Lake Nasser is unique in its performance as it is located in a barren desert. The Nile flood originates from the Ethiopian plateau and flows once a year during late summer. It is characterized by its high turbidity as it carries a heavy load of sand, silt, and clay [1].

Planktons are microscopic organisms drifted by the water flow and are considered the main food web in the freshwater. They are constituted from phytoplankton and zooplankton. These organisms are crucial to life in the aquatic environment because they are considered the base of the food chain. The qualitative and quantitative abundance of the phytoplankton and zooplankton is significantly associated with current water quality conditions. So, the abundance and biodiversity of the planktons serve as an ecological indicator of the aquatic environment due to their quick response to any changes in the environmental factors of the aquatic systems [2] [3]. In Lake Nasser, the planktons are distributed and influenced by many factors such as flood events, turbidity, water levels, as well as other physicochemical factors. For instance, floods promote exchanges in water, sediments, organic matters, nutrients, and living organisms between the main river and the different floodplain units [4]. The fluctuations in the quantity of floodwaters from a year to another in the Nile are the most important factor affecting the abundance and community composition of organisms in the reservoir ecosystem [5].

High loads of turbidity may limit phytoplankton photosynthesis; thereby restricting the biomass development (chlorophyll-*a*) and subsequently, zooplankton diversity and density [6] [7]. Therefore, this research is conducted to recognize and assess the impact of the Nile flood with special reference to turbidity on the food chain in Lake Nasser.

2. Materials and Methods

High Aswan Dam Reservoir was created after the construction of the High Dam between 1958 and 1971. The reservoir is subtropical, divided into two parts with the majority of it belonging to the Egyptian side (extends for about 350 km between 22˚00' to 23˚58'N and 31˚30' to 33˚15'E) representing about 83% of the surface area of the reservoir, known as Lake Nasser and the rest belonging to the Sudanese territories (extends for about 150 km), known as Lake Nubia. The samples were collected from the subsurface water (50 cm) at eleven stations along the main channel of Lake Nasser during May before the flood season (BFS) and during October post the flood season (PFS) as in **Table 1** and **Figure 1**.

Two litters water sampler was used to collect the water samples from 11 sampling stations along the lake. These samples were kept in cleaned plastic bottles for the analysis of turbidity, total suspended solids (TSS) and total phosphorus (TP) according to [8]. The food chain was represented by Chlorophyll-*a* (phytoplankton) and zooplankton.

Chlorophyll-*a* (Chl. *a*) was measured by filtering of known volume (about 200 ml) of water sample immediately after collection onto GF/F paper. The filters were extracted in 90% hot methanol and measured at the different wavelengths using a spectrophotometer. Zooplankton was carried out by a vertical tow from

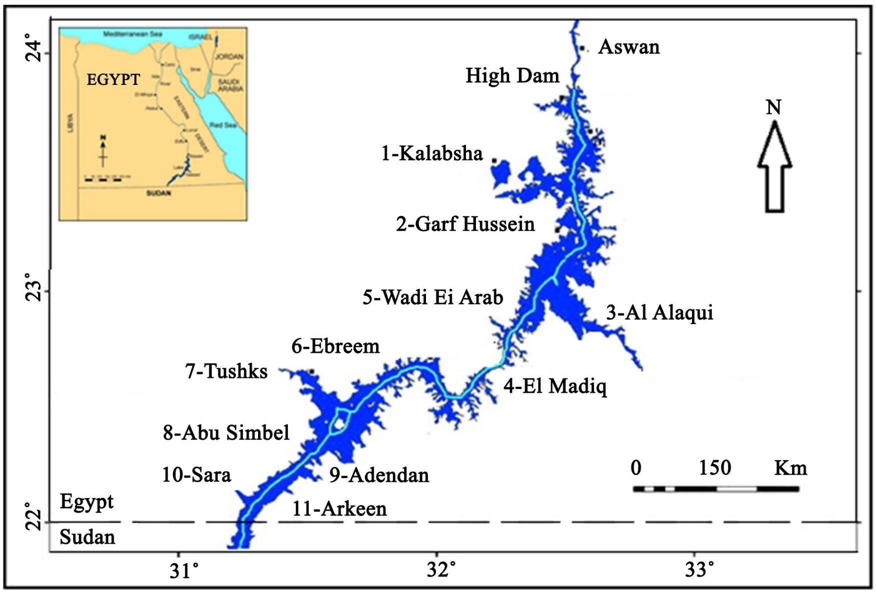

Figure 1. Sampling stations along Lake Nasser during the study period.

Table 1. Sampling stations description along Lake Nasser.

Stations Name	Km Up Stream	Position	
	Aswan High Dam	Latitude (N)	Longitude (E)
1. Kalabsha	41	23°36'52"	32°52'06"
2. Garf Hussain	80	23°12'20"	32 46'1"
3. El Alaki	95	23°06'15"	32°45'55"
4. El Madeek	130	22°54'37"	32°36'01"
5. Wadi El Arab	171	22°43'25"	32°27'28"
6. Ebreem	228	22°39'28"	31°59'02"
7. Tushka	247	22°26'4"	31°49'07"
8. Abu Simbel	281	22°19'23"	31°37'31"
9. Adendan	307	22°12'04"	31°28'54"
10. Sara	325	22°04'44"	31°22'10"
11. Arkeen	333	22°01'44"	31°21'14"

2 m to the surface, with a plankton net 55 µm mesh size. All samples were immediately fixed with 4% formalin. In the laboratory, the samples were examined, identified, and counted according to [9]-[17].

3. Results and Discussion

Lake Nasser, as one of the largest man-made lakes in Africa, is considered the main source of drinking and irrigation in Egypt, in addition to constitutes a very important sector in the Egyptian fisheries, both for significant total catch and for a large number of economically important fish species. Fish catch of Lake Nasser reached 19,751 tons during 2017 [18], so the study of its food chain became very important. The lake has prevalent lacustrine characteristics in front of the High Dam and riverine near the Sudan border, in addition to the transition zone in-between [5] [19].

It is worth mentioning that the water clarity for any waterbody is influenced by three variables, namely algal biomass (chlorophyll-*a*), non-algal suspended sediments (like silt and clay) and colored dissolved organic compounds that originated from humus substances [20] [21]. This means that the water turbidity or suspended solids values in Lake Nasser are controlled by these variables. **Figure 2** shows that the water turbidity values ranged between 1.70 - 10.10 NTU before the flood, while it ranged from 1.99 - 23.00 NTU after the flood. It is known that the sources of water turbidity in Lake Nasser may be autochthonous or allochthonous. Autochthones source occurs in the northern part due to the increase in primary productivity [22]. Elevated turbidity values at the southern stations in October (AF season) could be stemmed mostly from the flood water (allochthonous source) that loaded with suspended inorganic matters (silt and clay) at these stations [23]. The flood impact reached to Tushka area coming from Lake Nubia (Sudan), where the water turbidity decreased gradually from 23.00 NTU in the Arkeen area beside the Sudan border to only 3.47 NTU at Tushka after the flood period. These results are supported by the finding of [24], which found that the main channel sediments in the southern stations are mainly silty clay and clayey silt with a high percentage of clay.

Total suspended solids and turbidity complement each other, they are both influenced differently. TSS along the lake displayed a similar trend as water turbidity, and this was confirmed by the finding of [25]. They ranged between the lowest values at El Alaki (2.0 mg·l^{-1}) to the highest one at Arkeen (13.0 mg·l^{-1}) in the BF season and between 3.0 mg·l^{-1} (at most of the northern stations) to 28.0 mg·l^{-1} (at Arkeen) in AF season (**Figure 3**). The impact of increasing the total

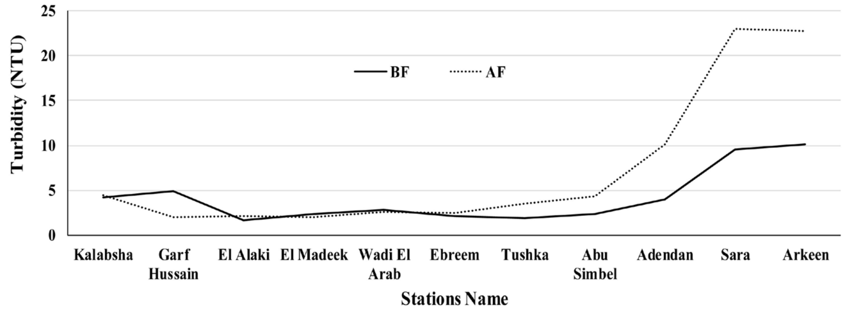

Figure 2. Turbidity (NTU) values before and after flood seasons at Lake Nasser.

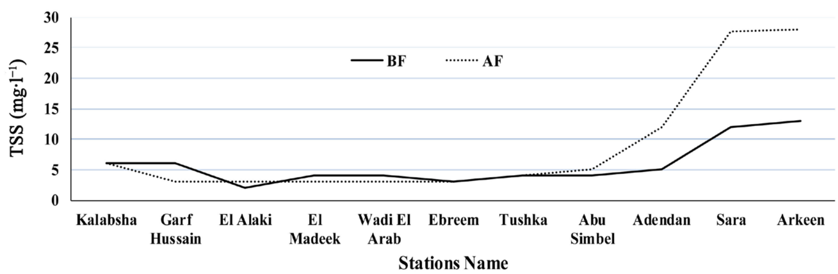

Figure 3. Total suspended solids (mg·l^{-1}) at Lake Nasser before and after flood seasons.

suspended solids (TSS) on the biomass of phytoplankton (Chlorophyll-*a*) appeared more pronounced at the stations near the border with Sudan, especially in AF season. This can affect the abundance and community composition of phytoplankton and zooplankton species by damaging the primary production, thereby the availability of food supply for the aquatic organisms in the lake water [26]. [27] pointed out that some sources of suspended matters like that resulting from sediment resuspension had a great impact on the freshwater organisms by affecting their ecosystem structure and function.

Total phosphorus concentration varied from 0.03 mg·l^{-1} to 0.06 mg·l^{-1} (average 0.05 mg·l^{-1}) during BF season, while it ranged from 0.08 mg·l^{-1} to 0.12 mg·l^{-1} (average 0.09 mg·l^{-1}) during AF season (**Figure 4**). It is noted that phosphate concentration recorded with increasing values in AF season neared to double values in BF season. Also, it showed a decreasing trend northward. The total phosphorus enters the lake in particulate form or is associated with the suspended solids during the flood. Most of the phosphorus concentration is removed from the water column to the lake bottom by sedimentation [28], while the remaining fraction is uptake by the biological activities through the photosynthesis process.

The concentration of chlorophyll-*a* is considered as a proxy for phytoplankton standing crop [29] [30]. Its range was 2 - 32 mg·l^{-1} (average 9 mg·l^{-1}) and 4 - 40 mg·l^{-1} (average 14 mg·l^{-1}) in BF and AF seasons, respectively (**Figure 5**). The maximum value was recorded at Abu Simbel in AF season, due to pushing the flood to nutrients and plankton. Chlorophyll-*a* concentration decreased at Sara and Arkeen ($r = 0.920$, $p < 0.001$). The decline of Chlorophyll-*a* concentration at these two stations in AF season is mainly due to the high level of turbidity at these stations that can light-limit phytoplankton photosynthesis and subsequently reduce biomass development [6].

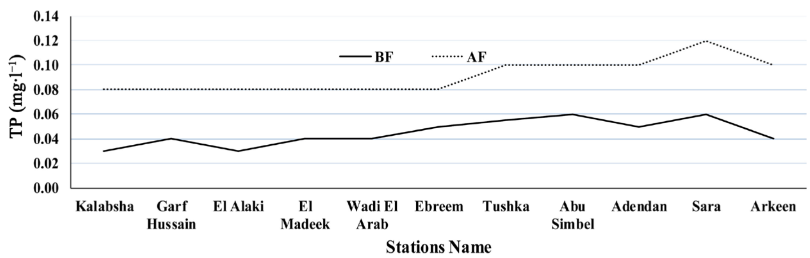

Figure 4. Total phosphorus (mg·l^{-1}) at Lake Nasser stations before and after the flood seasons.

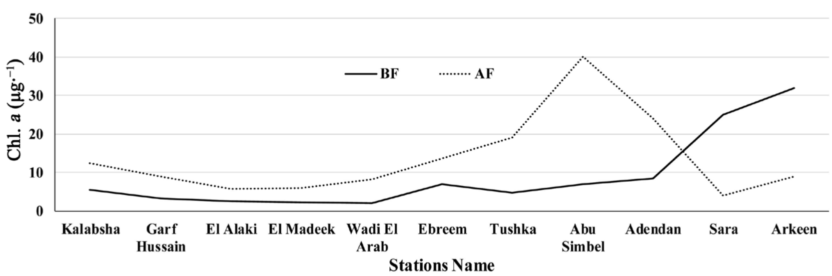

Figure 5. Chlorophyll-*a* (μg·l^{-1}) at Lake Nasser stations before and after flood seasons.

Zooplankton in a lake, as an important part of the food chain in the aquatic ecosystem, is very sensitive to reflect the different environmental changes (such as nutrient, flood storm, turbidity, and TSS) and hence considered as a good indicator for changing in water quality variables [31] [32]. The community of zooplankton during the study is mainly composed of three taxonomic groups, including rotifers, cladocerans, and copepods. Studies by various investigators indicated that the zooplankton in the Lake Nasser community is represented by copepods, rotifers, and cladocerans [33] [34] [35].

Zooplankton density in Lake Nasser changes with the fluctuation in the lake water level, whereas it was varied according to the amount and the period of a flood each year [36]. The maximum standing crop of zooplankton appeared at the highest water level after the flood had entered (37,606 org. m^{-3}), while the minimum one was observed at a low water level before flood season (10,026 org. m^{-3}) as in **Figure 6**. Zooplankton communities in Lake Nasser commonly increase in abundance after the flood than before flood season.

The changes in zooplankton during the two sampling seasons coincided with those of the phytoplankton and are concurrent with turbidity, as reported by [37] [38]. Besides, the competition among plankton species was intensified as a result of the turbidity of the water [39]. These results are similar to that obtained by [34] which concluded that the southern part (upstream) is richer in zooplankton than the northern one (downstream), as in **Figure 6**, and this coincided with the increased nutrient level in the water coming with the flood [40].

Lake Nasser water is classified as mesotrophic and good habitats for copepod organisms [34] [41] [42]. Copepods were the main dominant group of the zooplankton community in AF, followed by cladocerans and rotifers, contributing 38.04%, 37.21%, and 24.75% of the total zooplankton count, while these contributing in BF 34.78%, 28.44% and 36.78% of the total zooplankton count, respectively. It was correlated positively with turbidity ($r = 0.644$ and $p < 0.05$). The zooplankton distribution showed the dominance of crustaceans (Copepoda and Cladocera) on rotifers at the three parts of the lake after the flood, while an opposite trend occurred before the flood. They had positively correlated with turbidity ($r = 0.644$, $p < 0.05$ for copepods, and $r = 0.453$, $p > 0.05$ for cladocerans).

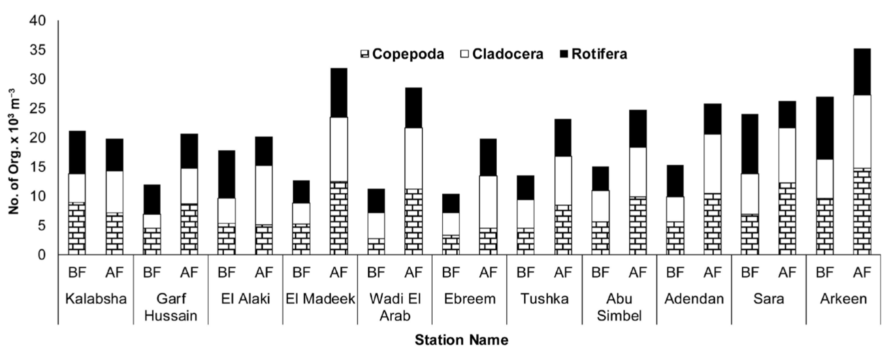

Figure 6. Distribution of zooplankton organisms (org. m^{-3}) recorded at Lake Nasser stations before and after flood seasons.

All the recorded crustaceans increased in the number of organisms by the turbidity of flood at the riverine part of the lake (Sara and Arkeen). For rotifers, most species increased in counts by turbidity increases. Some rotifer species appeared only in turbid water after the flood season such as *Brachionus calyciflorus*, *B. caudatus, Keratella tropica,* and *Polyarthra vulgaris* (**Table 2**).

Large zooplankton organisms (adult copepods and cladocerans) increased after the flood season in counts more than the small zooplankton organisms (rotifers and juvenile stages) in comparison with before the flood period. Juvenile stages of copepods were negatively influenced by clay particles. High concentrations of suspended sediments might have negative effects on copepod recruitment in the field [43] [44]. They stated that the feeding efficiency of copepods on phytoplankton decreased in the presence of suspended sediments, thus potentially decreasing the copepod egg production rate (**Figure 7**).

Table 2. Occurrence of zooplankton species to total zooplankton number and to group number before flood and after flood seasons.

Group	Species	BFS		AFS	
		To Total zoopl.	To group	To Total zoopl.	To group
Copepoda	*Mesocyclops ogunnus*	*	**	*	**
	Thermocyclops neglectus	*	*	**	***
	Thermodiaptomus galebi	**	****	**	***
Cladocera	*Alona rectangula*	*	*	*	*
	Bosmina longirostris	*	***	*	**
	Ceriodaphnia cornuta	*	**	*	**
	Chydorus sphaericus	0	0	*	*
	Daphnia longispina	*	*	*	**
	Diaphanosoma excisum	**	***	**	***
Rotifera	*Annuropsis fissa*	*	*	0	0
	Asplanchna priodonta	*	*	0	0
	Brachionus calyciflorus	0	0	*	**
	Brachionus caudatus	0	0	*	*
	Brachionus falcatus	*	*	*	*
	Brachionus patulus	*	*	*	**
	Cephalodella catellina	*	*	0	0
	Collotheca sp.	**	***	*	**
	Epiphanes sp.	*	*	0	0
	Filina longiseta	*	*	*	**
	Keratella cochlearis	**	***	*	**
	Keratella procurva	*	**	*	*
	Keratella tropica	0	0	*	*
	Lecane luna	*	*	0	0
	Monostyla bulla	0	0	*	*
	Polyarthra vulgaris	0	0	*	*
	Ptygura libera	0	0	*	*
	Trichocera chattoni	*	*	0	0

Note: 0, absent; *, >10%; **, 10% - 25%; ***, 25% - 50%; ****, 50% - 75%; *****, 75% - 100%.

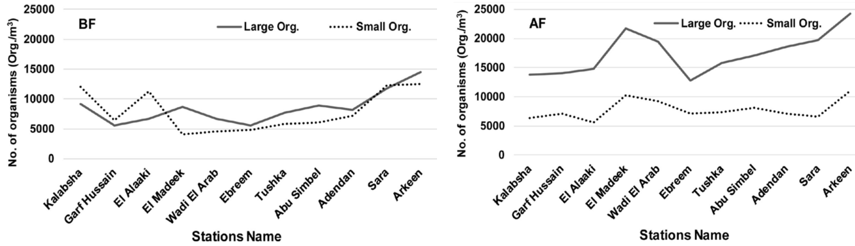

Figure 7. Spatial distribution of small and large zooplankton communities at Lake Nasser before the flood season (BF) and after flood season (AF). Small organisms (rotifers and juvenile stages); large organisms (adult copepods, and cladocerans).

Copepods are positively correlated with water turbidity in AF season, while cladocerans have occurred in habitats with low levels of turbidity in the BF season. This study recommended further environmental and biological monitoring that must be devoted to the lake about the planktonic organisms for increasing its fish production.

4. Conclusions

This paper concluded a great negative impact of turbidity on chlorophyll-*a* (as represented for phytoplankton biomass). For zooplankton, the highest standing crop was higher after the flood correlated with high turbidity, with the dominance of large zooplankton organisms after flood season than the small zooplankton organisms. The negative impact of flood turbidity had appeared on crustacean organisms.

It is often difficult to distinguish the effects of turbidity in the field from other effects of water such as nutrient loading or advection. Future studies need to assess the impact of mineral turbidity on the structure of freshwater plankton communities for increasing the fish production of the lake.

Conflicts of Interest

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

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