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Assessing Zooplankton Population Dynamics in the River Nile Around EL-Warrak Island (Egypt) for Saprobic Condition Evaluation

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ABSTRACT

The New Urban Communities Authority (NUCA) has allocated EGP 17.5 billion for the initial development of El-Warrak Island, encompassing green spaces, utilities, roads, residential units, and resident compensation. Thus, this research investigated the interplay between natural and anthropogenic factors due to the development affecting zooplankton dynamics to maintain ecological equilibrium and uphold species diversity. Four stations were strategically selected to represent all habitats surrounding El-Warrak Island. Findings revealed consistent water temperatures with minimal fluctuations, stable pH values with slight seasonal variations, and minor spatial and seasonal changes in EC and TDS values. The zooplankton community in the River Nile consisted of Rotifera, Protozoa, Copepoda, Cladocera, and free-living Nematoda, with an average total density of 595,297 ind. m^{-3}. Notably, Rotifera constituted the majority, representing 91.48% of the total zooplankton density. Station 1 exhibited the lowest zooplankton density, while Station 4 recorded the highest population density, averaging 198,868 and 950,574 ind. m^{-3}, respectively. Population density peaked in the cold season and decreased to its lowest level in the hot season. Thirteen distinct rotifer species were identified, with *Keratella cochlearis* being the most populous. The diversity index (H`) revealed that Station 1 exhibited the highest diversity (H' = 2.2). Moreover, the saprobic index values for stations 1, 2, 3, and 4 were determined to be 1.8, 1.7, 1.7, and 1.7, respectively, indicating a β-mesosaprobic condition at the investigated sites. In conclusion, intensive agricultural and domestic activities have been identified as significant contributors to high organic pollutant levels, impacting ecological health, and diminishing zooplankton species diversity. Therefore, effective mitigation and treatment methods should be implemented.

INTRODUCTION

The River Nile is a major north-flowing river in northeastern Africa that flows into the Mediterranean Sea. It holds the title of the longest river in Africa and has historically been thought of as the longest river in the world, stretching approximately 6,650 kilometers **(Dumont, 2009)**. The river's drainage basin spans eleven countries: the Democratic Republic of the Congo, Tanzania, Burundi, Rwanda, Uganda, Kenya, Ethiopia, Eritrea, South Sudan, Sudan, and Egypt.

Notably, the Nile is the main water source for Egypt, Sudan, and South Sudan. Furthermore, the Nile plays a vital role in the economy, supporting agriculture and fishing. Human activities, pollution, and eutrophication pose significant threats to the biodiversity and overall health of our freshwater ecosystems, as highlighted by **Abdel-Satar *et al*. (2017)**.

Zooplankton, as the animal component of the planktonic community, plays a critical role in aquatic ecosystems. They are unable to swim effectively against currents, and thus rely on drifting or being carried along by water currents in seas, lakes, or rivers. Zooplankton serves as an essential resource for higher trophic levels, including fish, and is pivotal in the transport of organic material in the biological pump. Their small size allows for rapid responsiveness to changes in phytoplankton abundance, especially during the spring bloom. Furthermore, zooplankton plays a significant role in the biomagnification of pollutants such as mercury and can act as a reservoir for various diseases. The study of zooplankton communities offers crucial insights into food availability in the food chain and functions as a bioindicator of potential anthropogenic impact in the area undergoing investigation. As valuable indicator species, zooplankton facilitates the transfer of energy from planktonic algae to larger invertebrate predators and fish. Their high sensitivity to environmental disturbances underscores their importance in ecosystem health assessments. Changes in their species composition, abundance, and body size distribution indicate shifts in water quality. Zooplankton exhibits swift responses to changes in nutrient input, and monitoring their presence aids in tracking nutrient pollution over time **(Khan, 2003; Hassan, 2008)**. Additionally, they are signals of environmental disturbance such as eutrophication, pollution, warming trends, and long-term changes **(Ahmed *et al*., 2017)**. They are also crucial in regulating phytoplankton populations by feeding on them, which helps prevent algal blooms and maintains a healthy balance in the ecosystem. Additionally, they are a key component in nutrient cycling as they excrete waste products that provide essential nutrients for other organisms in the ecosystem. The observed variation in zooplankton composition aligns with the impact of nutrient regulation and top-down effects by fish, as documented by **Makarewicz and Jones (1990)**. Notably, planktivore abundance increases in correlation with phytoplankton and zooplankton abundance, with these organisms exhibiting selective feeding on larger zooplankton **(Iglesias *et al*., 2011)**. Rotifers are an essential food for fish, particularly in the early stages of their external feeding, forming crucial links in aquatic food webs and inhabiting diverse trophic levels within the ecosystem **(Nikolsky, 1963)**.

Saprobity denotes organic pollution characterized by BOD_5, dissolved oxygen content, and specific communities of indicator organisms. The **Pantle and Buck (1955)** methodology, as modified by **Sládecek (1973)**, stands as one of the most universally applicable and suitable methods for the analysis of zooplankton communities. The primary objective of this method is to facilitate the comparability of water body studies across diverse regions. Despite numerous assessments of the River Nile's quality utilizing biotic indices, studies employing the saprobic index **(Pantle &Buck, 1955)** are scarce.

El-Warrak Island is an island area of 756 hectares (1,870 acres) in the Giza Governorate. The residents work in agriculture, fishing and various crafts. In 2022, The New Urban Communities Authority (NUCA) of the Egyptian Ministry of Housing released the plan set to develop Giza's El-Warrak Island, spanning over 6,360 square kilometers, at a budget of LE17.5 billion for the initial phase of El-Warrak Island development, as per the preliminary master plan. Consequently, these developments may affect the ecological status of the River Nile.

However, the crucial importance of this sector of the River Nile that there are few ecological studies on it. The species diversity of both zooplankton and macrobenthos were studied by **Sleem and Hassan (2010)**. **Abdelmageed *et al.* (2022)** evaluated the ecological status of EL-Warrak Island shore as a part of their study.

This study aimed to illuminate the interplay between natural and human influences on zooplankton dynamics for ecological equilibrium and species diversity conservation. Furthermore, it assessed the ecological status of the EL-Warrak Island sector of the River Nile using the saprobic index as a novel method in Egypt, alongside other standard biotic indices after the development process.

MATERIALS AND METHODS

Study area

In order to comprehensively cover the various agricultural and domestic habitats surrounding the island, Four stations were carefully selected (Fig. 1). The latitude and longitude coordinates of each station are presented in Table (1).

Table 1. Latitude and longitude coordinates of the investigated stations

Station 1	30°06'26"N 31°13'25"E
Station 2	30°07'21"N 31°12'49"E
Station 3	30°07'38"N 31°13'18"E
Station 4	30°06'47"N 31°14'15"E

Fig.1. A map of El-Warrak Island illustrating the studied stations

Sampling procedures

In August 2023 during the hot season and in December 2023 during the cold season, water and zooplankton samples were collected from the River Nile around EL-Warrak Island. The sampling was conducted in accordance with the Standard Methods for Examination of Water and Wastewater **(APHA, 2005)**.

Samples analyses

Abiotic factors

Water temperature, DO, EC, pH, as well as TDS were measured in the field using a multi-probe portable meter (WTW Model Oxi 197).

Biotic factors

In the field study, a volume of thirty liters of water was filtered from the subsurface layer of each site using a standard plankton net with a mesh size of 55µm. Subsequently, the collected samples were promptly preserved in plastic jars utilizing a 5% formalin solution. Upon arrival at the laboratory, a sub-sample of 1ml was transferred to a counting cell (Rafter Sedgwick Cell) and subjected to examination under a binocular compound microscope. This meticulous process was repeated three times for each sample, and the resulting averages were calculated using the equation as specified in the standard methods of **APHA (2005)**. The total count of each group was expressed as individual m^{-3}.

Statistical analysis

Diversity index

The Shannon-Wiener diversity index (H') was determined using the computer software Primer 5 to estimate the influence of pollution on species diversity and the ecosystem health. This index is calculated as:

$H` = -\Sigma p_i * ln(p_i)$ (1)

Where,

- Σ: A symbol that means "sum"
- *ln*: Natural log
- p_i: The proportion of the community made up of species *i*

Where, the higher the H` value, the higher the species diversity in the ecosystem.

Similarity index

The Bray-Curtiz similarity index was applied to assess the similarity of zooplankton communities at the four stations. The software Primer 5 was used to generate the similarity dendrogram.

Saprobic index

One of the most universally applicable, straightforward, and appropriate methods for the analysis of zooplankton communities is the **Pantle and Buck (1955)** methodology, as modified by **Sládecek(1973)**. The primary aim of this method is to facilitate the comparison of water body studies across different regions. The saprobic index was computed using the following formula:

$$S=\frac{\sum(hs)}{\sum h} \qquad (2)$$

Where,"h" is the frequency of occurrence of individual species as follows:
1. Very rare; 2. Rare; 3. Not infrequent; 5. Common; 7. Very common; 9. Abundant
and "s" is the saprobic index of each indicator species according to **Sládecek (1973)**.

The saprobic index S, calculated from formula 1 as follows:
The oligosaprobic zone is 0 – 1.5 which means clean water;
β-mesosaprobic zone is 1.51 – 2.5 which means slightly polluted;
α-mesosaprobic zone is 2.51- 3.5 which means heavily polluted, and
polysaprobic zone is 3.51 – 4.5 which means very heavily polluted.

RESULTS AND DISCUSSION

Water quality features

The analysis indicated minimal water temperature fluctuation over time with insignificant temporal variance. Spatially, pH values exhibited negligible variation, though a slight seasonal disparity was noted, with higher values recorded during the hot season (Table 2). This observation is consistent with the findings of **Nassif (2012)** and **Nassif andAmer (2023)**, attributing the phenomenon to the emission of acidic gases from organic matter decomposition. Regarding EC values, limited spatial variation and minor seasonal fluctuations were observed. While TDS values displayed slight spatial diversity, distinct temporal variation was evident, with higher values recorded during the cold season. This phenomenon was elucidated by **Abdo and El Nasharty (2010)**, linking it to microorganism decay and degradation during the cold season, resulting in elevated TDS and EC levels.

Table.2. Temporal and spatial variations of the abiotic parameters for the stations under investigation

Temp.	**St 1**	**St 2**	**St 3**	**St 4**	**Average**
Hot season	31.20	35.80	34.80	35.20	34.25
Cold season	17.30	17.80	19.20	20.80	18.78
Annual average	**24.25**	**26.80**	**27.00**	**28.00**	**26.51**
pH					
Hot season	8.1	8.2	8.1	8.01	8.10
Cold season	7.8	7.7	7.8	7.81	7.78
Annual average	**7.95**	**7.95**	**7.95**	**7.91**	**7.94**
EC					
Hot season	0.381	0.37	0.355	0.365	0.3678
Cold season	0.425	0.414	0.433	0.420	0.4230
Annual average	**0.403**	**0.392**	**0.394**	**0.3925**	**0.3954**
TDS					
Hot season	250.00	240.00	225.00	240.00	238.75
Cold season	276.00	265.00	270.00	269.00	270.00
Annual average	**263.00**	**252.50**	**247.50**	**254.50**	**254.38**
DO					
Hot season	4.90	4.60	4.80	5.20	4.88
Cold season	5.80	5.50	5.90	6.10	5.83
Annual average	**5.35**	**5.05**	**5.35**	**5.65**	**5.35**

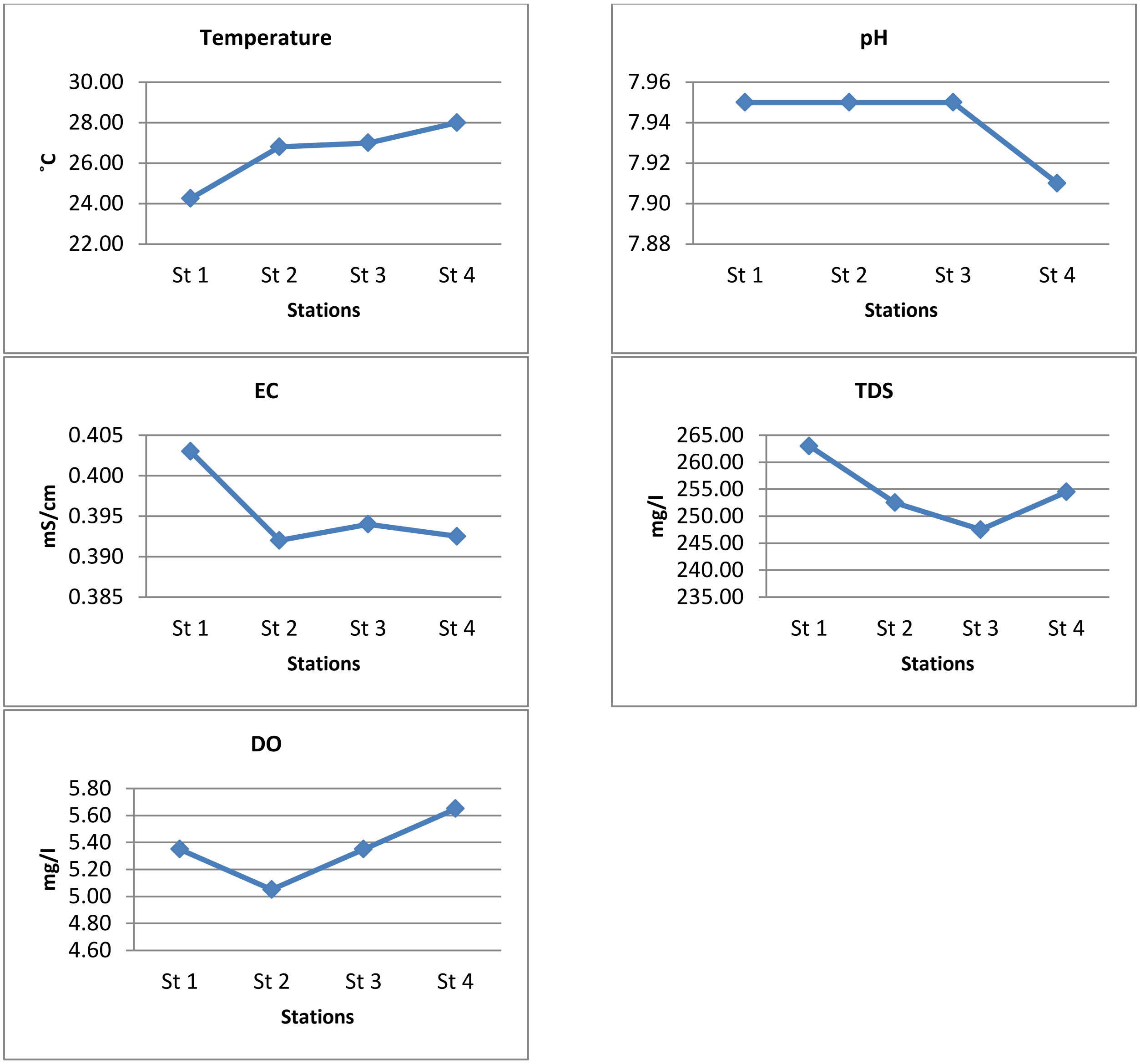

Fig. 2. Annual average of the main abiotic parameters in the investigation stations

Zooplankton abundance and community composition

A total of 19 zooplankton taxa, including uncharacterized larvae, copepodite stages, and free-living nematodes, were identified during the current investigation. The zooplankton community in the River Nile comprises the taxa Rotifera, Protozoa, Copepoda, Cladocera, and free-living Nematoda, with an average total density of 595,297 individuals per cubic meter. Rotifera, representing 91.48% of the total zooplankton density, emerges as the most predominant category, as depicted in Fig. (3).The research findings align with previous studies by **Mageed (2001)**, **Abdel Aziz and Aboul Ezz (2004)**, **Bedair (2006)**, **Amer (2007)**, **Sleem and Hassan (2010)**, and **Nassif and Amer (2023)**. They all observed that small zooplankton such as the rotifers tend to be prevalent in rivers due to their short life cycle compared to larger crustaceans. This prevalence is also linked to eutrophication, which impacts zooplankton composition and leads to a shift from larger species like Copepoda and Cladocera to smaller ones like the rotifers **(Emam, 2006)**. A study by **Abdel Mageed *et al.* (2022)** in the same section of the River Nile confirmed the relation of the rotifer dominance to the trophic status of the area under investigation.

As shown in Fig. (4), station 1 exhibited the least plankton density and station 4 showed its greatest density with an average of 198,868 and 950,574 ind. m^{-3}, respectively. The population density reached its highest point in the cold season (1,106,584 ind. m^{-3}) and dropped to its lowest level (84,010 ind. m^{-3}) in the hot season. This observation concurs with the findings of **Abdel Aziz (2005)**, **Zakaria (2007)** and **Sleem and Hassan (2010)**, and this can be attributed to favorable living conditions such as stable water, food availability, and comfortable temperatures. **Amer (2007)** suggests that the lowest density during the hot season may be ascribed to the presence of the juvenile planktivorous fish, which mainly feed on zooplankton.

The recent investigation identified 13 distinct species of the rotifers. Among these species, *Keratella cochlearis* (Gosse, 1851) exhibited the highest population density, followed by *Polyarthra vulgaris* (Ehrenberg, 1834) and *Trichocerca chattoni* (de Beauchamp, 1907), representing approximately 79.02, 6.97, and 4.02% of the total rotifer abundance, respectively. These findings corroborate with those of **Nassif (2012)** and **Nassif and Amer (2023)** in the Ismailia Canal, where similar dominant species were identified, including *Polyarthra vulgaris*, *Collotheca pelgica*, *Trichocerca pusilla*, *Keratella cochlearis*, and *Brachionus calyciflorus*. According to **El-Shabrawy and Khalifa (2002)** and **Mola *et al*. (2011)**, the prevalence of eutrophic indicators such as *Polyarthra vulgaris* and *Keratella cochlearis* suggests a potential eutrophic state and pollution in this section of the River Nile. Furthermore, **Abdel Aziz and Aboul Ezz (2004)** have highlighted that the majority of the rotifer species are indicative of a highly polluted ecosystem and are considered polysaprobic organisms.

Protozoa comprised four distinct species: *Vorticella campanula* (Ehrenberg, 1831), *Arcella vulgaris* (Ehrenberg, 1830), *Difflugia pyriformis* (Perty, 1849), and *Strobilidium Gyrans* (Stokes, 1887). During winter, the population density reached an average of 51,351 ind. m^{-3}, whereas it dropped to an average of 11,566 ind. m^{-3} in summer, coinciding with the findings of **Amer (2007)**. This trend could be traced back to the low dissolved oxygen (DO) levels, the increase in water temperature, and the proliferation of bacteria during the summer season. Furthermore, protozoa serve crucial ecological functions in aquatic ecosystems, providing an energy to higher fauna and facilitating decomposition processes. Their community diversity can also be utilized as an indicator of varying pollution levels **(Laybourn, 1984)**.

The implementation of intensive agricultural practices leads to heightened levels of organic pollutants. Research has demonstrated that water exhibiting diminished organic content yields reduced species diversity and a decreased presence of bacterial-feeding protozoa, as documented by **Szentivany and Tirjakova (1994)**. These protozoa serve as primary grazers of microorganisms in aquatic ecosystems and represent the principal consumers in oxygen-deprived habitats.

Copepoda accounted for 1.77% of the total zooplankton population, with an average of 10,542 individuals per cubic meter. This group comprised Nauplius larvae and copepodite stages, representing 79.84 and 20.16% of the population, respectively. Stations 4 and 3 demonstrated the highest densities, with averages of 12,333 and 12,250 individuals per cubic meter, respectively. In contrast, station 1 exhibited the lowest density, averaging 7,167 individuals per cubic meter. Notably, the proliferation of Copepoda was observed to favor the cold season, while its density decreased by a quarter during the hot season.

It is noteworthy that *Alona intermedia* (Chengalath, 1982) and *Bosmina longirostrus* (O. F. Müller, 1776) were identified as the cladoceran species present in the study area. *B. longirostrus* emerged as the predominant species, constituting 52.92% of the total cladoceran community; *A. intermedia* accounted for 47.08% of the cladoceran population. Station 2 exhibited the highest density of *B. longirostrus*, averaging 6,500 individuals per cubic meter, while stations 4 and 3 demonstrated the highest densities of *A. intermedia*, averaging 5,333 and 4,750 individuals per cubic meter, respectively. Additionally, free-living nematodes represented 0.27% of the zooplankton community, showing minimal spatial variation. Notably, station 1 recorded the highest density of nematodes, averaging 2,142 individuals per cubic meter.

Zooplankton diversity index (H`)

In Table (3), a slight variance in the diversity index (H') is observed across the stations. Stations 4 and 3 exhibited the lowest diversity with a diversity index of H' = 1.33 while maintaining the highest population densities at 950,574 and 860,602 individuals per cubic meter, respectively. This phenomenon can be attributed to the substantial prevalence of the rotifers, which accounted for 94.16 and 94.22% of stations 4 and 3, respectively. As reported by **Arora (1966)**, the predominance of the rotifers in lake water is an indicator of pollution due to the direct influx of untreated domestic water. Furthermore, **Karabin (1985)** attributed the increase in the rotifers' abundance in the eutrophic ecosystem to the high decomposition rate of the dead phytoplankton by the enriched bacterial production. Therefore, it can be inferred that these stations suffer from pollution predominantly from domestic sewage. Conversely, station 1 demonstrated the highest diversity index value (H' = 2.2).

Similarity dendrogram (Fig. 5) reveals the different habitats of the investigated area. Two main clusters of habitats were found. The first cluster comprises stations 3 and 4 which revealed a very close community composition. The second cluster comprises stations 1 and 2 illustrating a degree of similarity.

Saprobic index

According to equation (2), the average saprobic index of the investigation area is 1.93, revealing that the sector of the River Nile under investigation falls in the β-mesosaprobic zone. This zone refers to a level of saprobity or pollution in aquatic environments, indicating a moderate degree of decay of organic matter. This means that this region is slightly polluted. The results revealed that the calculated saprobic index values for stations 1, 2, 3, and 4 were 1.8, 1.7, 1.7, and 1.7, placing them within the β-mesosaprobic zone. This could be explained by the previous study conducted by **Pejler (1957)**, who reported *Brachionus* species, *Keratella cochlearis*, *K. quadrata*, *Trichocerca cylindrical*, *Polyarthra euryptera*, *Filinia longiseta* in mesotrophic to eutrophic waters. **Baruha *et al.* (1993)** verified that *Brachionus*spp. and *Keratella* spp. were indicators of eutrophication. This eutrophication, consequently, can induce transformations in the species composition and increase the tolerant rotifer species abundance, as declared by **Spoljar *et al.* (2011)**.

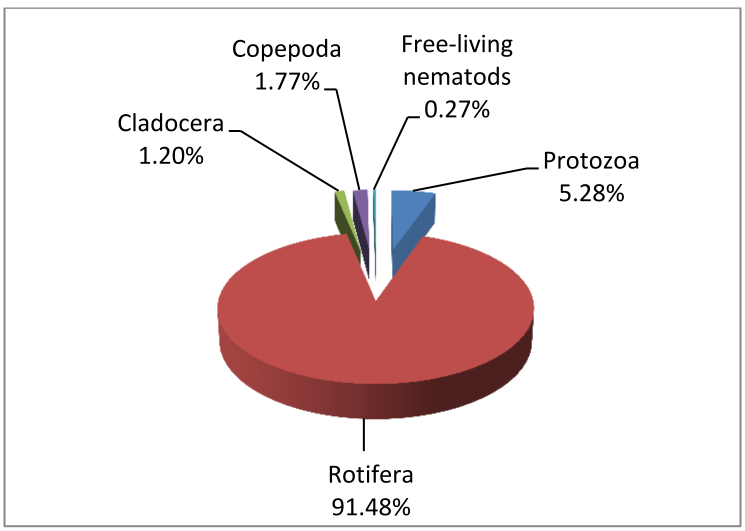

Fig. 3. Community structure of the recorded zooplankton in the investigation area

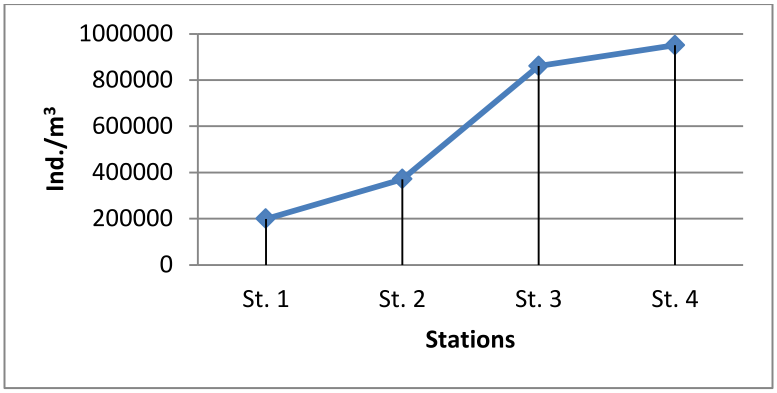

Fig. 4. Zooplankton spatial distribution of the investigation stations

Fig. 5. Similarity dendrogram of the area under investigation

Table 3. Biodiversity indices of zooplankton resident in the area under investigation

Station	No. of Sp.	Density	Richness	Evennes	Shannon	Simpson
St. 1	19	198868	1.94	0.68	2.20	0.81
St. 2	18	371144	1.78	0.57	1.85	0.73
St. 3	19	860602	1.74	0.41	1.33	0.61
St. 4	19	950574	1.73	0.41	1.33	0.62

CONCLUSION

The study aimed to monitor zooplankton populations in the River Nile near El-Warraq Island, assessing the saprobic condition of the water and identifying the potential sources of pollution or stress.The saprobic index reveals that the sector of the River Nile is placed in β-mesosaprobic zone. Therefore, this study concluded that intensive agricultural activities lead to high levels of organic pollutants, impacting water quality and reducing species diversity and the proportion of bacterial-feeding protozoa. These protozoa are crucial for grazing microbes in aquatic environments, particularly in anoxic habitats. Notably, zooplankton convert a considerable amount of their food into biomass, making it available to higher trophic level. Consequently, their diversity affects the fish growth rate, productivity, and fish quality, which in turn impacts the human health. Hence, it is advised to find the methods to mitigate and treat the agricultural and domestic drainage water before spilling into the River Nile.

REFERENCES

Abdel Aziz, N.E. (2005). Short term variations of zooplankton community in the west Naubaria Canal, Alexandria, Egypt. Egypt. J. Aquat. Research. 31 (1): 119-131.

Abdel-Aziz, N. E.and Aboul Ezz, S. M. (2004). The structure of zooplankton community in Lake Maryout, Alexandria, Egypt. *Egyptian Journal of Aquatic Research*, *30*(A): 160-170.

Abdelmageed, A. A.; Ellah, R. G. A.; Abdel-Satar, A. M.; Gawad, S. S. A.; Khalifa, N.; Zaher, S. S., ... and Al-Afify, A. D. (2022). Evaluation of the ecological health and food chain on the shores of four River Nile Islands, Egypt. *Environmental Monitoring and Assessment*, *194*(4): 309.

Abdel-Satar, A. M.; Ali, M. H. and Goher, M. E. (2017). Indices of water quality and metal pollution of Nile River, Egypt. *Egyptian Journal of Aquatic Research, 43*(1): 21–29. https:// doi. org/ 10. 1016/j. ejar. 2016. 12. 006

Abdo, M. H., & El-Nasharty, S. M. (2010). Physico-chemical evaluations and trace metals distribution in water-surficial sediment of Ismailia Canal, Egypt. *Nature and Science*, *8*(5): 198-206.

Ahmed, M. H.; Abd El-Hamed, N. N. B.; Shalby, N. I. (2017). Impact of physico-chemical parameters on composition and diversity of zooplankton community in Al-Nozha hydrodrome, Alexandria, Egypt. Egyptian J. of Aquatic Biology & Fisheries. , 21(1): 49-62.

Amer, A. S. (2007). Effect of different type pollutants on Bactria-Zooplankton interaction in Nile water. *A thesis submitted of Ph. D. in science (Zoology), Girls College, Ain Shams Uni*.

APHA (2005). American Water Works Association, Water Environment Federation. Standard Methods for the Examination of Water and Wastewater, 21th ed. American Public Health Association, Washington, DC. 2005.

Arora, H. C. (1966). Studies on Indian Rotifera - III. J. Zoo. Soc. India, 16: 1-6.

Bahura, C. K.; Bahura, P. and Saxena, M. M. (1993). Zooplanktonic community of Shivbari Temple tank, Bikaner, J. Ecobiol., 5: 5-8.

Bedair, S. M. (2006). *Environmental studies on zooplankton and phytoplankton in some polluted areas of the River Nile and their relation with feeding habit of fish* (Doctoral dissertation, Ph. D. Thesis, Fac. Of Sci. Zagazig Uni).

Dumont, H. J. (Ed.). (2009). *The Nile: origin, environments, limnology and human use* (Vol. 89). Springer Science & Business Media.

El-Shabrawy, G.M and Khalifa, N. (2002). Zooplankton abundance and community structure in the Northern part and estuary of Rosetta Nile Branch in relation to some environmental variables. Egypt. J. Aquat. Biol. & Fish., vol.6 (4): 69-90.

Emam, W. (2006). Preliminary study on the impact of water pollution in El-Rahawy drain dumping in Rosetta Nile branch on zooplankton and benthic invertebrates. M. Sc. Thesis, Zoo. Dept. Fac. Sci. Ain Shams Univ.

Hassan, M.M. (2008). Ecological studies on zooplankton and macrobenthos of Lake Edku, Egypt. Ph D. thesis Ain Shams University, Faculty of Science, Zoology Dep., Cairo, Egypt

Iglesias, C.; Mazzeo, N.; Meerhoff, M.; Lacerot, G.; Clemente, J. M.; Scasso, F., et al. (2011). High predation is of key importance for dominance of small-bodied zooplankton in warm shallow lakes: Evidence from lakes, fish exclosures and surface sediments. *Hydrobiologia*, *667*(1): 133–147. https:// doi. org/ 10. 1007/ s10750- 011- 0645-0

Jude, B.A.; Kirn, T.J.; Taylor R.K. (2005). "A colonization factor links Vibrio cholerae environmental survival and human infection". *Nature*. **438** (7069): 863–6.

Karabin, A. (1985). Pelagic zooplankton (Rotatoria + Crustacea). Variation in the process of Lake Eutrophication. I. Structural and quantitative features, Ekol. Pol., 33(4): 567-616.

Khan., R.A. (2003). Faunal Diversity of Zooplankton in Freshwater Wetlands of Southeastern West Bengal Zoological Survey. . In, pp. 107 p., plates,[Records of the Zoological Survey of India : Occasional Paper No. 204]. Kolkata of India

Pantle, R., & Buck, H. (1955). Die biologische Uberwachung der Gewässer und die Darstellung der Ergebnisse.

Pejler, B. (1957). Taxonomical and ecological studies on planktonic Rotatoria from Northern Swedish Lapland. Kungl. Svenska Vetenskapsakad. Handl., 6(5): 1-68.

Laybourn-Parry, J. (1984). *A functional biology of free-living protozoa*. Univ of California Press.

Mageed, A.A. (2001). Zooplankton composition of some industrial polluted areas in the River Nile ecosystem. Egyptian Journal of Aquatic Biology and Fish, Vol.5 (2): 1-20.

Makarewicz, J. C., & Jones, H. D. (1990). Occurrence of By thotrephes cederstroemi in Lake Ontario offshore waters. *Journalof Great Lakes Research, 16*(1): 143–147. https:// doi. org/ 10.1016/ S0380- 1330(90) 71407-4

Mola, H. R. A; Parveen, S.; Ganai, A. H.; Kabir, H. A. and Ahamed, U. (2011). Longitudinal distribution of zooplankton in the River Nile, Egypt. J. Curr. Sci. 16 (1): 33-45.

Nassif, M. G. (2012). Ecological studies on aquatic invertebrates of Ismailia Canal, Egypt. M Sc Thesis, Faculty of science, Ain Shams University, Egypt.

Nassif, M. G. and Amer, A. S. (2023). Applying various indices to evaluate the effects of fertilizer discharges on zooplankton biodiversity and water quality of Ismailia Canal, Egypt. *The Egyptian Journal of Aquatic Research*, *49*(4): 507-512.

Nikolsky, G. V. (1963). The Ecology of Fishes Publisher: Academic Press, pp. 352.

Sládecek, V. (1973). System of water quality from the biological point of view. *Archiv fur Hydrobiologie (Ergebnisse der Limnologie)*, *7*: 1-218.

Sleem, S. H. and Hassan, M. M. (2010). Impact of Pollution on Invertebrates Biodiversity in the River Nile Associated With Dahab and El-Warrak Islands, Egypt. *International Journal of Environmental Science and Engineering (IJESE)*, *1*: 15-25.

Spoljar, M.; Tomljanovic, T. and Lalic, I. (2011). Eutrophication impact on zooplankton community: a shallow lake approach, Holist. Approach Environ., 1 (4): 131-142.

Szentivány, M. and Tirjaková, E. (1994). The structure and dynamics of the community of Ciliophora in the benthos of the Karlova Ves (Bratislava) branch of the Danube. *Acta Zoologica Universitatis Comenianae*, *38*: 83-102.

Zakaria, H. Y. (2007). On the distribution of zooplankton assemblages in Abu Qir Bay, Alexandria, Egypt. Egyptian Journal of Aquatic Research, 33 (1): 238-256.