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Original research

Inspecting environmental effects on Zooplankton diversity in Lake Qarun, Fayoum Province, Egypt

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Abstract:

Lake Qarun (Fayoum Province, Egypt) is characterized as a highly eutrophic lake. Management of zooplankton resources in the lake received slight attention. A total of 22 and 23 zooplankton taxa were recorded at some lake stations (from Q1 to Q10) during the autumn and winter seasons respectively. During the autumn, the recorded zooplankton taxa were divided into four groups namely: Rotifera (47.63%), Copepoda (29.23%), Protozoa (18.4%) and Meroplankton (4.73%). Concerning the winter, the recorded zooplankton taxa were divided into five groups namely: Copepoda (36.02%), Rotifera (30.72%), Protozoa (23.48%), Meroplankton (9.69%) and Cladocera (0.038%). The Multiple regression analysis indicated that Shannon diversity index values were significantly influenced by the temperature, transparency, EC, pH and dissolved oxygen. This investigation provides informative information about the dynamics and biodiversity of zooplankton communities in the lake and their interactions with certain environmental factors. The results explored the variations in species diversity, richness, and evenness among the evaluated lake stations. Stations with higher diversity indices tend to have higher species richness and a more even distribution of individuals among species. Understanding these variations can provide valuable insights into the ecological health and dynamics of another similar aquatic ecosystem.

Keywords: Lake Qarun, Zooplankton, Abundance, Diversity and Environment.

1. Introduction

El-Fayoum region is considered a hot and arid climate, causing high rates of evaporation from Lake Qarun (about 80 kilometers southwest of Cairo). The lake is an inland saline water basin approximately 40 km long and 5.7 km wide (situated within the longitudes of 30° 24' and 30° 49' E and latitudes 29° 24' and 29° 33' N). The water levels in the lake vary dependent on seasonal variations and water management routines. This lake collects runoff drainage water from agricultural lands and Bahr Yussef (an ancient branch of the Nile supplies the Fayoum with irrigation water). In this environment electrolytes and nutrient salts could accumulate, making this lake more saline and eutrophic (Wilbert, 1995, Mageed, 2005, EL-Shabrawy et al., 2015 and Al-Afify et al., 2019).

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The salinity is increasing with time. So, evaluation of the aquatic biological resources should be carried out continually for the management of such ecological areas. Management of aquatic biological resources including the zooplankton resources (which play a critical role in the ecology of the aquatic systems) are affected by the accuracy of the characterization and documentation methods. Also, the evaluation of the correlations among the zooplankton biodiversity and independent variables including various abiotic factors could be informative for good management of these biological resources (Mageed et al., 1998, El-Naggar et al., 2016 and Al-Afify et al., 2019).

The validity of lakes such as Lake Qarun for enhancing fish productivity is positively correlated with physical, chemical, and biological conditions.

The anthropogenic activities harshly impact the water quality, resulting in hazards like contamination, enrichment and sedimentation (Al-Afify et al., 2019).

Al-Afify et al., (2019) confirmed that the discharge of municipal and agricultural sewage waste into Lake Qarun causes significant impacts to its water quality. The Water Quality Index revealed poor conditions for irrigation and aquatic life in the lake, with the presence of fecal matter and bacteria such as *E. coli* indicating biological pollution. Also, the chemical, physical and microbiological assigns of Lake Qarun are greatly impacted by some considerations like evaporation rate and climatic conditions.

Inspecting aquatic biological resources in certain ecological areas such as Lake Qarun, requires certain activities including characterization and documentation of the biodiversity within and among these resources via informative methods. In this field, some statistical indices are widely applied for evaluating the variations among zooplankton species and/or populations (Tahoun et al., 2021).

Fish productivity in lakes, is correlated with the availability of planktonic food. Also, alterations in zooplankton resources can subsequently affect fish productivity (Godbout and Peters, 1988).

Lake Qarun represents a suitable environment for the introduction of marine fish species, especially those that feed on plankton, to utilize the abundant planktonic resources effectively, which have not been fully utilized until now.

Both Khalifa and El-Shabrawy (2007) and Mageed (1996) observed that some of the zooplankton species are transported to Lake Qarun via the transplantation of fish such as Mullet fry from the Mediterranean Sea.

The productivity of fisheries is related to the distribution and/or abundance of appointed natural feeding including zooplankton and/or phytoplankton resources. Estimating the biodiversity indices in this lake could be an informative indication for ecologists and conservationists to quantify and compare the diversity and evenness of species across different habitats or over time within a certain habitat (Tahoun et al., 2021).

Species evenness requires ecologists to recognize the abundance of a taxon relative to other taxa in each community. The relative abundance and composition of taxa are affected also by the type of habitat including the bottom sediments, water column and aquatic plants (Difonzo and Campbell 1988, Tahoun et al., 2021 and Elsebaie et al., 2023).

The present work aims to inspect the environmental effects on Zooplankton diversity in Lake Qarun, Fayoum Province, Egypt.

2. Materials and methods

2.1. Collection, preservation, and identification of zooplankton samples

Zooplankton samples were collected from Lake Qarun (Fayoum Province, Egypt) during the autumn and winter seasons, of 2019.

Samples were collected from 10 different stations (Fig.1) during the two seasons. The detected sampling stations were chosen to offer a comprehensive understanding of the lake's environmental status. By covering various ecological conditions and reducing selection bias.

A total of 30 litters of water were filtered through a plankton net of Mesh diameter 55 µm. A standard plastic bucket of 15-liter capacity was used to draw water from 5 different points on the pond surface.

Zooplankton samples were immediately preserved in 4% neutral formalin and identified based on morphological characterization. Zooplankton characterization was carried out according to Shiel and Koste (1992), Einsle (1996), Smirnov (1996) with some modifications as described by Tahoun et al., (2021).

2.2. Physico-chemical characterization:

Physico-chemical parameters were analysed and evaluated at chemical laboratories (National Institute of Oceanography and fisheries, Egypt) according to the standard methods (APHA, 2005).

Transparency, pH, Water temperature, and Electrical conductivity were in situ measured using the Hydrolab model Multi Set 430i WTW. The Biological oxygen demand, Dissolved oxygen, NO^{-}_{3}, NH_3 and Orthophosphate, were determined as described by Al-Afify et al., (2019).

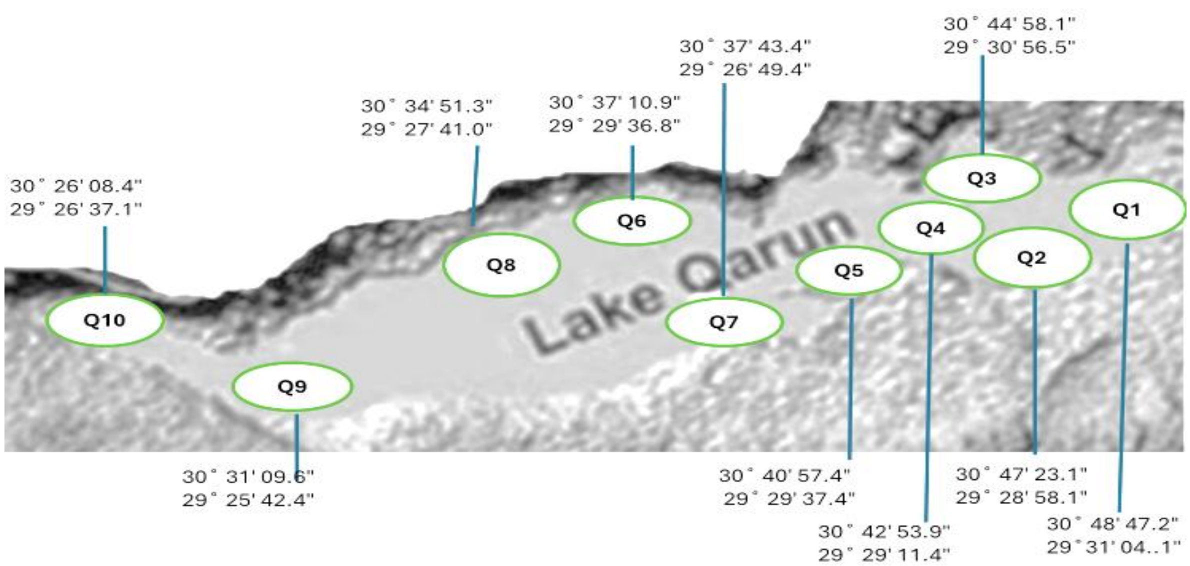

Fig.1. The map of selected stations at the Lake Qarun.

2.3.Statistical analyses

Shannon-Winner diversity (Shannon,1948), species richness or the Margalef's Index (Margalef,1958), evenness or Equitability (Pielou,1966), similarity index (Bray and Curtis1957), Multiple regression analysis (Draper and Smith1998), correlations between some environmental variables and the zooplankton assemblages were calculated using Past software **(Hammer et al., 2001).**

3. Results and discussion

3.1. Zooplankton distribution

3.1.1. Autumn season

A total of 22 zooplankton taxa were recorded at the Lake Qarun (stations from Q1 to Q10) as presented in Tables (1 and 2). The recorded zooplankton taxa were divided into four groups namely: Rotifera (47.63%), Copepoda (29.23%), Protozoa (18.4%) and Meroplankton (4.73%). The highest number of zooplankton individuals (1388000 Org./m^3) was calculated at the Q1 station whereas the lowest counts (296007 Org./m^3) were identified at the Q8 station. The percentage of each identified zooplankton group at Lake Qarun in the autumn and winter seasons was presented in (Fig.2).

The Rotifera group was represented by nine taxa. The highest number of Rotifera individuals (708000 Org./m^3) was calculated at the Q1 station whereas the lowest counts (32000 Org./m^3) were identified at the Q8 station.

The Copepoda group was represented by four species. The highest number of Copepoda individuals (380000 Org./m^3) was calculated at the Q3 station whereas the lowest counts (88000 Org./m^3) were identified at the Q6 station.

The Protozoa group was represented by eight taxa. The highest number of Protozoa individuals (476000 Org./m^3) was calculated at the Q1 station whereas the lowest counts (4000 Org./m^3) were identified at the Q8 station.

The Meroplankton group was represented by polychaeta larvae (Table 1). The highest number of Polychaeta larvae individuals (32009 Org./m3) was calculated at the Q10 station whereas the lowest counts (32000 Org./m3) were identified at the Q1 station.

Table 1. The documented zooplankton taxa in Lake Qarun during autumn and winter season

Zooplankton species	Season		Zooplankton species	Season	
	Au	Wi		Au	Wi
Protozoa			*Keratella tropica*	A	P
Arcella spp.	P	P	Bdelloidea	A	P
Centropyxis aculeata	P	P	*Epiphanes macroura*	P	A
Ciliophora sp.	P	P	*Philodina* sp.	P	A
Didinium nasutum	A	P	*Polyarthra valgaris*	P	A
Euplotes vennus	P	P	*Scaridium longicaudum*	A	P
Favella sp.	P	A	*Synchaeta kitina*	P	P
Globigerina sp.	P	A	*Synchaeta oblonga*	P	P
Sphaerophrya sp.	P	A	*Trichocerca pusilla*	P	P
Tintinnopsis sp.	P	P	**Copepoda**		
Rotifera			*Paracartia latisetosa*	P	P

Table 1 (continued).

Asplanchnella pridonta	A	P	*Cirripedia larvae*	P	P
Brachionus angularis	P	A	*Cyclopoid copepods*	P	P
Brachionus calyciflorus	A	P	Nauplius larva	P	P
Brachionus plicatilis	P	P	**Meroplankton**		
Brachionus cf. rotundiformis	A	P	Polycheata larvae	P	P
Brachionus urceolaris	P	A	**Cladocera**		
Keratella cochlearis	A	P	*Daphnia longispina*	A	P

P= Present, A= absent, Au=Autumn and Wi= Winter

Table 2. Standing crop of zooplankton groups (Org./m^3) at the Lake Qarun stations

	Autumn					**Winter**					
Sta.	**P**	**R**	**C**	**M**	**Total**	**P**	**R**	**C**	**Cl**	**M**	**Total**
Q1	476000	708000	172000	32000	1388000	536000	964000	36000	0	48000	1584000
Q2	60000	704000	132000	32001	928001	220000	392000	376000	0	96000	1084000
Q3	60000	240000	380000	32002	712002	344000	936000	80000	0	8000	1368000
Q4	56000	336000	252000	32003	676003	512000	324000	300000	0	48000	1184000
Q5	116000	308000	240000	32004	696004	116000	528000	672000	0	144000	1460000
Q6	32000	556000	88000	32005	708005	8000	4000	1388000	4000	536000	1944000
Q7	356000	108000	112000	32006	608006	76000	0	504000	0	88000	668000
Q8	4000	32000	228000	32007	296007	60000	0	112000	0	12000	184000
Q9	48000	88000	236000	32008	404008	208000	0	200000	0	8000	416000
Q10	36000	140000	136000	32009	344009	332000	8000	32000	0	8000	380000
Sum	1244000	3220000	1976000	320045	6760045	2412000	3156000	3700000	4000	996000	10272000

Sta.= Station, P=Protozoa, R=Rotifera, C=Copepoda, Cl=Cladocera, M=Meroplankton

3.1.2. Winter season

A total of 23 zooplankton taxa were recorded at Qaroun Lake (stations from Q1 to Q10) as presented in Tables (1 and 2). The recorded zooplankton taxa were divided into five groups namely: Copepoda (36.02%), Rotifera (30.72%), Protozoa (23.48%), Meroplankton (9.69%) and Cladocera (0.038%). The highest number of zooplankton individuals (1940000 Org./m^3) was calculated at the Q6 station whereas the lowest counts (184000 Org./m^3) were identified at the Q8 station. The percentage of each identified zooplankton group at Lake Qarun in the autumn and winter seasons was presented in (Fig.2).

The Copepoda group was represented by four species. The highest number of Copepoda individuals (1388000 Org./m^3) was calculated at the Q6 station whereas the lowest counts (32000 Org./m^3) were identified at the Q10 station.

The Rotifera group was represented by 11 species. No recorded Rotifera species was identified in three stations (Q7, Q8 and Q9). The highest number of Rotifera individuals (964000 Org./m^3) was calculated at the Q1 station.

The Protozoa group was represented by six species. The highest number of Protozoa individuals (536000 Org./m^3) was calculated at the Q1 station whereas the lowest counts (8000 Org./m^3) were identified at the Q6 station.

The Meroplankton group was represented by polychaeta larvae (Table 1). The highest number of Meroplankton individuals (536000 Org./m^3) was calculated at the Q6 station whereas the lowest counts (8000 Org./m^3) were identified at the Q3, Q9 and Q10 stations.

The Cladocera group was represented by only one species (*D.longispina*) recorded at the Q6 station (4000 Org./m^3).

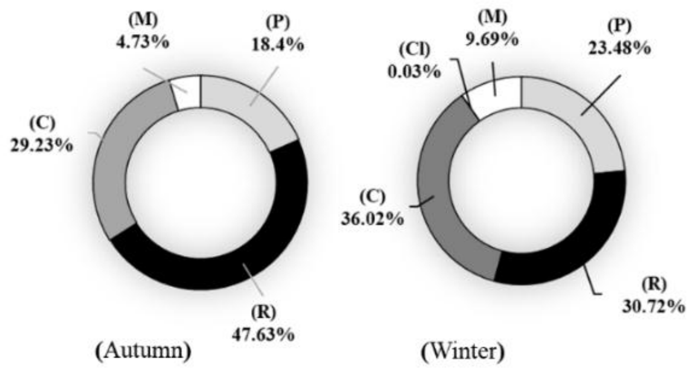

Fig.2. The percentage of each identified zooplankton group at Lake Qarun in the autumn and winter seasons. P= Protozoa, R= Rotifera, C= Copepoda, Cl= Cladocera and M= Meroplankton

3.2. The diversity indices

The diversity indices (Shannon diversity index, Equitability and Margalef index) during two seasons were calculated (Fig.3). During the autumn, the Shannon diversity values ranged from 1.615 (station 8) to 2.185 (station 5). The Margalef index values ranged from 0.5215 (station 4) to 0.9413 (station 10). The Equitability values ranged from 0.7324 (station 3) to 0.8798 (station 7).

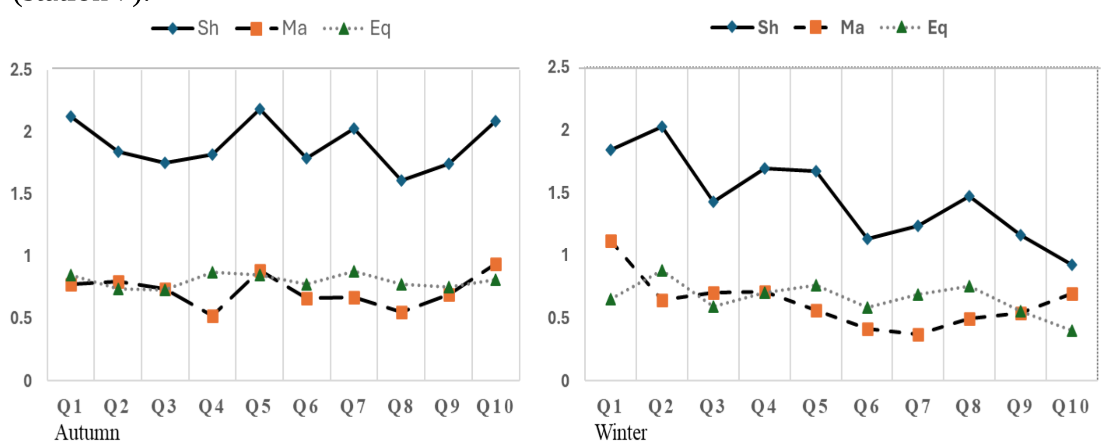

Fig. 3. Diversity indices of zooplankton community at different Lake Qarun stations (from Q1 to Q10). Sh=Shannon index, Ma=Margalef index and Eq=Equitability.

Regarding the winter season, the Shannon diversity values ranged from 0.924 (station 10) to 2.032 (station 2). The Margalef index (species richness) values ranged from 0.3728 (station 7) to 1.121 (station 1). The Equitability (Evenness) values ranged from 0.4015 (station 10) to 0.8823 (station 2).

During the autumn season, the diversity indices were not significantly influenced by any of the estimated independent factors. On the other hand, during the winter, the Multiple regression analysis (Table 3) indicated that Shannon diversity index values were significantly influenced by the temperature (p= 0.03), transparency (p= 0.01), EC (p= 0.03), pH (p= 0.04) and dissolved oxygen (p= 0.01). Also, the equitability indices were influenced by the temperature (p= 0.04), transparency (p= 0.04) and DO (p= 0.04) fluctuations. The zooplankton density (Org./m^3) values were found to be significantly impacted by environmental variables including the transparency (p= 0.003), EC (p= 0.001), pH (p= 0.009), DO (p= 0.04), NH_3 (p= 0.03), and PO_4 (p= 0.002) during the winter season.

Table3. The relations among biodiversity indices and some environmental factors in the evaluated stations using Multiple regression analysis.

			Const.	Temp.	Trans.	EC	pH	DO	NH_3	PO_4
Au	Eq	p	0.12	0.12	0.13	0.55	0.08	0.07	0.93	0.05
		R^2		0.007	0.04	0	0.003	0.05	0.002	0.08
	Ma	p	0.4	0.97	0.53	0.59	0.42	0.58	0.5	0.62
		R^2		0.04	0.17	0.08	0.06	0.01	0.06	0
	Sh	p	0.908	0.42	0.13	0.43	0.93	0.56	0.46	0.11
		R^2		0.02	0.32	0.08	0.03	0.06	0.06	0.05
	Ind	p	0.5	0.8	0.17	0.5	0.53	0.77	0.24	0.71
		R^2		0.27	0.61	0.57	0.008	0.0001	0.67	0.01
Win	Eq	p	0.07	0.04	0.04	0.13	0.443	0.04	0.72	0.68
		R^2		0.03	0.007	0.01	0.09	0.17	0.07	0.001
	Ma	p	0.9	0.36	0.68	0.88	0.21	0.82	0.36	0.49
		R^2		0.193	0.084	0.4673	0.0007	0.035	0.002	0.278
	Sh	p	0.03	0.03	0.01	0.03	0.04	0.01	0.23	0.24
		R^2		0.01	0.003	0.19	0.07	0.12	0.03	0.06
	Ind	p	0.003	0.07	0.003	0.001	0.009	0.04	0.03	0.002
		R^2		0.03	0.1	0.16	0.0002	0.07	0.0006	0.03

Au=Autumn, Wi= Winter, p= probability, R^2= Multiple regression, Const.= Constant, Temp.= Temperature, Trans.= Transparency, EC = Electric conductivity, DO = Dissolved Oxygen, PO_4= phosphate, NH_3= ammonia, Sh=Shannon index, Ma=Margalef index, Ind=individuals and Eq=Equitability.

3.3. Cluster analysis.

Clustering analysis among the evaluated stations based on zooplankton abundance during the autumn (a) and winter (b) was presented in Fig. (4). During the autumn season, the station Q3 is distantly related to the Q8 station. The other stations were divided into two groups (I and II). Group I comprise stations 1, 2, and 6, whereas Group II consists of stations 4, 5, 7, 9 and 10.

Regarding the winter season, the station Q1 is distantly related to the Q6 station. The other stations were divided into two groups (I and II). Group I comprise stations 1, 2, 3, 4, 5 and 10, whereas Group II consists of stations 7, 8, and 9.

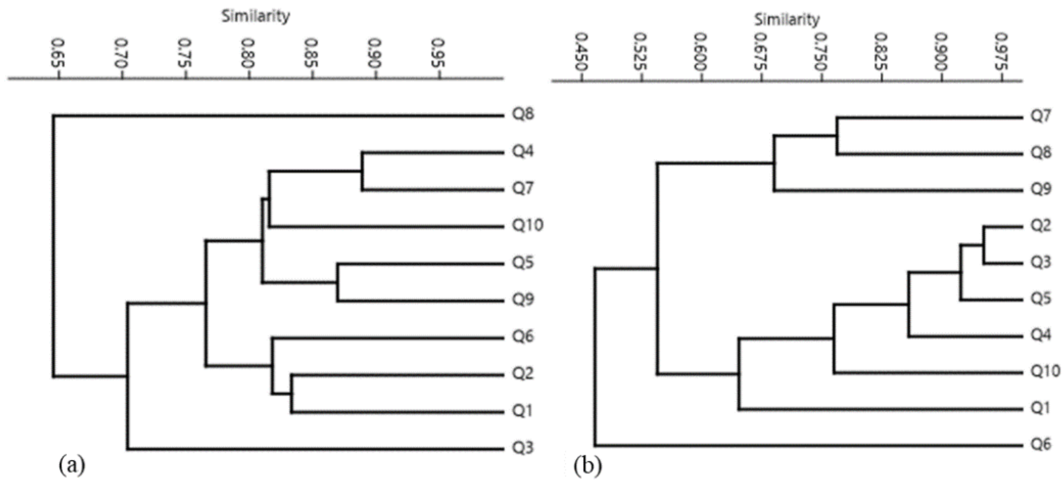

Fig.4. Clustering analysis among the evaluated stations based on zooplankton diversity variations during the autumn (a) and winter (b).

In the present study, the differences in the zooplankton community composition could be due to various independent environmental factors and/or the introduction of marine plankton species (Mageed, 2005). The zooplankton community in the two evaluated seasons (autumn and winter) was dominated by Rotifera, and Copepoda while Protozoa constituted 18.4% and 23.48% of the zooplankton taxa during the autumn and winter respectively.

Comparatively with other investigations like Mageed (1998) on the same lake, the number of zooplankton species is influenced by eutrophication levels. This observation was previously confirmed by Ruttner-Kolisko (1974). They observed that the species richness at first rises with the eutrophication of the water up to a definite point and then declines again. Also, high eutrophication levels lead to mass mortality of aquatic organisms including zooplankton due to extraordinary oxygen consumption by intensified phytoplankton density (Saad, 2003). Mageed (2005) confirmed that the zooplankton community was dominated by the protozoan group, and its peak of flourishing was noticed during spring season.

We observed that the percentage of Protozoa in the winter is higher than that recorded in the autumn. On the other hand, the percentage of Rotifera in the winter is lower than that recorded in the autumn. Both (rotifers and protozoans) become more valuable zooplankton indicators for pollution in the eutrophic lakes. Also, the Protozoa can grow in organic-rich waters such as Lake Qarun (Mageed 1998).

In the autumn season, the Rotifera (9 species) group (3220000 Org./m^3) is dominated by the genus *Brachionus* especially *B. plicatilis* (1672000 Org./m^3). On the other hand, the *B.plicatilis* (12000 Org./m^3) was detected in the Q1 station only in the second season (winter). This species is considered a marine zooplankton form with euryhaline affinities (Williams 1987, Egborge 1994 and Mageed, 2005). Mageed, (2005) observed that this group (comprising 13.2% of total zooplankton density) flourished during the summer and autumn seasons in Lake Qarun.

The dominance of *Brachionus* in the autumn season could be due to habitat preference, and availability of phytoplanktonic food due to the increased eutrophication relatively in this season. Comparatively with other lakes, Hassan et al., (2017) investigated the impact of water quality on zooplankton biodiversity in some different Lake Edku stations. They attributed the dominance of the *Brachionus* in the lake to the same reason. The Value of macrophytes for invertebrate biodiversity in subtropical water bodies was discussed by Ali (2007). On the other hand, Hassan et al., (2017) attributed the dominance of rotifers in certain water body could be due to decreased heterogeneity and its dominance by organically polluted water. Hrodey et al. (2008) concluded that reduced habitat heterogeneity may lead to heightened richness of highly adaptive taxa.

During the winter, the Rotifera (11 species) was dominated by both *Synchaeta kitina* (From Q1 to Q5) and *S.oblonga* (Stations, Q1, Q2, Q3, Q4, Q5 and Q10). This observation was also confirmed by Mageed, (2005). He observed that the *Synchaeta* (freshwater rotifer) was the dominant genus, of the total rotifers recorded in the Lake Qarun.

The Copepoda is dominated by *P. latisetosa* and Nauplius larvae in both two seasons. The density of the group in autumn (1976000 Org./m^3) was lower than that recorded in the winter (3700000 Org./m^3). Mageed, (2005) confirmed that the flourishing season of copepods was during the winter season.

In autumn the Protozoa is dominated by *E. v*ennus. The presence of this species may suggest mesotrophic or eutrophic conditions, illustrated by moderate to high levels of nutrients.

In winter the Protozoa is dominated by *D. nasutum*. This observation was confirmed by (Mageed, 2005). Mageed, (2005) characterized this species as a Beta-mesosaprobic species (have a moderate tolerance to organic pollution in aquatic environments). This characterization could help assess the health of aquatic ecosystems (based on the abundance of different saprobic organisms).

During the autumn season, the highest number of zooplankton (1388000 Org./m^3) was recorded in the station Q1 (dominated by Rotifera,51%). This could be attributed to the station's location (opposite to El-Bats Drain). The biodiversity in certain stations could be affected by certain an independent factor such as station location (Mageed 1998).

Regarding the second season (winter), the highest number of zooplankton (1944000 Org./m^3) was recorded in the station Q6 (dominated by Copepoda, 71.39%).

Mageed (1998) found that the maximum zooplankton density was recorded at the middle of Lake Qarun. He attributed that, to the effects of the agricultural drainage water inflow through the drains at the middle of the lake through the El-Wadi Drain (carries the fertilizers of the agricultural lands and the discharge of the fish farms).

The Cladocera (water fleas) as a bioindicator for water quality and pollution (Hassan et al., 2017) constitute only 0.038% of the total zooplankton in the winter season. It is represented by *D.longispina*. No Cladocera was recorded the autumn. The sensitivity of Cladocera to polluted waters and alteration of water qualities was confirmed by Flower (2001) and Hassan et al. (2017). Hassan et al. (2017) observed that the large Cladocera species are habitually restricted to the freshwater environment; however, those living in brackish water environments are smaller in size and exhibit reduced reproduction.

In the winter season, the Multiple regression analysis indicated that Shannon diversity index values were significantly influenced by the temperature, transparency, EC, pH and dissolved oxygen. Also, the equitability indices were influenced by temperature fluctuations.

On the other hand, all of the biodiversity indices are not significantly influenced by any of the independent factors during the autumn season. Influencing of the zooplankton diversity by certain environmental factors in certain conditions in this lake was also observed by Mageed, (2005). He observed that the presence of copepods and rare rotifer forms was influenced by seasonal fluctuations correlated with water temperature.

We found that zooplankton density (Org./m^3) values were significantly impacted by environmental variables including transparency, EC, pH, DO, NH_3, and PO_4 during the winter season. The fluctuations in the zooplankton density (Org./m^3) from station to station could be due to that most of the agricultural drainage water inflows through the drains at the middle of the lake through El-wadi Drain which carries the fertilizers of the agricultural lands and the discharge of the fish farms (Mageed, 2005).

The results showed that the species diversity among the different evaluated stations was varied, with some stations displaying higher diversity than the others.

During the autumn season, the highest diversity values were detected in three stations coded as Q1, Q5 and Q10. The lowest value was detected in station Q8 suggesting lower species diversity compared to other stations.

Station Q10 exhibited the highest Margalef index, reflecting higher species richness compared to other stations. Station Q7 has the greatest equitability index value, indicating a relatively even distribution of individuals among different species. On the other hand, station Q3 has a minimal equitability index value, suggesting a less even distribution of individuals among species.

Regarding the winter season, both stations Q2 and Q4 have high diversity values, indicating relatively great species diversity. Stations Q6, Q7, Q9, and Q10 have the lowest diversity indices, indicating lower species diversity compared to the other stations.

Station Q1 exhibited the highest Margalef index, reflecting higher species richness compared to other stations. Both Q6 and Q7 stations have low index values, indicating lower species richness.

Station Q2 has the greatest equitability index value, indicating a relatively even distribution of individuals among different species. On the other hand, station Q10 has the lowest equitability index value, suggesting a less even distribution of individuals among species.

Zooplankton species play a critical role in the Lake ecosystems, as it graze on the phytoplankton, in this manner regulating algal biomass and structure (Christoffersen et al., 1993).

Intensified nutrient inputs from watersheds lead to enhance phytoplankton and zooplankton dynamics. EL-Shabrawy and Taha, (1999) observed that zooplankton controls phytoplankton densities in Lake Qarun. Our results showed that B. plicatilis was the main dominant rotifer (51.91%) during the autumn. On the other hand, it constitutes about (0.38%) of the rotifer group during the winter season. EL-Shabrawy and Taha (1999) confirmed that this species was the main dominant rotifer, in the lake during the summer. It primarily feeds on *Nitzchia sigma* and *N. frustulum.*

The efficiency of reconstruction of relatedness among the evaluated stations based on the zooplankton abundance value variations was useful in exploring the biological relations among them. The validity of this process would depend on several factors, including the appropriateness of the applied statistical methods, and the ecological relevance of the relationships identified (Tahoun et al., 2021 and Heneash et al., 2022). Information revealed from this analysis would be informative in formulating policies and frameworks for the sustainable management of in Lake Qarun.

4. Conclusions

Lake Qarun is considered a warm polymictic water body with frequent general circulation. The recorded zooplankton taxa during autumn were divided into four groups namely: Rotifera (47.63%), Copepoda (29.23%), Protozoa (18.4%) and Meroplankton (4.73%). Regarding the winter season, the zooplankton taxa were divided into five groups namely: Copepoda (36.02%), Rotifera (30.72%), Protozoa (23.48%), Meroplankton (9.69%) and Cladocera (0.038%). Lake Qarun habitats are impacted by human activities. As revealed from the Multiple regression analysis, the density and diversity of zooplankton in the lake are influenced by some environmental factors including transparency, EC, pH, DO, NH_3, and PO_4.

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