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Assessment of Water Quality and Zooplankton Community Structure in the River Nile, Qena Governorate, Egypt

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ABSTRACT

Zooplankton is an important bio-indicator of ecosystem integrity. The present study aimed to evaluate zooplankton community and measure some physical and chemical characteristics of the water, during the period from September 2020 to August 2021. Samples were collected from 15 sites located in the River Nile and its tributaries (26°9'18.22"N and 32°42'57.64"E) at Qena Governorate. Eleven representatives of water samples were collected to measure physico-chemical parameters, including temperature, pH, total dissolved solids, conductivity, turbidity, dissolved oxygen and some heavy metals (manganese, copper, zinc, chrome and cobalt). Investigation of the physio-chemical parameters showed that pH, turbidity, dissolved oxygen, total dissolved solids, and conductivity recorded maximum values in winter. Heavy metals such as cobalt (Co) recorded the highest concentration in winter and the lowest in autumn. Chromium (Cr) recorded the highest concentration in autumn and the lowest in spring. Manganese (Mn) recorded the highest concentration in spring and the lowest in autumn. Copper (Cu) and zinc (Zn) concentrations reached their highest in summer and lowest in autumn. On the other hand, Cladocera and Copepoda were the most dominant populations, which were negatively correlated with water temperature (r=-0.474) and (r=-0.118), respectively.While, they were positively correlated with total dissolved solids, conductivity, turbidity and cobalt.

INTRODUCTION

Monitoring water quality is an important part of managing vital water resources and ecosystems. The quality of the environment can only be described by measuring physical and chemical factors at a specific time (temporary). Biological indicators can be observed in real time, providing simple directions for tracking pollution. Plankton is remarkably one of the biological factors that can be used as an indicator of environmental conditions **(Fichot *et al.*, 2016; Yanuhar *et al.*, 2019)**.

Zooplankton are crucial in the ecosystem in monitoring water quality, pollution, and the state of eutrophication **(Eddy *et al.*, 2021; Magouz *et al.*, 2021; Peng *et al.*,**

2021). They are particularly susceptible to environmental changes due to their small size and short life cycle, and they have a wide distribution in aquatic environments **(Whitman *et al.*, 2004; Garca-Comas *et al.*, 2014; Chiba *et al.*, 2018)**. These organisms react quickly to a variety of environmental changes, including water temperature, pH, conductivity and nutrients **(Yakubu *et al.*, 2000)**. Environmental changes and ecological processes shape zooplankton communities in terms of taxonomic composition **(Buttay *et al.*, 2015; Cruz-Rosado *et al.*, 2020)**, as well as spatial and temporal abundance **(Färber Lorda *et al.*, 2019; Shropshire *et al.*, 2020)**. This may lead to zooplankton biodiversity loss **(Gazonato Neto *et al.*, 2014**; **Parmar *et al.*, 2016)** which can affect ecosystem services and result in economic consequences **(Johnston *et al.*, 2015; Bucklin *et al.*, 2016**; **Everaert *et al.*, 2018)**.

Heavy metals are high-atomic-weight elements that are poisonous to a wide range of life forms, even at extremely low quantities. They are originated from natural and artificial sources. Heavy metals persist in the environment and do not breakdown into harmless end products; heavy metals' bioaccumulation and biomagnification capabilities affect aquatic ecosystems **(Putshaka *et al.*, 2015; Ranasinghe *et al.*, 2016; Trevizani *et al.*, 2018)**. Significant amounts of heavy metals may be adsorbed onto cell surfaces or actively accumulate in the bodies of these microscopic organisms, which have a large surface area (surface/volume ratio) **(Severini *et al.*, 2009**; **Achary *et al.*, 2020)**.

To the best of the present authors` knowledge, there are little or sparse information on the assessment of zooplankton in relation to physico-chemical parameters of water at Qena Governorate. Therefore, the present investigation was undertaken to characterize zooplankton communities and determine their distribution in relation to physico-chemical parameters.

MATERIALS AND METHODS

1. Study area

The study was carried out in Qena Governorate. Water samples were monthly collected during September 2020 to August 2021. Forty five (45) samples were collected from 15 sites representing different environmental habitats (7 sites along the Nile's main flow and 8 sites along its tributaries). Data on the sampling sites with their latitude and longitude are presented in Fig. (1).

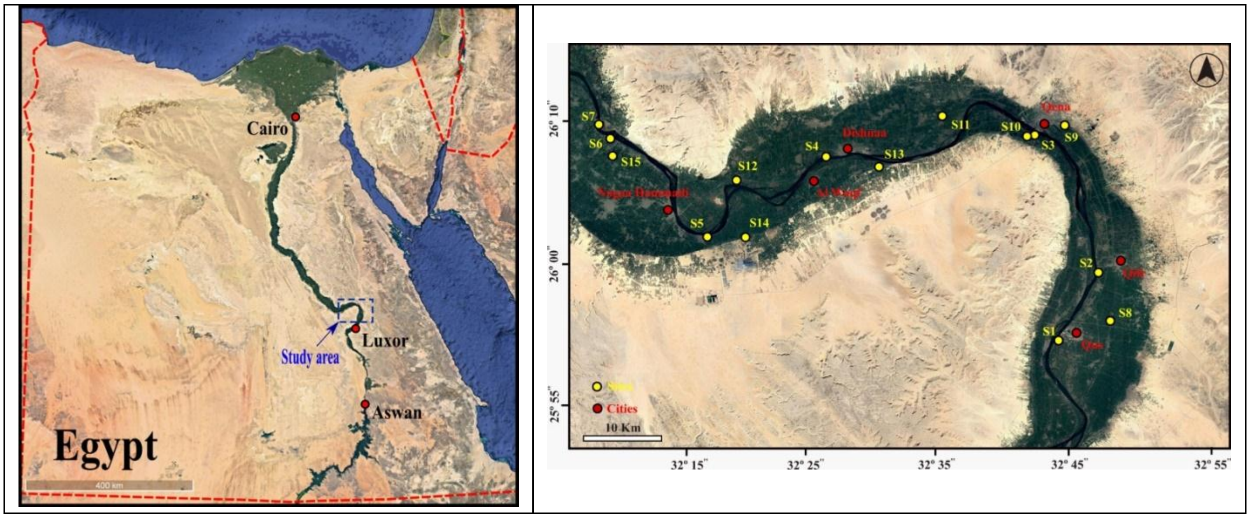

Fig. 1. A map showing the locations of the studied sites

2. Measurements of the physico-chemical parameters

Six physical parameters were evaluated including, water temperature, pH, total dissolved solids (TDS), conductivity, turbidity and dissolved oxygen (DO). Water temperature was measured using a mercury thermometer. The hydrogen ion (pH) was determined by pH meter model HANNA. TDS and conductivity were measured by the Cole–Parmer model Check-mate 90 (CORNING). Turbidity was measured by turbidity meter model TU-2016 NTU. Dissolved oxygen (DO) was measured applying the titration method.

The concentrations of five heavy metals {manganese (Mn), copper (Cu), zinc (Zn), chromium (Cr) and cobalt (Co)} in water were monthly measured and recorded during the study period, and their seasonal variations at the studied sites were investigated. These heavy metals were measured by atomic absorption spectrometer according to standard methods.

3. Zooplankton sampling

The samples were collected using plankton net, which is a cone-shaped net. Samples were gathered from three different depths by vertical net hauls. The zooplankton organisms retained in the net were placed carefully into suitable jars, labeled and immediately fixed with 95% ethanol. The identification process was conducted by using different keys **(Wilson & Yeatman, 1959; Obuid-Allah, 2001; Elfeky & Sayed, 2014)**.

4. Statistical analysis

The seasonal mean variations of zooplankton groups and environmental factors of the studied sites were analyzed using one-way analysis of variance (ANOVA). The correlation coefficients between zooplankton groups and physico-chemical parameters were calculated by linear Pearson correlation. Cluster analysis was used to measure the similarity between all studied sites in terms of physico-chemical paeameters (Origin pro

2021). The effects of physico-chemical parameters on zooplankton taxa were studied by drawing heat maps using Origin pro (2021). Principal component analysis (PCA) was performed by using Origin pro (2021) to show the distribution of physico-chemical parameters during the period of study in all investigated sites.

RESULTS

The present investigation was carried out at the governorate of Qena on 15 sites situated at the Nile River and its tributaries. Some physico-chemical parameters, such as water temperature, pH, total dissolved solids, conductivity, turbidity, dissolved oxygen and some heavy metals (Mn, Cu, Zn, Cr, Co) were measured to study their effects on the distribution of zooplankton.

The results revealed that the highest value of water temperature was recorded at site 12 (28.45±5.13ºC) and the lowest value was (22.97±3.84ºC) at site 3. The highest value of pH was recorded at site 7 (8.36±0.49), while the lowest was registered at site 12 (7.70±0.34). The maximum values of total dissolved solids and conductivity were recorded at site 10 and reached (206.68±147.85) mg/l, (413.47±294.76) µS/cm, respectively; while, the lowest values were recorded at site 1 reaching (147.81±13.45) mg/l, (294.72±27.45) µS/cm, respectively. Turbidity (NTU) recorded the highest value at site 6 (46.91±49.49 NTU); whereas, the lowest value (15.21±14.17NTU) was recorded at site 1. Dissolved oxygen recorded the maximum value (4.35±1.47) mg/l at site 13 and the minimum at site12 (3.84±1.37) mg/l (Fig. 2).

The highest concentration of manganese was recorded at site 10, while it recorded the lowest concentration at site 2. Copper recorded the maximum concentration at site 11 while the minimum was at site 2. Zinc showed the maximum concentration at site 13, while it recorded (0) value at most of the Nile River sites (1, 2, 3, 4, 6 and 7). Chromium recorded the maximum concentration at site 9 and the minimum was at site 5. Cobalt recorded the maximum concentration at site 9, while the minimum concentration was at site 4 (Fig. 3).

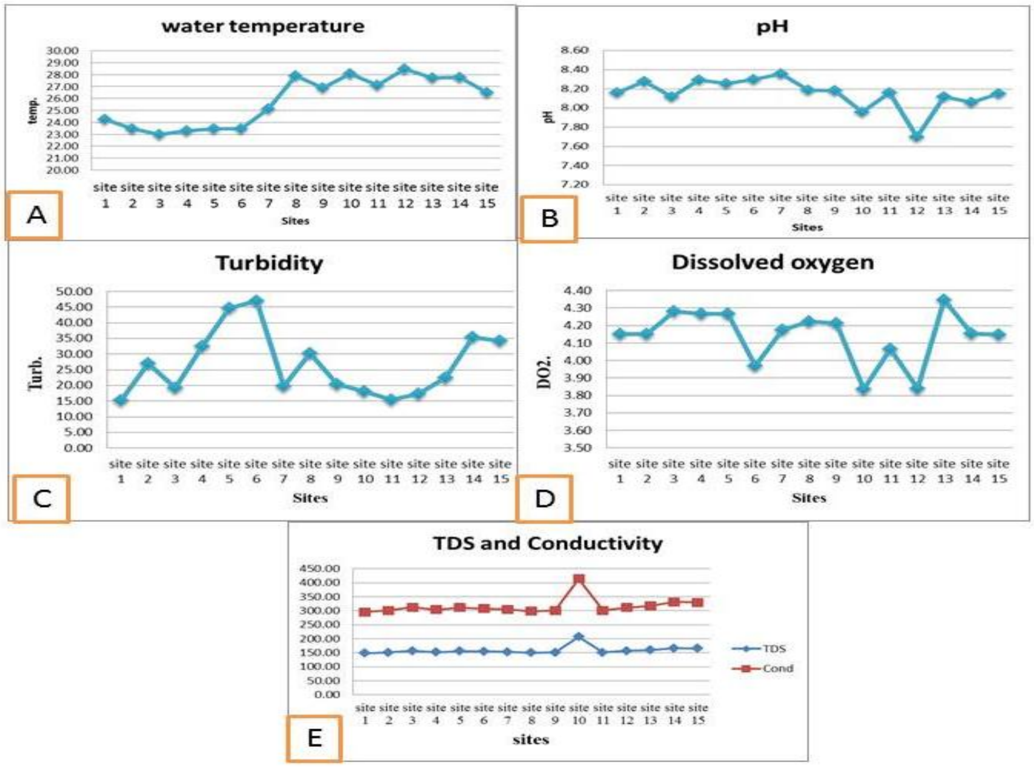

Fig. 2. The mean of physico-chemical parameters at the investigated sites during the study period

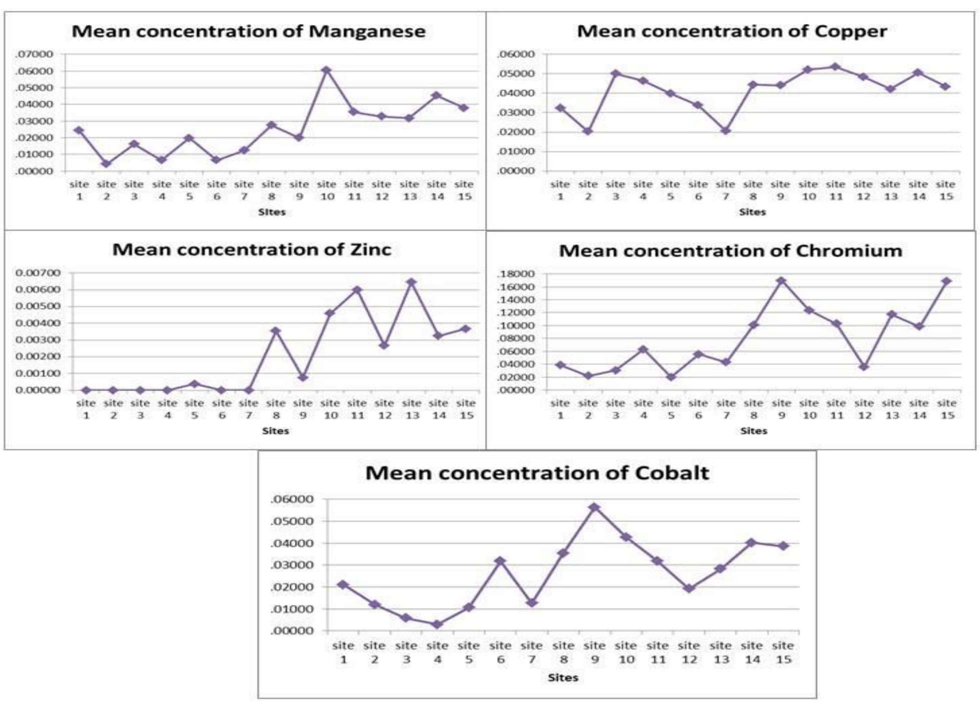

Fig. 3. The mean of heavy metals at the investigated sites during the period of study

Seasonal fluctuations in physico-chemical parameters and heavy metal concentrations

According to the annual average values, surface water temperature recorded the minimum value (26.44±2.72ºC) in winter and the maximum value (30.42± 2.20ºC) was in summer. The hydrogen ion concentration (pH) recorded the highest value in autumn (8.45±0.38) and the lowest value in spring (7.69±0.41). The seasonal mean value of total dissolved solids ranged from a low value (142.81±9.89 mg/l) in summer in summer to a high value (184.11±78.88 mg/l) in winter. The seasonal mean value of conductivity ranged from (286.66±20.08 μs/cm) in summer to (366.72±157.58 μs/cm) in winter. The seasonal mean value of turbidity ranged from (10.31±7.80 NTU) in summer to (61.35±50.91 NTU) in autumn. The seasonal mean value of dissolved oxygen ranged from (3.35±0.67 mg/l) in summer to (5.75±0.98 mg/l) in autumn (Fig. 4).

Manganese (Mn) recorded the highest concentration in spring (0.0286 ±0.0236) and the lowest concentration in autumn (0.0205±0.0226). Copper (Cu) recorded the highest concentration in summer (0.0952±0.0448) and recorded 0 value in autumn. Zinc (Zn) recorded the highest concentration in summer (0.0054±0.0109) and the lowest in autumn (0.0007±0.0043). Chromium (Cr) recorded the highest concentration in autumn (0.1173± 0.1550) and the lowest in spring (0.0513±0.0411). The highest concentration of cobalt (0.0304±0.0341) was recorded in winter and the lowest (0.0254±0.0323) was in autumn **(Fig. 4)**

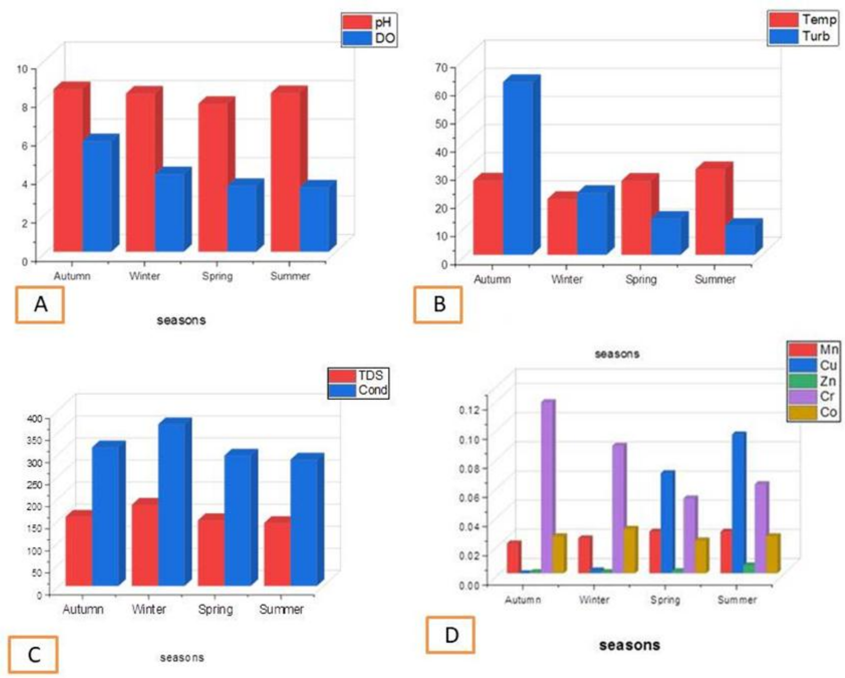

Fig. 4. Seasonal mean of both physico-chemical parameters and heavy metals concentrations during the period of study

Statistical analysis

By applying the correlation analysis of the collected data between the measured physico-chemical parameters, it was concluded that water temperature was positively correlated with Mn (r = 0.245), Cu (r = 0.388), and Zn (r = 0.264), while negatively correlated with TDS (r = 0-.218), conductivity (r = -0.211), turbidity (r = -0.121) and dissolved oxygen (r = -0.098). The pH was positively correlated with turbidity (r = 0.413) and dissolved oxygen (r = 0.319), while negatively correlated with Mn (r = -0.159) and Cu (-0.456). TDS was positively correlated with conductivity (r = 0.998), Mn (r = 0.202), Cr (r = 0.114)and Co (r = 0.130) while negatively correlated with Cu (r= -0.181). Conductivity was positively correlated with turbidity (r = 0.087), Mn (r = 0.206), Cr and negatively with Cu (r = -0.178). Turbidity was positively correlated with dissolved oxygen (r = 0.340), while correlated negatively with Mn (r = -0.085), Cu (r = -0.336) and Zn (r = -0.103). Dissolved oxygen was correlated positively with Cr (r = 0.296) and negatively with Mn (r = -0.201), Cu (r = -0.502) and Zn (r = -0.197). Mn was positively correlated with Cu (r = 0.206), Zn (r = 0.317), Cr (r = 0.119) and Co (r = 0.200). Cu was positively correlated with Zn (r = 0.236) and negatively with Cr (r = -0.109). Cr was positively correlated with Co (r =0.278) (Table 1).

During the sampling period, 48 different zooplankton taxa **(PLATE I)** were identified and classified into four groups. Cladocera comprising the most species (23), followed by Copepoda (12 species with additionally copepodite stage and Nauplius stage). Rotifera was the third abundant group (8 species), while Ostracoda (3 species) was the least abundant one. Taxa collected were assigned in 33 genera and 46 species that fall in 15 families, in addition to copepodite stage and Nauplius stage. The identified families included the followings: seven families belonging to Cladocera: Bosminidae, Daphniidae, Ilyocryptidae, Macrothricidae, Chydoridae, Sididae and Moinidae. Three families belonging to Copepoda: Diaptomidae, Cyclopidae, Miraciidae. Four families belonging to Rotifera: Notommatidae, Lecanidae, Brachionidae and Trichocercidae. One family (Cyprididae) belonging to Ostracoda.

Cladocera showed maximum density in winter and the lowest density in summer. It showed significant positive correlation with TDS (r = 0.119), conductivity (r = 0.117), turbidity (r = 0.100), Co (r = 0.092) and negative with water temperature (r = -0.474), Cu (r = -0.202), Zn (r = -0.093). The highest density of Copepoda was noticed in autumn, while the lowest density was recorded in summer. It exhibited positive correlation with TDS (r = 0.133), conductivity (r = 0.134), turbidity (r = 0.187), Cladocera (r =0.287) and negative with water temperature (r = -0.118), Cu (r = -0.186). In winter, Rotifera showed the maximum density and the lowest was recorded in summer. It showed significant positive correlation with Copepoda (r = 0.170). Autumn and spring showed the highest density of Ostracoda, while the lowest density was recorded in summer. Ostracoda exhibited positive correlation with Cladocera (r = 0.113). (**Table 1** and **Fig. 5).**

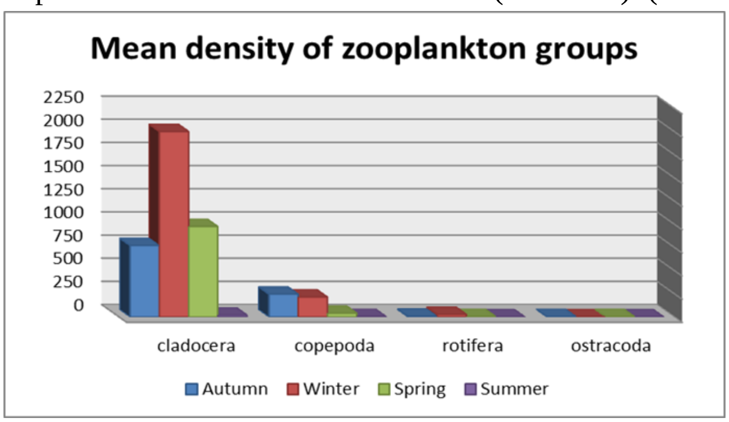

Fig. (5): Seasonal mean of zooplankton groups in all investigated sites

Table (1): Correlation between physico-chemical parameters and zooplankton groups

	Temp.	Ph	TDS	Cond.	Turb.	Do	Mn	Cu	Zn	Cr	Co	Cladocera	Copepoda	Rotifera
Temp.														
pH	-.063													
TDS	-.218-**	-.014												
Cond.	-.211-**	-.005	.998**											
Turb.	-.121-**	.413**	.076	.087*										
Do	-.098-*	.319**	-.043	-.043	.340**									
Mn	.245**	-.159-**	.202**	.206**	-.085-*	-.201-**								
Cu	.388**	-.456-**	-.181-**	-.178-**	-.336-**	-.502-**	.206**							
Zn	.264**	-.001	-.029	-.030	-.103-*	-.197-**	.317**	.236**						
Cr	.036	.001	.114**	.114**	-.017	.296**	.119**	-.109-*	.001					
Co	.084	.025	.130**	.133**	.011	-.033	.200**	.006	.042	.278**				
Cladocera	-.474-**	.083	.119**	.117**	.100*	-.001	.013	-.202-**	-.093-*	-.054	.092*			
Copepoda	-.118-**	.070	.133**	.134**	.187**	.082	-.003	-.186-**	-.036	.043	.068	.287**		
Rotifera	-.027	-.070	.058	.056	-.002	.000	-.051	-.051	-.031	.052	-.016	-.001	.170**	
Ostracoda	-.052	.001	.002	.004	.046	.023	.006	-.014	-.012	.001	.015	.113**	.042	-.015

Temp: Water temperature; **TDS:** Total dissolved solids; **Cond.:** Conductivity**; Turb.:** Turbidity**; Do:**Dissolved oxygen; **Mn:** Manganese**; Cu:** Copper; **Zn:** Zinc**, Cr:** Chrome**; Co:** Cobalt

Cluster analysis:

The similarity between the fifteen (15) studied sites in physico-chemical parameters was analyzed by cluster analysis. The dendrogram showed that sites 1,7,9,11 formed separate cluster with similarity 90%. Sites 2,4,8 formed separate clusters with similarity 95%. Moreover, sites 3,12,13 clustered together separately with 90%, sites 5, 6 with 96% and sites 14, 15 with 97%; site 10 formed as outlier with 0% similarity **(Fig. 6)**

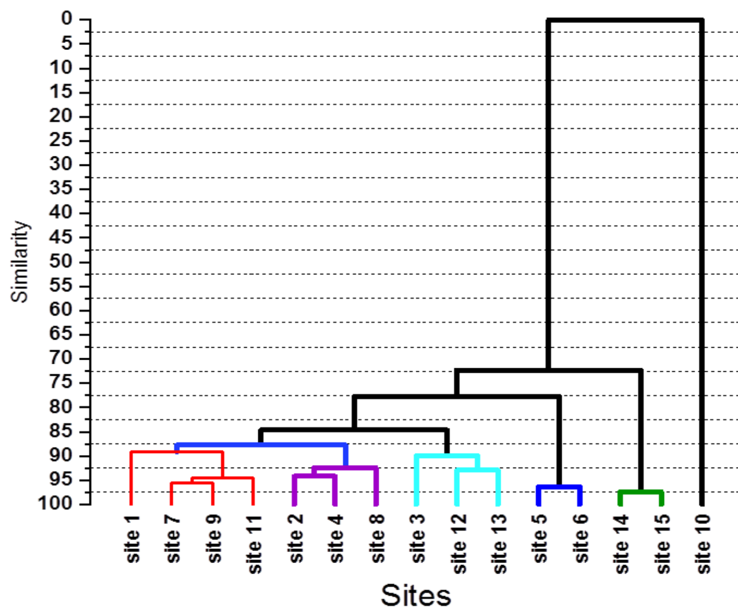

Fig. (6): Dendrogram for ecological factors and heavy metals in all investigated sites

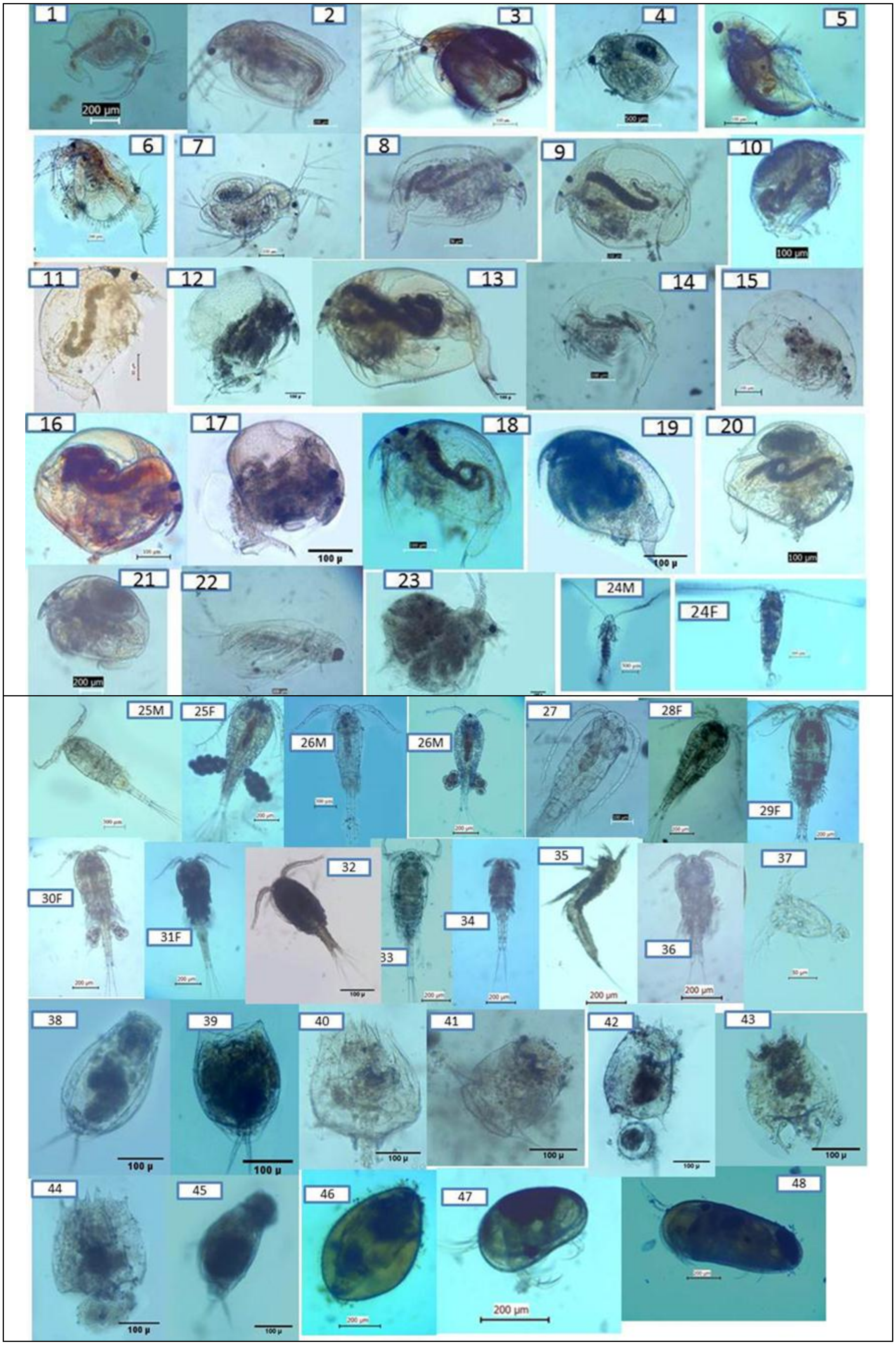
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PLATE I:

1- *Bosmina longirostris*, 2-*Simocephalus expinosus*,3-*Simocephalus vetulus*, 4-*Ceriodaphnia reticulata*, 5-*Daphnia longispina*, 6-*Ilyocryptus sordidus*, 7-*Macrothrix laticornis*, 8-*Alona bukobensis*(a), 9-*Alona bukobensis*(b), 10-*Alona bukobensis*(c), 11-*Alona rectangular*, 12-*Alona* sp. 13-*Euryalona* sp. 14-*Camptocercus australis*,15-*Leydigia quadrangularis*,16-*Chydorus sphaericus*,17-*Chydorus* sp. 18 *Disparalona rostrata 19- Pleuroxus straminius*,*20-Pleuroxus aduncus*,21-*Dunhevedia crassa*,22-*Diaphanosom birgei* 23- *Moina micrura* 24 -*Thermodiaptomus galebi* , 25-*Mesocyclops ogunnus* 26-*Thermocyclops consimilis 27-Thermocyclops neglectus 28-Tropocyclops confinis 29-Macrocyclops albidus 30-Microcylops varicans* 31-*Microcylops linjanticus* 32-*Paracyclops fimbriatus 33-Afrocyclops gibsoni 34-Eucyclops serrulatus* 35- *Shizopera nilotica* 36- Copepodite stage 37- Nauplius stage 38-*Cephalodella gibba* 39- *Lecane lune* 40-*Brachionus rubens* 41-*Brachionus qudridentatus* 42-*Brachionus zahniseri* 43-*Brachionus* sp. 44-*Brachionus urceolaris* 45- *Trichocerca porcellus*. 46-*Cypridopsis vidua* 47- *Potamocypris variegate* 48- *candona* sp. M=Male, F=Female

Correlation between zooplankton species and physico-chemical parameters:

Based on the heatmap of the correlation coefficient of zooplankton species and physicochemical parameters. *Bosmina longirostris* correlated negatively with water temperature, turbidity and Cu. *Simocephalus expinosus* correlated negatively with water temperature and positively with turbidity. *Simocephalus vetulus* correlated negatively with water temperature and positively with turbidity and Co. *Ceriodaphnia reticulata* correlated negatively with water temperature, Cu, Zn and positively with pH, TDS, conductivity, turbidity and dissolved oxygen. *Daphnia longispina* correlated positively with Cobalt. *Ilyocryptus sordidus* correlated negatively with water temperature and pH. *Macrothrix laticornis* correlated negatively with Cu *Alona bukobensis* (b) correlated positively with pH, turbidity and dissolved oxygen; and negatively with Cu *Camptocercus australis* correlated positively with Zn. *Leydigia quadrangularis* correlated positively with pH. *Chydorus sphaericus* correlated positively with TDS, conductivity, Co and negatively with water temperature, Cu. *Disparalona rostrata* correlated negatively with water temperature, Cu. *Pleuroxus aduncus* correlated positively with dissolved oxygen. *Dunhevedia crassa* correlated positively with turbidity. *Thermodiaptomus galebi* correlated positively with pH, dissolved oxygen and negatively with water temperature, Mn, Cu. *Mesocyclops ogunnus* correlated positively with pH, TDS, conductivity, turbidity, dissolved oxygen, Co and negatively with Cu. *Thermocyclops consimilis* correlated positively with pH, TDS, conductivity, turbidity, Mn and Co and negatively with water temperature, Cu. *Thermocyclops neglectus* correlated positively with pH, dissolved oxygen, Zn and negatively with Cu. *Tropocyclops confinis* correlated positively with turbidity and Cr. *Microcylops varicans* correlated positively with pH and negatively with Cu. *Microcylops linjanticus* correlated positively with pH, turbidity, dissolved oxygen, Mn, Co and negatively with Cu. *Afrocyclops gibsoni* and *Shizopera nilotica* correlated negatively with pH. Copepodite stage correlated positively with TDS, conductivity, dissolved oxygen, Mn and Co and negatively with Cu. *Brachionus qudridentatus* correlated positively with Mn. *Brachionus zahniseri* and *Brachionus* sp. correlated positively with dissolved oxygen. *Brachionus urceolaris* correlated positively with dissolved oxygen and Cr. *Potamocypris variegata* correlated positively with Zn. *Candona* sp. correlated positively with Co **(Fig. 7)**.

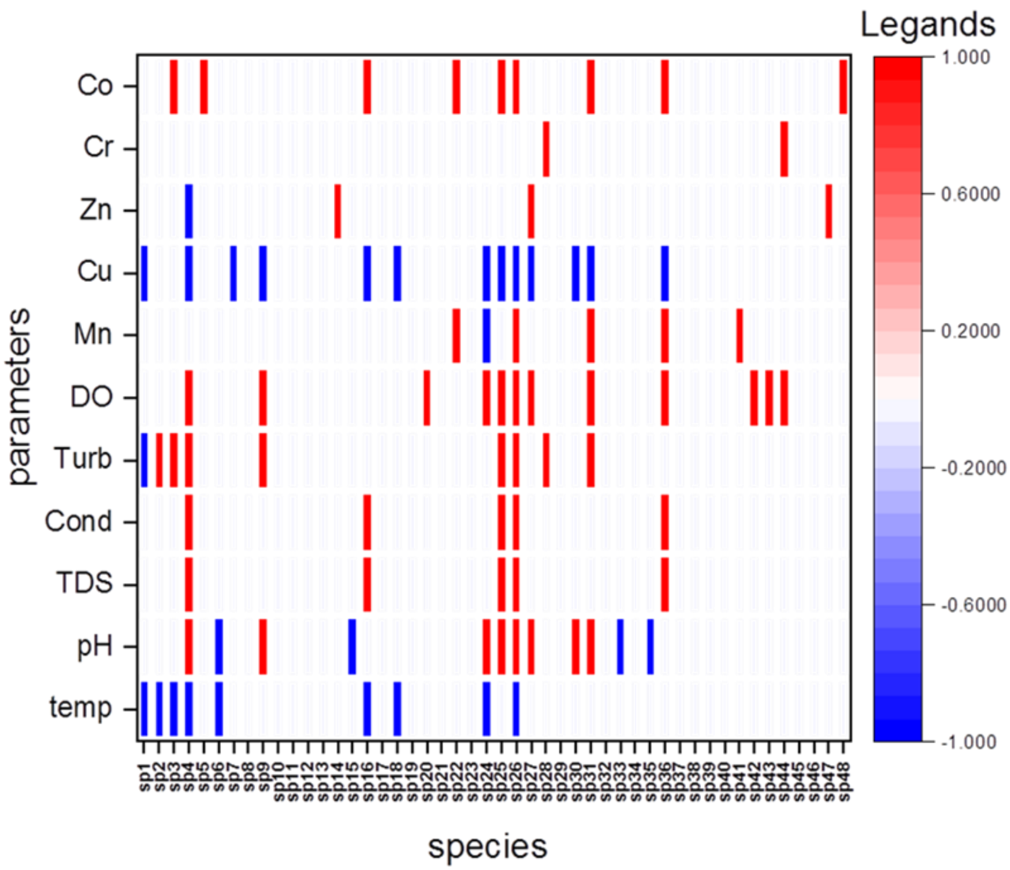

Fig. (7): Heatmap of the correlation coefficient of zooplankton species and physico-chemical parameters in all investigated sites.

Principal component analysis (PCA):

Principal component analysis was conducted to show the similarity between the investigated sites and physic-chemical parameters. PCA 1 axes 1 and 2 represent 65.58% of the total variation of physic-chemical parameters. Pc 1 representing the major axis of variation with a (50.48%) variance explained positive relation with TDS, conductivity, water temp., Cr, Co, Zn, Cu, Mn in sites 8, 9, 10, 11, 12, 13, 14 and 15. Pc 2 representing a (15.10%) variance explained positive relation with pH, DO and turbidity in sites 1, 2, 3, 4, 5, 6 and 7 **(Fig. 8)**.

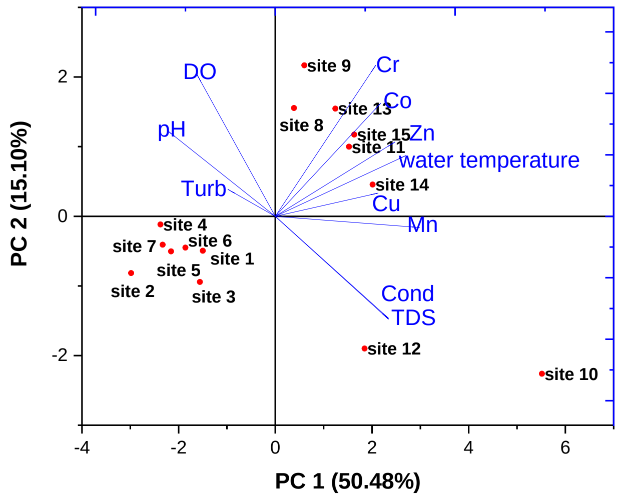

Fig. (8): PCA ordination graph showing the distribution of ecological factors during the period of study in all investigated sites.

DISCUSSION

Water quality monitoring is the initial step toward management and conservation of aquatic ecosystems. Chemical and physical parameters such as temperature, pH, salinity, dissolved oxygen, biological oxygen demand, chemical oxygen demand, nutrients, reactive phosphate, heavy metal pollution, and others are regarded the main limiting elements affecting aquatic species' survival and growth **(Ashour & Kamel 2017; Ashour *et al.*, 2020** and **Abbas *et al.*, 2020)**. Temperature influences not only the survival and distribution of aquatic organisms, but also their growth, activity, development, the activation of reproduction processes, and disease susceptibility **(Moustafa *et al.*, 2010)** The decrease or increase in water temperature is primarily influenced by climatic conditions, sampling times, and hours of sunlight, but it is also influenced by specific aquatic environmental factors such as turbidity, wind force, plant cover, and humidity **(Khalifa & Sabae, 2012)**. As expectantly, the present study showed the surface water temperature reached the highest value in summer and the lowest value was in winter, this agrees with **(Obuid-Allah *et al.*, 2020; Hegab *et al.*, 2021** and **Alprol *et al*., 2021)**.

The biological activities of microbial metabolites can be influenced by pH levels that can further influence utilization of succeeding metabolic products **(Alprol *et al.*, 2021)**. The present study showed a tendency of pH values towards alkaline side this agrees with **(Ali *et al.*, 2014)**. Conductivity and Total dissolved salts (TDS) recorded the highest values in winter and the lowest values were in summer. According to **Kobbia *et al.* (1995)** and **Fathi & Al-Kahtani (2009)**, highest value of electrical conductivity could be related to high pollution levels in water caused by high nutrient loads in water. **Saad *et al.* (2011)** estimated that the lowest readings of EC in River Nile during hot seasons can be linked to an increase in water level during flood periods and phytoplankton consumption of dissolved salts.

Dissolved oxygen (DO) is one of the most essential elements affecting the biota in the aquatic ecosystem (Abo-Taleb et al., 2020). This study recorded the lowest seasonal value of dissolved oxygen was in summer while, the highest value was in autumn. This result is in accordance with concerned with (Saravanakumar et al., 2021 and Alnagaawy et al., 2018) who explained that the amount of DO in water may be determined by its salinity and temperature, since cold liquid can contain more DO than warmish liquid. The maximum average turbidity value was recorded in the autumn, this agrees with **(Obuid-Allah *et al.*, 2020)**.

Heavy metals are one of the most serious contaminants in the aquatic ecosystem, attracting worldwide attention due to their toxicity, persistence, and bioaccumulation problems, which can have negative consequences for living organisms and the entire aquatic ecosystem **(Xu *et al.*, 2018)**. Heavy metals typically reach the aquatic environment through geological matrix erosion or through anthropogenic activities such as industrial effluents, home sewage, and mining wastes **(Bahnasawy *et al.*, 2011)**. Cu, Co and Zn are important trace metals for living organisms, but in higher concentrations, they become toxic **(Igiri *et al.*, 2018)**. The present study revealed that concentrations of measured heavy metals were relatively low. This may be attribute to the increase of the alkalinity of water which determines the concentration of these metals in unpolluted natural water.

Manganese (Mn) is a metal that is required for metabolic processes **(Boselli *et al.*, 2021)**. The dissolution of minerals from soil by rain, surface, and waste water filtering increases manganese in groundwater sources **(Ghosh *et al.*, 2008)**. Manganese can be found in the environment as well as in human activities such as mining and landfill leaching **(Rahmani *et al.*, 2004)**. In the present study Mn recorded the maximum value in spring and the minimum in autumn, this agrees with **(Al-Afify & Abdel-Satar, 2020)**. Zn^{2+} and Cu^{2+} are more biologically essential as natural constituents of aquatic ecosystems and generally, only become toxic at very high concentrations **(Bahnasawy *et al.*, 2011)**. In the present study, it was notified that Copper and Zinc recorded the highest value during hot season (summer) and the lowest value was in autumn. The highest concentration of zinc and copper in hot seasons may be attributed to heavy metals being released from sediments into the overlying water as a result of high temperature, this result agrees with **(Li *et al.*, 2013** and **Achary *et al.*, 2020)**. The decrease of both zinc and copper in autumn may be due to heavy metal precipitation from the water column into the sediments at somewhat higher pH levels.

In the aquatic environment, chromium is one of the biochemically active transition metals. The seasonal average values of chromium concentration were higher in autumn and winter than the concentration in spring and summer. This result is in accordance with **Masoud *et al.* (2005)** who explained that the chromium consumption by phytoplankton is higher in spring and summer than in the autumn and winter. **Abolude *et al.* (2009)** stated that Cr was significantly higher in the rainy season than the dry season.

The present study revealed a negative correlation between water temperature and dissolved oxygen, this result is in accordance with **Hussain *et al.* (2010)** and **Walczyńska & Sobczyk (2017)** who illustrated an opposite relationship between water temperature and dissolved oxygen. Moreover, water temperature was negatively correlated with TDS and conductivity. This coincided with **Obuid-Allah *et al*. (2020)**. Contrarily, **Poisson (1980)** explained that the temperature of water affects the conductivity of ions, when the water is heated, ions flow faster. As a result, when the water temperature rises, the apparent conductivity rises as well. Water temperature was positively correlated with heavy metals such as Mn, Cu, Zn, this agrees with **Li *et al.* (2013)** who stated that, the release rates of metals at higher temperature were increased more rapidly than at low temperature. Furthermore, there was a positive correlation between total dissolved solids and conductivity. This result agrees with **Ngabirano *et al*. (2016)** and **Rusydi (2018)** who stated that these two parameters are correlated and usually expressed by a simple equation: TDS = k EC (in 25 °C). Mn was negatively correlated with pH, this result agrees with **(Prasada & Danso-Amoako, 2014)**.

The maximum density of Cladocera was recorded in winter and the minimum in summer and this agrees with **Annalakshmi & Amsath (2012)** who illustrated that winter is the most suitable time for zooplankton species to grow and multiply. The result showed a negative correlation between Cladocera and water temperature, this is in accordance with **Sommer *et al.* (2012)** and **Strecker *et al.* (2014)**. They explained the negatively effect of warmer temperature on zooplankton in unproductive ecosystems; this could be owing to the influence of significant synergetic interactions between thermal stress and food limitation on Cladocera development and reproduction. Otherwise the positive correlation between Cladocera with total dissolved solids (TDS) and conductivity. This result agreed with **Obuid-Allah *et al.* (2020)** and disagreed with **Abdulwahab & Rabee (2015)** and **Hegab *et al.* (2021)** who indicated that Cladocera showed negative correlation with TDS and conductivity. The maximum density of Copepoda was noticed in autumn, while the lowest was noticed in summer. Copepoda showed positive correlation with TDS, this result agreed with **Tian *et al.* (2017)**. Moreover, Copepoda exhibited negative correlation with water temperature. Contrarily, **Tian *et al.* (2017)** observed a positive correlation with water temperature. The strong significant correlation between Copepoda and Cladocera might indicate a predation effect by copepods on adult cladocerans or their eggs. This result is in accordance with **Forneman *et al.* (2002)** and **Gaudy *et al.* (2004)**.

CONCLUSION

In conclusion, physico-chemical parameters are important factors influencing zooplankton composition, distribution and abundance. Cladocera and Copepoda were the most dominant populations during the period of study. Water temperature correlated negatively with Cladocera and Copepoda. Total dissolved solids, conductivity, turbidity and cobalt correlated positively with Cladocera and Copepoda. pH, turbidity, dissolved oxygen, total dissolved solids, conductivity, chromium and cobalt all reached their highest values during the rainy seasons. While, water temperature, manganese, copper and zinc reached their highest values during hot seasons.

REFERENCES

Abdulwahab, S. and **Rabee, A.M. (2015).** Ecological factors affecting the distribution of the zooplankton community in the Tigris River at Baghdad region, Iraq. Egyptian Journal of Aquatic Research, **41**(2): 187-196.

Abolude, D.S.; Davies, O.A. and **Chia, A.M. (2009).** Distribution and concentration of trace elements in Kubanni reservoir in Northern Nigeria. Research Journal of Environmental and Earth Sciences, **1**(2): 39-44.

Abo-Taleb, H.A.; Amr, Z.F.; Ashour, M.; Mabrouk, M.M.; Sallam, A.E. and **El-feky, M.M.M. (2020).** Isolation and cultivation of the freshwater amphipod, *Gammarus pulex* (Linnaeus, 1758), with an evaluation of its chemical and nutritional content. Egyptian Journal of Aquatic Biology and Fisheries, **24**(2): 69-82.

Achary, S.; Panigrahi, S.; Panigrahy, R.C.; Prabhu, R.K.; Sekar, J.K. and **Satpathy, K.K. (2020).** Concentration factor of metals in zooplankton and their seasonality in Kalpakkam coast, southwest Bay of Bengal. Environmental Chemistry and Ecotoxicology, **2**: 12-23.

Al-Afify, A.D. and **Abdel-Satar, A.M. (2020).** Risk assessment of heavy metal pollution in water, sediment and plants in the Nile River in the Cairo region, Egypt. Oceanological and Hydrobiological Studies, **49**(1): 1-12.

Ali, E.M.; Shabaan-Dessouki, S.A.; Soliman, A.A. and **El Shenaw, A.S. (2014).** Characterization of Chemical Water Quality in the Nile River, Egypt. Int. J. Pure App. Biosci., **2**(3): 35-53.

Alnagaawy, A.M.; Sherif, M.H.; Mohammed, G.A. and **Shehata, A.S. (2018).** Impact of industrial pollutants on some water quality parameters of Edku, Mariout lakes and the Nile River. Int J Environ., **7**(1): 1-15.

Alprol, A.E.; Heneash, A.M.; Soliman, A.M.; Ashour, M.; Alsanie, W.F.; Gaber, A. and **Mansour, A.T. (2021).** Assessment of water quality, eutrophication, and zooplankton community in Lake Burullus, Egypt. Diversity, **13**(6): 268-339.

Annalakshmi, G. and **Amsath, A. (2012).** Studies on the hydrobiology of river Cauvery and its tributaries Arasalar from Kumbakonam region (Tamilnadu, India) with reference to zooplankton. IJABPT, **3**: 325-336.

Ashour, M. and **Kamel, A. (2017).** Enhance growth and biochemical composition of *Nannochloropsis oceanica*, cultured under nutrient limitation, using commercial agricultural fertilizers. J. Mar. Sci. Res. Dev., **7**: 233.

Ashour, M.; Mabrouk, M.M.; Ayoub, H.F.; El-Feky, M.M.; Zaki, S.Z.; Hoseinifar, S.H. and **Goda, A. (2020).** Effect of dietary seaweed extract supplementation on growth, feed utilization, hematological indices, and non-specific immunity of Nile Tilapia, *Oreochromis niloticus* challenged with *Aeromonas hydrophila*. Journal of Applied Phycology, **32**(5): 3467-3479.

Bahnasawy, M.; Khidr, A.A. and **Dheina, N. (2011).** Assessment of heavy metal concentrations in water, plankton, and fish of Lake Manzala, Egypt. Turkish Journal of Zoology, **35**(2): 271-280.

Boselli, E.; Wu, Z.; Friedman, A.; Claus Henn, B. and **Papautsky, I. (2021).** Validation of Electrochemical Sensor for Determination of Manganese in Drinking Water. Environmental Science & Technology, **55**(11): 7501-7509.

Bucklin, A.; Lindeque, P.K.; Rodriguez-Ezpeleta, N.; Albaina, A. and **Lehtiniemi, M. (2016).** Metabarcoding of marine zooplankton: Prospects, progress and pitfalls. Journal of Plankton Research, **38**(3): 393–400.

Buttay, L.; Miranda, A.; Casas, G.; González-Quirós, R. and **Nogueira, E. (2015).** Long-term and seasonal zooplankton dynamics in the northwest Iberian shelf and its relationship with meteo-climatic and hydrographic variability. Journal of Plankton Research, **38**(1): 106–121.

Chiba, S.; Batten, S.; Martin, C.S.; Ivory, S.; Miloslavich, P. and **Weatherdon, L.V. (2018).** Zooplankton monitoring to contribute towards addressing global biodiversity conservation challenges. Journal of Plankton Research, **40**(5): 509-518.

Cruz-Rosado, L.; Contreras-Sánchez, W.M.; Hernández-Vidal, U.; Gómez-Gutiérrez, J.; de Contreras-García, M.J. and **McDonal-Vera, A. (2020).** Seasonal variability of near-surface zooplankton community structure in the southern gulf of Mexico. Latin American Journal of Aquatic Research, **48**(4): 649–661.

Eddy, T.D.; Bernhardt, J.R.; Blanchard, J.L.; Cheung, W.W.; Colléter, M.; Du Pontavice, H., ... & Watson, R.A. (2021). Energy flow through marine ecosystems: confronting transfer efficiency. Trends in Ecology & Evolution, **36**(1): 76-86.

Elfeky, F. A. and Sayed, N. K. (2014). Distribution and abundance of rotifers in the River Nile, Egypt. World Journal of Fish and Marine Sciences, **6**(6): 557-563.

Everaert, G.; Deschutter, Y.; De Troch, M.; Janssen, C.R. and **De Schamphelaere, K. (2018).** Multimodel inference to quantify the relative importance of abiotic factors in the population dynamics of marine zooplankton. Journal of Marine Systems, **181**: 91–98.

Färber Lorda, J.; Athié, G.; Camacho Ibar, V.; Daessle, L. W. and Molina, O. (2019). The relationship between zooplankton distribution and hydrography in oceanic waters of the Southern Gulf of Mexico. Journal of Marine Systems, **192**: 28–41.

Fathi, A.A. and **Al-Kahtani, M.A. (2009).** Water Quality and Planktonic Communities in Al-Khadoud Spring, Al-Hassa, Saudi Arabia. Ame. J. of Envi. Sci., **5**(3): 434-443.

Fichot, C.G.; Downing, B.D.; Bergamaschi, B.A.; Windham-Myers, L.; Marvin-DiPasquale, M.; Thompson, D.R. and **Gierach, M.M. (2016).** High-resolution remote sensing of water quality in the San Francisco Bay–Delta Estuary. Environmental Science & Technology, **50**(2): 573-583.

Froneman, P.W.; Pakhomov, E.A.; Gurney, L.J. and **Hunt, B.P.V. (2002).** Predation impact of carnivorous macrozooplankton in the vicinity of Prince Edward Island archiplago (Southern Ocean) in austral autumn 1998. Deep-Sea Res. II., **49**: 3243-3254.

García-Comas, C.; Chang, C.Y.; Ye, L.; Sastri, A.R.; Lee,Y.C.; Gong, G.C. and **Hsieh, C.H. (2014).** Mesozooplankton size structure in response to environmental conditions in the East China Sea: How much does size spectra theory fit empirical data of a dynamic coastal area? Progress in Oceanography, **121**: 141-157.

Gaudy, R.; Borgne, R.I.; Landry, M.R. and **Champalbert, G. (2004).** Biomass، feeding and metabolism of mesozooplankton in the equatorial Pacific along180. Deep-Sea Research II, **51**: 629-645.

Gazonato Neto, A.J.; da Silva, L.C.; Saggio, A.A. and **Rocha, O. (2014).** Zooplankton communities as eutrophication bioindicators in tropical reservoirs. Biota Neotropica, **14**(4): 1–12.

Ghosh, D.; Solanki, H. and **Purkait, M.K. (2008).** Removal of Fe (II) from tap water by electrocoagulation technique. Journal of hazardous materials, **155**(1-2): 135-143.

Hegab, M.H.; Khalifa, N. and **Aly, W. (2021).** Zooplankton communities in Lake Nasser, Egypt, under the current flood regime, before the construction of Grand Ethiopian Renaissance Dam (GERD). African Journal of Aquatic Science, **46**(3): 329-339.

Hussain, N.A.; Lazem, L.F.; Resan, A.K.; Taher, M.A. and **Sabbar, A.A. (2010).** Long term monitoring of Water characteristic of three restored Southern marshes during the years 2005, 2006, 2007 and 2008. Basrah J. Sci., **28**(2): 216-227.

Igiri, B.E.; Okoduwa, S.I.; Idoko, G.O.; Akabuogu, E.P.; Adeyi, A.O. and **Ejiogu, I.K. (2018).** Toxicity and bioremediation of heavy metals contaminated ecosystem from tannery wastewater: A review. Journal of toxicology, 2018:1-16.

Johnston, E.L.; Mayer-Pinto, M. and **Crowe, T.P. (2015).** Chemical contaminant effects on marine ecosystem functioning. Journal of Applied Ecology, **52**(1): 140–149.

Khalifa, N. and **Sabae, S.Z. (2012).**Investigation on Mutual relations between bacteria and zooplankton in Damietta branch, River Nile, Egypt. Journal of Applied Sciences Research, **8**(5): 2679-2688.

Kobbia, I.M.; Metwali, R.M. and **El-Adel, H.M. (1995).** Influence of water effluents of soap and oil factory at Benha on Nile phytoplankton communities. Egy. J. of Bot., **35**: 45-57.

Li, H.; Shi, A.; Li, M. and **Zhang, X. (2013).** Effect of pH, temperature, dissolved oxygen, and flow rate of overlying water on heavy metals release from storm sewer sediments. Journal of Chemistry, Vol. (2013):1-11.

Magouz, F.I.; Essa, M.A.; Matter, M.; Mansour, A.T.; Gaber, A. and **Ashour, M. (2021).** Effect of different salinity levels on Copepoda (*Oithona nana*) population dynamics, production, and composition. Diversity, **30**: 190.

Masoud, M.S.; Elewa, A.A.; Ali, A.E. and **Mohamed, E.A. (2005).** Distribution of some metal concentrations in water and sediments of Lake Edku, Egypt. Bulletin of the Chemists and Technologists of Macedonia, **24**(1): 21-34.

Moustafa, M.M.; Ali, M.H.H.; Abdel-Satar, A.M.; Mohamed, T.Y. and **Madbouly, S.M. (2010).** Water quality assessment of Rosetta and Damietta branchs, River Nile, Egypt. African J. Biol. Sci., **6**(2):127-142.

Ngabirano, H.; Byamugisha, D. and **Ntambi, E. (2016).** Effects of seasonal variations in physical parameters on quality of gravity flow water in Kyanamira Sub-County, Kabale District, Uganda. Journal of Water Resource and Protection, **8**: 1297-1309

Obuid-Allah, A.H. (2001). A review article on: Diversity of Cladocera and Copepoda in the freshwater bodies of Egypt and factors affecting it. Zool. Depart. Fac. Sci., Assiut Univ.

Obuid-Allah, A.H.; Moustafa, A.S.; Hussien, EL. H.M.; Gaber, A.M. and **Mohammad, W.A. (2020).** Distribution of Zooplankton Community in the River Nile at Esna Barrages, Egypt in relation to some ecological factors. Egyp. J. Aqu. Biol. & Fish., **24**(1): 131–143.

Parmar, T.K.; Rawtani, D. and **Agrawal, Y.K. (2016).** Bioindicators: The natural indicator of environmental pollution. Frontiers in Life Science, **9**(2): 110–118.

Peng, L.; Xue, X. G.; Liao, J.; Zhao, J.; Tang, Q.H. and **Lin, Q.Q. (2021).** Potential impact of population increases of non-native tilapia on fish catch and plankton structure: a case study of Tangxi Reservoir in southern China. Aquat. Invasions, **16**: 329–348.

Poisson, A. (1980). Conductivity/salinity/temperature relationship of diluted and concentrated standard seawater. IEEE Journal of Oceanic Engineering, **5**(1): 41-50.

Prasad, T.D. and **Danso-Amoako, E. (2014).** Influence of chemical and biological parameters on iron and manganese accumulation in water distribution networks. Proceeding of Engineering, **70**: 1353-1361.

Putshaka, J.D.; Akyengo, O.; Yakubu, A. and **Adejube, A.A. H. (2015).** Bioaccumulation of heavy metals in Fish (*Tilapia zilli*) and Bullfrog (*Pyxicephalus edulis*) from River Challawa Kano State Nigeria. International Journal of Ecological Science and Environmental Engineering, **2**(4): 30–34.

Rahmani, A.R.; Mahvi, A.H.; Mesdaghinia, A.R. and **Nasseri, S. (2004).** Investigation of ammonia removal from polluted waters by Clinoptilolite zeolite. International Journal of Environmental Science & Technology, **1**(2): 125-133.

Ranasinghe, P.; Weerasinghe, S. and **Kaumal, M.N. (2016).** Determination of heavy metals in tilapia using various digestion methods. Int J Sci Res Inno Technol., **3**: 38-48.

Rusydi, A.F. (2018). Correlation between conductivity and total dissolved solid in various type of water: A review. In IOP conference series: earth and environmental science, **118**(1): 12-19.

Saad, S.M.M.; El-Deeb, A.E.; Tayel, S.I. and **Ahmed N.A.M. (2011).** Haematological and histopathological studies on *Claris gariepinus* in relation to water quality along Rossetta branch, River Nile, Egypt. Egy. J. Exp. Biol. (Zool.), **7**(2): 223-233.

Saravanakumar, M.; Murugesan, P.; Damotharan, P. and **Punniyamoorthy, R. (2021).** Seasonal Composition and Diversity of Zooplankton in Pichavaram Mangrove Forest, Southeast Coast of India. International Journal for Modern Trends in Science and Technology, **7**(09): 60-70.

Severini, M.D.F.; Botte, S.E.; Hoffmeyer, M.S. and **Marcovecchio, J.E. (2009).** Spatial and temporal distribution of cadmium and copper in water and zooplankton in the Bahía Blanca estuary, Argentina. Estuarine, Coastal and Shelf Science, **85**(1): 57-66.

Sharawy, Z.Z. (2020). Novel comprehensive molecular and ecological study introducing coastal mud shrimp (*Solenocera crassicornis*) recorded at the Gulf of suez, Egypt. Journal of Marine Science and Engineering, **9**(1): 1-13

Shropshire, T.A.; Morey, S.L.; Chassignet, E.P.; Bozec, A.; Coles, V.J.; Landry, M.R.; Swalethorp, R.; Zapfe, G. and **Stukel, M.R. (2020).** Quantifying spatiotemporal variability in zooplankton dynamics in the Gulf of Mexico with a physical-biogeochemical model. Biogeosciences, **17**(13): 3385–3407.

Sommer, U.; Adrian, R.; Bauer, B. and **Winder, M. (2012).** The response of temperate aquatic ecosystems to global warming: novel insights from a multidisciplinary project. Marine Biology, **159**(11): 2367-2377.

Strecker, A.L.; Cobb T.P. and **Vine Brooke, R.D. (2014).** Effect of experimental greenhouse warming on Phytoplankton and Zooplankton in fishes alpine ponds. Limnol. Oceangr., **49**: 1182-1190.

Tian, W.; Zhang, H.; Zhang, J.; Zhao, L.; Miao, M. and **Huang, H. (2017).** Responses of zooplankton community to environmental factors and phytoplankton biomass in Lake Nansihu, China. Pak. J. Zool, **49**(2): 493-504.

Trevizani, T.H.; Petti, M.A.V.; Ribeiro, A.P.; Corbisier, T.N. and **Figueira, R.C.L. (2018).** Heavy metal concentrations in the benthic trophic web of martel inlet, admiralty Bay (King George Island, Antarctica). Marine pollution bulletin, **130**: 198-205.

Walczyńska, A. and **Sobczyk, Ł. (2017).** The underestimated role of temperature–oxygen relationship in large-scale studies on size-to-temperature response. Ecology and evolution, **7**(18): 7434-7441.

Whitman, R.L.; Nevers, M.B.; Goodrich, M.L.; Murphy, P.C. and **Davis, B.M. (2004).** Characterization of Lake Michigan coastal lakes using zooplankton assemblages. Ecological Indicators, **4**(4): 277-286.

Wilson, M.S. and **Yeatman, H.C. (1959).** Free living copepod. In: ward, H.B. and Whpple, C.C. Freshwater Biology, 2nd ed. 1959 (ed. W.T. Edondson), pp: 735-868.

Xu, J.; Chen, Y.; Zheng, L.; Liu, B.; Liu, J. and **Wang, X. (2018).** Assessment of heavy metal pollution in the sediment of the main tributaries of Dongting Lake, China. Water, **10**(8): 1060.

Yakubu, F.; Sikoki, F.D.; Abowei, J.F.N. and **Hart, S.A. (2000).** A comparative study of phytoplankton communities of some rivers creeks and borrow pits in the Niger Delta Area. J. Appl. Sci. Environ. Manage, **4**(2): 41-46.

Yanuhar, U.; Caesar, N.R.; Setiawan, F.; Sumsanto, M.; Musa, M. and **Wuragil, D.K. (2019).** The aquatic environmental quality of koi fish (*Cyprinus carpio*) pond infected by *Myxobolus* sp. based on the biological status of the phytoplankton. In Journal of Physics: Conference Series, **1146** (1): 12-17.