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Biodiversity of Cladocera and Water Quality for Euphrates River in the Eastern of Al- Qadisiyah Governorate, Iraq

Idrees A. A. Al-Bahathy[1], Zahraa Zahraw Al-Janabi[2], Rafid Ahmed Taha[3], Manal M. Adel[4]

[1]College of Engineering, Al-Qasim Green University, Babil, Iraq
[2]Environment Research Center / University of Technology, Iraq
[3]Directorate of Education in Basra, Ministry of Education, Iraq
[4]Pests & Plant Protection Dep. National Research Center,Cairo, Egypt

[*]**Corresponding Author: mhassanein11@hotmail.com**

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ABSTRACT

This study was conducted to evaluate the effect of urban wastewater on the characteristics of the Cladocera community in the Euphrates River. Three sampling sites were selected along the Euphrates River near Al-Shinafiyah town on the eastern side of Al-Qadisiyah Governorate, Iraq. The first site was upstream of Al-Shinafiyah town as a control site, and the second site was inside the town, whereas the third site was downstream of the town. Twenty-four taxa of Cladocera were investigated in this study. The higher mean density and richness index in the Euphrates River was in site (1), with values of 1237.5Ind./ m3 and 0.89, respectively. While, the second site recorded The lower mean density and richness index with 587.3Ind./ m3 and 0.70, respectively. The similarity index was at a higher value between sites 1 and 2 reaching 58.3%, while the lowest value was between sites 2 and 3 reaching 45.8%. WQI_{min} (minimum Water Quality index) recorded a drop in the water quality by 63.3% compared with other sites, especially in summer. This decline can be attributed to the combined effect of the city sewage and the channel with industrial effluents, particularly site 2 inside Al-Shinafiyah City, which is associated with a low density of Cladocera.

INTRODUCTION

Freshwater water bodies are critical to aquatic biodiversity and are highly affected by environmental stress **(Polazzo *et al.*, 2022)**. The habitats of freshwater have a critical role in maintaining biodiversity globally **(Piczak *et al.*, 2023)**. The zooplankton communities (Rotifera, Cladocera, Copepoda) occupy the median position in the riverine ecosystem and play a crucial role in the food chain. These microorganisms are not only grazy on producers (phytoplankton) but also serve as a prey for higher trophic levels (Insect larvae, fish) **(Taranu *et al.*, 2023)**. Zooplankton groups such as Cladocera are impacted by abiotic and biotic factors (e.g. light, hydrology, water physicochemical characteristics, parasitism, competition, and predation). Spatial and temporal variation occurs to these factors in aquatic life **(Jones *et al*., 2015)**. Thus, Cladocera communities are impacted by these variations. Zooplankton is increasingly used as bioindicators in aquatic life **(Abdul *et al*., 2016)**. Therefore, many local studies addressed zooplankton groups (Rotifera, Cladocera, Copepoda) as bioindicators of changes in the aquatic environment. Notable studies include those of **Al-Bahathy and Nashaat (2021)**, **Nashaat *et al*. (2021)**, **Majeed *et al*. (2022)**, **Nashaat and Al-Bahathy (2022)** and **Al-bahathy *et al*. (2023)**.

For a better understanding of the water state regardless of the scientific details and rigid interpretation of all physical, chemical, and biological aspects of water, many researchers choose to use water quality indices to facilitate these issues, where WQI can easily allow summarizing the huge data provided from the monitoring programme into a simple number to rang which would be more understandable for decision-maker and public **(Al-janabi *et al*., 2021)**.

Principal component analysis (PCA) and correlation coefficient are two multivariate statistical techniques that can be used to reduce the complexity (number of variables) of large water quality data sets without sacrificing the raw data **(Chen *et al*., 2018)**. In addition to providing a quick fix for pollution issues for straightforward and affordable water quality evaluation, the application of these methodologies aids in the interpretation of complicated information. This helps to better understand the water quality condition and identify prospective sources or factors that influence water sources **(Vadde *et al*., 2018)**.

PCA is a frequently used analytical technique in science for reducing the dimensionality of a data collection, while maintaining the characteristics of the variables that most influence variance **(Elhaik, 2022)**. The defining of PCs also facilitates in the extraction of associated variables, which offer more details than single variables and help comprehend the mechanisms that influence water chemistry. In this work, the eigenvalues and relevant eigenvectors were extracted using the correlation matrix, resulting in the principal axes (PAs) and principal components (PCs) **(Teixeira *et al*., 2021)**.

The present study aimed to evaluate the effect of urban wastewater on the Cladocera community in the Euphrates River, Eastern of Al- Qadisiyah Governorate. This involved investigating these impacts on Cladocera density, using biological indices, and assessing the water quality in this area.

MATERIALS AND METHODS

1. Study sites

According to Fig. (1), three sites were selected on the Euphrates River for this study**,** eastern of Al- Qadisiyah Governorate. The first site of the Euphrates River lies upstream Al -Shinafiyah town as a reference site at 31.59731 "N, 44.619 "E. The second site is inside Al-Shinafiyah town at 31.58056"N, 44.64609"E, approximately 4km downstream the site 1. While, the third site is located about 10km downstream site 1 at 31.55357"N, 44.64383"E.

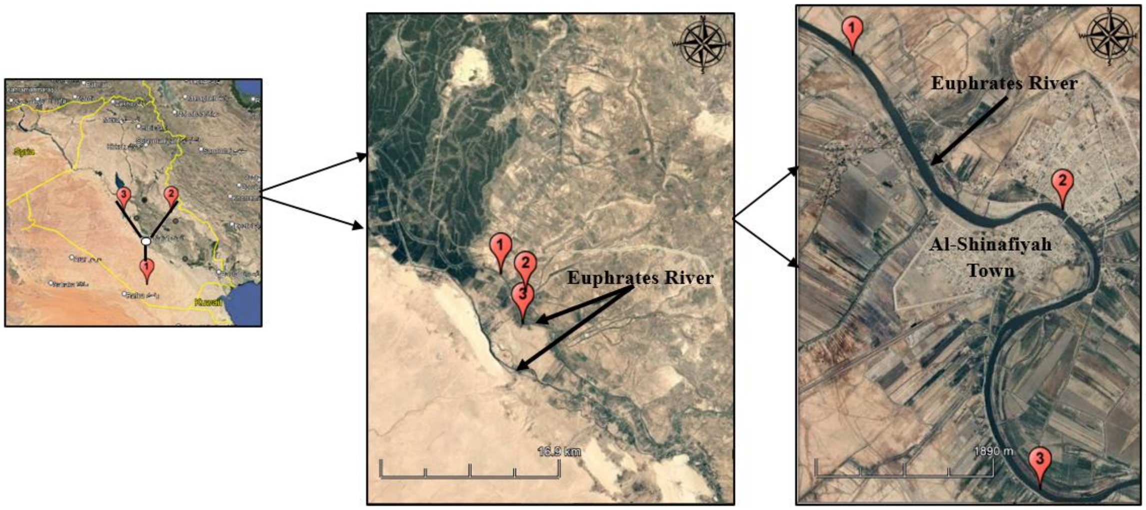

Fig. 1. Study sites of the Euphrates River, eastern of Al-Qadisiyah Governorate, Iraq

2. Sampling method

Samples were collected seasonally from three sites. Table (1) shows that some parameters such as TDS, pH, water temperature, and turbidity were directly measured in the field. Dissolved oxygen (DO) and BOD_5 were examined in the laboratory by the Winkler method, according to the standard methods outlined by **APHA (2017)**. Electrical conductivity was calculated according to the method of **Anna (2018)**. The results were compared with the standards of the Canadian Water Quality Guidelines for the Protection of Aquatic Life **(CCME, 2007)**.

Cladocera sampling method involved filtering 40L of water using a mesh with pores of 55µm. The samples were then preserved in a formalin solution of 4%. The Cladocerans taxa were identified using a compound microscope, following the guidelines of **Tranter *et al*. (1981)**.

Table 1. Physical-chemical parameters in the study area

Site	S1		S2		S3		Standard
Parameter	Min-Max	Average	Min-Max	Average	Min-Max	Average	
pH	7-7.6	7.25	7.1-7.8	7.37	7-7.8	7.31	**7.5**
Water temp.	14.9-29.6	21.775	14.8-29.2	21.775	15-30.5	22.5	**15**
Turbidity	14.01-32.6	26.928	25.4-45.7	35.8125	6.02-18.5	12.442	**45**
BOD_5	2-7	3.77	1.3-6	4.25	0.5-6	2.625	**4**
DO	9-11.5	9.525	5-11.3	8.225	7.5-12	9.875	**5.5**
TDS	340-630	501	340-630	502	360-640	510	**1000**
Conductivity	531.2- 984.3	782.8	531.2-984.3	7843	562.5-1000	796.8	**-**

3. Species richness index

The species richness index (D) was measured based on the equitation found in **Margalef (1968)**. The species' number was counted as one per cubic meter, as follows:

$$D = \frac{S - 1}{\ln N}$$

D= Relative abundance.
S= The number of observed species.

4. Relative abundance (Ra)

The relative abundance was calculated using the formula of Odum (1970), as follows::
-Rare (R) are Cladocera occurring in less than 10%.
-Less abundant species (La) Cladocera occurring 10- 40% of the sample.
-Abundant species (A) occurring in 40- 70% of samples.
- Dominant species (D) occurring more than 70%.

$$\textbf{Relative Abundance} = \left(\frac{\boldsymbol{n}}{\sum \boldsymbol{N}}\right) \times \mathbf{100}$$

n= total number of individual.
N= Total number of species.

5. Similarity index (Jaccard index)

Similarity index was measured to resemble between two samples (A and B); the index gives a scale of similarity from 0 to 100, where 0 indicates that there is no similarity between the two samples, and 100 indicates perfect similarity; the formula implemetented by **Vijay and Rajesh (2020)** was used, as follows:

$$\boldsymbol{J = a/\,(a + b + c)}$$

a= the number of spices in sample A and sample B.
b= the number of spices in sample B but not found in sample A.
c= the number of spices in sample A but not found in sample B.

6-Minimum water Quality index ($\mathbf{WQI_{min}}$)

This water quality index, named the minimal index (WQI_{min}), can be calculated from only three parameters, where C_{turb} is the value due to turbidity after normalization, and C_{DO} is the value due to dissolved oxygen after normalization; C_{cond} is the value due to either conductivity or dissolved solids (TDS) after normalization (Table 2). This index suggested by **Pesce *et al.* (2000)** is based on the general characteristics of water, and was calculated using the following equation:

$$WQI_{min} = \frac{C_{Do} + C_{cond} + C_{turb}}{3}$$

Where, C represents the normalization factor used to convert the parameter value into a common scale (ranging from 0 to 100 with an interval of 100), as shown in Table (2). To show the overall water quality state, WQI_{min} values were graded into five classes, as shown in Table (3).

Table 2. Reference values (normalization factors) (**Pesce & Wunderlin 2000)**

Parameter	**Normalization factor (Ci)**										
	100	90	850	70	60	50	40	30	20	10	0
	Analytical values										
Turbidity	<5	<10	<15	<20	<25	<30	<40	<60	<80	≤100	>100
Conductivity	<750	<1000	<1250	<1500	<2000	<2500	<3000	<5000	<8000	≤12000	>12000
DO	≥7.5	>7	>6.5	>6	>5	>4	>3.5	>3	>2	>1	<1

Table 3. WQI_{min} Ranking **(Kim *et al.*, 2020)**

WQI_{min}					
Classes	Excellent	Good	Medium	Bad	Very bad
Scores	91–100	71–90	51–70	26–50	0–25

RESULTS

1. Density and richness of Cladocera

Fig. (2) and Table (4) show the density values of Cladocera which ranged from 375ind./ m3 in winter to 4000ind./ m3 in spring at site 1. On the other hand, the values of site 2 were lower. Consequently, they ranged from 510 to 1050ind./ m3. The lowest value was in autumn, whereas the highest value was in spring. The Cladocera density at site 3 increased in relation to site 2. The lower value was recorded in autumn, while the higher value was recorded in spring.

While, Fig.(3) and Table (4) display values of species richness index for Cladocerans during the study period. Values ranged from zero to 1.473 at site 1, with low values observed in winter and autumn, while the high values were recorded in spring.

On the other hand, the recorded values declined at site 2 and ranged from 0.8 to 1.5, the results indicated that the lower value was in winter, whereas the higher value was in spring, then it was slightly raised at site 3 compared to site 2 which ranged from 0.3 to 1.5.

Table (5) exhibits that twenty-four of Cladocera taxa revealed in this study. The taxa numbers of Cladocera decreased from 18 species at site 1 to 17 for sites 2 and 3.

Temporal variations of density and richness of Cladoceran showed that a peak was noticed in spring season. This could be owing to the suitable temperature for development and egg hatching, as mentioned by **Wu *et al.* (2014)**. The higher phytoplankton growth observed was in spring that considered food for Crustacean grazers, in contrast, the lower densities were recorded in summer.

Regarding spatial, site 1 had the highest values for Cladoceran density and richness. This could be traced back to the suitable conditions for the river as low current velocity, and intense macrophytes, as mentioned by **Czerniawski and Sługocki (2017)**, or maybe the good water quality at this site compared to other sites according to Table (1). In contrast, Cladocerans densities and richness at site 2 were lower than in other sites which may be related to the lack of necessary macrophytes to Cladoceran which serve as food and microhabitats, in addition to the near city location at site 2 which contributes to pollution stress **(Czerniawski & Sługocki, 2017)**.

Consistent with this study, both temporal and spatial values of Cladoceran density and richness align with findings with other studies, such as those by **Merhoon *et al.* (2017)** and **Majeed *et al.* (2023)**. Furthermore, global studies, such as those by **Portinho *et al.* (2016**) and **Lopes *et al.* (2017)** revealed that the lower values for indices were in the study sites exposed to urban wastewater.

Conversely, the findings disagree with the study of **Kushwaha and Agrahari (2014)**, who studied Rapti River (India) and recorded the highest value of density and richness during the summer season.

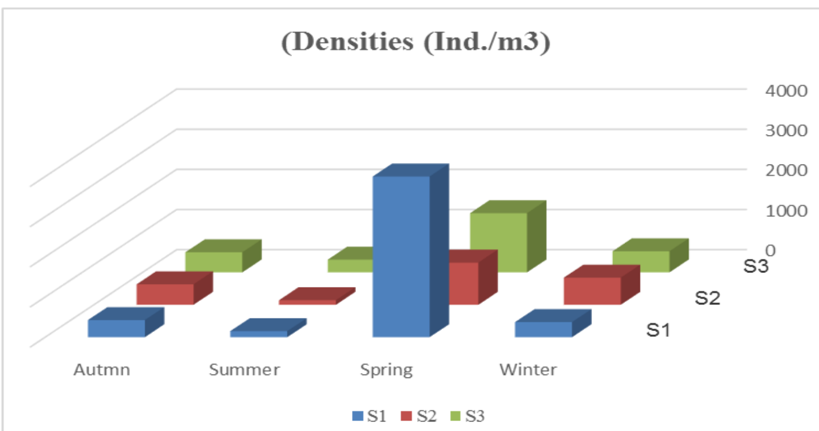

Fig. 2. Cladocera densities (ind/ m3) at study sites of the Euphrates River, eastern of Al-Qadisiyah Governorate during 2022

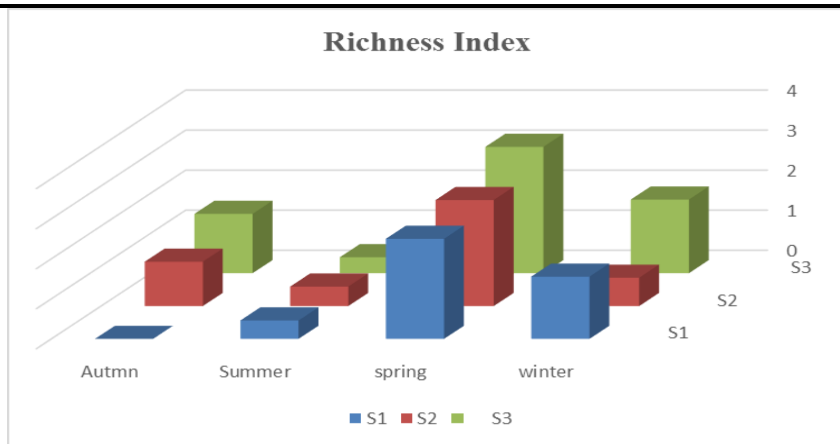

Fig. 3. Cladocera richness index at study sites of the Euphrates River, eastern of Al-Qadisiyah Governorate during 2022

Table 4. Mean values of Cladocera density and richness in study area

Indices	S1	S2	S3
Taxa numbers	18	17	17
Density(Ind./m3)	1237.5	587.3	704.15
Richness (D)	0.89	0.70	0.77

Fig. (4) and Table (5) detect the relative abundance index of most abundance Cladoceran taxa at all sites of the study area which was about 65% of total species dominated by *Chydorus piger, Bosmina longirostris, Alona rectangular* and *Macrothrix montana* and 35% for other species.

The ability of the faster adaptation dominant Cladoceran taxa to the fluctuation of environmental conditions made it outcompete other species in the study area, as mentioned by **Jiang *et al*. (2014)** .

These local studies, such as those of **Abed and Nashaat (2018)** and **Majeed *et al.* (2023**), highlighted the highest abundance to the Cladoceran species under study. Additionally, global studies by **Barbiero *et al.* (2009**), **Kolarova and Napiórkowski (2022**) and **Shchapov and Ozersky (2023)** support these findings.

Table 5. Relative abundance of Cladocera taxa identified in the Euphrates River, eastern of Al-Qadisiyah Governorate during 2022

No.	Cladocera	S1	S2	S3
1	***Alona costata* Sars, 1862**	**R**	**-**	**R**
2	***A. gutata* Sars 1862**	**R**	**R**	**R**
3	***A.karau* (Brooks, 1959)**	**R**	**-**	**-**
4	***A.rectangula* Sars 1862**	**R**	**R**	**R**
5	***Alonella detifera* Sars 1862**	**-**	**-**	**R**
6	***Alonella diaphana* Sars 1862**	**-**	**-**	**R**
7	***Alonopsis elongate* Sars, 1861**	**LA**	**R**	**-**
8	***Bosmina coregoni* Baird, 1857**	**R**	**R**	**-**
9	***Bosmina longirostris*(Muller, 1785)**	**R**	**LA**	**LA**
10	***Comptocercus rectiostris* Schqdler, 1862**	**R**	**-**	**R**
11	***Ceriodaphienia rigaudi* Richard, 1894**	**R**	**LA**	**LA**
12	***Ceriodaphnia reticulate* (Jurine,1820)**	**-**	**R**	**R**
13	***Chydorus ovalis* Kurz, 1874**	**R**	**R**	**R**
14	***Chydorus piger* Sars, 1862**	**LA**	**R**	**LA**
15	***Chydorus spherecus* (Muller, 1785)**	**R**	**R**	**R**
16	***Daphnia galeata* Sars, 1864**	**-**	**-**	**R**
17	***Diaphanosoma brachyurum* (Liévin, 1848)**	**R**	**R**	**LA**
18	***Ilyocryptus sordidus* Sars, 1861**	**R**	**R**	**R**
19	***Macrothrix montana* Birge, 1904**	**R**	**R**	**-**
20	***Moina affinis* Leydig, 1860**	**R**	**-**	**R**
21	***Pleuroxus phastatus***	**-**	**R**	**-**
22	***Scapholebrus kigni***	**R**	**R**	**-**
23	***Simocephalus sevrulatus* (Koch, 1841)**	**R**	**R**	**-**
24	***S.vetulus* Schqdler, 1858**	**-**	**R**	**R**

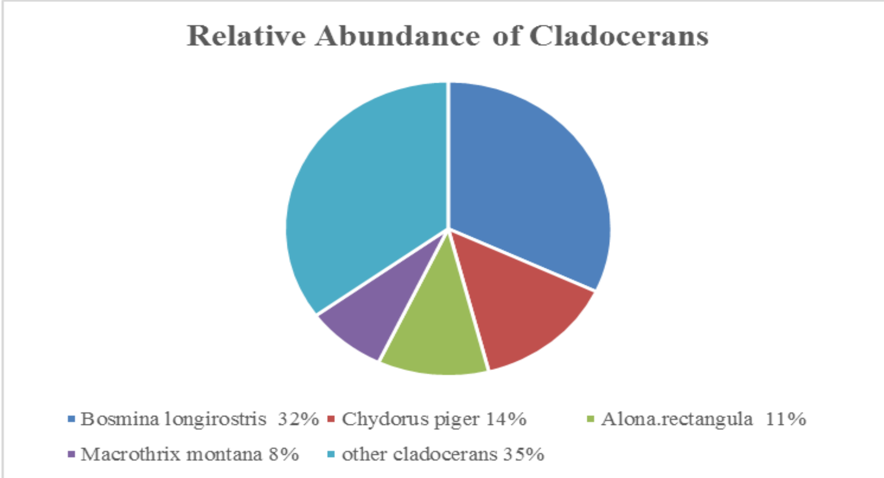

Fig. (4). Abundance of Cladocera taxa identified in the Euphrates River in the eastern of Al-Qadisiyah Governorate during 2022

2. Similarity index (Jaccard Index)

Table (6) and Fig. (5) show that the highest value was between sites 1 and 2 (58.33%). This could be attributed to proximity since it has similar hydrological characteristics. The lowest value of the similarity index for Cladocera samples was between sites 2 and 3, as well as between sites 1 and 3 (45.8%).

The results coincide with those of **Ostojić *et al.* (2015)** who revealed that similarity values in the Cladocera community between sites in the Sava River were changed with water quality parameters.

Table 6. Jaccrad coefficient matrix between sites for similarity of Cladocera count

Similarity index			
Site	**S1**	**S2**	**S3**
S1	-	58.33	50
S2	-	-	45.83
S3	-	-	-

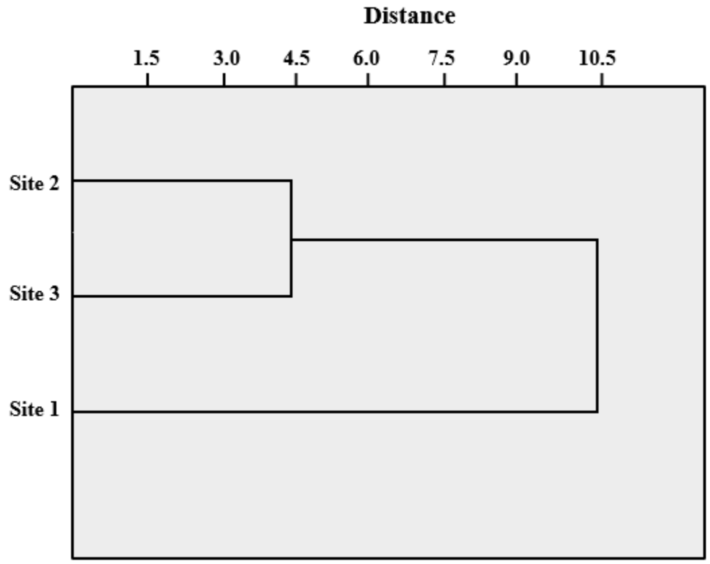

Fig. 5. Dendrogram of Jaccard Index percentages for similarity of Cladocera

3. WQI_{min}

The WQI_{min} parameters were chosen since they serve as key indicators for other water quality parameters. Dissolved oxygen is essential for aquatic life and can serve as a powerful indicator of the state of the aquatic ecosystem as a whole; it is directly correlated to the presence of organic pollution in water **(Bulbul & Abha, 2022)**. TDS are an indication of any salts, mineral acids, or other contaminants that have been dropped into a river, and high TDS concentrations can influence the taste and palatability of water **(Moran, 2018)**, while turbidity is directly related to suspended material and also with biological contamination. Additionally, turbidity can affect light penetration and subsequently affects the growth of aquatic life **(Howladar, 2017)**. Furthermore, it is simple to examine all three of these factors (even online monitoring is readily accessible). WQI_{min} values are shown in Fig. 6, where the water quality of this river is good which can promote the growth of the aquatic life. WQI_{min} predicts a drop in water quality in site 2 compared to other sites, especially in summer. WO_{min} anticipates a fall to 63.3% in the water quality which can be due to the combined impact of the channel with industrial effluents and city sewage, given that site 2 is inside Al-Shinafiyah City **(Dunia, 2015)**. The low density of Cladocera communities at this site aligns with the observed decrease in the water quality, as the presence of biota is affected by such changes.

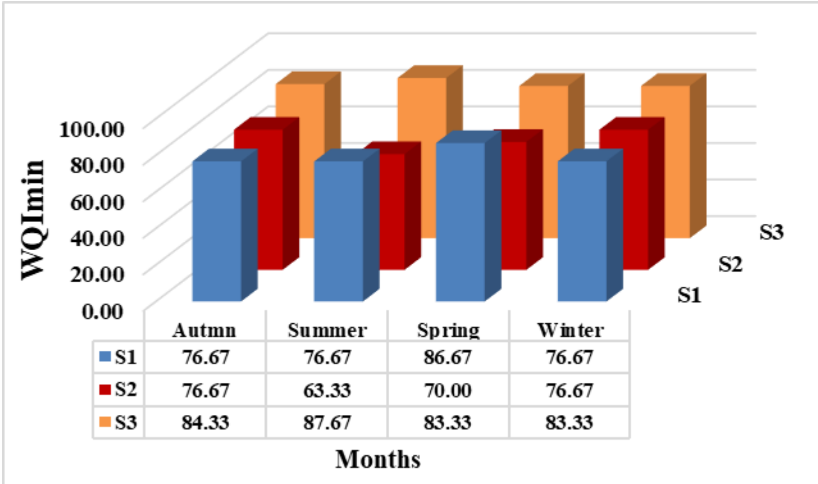

Fig. (6). WQI_{min} for the current study

5. Pearson's correlation

This study could get a complete sense of the data set and evaluate the relationship between the environmental parameters. It can identify the parameters with greater significance (0.05 significance level). The correlation coefficient (r) ranges from +1 to −1. When r is close to +1, the association is considered strongly positively correlated. The relationship is demarcated as anti-correlated when the r-value is close to –1 (negative correlation). If the value of r tends to be zero, the reading is considered less correlated and uncorrelated **(Al-janabi *et al.*, 2023)**. Only those variables in the data set with correlations of r = 0.6 are significant according to the Pearson coefficient **(Teixeira *et al.*, 2021)**. Fig. (7) provides information on the correlation between the water parameters taken into account in the present study. The blue box shows a positive relationship; the red box shows a negative correlation, and the darker blue or darker red shows a strong correlation. To determine which of them are related to one another and how strongly association exists, correlation maps are being used **(Selim *et al.*, 2023)**. Only a few parameters exhibited statistically significant correlations. Within the studied parameters, there is a positive and significant correlation between dissolved oxygen and pH (r = +0996). However, there is a strong negative correlation between dissolved oxygen and water temperature where hot water cannot hold dissolved oxygen in comparison to cold water, and increasing temperatures reduce DO solubility in water, generally assessing water quality can be more effectively guided by dissolved oxygen and water temperature **(Tan *et al.* 2022)**. pH has a negative relationship with BOD (-0.994) and water temperature (-98). There is a strong relation between BOD and water temperature (+0.952), on other hand, there is a negative relation between water temperature and Caldocera density (- 0.73), as **Majeed *et al*. (2022)** reported some organisms can't survive in warmer water.

The present investigation of the Cladocera density showed a positive correlation with TDS (+0.999) which was also observed in the study by **Khaire (2020)** in Chandani Dam on Chandani River. There is a negative correlation between density and BOD_5 (-0.48) which is confirmed by **Majeed *et al.* (2022)** who detected an inverse relation between these factors in the river.

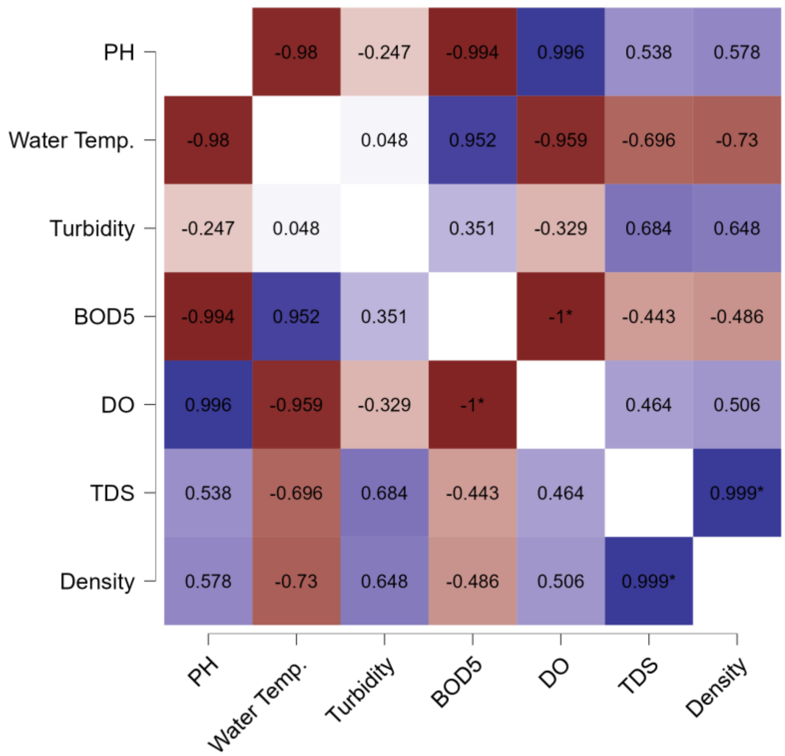

Fig. 7. Partial Pearson's heatmap

1- Principal component analysis

PCA was computed for all parameters from 3 sites on the Euphrates River to determine the most critical parameters affecting water quality by determining the eigenvalues that give the highest degree of factor significance. Significant eigenvalues are those that are greater than 1.0 (Table 7). There are three classes of PC: strong (> 0.75), moderate (0.50-0.75), and weak (0.30-0.50) **(Teixeira de Souza *et al.*, 2021)**.

One component was extracted from the PCA, which facilitates the identification of pollution sources using water parameters. Table (7) and Fig. (8) illustrate this study's component loadings of the most significant parameters. The green color represents the positive loading and the more the line gets thicker, the more the PC becomes close to 1.

PC1 was loaded heavily on Turbidity > pH> Water temp. > DO > TDS >BOD_5. These parameters are considered the most important factors with the strongest impact. This component refers to the discharge of industrial and agricultural activity **(Akhtar *et al*., 2021)**, where this area has serious problems with salinity and drainage.

Table 7. Component loadings of water quality parameters of the study

Parameter	PC1	Uniqueness
Turbidity	0.998	0.005
pH	0.997	0.007
Water temp.	0.959	0.081
DO	0.953	0.092
TDS	0.940	0.116
BOD5	0.858	0.264

Note. Applied rotation method is varimax.

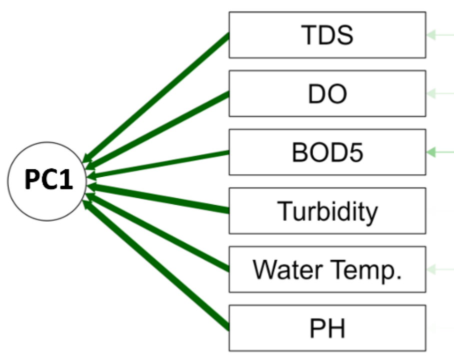

Fig. 8. Component loading diagram of water quality parameters of the study

CONCLUSION

The results indicated that a density peak was noticed in spring, in contrast, the lower densities were observed in summer. Site 1 had the highest values for Cladoceran density and richness compared to other sites. In contrast, Cladocerans densities and richness at site 2 were lower than those at other sites, which may be related to the lack of necessary macrophytes to Cladoceran serving as food and microhabitats, in addition to the near city location for site 2 which contributes to pollution stress. The relative abundance index of most abundance Cladoceran taxa at all sites was about 65% of the total species. *Chydorus piger*, *Bosmina longirostris*, *Alona rectangular* and *Macrothrix montana* were the most abundant. The similarity index value was the highest between sites 1 and 2 (58.33%) due to the near distance between them, thus converging the hydrological characteristics. WQI_{min} predicts a fall to 63.3% in the water quality compared to other sites especially in summer, which can be related directly to the effect of the sewage dumped to river and the presence of the channel with industrial effluents where site 2 is inside the Al-Shinafiyah City. The low density of Cladocera communities at this site aligns with the observed decrease in the water quality, as the presence of biota is affected by such changes.

REFERENCES

Abdul, W. O.; Adekoya, E. O.; Ademolu, K. O.; Omoniyi, I. T.; Odulate, D. O.; Akindokun, T. E. and Olajide, A. E. (2016). The effects of environmental parameters on zooplankton assemblages in tropical coastal. The Egyptian Journal of Aquatic Research, 42(3): 281–287. https://doi.org/10.1016/j.ejar.2016.05.005

Abed, I. F. and Nashaat, M. R. (2018). Interactions between the ecological dejiala river properties, Southern Iraq. Iraqi Journal of Science, 59(2): 1026–1040. https://doi.org/10.24996/IJS.2018.59.2C.6

A**khtar, N.; Syakir Ishak, M.I.; Bhawani, S.A. and Umar, K.** (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. Water (Switzerland), 13(2660): 1–35. doi: 10.3390/w13192660.

Al-bahathy, I. A. A.; Al-janabi, Z. Z.; Al-ani, R. R. and Maktoof, A. A. (2023). Application of the Water Quality and Water Pollution Indexes for Assessing Changes in Water Quality of the Tigris River in the South Part of Iraq, 24(5): 177–184.

Al-Bahathy, I. A. A. and Nashaat, M. R. (2021). Impact of Hindiya Dam on Rotifera Community of Euphrates River on the Northern of Babil Governorate, Iraq. Iraqi Journal of Science, 62(9): 2872–2886. https://doi.org/10.24996/ijs.2021.62.9.4

Aljanabi, Z.Z.; Al-Obaidy, A.H.M.J. and Hassan F. M. (2021)brief review of water quality indices and their applications, IOP Conf. Series: Earth and Environmental Science 779: 012088 doi:10.1088/1755-1315/779/1/012088

Al-Safi, D. R. M.; Nashaat, M. R. and AL-Sariy, J. S. (2022). Biodiversity and Structure of Rotifera Communities in the Great Garraf Drain Channel, Southern Iraq. Iraqi Journal of Science, 63(8): 3300–3312. https://doi.org/10.24996/ijs.2022.63.8.5

Anna, F. Rusydi (2018). Correlation between conductivity and total dissolved solid in various type of water: A review. IOP Conf. Series: Earth and Environmental Science 118 (2018) :012019 doi :10.1088/1755-1315/118/1/012019

APHA, American Public Health Association (2017). Standard Methods for Examination of Water and Wastewater. 23rd edit. Edited by E. W. R. Rodger B. Baird, Andrew D. Eaton.; Washington, DC 20001-3710.

B**arbiero, R. P.; Balcer, M.; Rockwell, D. C. and Tuchman, M. L.** (2009). Recent shifts in the crustacean zooplankton community of Lake Huron. Canadian Journal of Fisheries and Aquatic Sciences, 66(5): 816–828. https://doi.org/10.1139/F09-036

Bulbul, A., Anuska, and Abha Mishra (2022). Effects of dissolved oxygen concentration on freshwater fish: A review. International Journal of Fisheries and Aquatic Studies , 10(4): 113-127

CCME, Canadian Water Quality Guidelines for the Protection of Aquatic Life. (2007). Update 7.1, Canadian Council of Ministers of the Environment, Winnipeg.

Chen, T.; Zhang, H.; Sun, C.; Li H. and Gao Y. (2018). Multivariate statistical approaches to identify the major factors governing groundwater quality. Appl Water Sci 8: 215. https://doi.org/10.1007/s13201-018-0837-0

Czerniawski, R. and Sługocki, Ł. (2017). Analysis of zooplankton assemblages from man-made ditches in relation to current velocity. Oceanological and Hydrobiological Studies, 46(2):199–211.

Dunia, B. G. Alghanimy (2015). Assessment of water quality of Euphrates River (between the cities ofAl-Kifl and Al-Shinafiyah) Iraq. College ofEducation, University of AL- Qadisiyah. PhD thesis.

Elhaik, E. (2022). Principal Component Analyses (PCA)-based findings in population genetic studies are highly biased and must be reevaluated. Sci Rep 12: 14683. https://doi.org/10.1038/s41598-022-14395-4

Howladar, M.; Farhad, A.; Numanbakth, M.D.A. and Faruque M.O. (2017). An application of water quality index (WQI) and multivariate statistics to evaluate the water quality around the maddhapara mining industrial area, Dinajpur, Bangladesh. Environ. Syt. Res. 2017:6:13.

Jiang, X.; Yang, W.; Xiang, X.; Niu, Y.; Chen, L. and Zhang, J. (2014). Cyanobacteria alter competitive outcomes between Daphnia and Bosmina in dependence on environmental conditions. Fundamental and Applied Limnology, 184(1):11–22.

J**ones, S.; Carrasco, N. K. and Perissinotto, R.** (2015). Turbidity effects on the feeding, respiration and mortality of the copepod Pseudodiaptomus stuhlmanni in the St Lucia Estuary, South Africa. Journal of Experimental Marine Biology and Ecology, 469: 63–68.

Khaire, B. S. (2020). Correlations of Zooplankton Population with Some Physico-chemical Parameters of Chandani Dam, Maharashtra (India). International Journal of Innovative Science, Engineering & Technology, 7 (11): 140- 147, 2020

Kolarova, N. and Napiórkowski, P. (2022). How do specific environmental conditions in canals affect the structure and variability of the zooplankton community? Water, 14(6): 979.

Kushwaha, V. B. and Agrahari, M. (2014). Effect of domestic sewage on zooplankton community in River Rapti at Gorakhpur, India. World Journal of Zoology, 9(2): 86–92.

Lopes, V. G.; Castelo Branco, C. W.; Kozlowsky-Suzuki, B.; Sousa-Filho, I. F.; Souza, L. C. e. and Bini, L. M. (2017). Predicting temporal variation in zooplankton beta diversity is challenging. PLoS One, 12(11): e0187499.

Majeed, O. S.; Muhanned, R. Nashaatm; and Ahmed, J. M. Al-Azawi (2022). Physicochemical Parameters of River Water and their Relation to Zooplankton: A Review. IOP Conf. Series: Earth and Environmental Science 1120 (2022): 012040. doi:10.1088/1755-1315/1120/1/012040

Majeed, O. S.; Nashaat, M. R. and Al-Azawi, A. J. M. (2023). Effect of AL-Tharthar Canal on the Zooplankton Composition and Diversity in the Tigris River. Al-Mustansiriyah Journal of Science, 33(5): 53–64. https://doi.org/10.23851/mjs.v33i5.1314

Margalef, R. (1968). Perspectives in ecological theory.

Merhoon, K. A.; Nashaat, M. R. and Alkam, F. M. (2017). Environmental and Vertical Distribution Study of Zooplankton in AL-Diwaniyah River/Iraq. Journal of Biodiversity and Environmental Scinces (JBES), 10(6): 2017–2228.

Moran, S. (2018). Clean water characterization and treatment objectives, An Applied Guide to Water and Effluent Treatment Plant Design: Chapter 6, Clean water characterization and treatment objectives. Elsevier. doi: 10.1016/b978-0-12-811309-7.00006-0.

Nargs, A. A. and Luay A. A. (2020). RESEARCH PAPER A Study of Zooplankton Community in Alwand River and Dam- Iraq, ZANCO Journal of Pure and Applied Sciences, 32(3):116-126. DOI: http://dx.doi.org/10.21271/zjpas.

Nashaat, M. R. and Al-Bahathy, I. A. A. (2022). Impact of Hindiya Dam on the Limnological Features of Euphrates River to the North of Babil Governorate, Iraq. Baghdad Science Journal, 19(3): 447.

Nashaat, M. R.; Muftin, F. S.; Abbas, E. K. and Eman H, A. (2021). Occurrence and composition of copepods abundance in Tigris river, southern Baghdad, and effects of Rasheed power plant effluents on its biodiversity. Journal of Physics: Conference Series, 1879(2): 22022. https://doi.org/10.1088/1742-6596/1879/2/022022

Odum, W. E. (1970). Insidious alteration of the estuarine environment. Transactions of the American Fisheries Society, 99(4): 836–847.

Ostojić, A. M.; Radojević, I. D. and Balkić, A. G. (2015). Zooplankton community along the Sava River. The Sava River, 317–334.

Piczak, M.; Perry, D.; Cooke, S. J.; Harrison, I.; Benitez, S.; Koning, A. A.; Peng L; Limbu P; Karen, E. S.; Salinas-Rodriguez S.; Koehn, J. D. and Creed, I. F. (2023). Protecting and restoring habitats to benefit freshwater biodiversity. Environmental Reviews, (ja). https://doi.org/10.1139/er-2023-0034

Polazzo, F.; Dos Anjos, T. B. O.; Arenas-Sánchez, A.; Romo, S.; Vighi, M. and Rico, A. (2022). Effect of multiple agricultural stressors on freshwater ecosystems: The role of community structure, trophic status, and biodiversity-functioning relationships on ecosystem responses. Science of The Total Environment, 807:151052.

Portinho, J. L.; Perbiche-Neves, G. and Nogueira, M. G. (2016). Zooplankton community and tributary effects in free-flowing section downstream a large tropical reservoir. International Review of Hydrobiology, 101(1–2): 48–56.

Selim, A.; Shuvo, S. N. A.; Moniruzzaman, M.; Islam, M. M.; Shah, S. and Ohiduzzaman, M. (2023). Predictive Models for Dissolved Oxygen in an Urban Lake by Regression Analysis and Artificial Neural Network. Total Environment Research Themes, Volume 7:100066. https://doi.org/10.1016/j.totert.2023.100066.

S**hchapov, K. and Ozersky, T.** (2023). Opening the black box of winter: Full-year dynamics of crustacean zooplankton along a nearshore depth gradient in a large lake. Limnology and Oceanography. 68 (7): 1438-1451. https://doi.org/10.1002/lno.12355

Silvia F. P. and Daniel A. W. (2000). Use of Water Quality Indices To Verify The Impact of Coâ Rdoba City (Argentina) on Suquõâa River. Wat. Res. 34(11): 2915-2926.

T**aranu, Z. E.; Legendre, P.; Cusson, E. and Pinel-Alloul, B.** (2023). Riverscale distribution of zooplankton in the St. Lawrence River in relation to hydrological networks, hydroperiods and local environmental gradients. Hydrobiologia, 1–22. https://doi.org/10.1007/s10750-023-05259-7

Tasneem, A. and Abbasi S.A. Water Quality Indices. 1st Editio. Elsevier; 2012: 840 p.

Teixeira d.S.A.; Carneiro, L.A.T.; da Silva Junior, O.P.; de Carvalho, S.L. and Américo-Pinheiro, J.H.P. (2021). Assessment of water quality using principal component analysis: a case study of the Marrecas stream basin in Brazil. Environmental Technology, 42(27): 4286–4295. doi: 10.1080/09593330. 2020.1754922

Tranter, D. J.; Bulleid, N. C.; Campbell, R.; Higgins, H. W.; Rowe, F., Tranter, H. A. and Smith, D. F. (1981). Nocturnal movements of phototactic zooplankton in shallow waters. Marine Biology, 61: 317–326.

Vadde, K.K.; Wang, J.; Cao, L.; Yuan, T.; McCarthy, A.J. and Sekar, R. (2018). Assessment of Water Quality and Identification of Pollution Risk Locations in Tiaoxi River (Taihu Watershed), China. Water , 10: 183. https://doi.org/10. 3390/w10020183

Verma, V. and Aggarwal, R.K. (2020). A comparative analysis of similarity measures akin to the Jaccard index in collaborative recommendations: empirical and theoretical perspective. Soc. Netw. Anal. Min. 10: 43. https://doi.org/10.1007/s13278-020-00660-9

Wenwu, T.; Jianjun Z.; Jiang W.; Yifu S.; Xing L.; Manqin L.; Ziqiu Z.; Haijun L.; Guang S. and Peng G. (2022) Correlation Analysis of Water Temperature and Dissolved Oxygen Based on Water Quality Monitoring Data. Conference paper, Part of the Communications in Computer and Information Science book series (CCIS,volume 1587): pp 340–352.

Wu, X.; He, D.; Yang, G.; Ye, L.; Zhu, C.; Jia, H. and Hu, J. (2014). Seasonal variability of water quality and metazooplankton community structure in Xiaowan Reservoir of the upper Mekong River. Journal of Limnology, 73(1):167–176. https://doi.org/10.4081/jlimnol.2014.801

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