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Cladoceran Diversity within Samarra Impoundment, Iraq

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Abstract

This research is considered the first of its kind in this sector of the river for more than three decades and aims to evaluate the diversity, abundance, richness and spatiotemporal variations of Cladocera within Samarra Impoundment water. The samples of these crustaceans were collected from three sites in the impoundment every two months between February 2023 and December 2024. We identified 19 taxa belonging to five Cladocerian families. The most abundant genera were *Alona* sp., *Bosmina* sp., *Chydorus* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp., *Daphnia* sp. and *Moina* sp. The minimum and maximum densities were observed in spring and winter, respectively. The average values for evenness, richness and diversity indices were 0. 9, 0.82 and 0.88; 2.10, 1.98 and 1.71; 1.62, 1.55, and 1.43 bits/ind. at sites 1, 2 and 3, respectively. Seasonally, the lowest and highest values of richness and evenness indices were observed in summer and spring, respectively. The diversity index was observed in the summer and winter seasons. Furthermore, the analysis of the Jaccard similarity index indicated the highest value between the species at sites 1 and 3, reaching 39.98%.

Keywords: Ecological Indices, Dam and Reservoir, Samarra Impoundment, Similarity Index, Cladocera Diversity.

1. Introduction

Cladocera, commonly referred to as "water fleas" are a group of aquatic microcrustaceans whose size varies between 0.2 to 4 mm. They swim using their antennae, with series of jerks similar to flea jumps. There are approximately 700 known species[1,2]. The majority of Cladocera species live in freshwater, though some can also inhabit marine environments[1-3]. They respond significantly to various environmental factors, making them one of the most important freshwater biological indicators for a wide range of variables, including nutrients, temperature, dissolved oxygen, salinity, and pH[4]. The diversity of zooplankton, particularly Cladocera, is a vital biological indicator in aquatic environments. They play a significant role in ecosystem functioning and can be used to assess ecological quality, especially species such as Daphnids, Bosminids, and Chydorids[5]. Cladocera are vital in the food chain, serving as the main nutritional source for almost all aquatic species [6– 8]. Reservoirs serve as the primary source of zooplankton in rivers and streams[9, 10]. The zooplankton population from the reservoir can be transported downstream into the river through water flow, contributing to the natural processes of a larger river ecosystem. Consequently, zooplankton densities in the river may be higher compared to natural sections upstream of the dam[6].

Rotifers, Cladocerans, and Copepods are the main groups of zooplankton found in reservoirs[11, 12]. Reservoirs are created by dams across the rivers for various purposes, including water retention, flood control, irrigation, supporting economic growth by meeting industrial water demands, and generating electricity[13, 14]. Reservoirs can be classified depending on their purposes; therefore, the Samarra Reservoir is considered a multipurpose reservoir used for controlling floods, irrigation, water supply, hydroelectric generation, and recreation[15].
Multiple local studies have shown that Cladocerans are widely distributed in various aquatic systems such as rivers, lakes, ponds, and reservoirs. Six Cladocerans species in Alwand River and Dam southeast of Khanaqin City were identified, including *Bosmina coregoni*, *B. longirostris*, *Eubosmina tubicen*, *Alona rectangular*, *Cerodaphnia reticulata* and *Scapholeberis kingi*[16]. Sixty-five species belonging to 25 genera of Cladocera were identified in the Shatt Al-Arab waters[17]. Twenty-one species in two different running waters: 19 species in the Tigris River and 16 species in Tharthar water. The most abundant species were *Diaphanosoma brachyurum*, *B. longirostris*, *C. rigaudi* and *Moina affinis* in the Tigris River. While in the Tharthar Canal were *D. brachyurum*, *D. longiremis* and *M. affinis*[18]. Furthermore, 24 Cladoceran species in the Euphrates River and dominated by *Chydorus piger*, *B. longirostris*, *A. rectangular* and *Macrothrix montana*[19]. This study aimed to provide a comprehensive description of the diversity, abundance, richness and spatiotemporal variations of Cladocerans within the Samarra Impoundment.

2. Materials and Methods

2.1. Study Area

The Samarra Dam is one of the important dams built on the Tigris River, located near Samarra City in Salah Al-Din Province, and was operated in 1956 by the Ministry of Water Resources[20]. The dam's primary function is to protect downstream cities from floods by diverting excess water from the Tigris River to the Tharthar Depression through the Tharthar Valley during the flood season, while also providing irrigation water and producing hydroelectric power. The outflow from the reservoir has significantly declined in recent years due to climatic changes[20–23].

2.2. Location of the Sampling Sites

Three sampling sites were selected for this study. The first site was located upstream of the reservoir, directly at the river's entrance, with coordinates of 34°12'25.8"N and 43°50'50.2"E. The second site was near the Samarra Dam at 34°12'22.8"N and 43°51'28.0"E. The third site was situated close to the Tharthar Regulator, at the same coordinates as the second site, 34°11'53.4"N and 43°51'04.9"E (**Figure 1 and Table 1**).

Figure 1. Satellite view of the impoundment area (Google Earth).

Table 1. Geographic coordinates of each sampling site.

Sites	Latitude	Longitude	Details
1	34°12'25.8"N	43°50'50.2"E	below, a river flows into a reservoir.
2	34°12'22.8"N	43°51'28.0"E	lies close to the Samarra Dam.
3	34°11'53.4"N	43°51'04.9"E	lies close to the Tharthar Regulator.

2.3. Sampling Collection

Throughout the entire year of 2023, water samples were collected from the littoral zone at depths of less than 1 m every two months. A total of 45 liters of water was filtered through a planktonic net with a 55-micron[24, 25]. Each sample was preserved in 4% formalin. Within the reservoir, there is a relationship between epilimnetic temperature and atmospheric temperature (solar insolation) that is readily apparent across the study[26].

2.4. Identification

After the sample was condensed, the Cladoceria were identified to the lowest taxonomic level using a specialized counting chamber and a compound microscope. This rectangular hollow chamber held exactly one milliliter of the water sample[27]. In **Equation 1**, the densities were calculated based on the method described in reference [27].

$$\text{Cladoceran (Ind./m}^3) = \frac{n}{\text{Volume of sample}} \times 10^3 \qquad (1)$$

n: Cladoceran number.

Identification is based on the revisions by[28–30]. This data was supplemented by recently published additions. The results are presented as the number of Cladoceria per m^3.

2.5. Ecological Indicators

The indices listed in **Table 2** were used to evaluate diversity; 1. Abundance Index[31] 2. Constancy Index (S)[32] 3. Jaccard Similarity Index[33] 4. Evenness Index (*J*)[34] 5. Richness Index (D)[35] 6. Diversity Index (*H'*)[36]. The results were expressed in bits per individual, where one bit was defined as a single piece of information. Results below one bit per individual indicate low diversity, while results exceeding three bits per individual suggest significant diversity[37, 38].

Table 2. Explain the ecological diversity indices.

Index	Formula	Explanation
Abundance	Ra = N/Ns χ 100	N: Number of individuals. Ns: Total number.
Constancy	S = n/N χ 100	N: positive sample number. N: total sample number.
Evenness	*J* = H/Ln S	Ln S: Diversity largest theoretical value. H: Shannon Weiner value. S: Taxonomic unit number in each site.
Richness	D = (S-1)/ log N	S: Species number. N: Individuals total numbers.
Diversity (Shannon-Weiner)	*H'* = -Σ ni/n χ Ln (ni/n)	ni: Number of individuals per taxonomic unit. n: Total summation of individuals.

3. Results

3.1. Cladocerian composition and classification

According to the Global Biodiversity Information Facility (GBIF) and the previously mentioned taxonomic, we identified 19 species of Cladocera belonging to five families: 10 taxa in site 1, 14 taxa in site 2, and 9 taxa in site 3. Our findings showed that the genus *Alona* accrued with 5 species, *Bosmina* accrued with 2 species, *Chydorus* accrued with 2 species while the remaining genera had one species (**Table 3**).

3.2. Cladocera density and abundance species in the Samarra Impoundment

Figure 2 shows Cladocerans density. At the first site, the density values ranged from 111 Ind./m^3 to 688.8 Ind./m^3 in October and April, respectively. At site 2, the density ranged from 133.2 Ind./m^3 in December to 1954.7 Ind./m^3 in February. In the third site the values ranged between

66.6 and 288.7 Ind./m^3 in April and June, respectively. The average values of Cladoceran total density were 268.35, 912.55 and 175.77 ind./m^3 at sites 1, 2 and 3, respectively (**Table 4**).

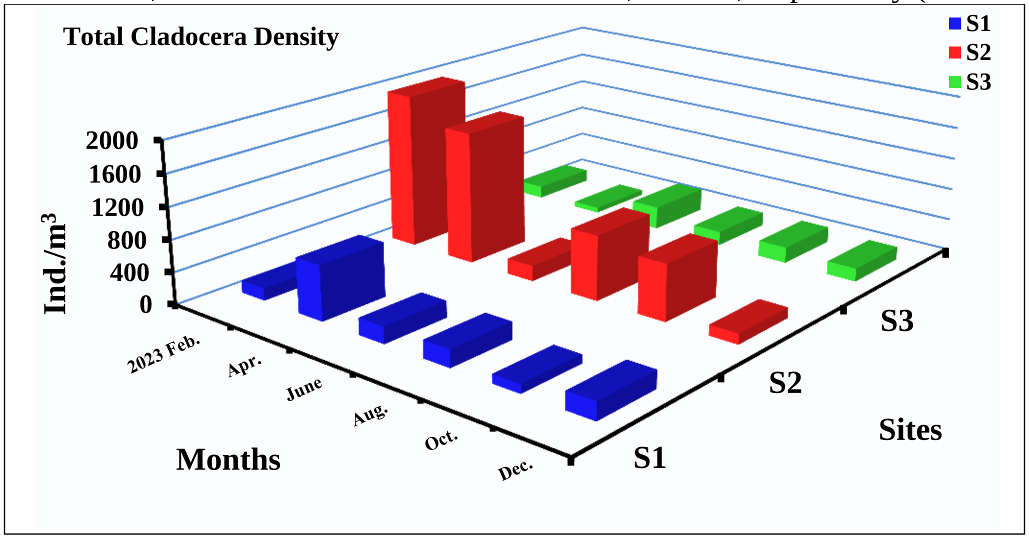

Figure 2. Spatiotemporal variations in Cladoceran density in the Samarra Impoundment.

The relative abundance index of Cladocera in the Samarra Impoundment water indicated that *A.gutata*, *A.affinis*, *A.intermedia*, *A.rectangular*, *B.longirostris*, *B. coregoni*, *C.rigaudi*, *C.spherecus*, *C.piger*, *Daphnia pulex*, *D.brachyurum*, *Dunhridia crassa*, *M.affinis*, *S.vetulus* were the most abundant cladoceran fauna in the Samarra Impoundment as shown in **Table 3** and **Figure 3**. The higher abundance of Cladoceran species at site 1 were *D. brachyurum* (23%), *A. rectangular* (19%), *B. longirostris* (11%), *Chydorus piger* (11%), *M. affinis* (11%), *A. affinis* (8%) and *A. gutata* (7%). In site 2 the abundance of *A.rectangular*, *A.gutata*, *B.longirostris*, *C.piger*, *C.spherecus*, *D.pulex*, *Alona costata*, *M.affinis*, *S.vetulus* and *A.intermedia* were 21%, 15%, 11%, 8%, 8%, 8%, 7%, 6%, 5% and 5%, respectively. In site 3, *C. rigaudi*, *C. piger*, *Dunhevedia crassa*, *D.brachyurum*, *A.rectangular*, *B.coregoni*, *A.gutata*, and *A.costata* were recorded at 20%, 15%, 15%, 11%, 11%, 10%, 6% and 6%, respectively, as shown in **Figure 3**.

Table 3. List of abundance and consistent species occurring in the period between February and December 2023 in the Samarra Impoundment.

Family	Taxa	Relative abundance			Constancy		
		S1	S2	S3	S1	S2	S3
Chydoridae	*Alona affinis* (Leydig, 1860)	R	-	-	C	-	-
	A. costata (Sars, 1862)	R	R	R	A	Ac	Ac
	A. gutata (Sars, 1862)	R	La	R	Ac	A	Ac
	A. rectangula (Sars, 1862)	La	La	La	C	C	Ac
	A. intermedia (Sars, 1862)	-	R	-	-	A	-
	Comptocercus rectiostris (Schödler, 1862)	-	R	-	-	Ac	-
	Chydorus piger (Sars, 1862)	La	R	La	C	Ac	C
	C. spherecus (Müller, 1776)	-	R	-	-	C	-
	Daphnia pulex (Leydig,1860)	-	R	-	-	Ac	-
	Dunhevedia crassa (King, 1853)	-	-	La	-	-	C
	Pleuroxus hamulatus (Birge, 1910)	-	R	-	-	A	-
Bosminidae	*Bosmina coregoni* (Baird, 1857)	-	-	La	-	-	C
	B. longirostris (Muller,1785)	La	La	R	C	C	A
Daphniidae	*Ceriodaphnia rigaudi* (Richard, 1894)	-	R	La	-	A	Ac
	Scapholebrus kigni (Schoedler, 1858)	R	-	-	Ac	-	-
	Simocephalus vetulus (Koch, 1841)	-	R	-	-	Ac	-
Sididae	*Diaphanosoma brachyurum* (Liévin, 1848)	La	-	La	C	-	Ac
Moinidae	*Moina affinis* (Birge, 1893)	La	R	-	C	Ac	-
	Immature Cladocera	R	R	-	Ac	C	-

The species classified as Dominan (D), Abundan (A), Less abundant (La) and Rare species (R) were with percentages of >70%, 40-70 %,10-39%, and <10%, respectively, for Abundance Index. As well, classified as constant (C), accessory (Ac) and accidental (A) where the percentages were >50%, 26%-50% and 1-25%, respectively, for the Constancy Index.

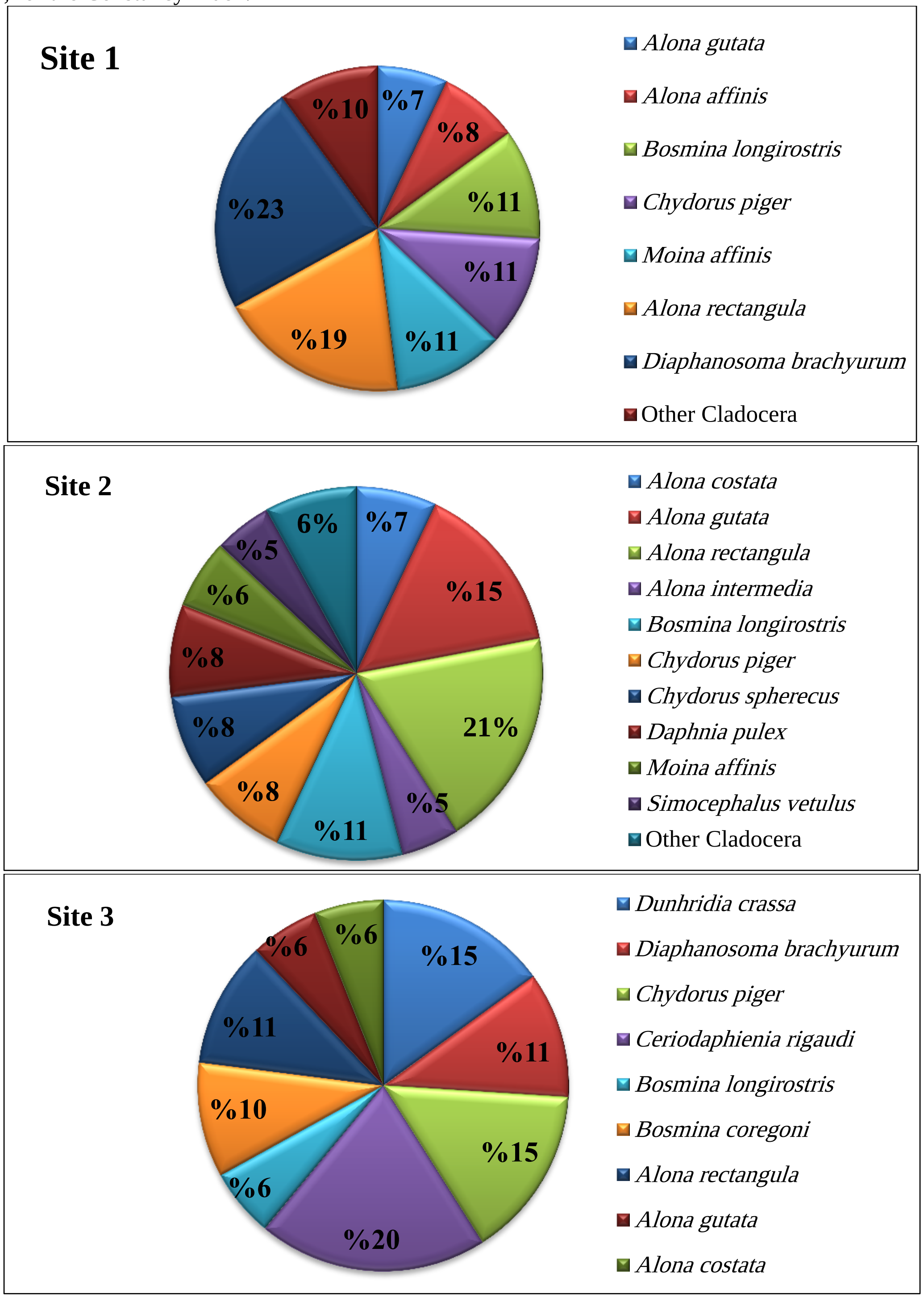

Figure 3. The percentage of the most abundant Cladocerans species in the Samarra Impoundment.

3.3. Ecological Indices

3.3.1. Cladocerans Richness Index (D)

Figure 4 shows the values of the Cladoceran richness index in the Samarra Impoundment during 2023. The values of this index varied from 0.97 in October to 2.55 in August and December at site 1. In contrast, at site 2, the values ranged from 0.43 in June to 2.79 in April. At site 3, the minimum value was 1.09 in April, whereas the maximum value was 2.22 in August.

Furthermore, the average values collected from all sites fell within the moderate to low ranges on the Margalef Richness Index[39–41]. The recorded values for sites 1, 2, and 3 were 2.10, 1.98, and 1.71, respectively (**Table 4**).

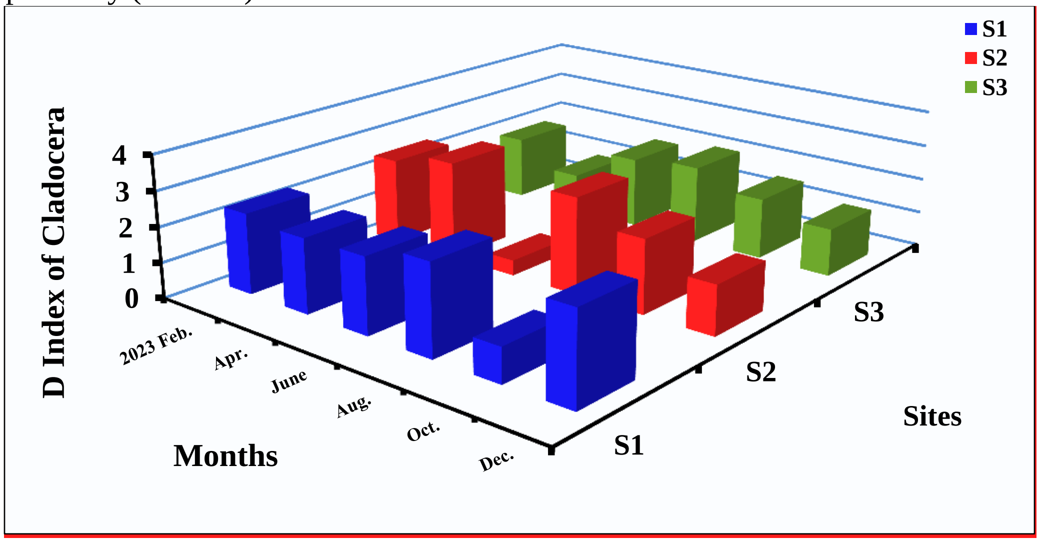

Figure 4. Spatiotemporal variations in the D index in the Samarra Impoundment.

3.3.2. Species Evenness Index (*J*)

At the first site, the values of the evenness index ranged from 0.76 in April to 0.97 in February and August. In the second site, the values varied from 0.511 in June to 0.95 in February. At the third site, the values fluctuated between 0.69 and 1 in August and April, respectively (**Figure 5**). Furthermore, the average values across all sites were greater than 0.5, which indicates that the species were homogeneous in appearance[42, 43]. The recorded values were 0.9, 0.82 and 0.88 for sites 1, 2 and 3, respectively (**Table 4**). Low microcrustacean diversity was observed in the Garças Reservoir, attributed to the dominance of only a few species[44].

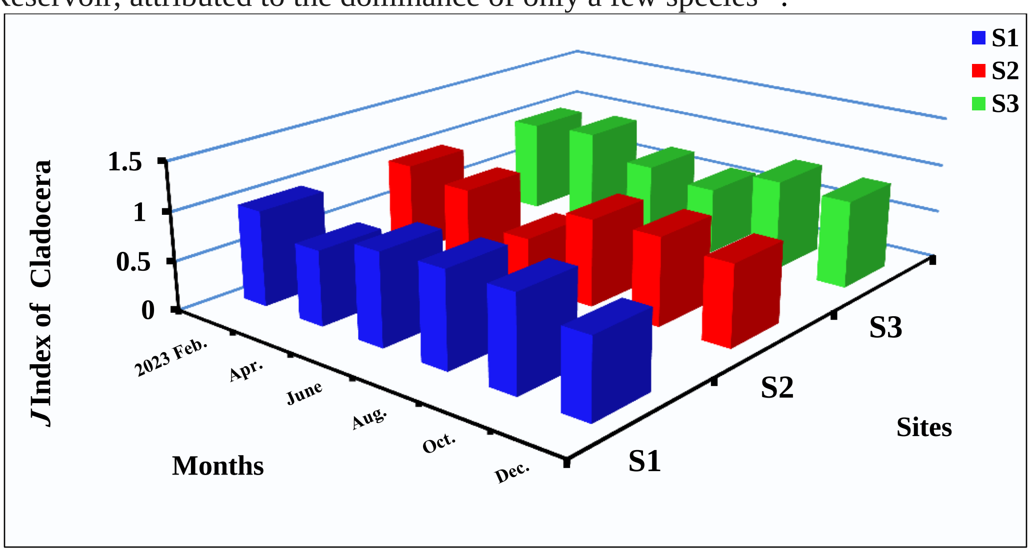

Figure 5. Spatiotemporal variations in the *J* index in the Samarra Impoundment.

3.3.3. Cladocerians Diversity Index (*H'*)

Figure 6 illustrates the diversity of Cladocerian in the Samarra Impoundment in 2023. At site 1, the diversity values ranged from 1.05 bits/individual in October to 1.88 bits/individual in August and December. At Site 2, the values varied from 0.35 bits/individual in June to 2.09 bits per individual, in February. In contrast, at site 3, the diversity figures were 1.09 bits/individual in April and 1.73 bits/individual in August.

Furthermore, the average values across all sites ranged between 1 and 2 bits/individual, which indicates a medium to high level of species diversity[45]. The recorded values were 1.62 bits/individual for site 1, 1.55 bits/individual for site 2, and 1.43 bits/individual for site 3 (**Table 4)**.

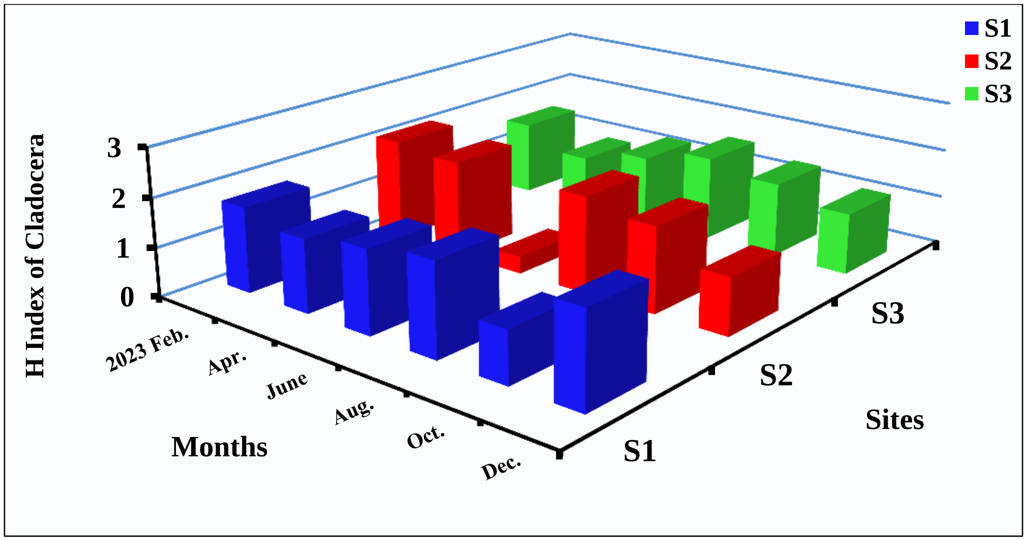

Figure 6. Spatiotemporal variations in the *H'* index in the Samarra Impoundment.

Table 4. Presents the average values of the Cladoceran diversity indices and total density.

Index	Sites		
	I	II	III
D	2.1	1.98	1.71
J	0.9	0.82	0.88
H'	1.62	1.55	1.43
Total density	268.35	912.55	175.77

3.3.4 Jaccard's Similarity Index

The maximum similarity index of 39.98% was observed between sites 3 and 1 (**Figure 7**). The low similarity index values indicate that changes in species abundance, rather than the presence or absence of specific species (**Table 3**). This is probably related to the differences between the two distinct habitats, such as limnological factors, hydrodynamic conditions, and the stability of water currents in reservoirs. A similar pattern was observed by[46] reported that the similarity index for Cladocerians in the Shatt Al-Arab water ranged from 37.5% to 66%. This variation was related to differences in environmental and hydrological factors among the sampling sites. In another study of the Shatt Al-Arab water, the values of the similarity index ranged from 13% to 63%. This variation was attributed to the same reasons discussed previously[47].

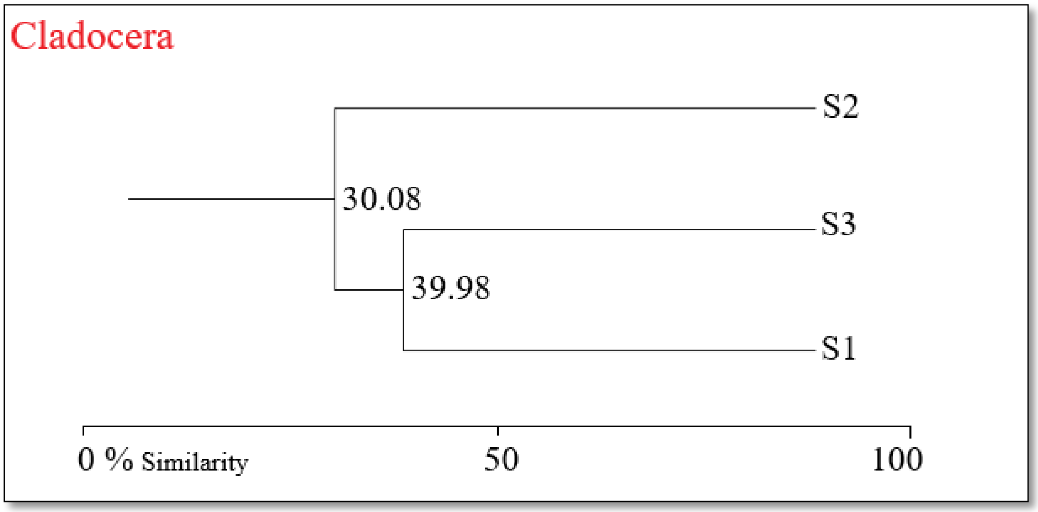

Figure 7. Dendrogram showing percentages of Jaccard's index for Cladocera.

3.3.5. Constancy Index (S)

Table 3 depicts the constant species in the three sites in the impoundment. In site 1, we recorded six species. The corresponding values for site 2 and 3 were 4 and 3, respectively.

According to the constancy index, the species *A. affinis, A. rectangula*, *C. piger*, *B. longirostris*, *D. brachyurum* and *M. affinis* were the most constant species in site1. At the second site, the most constant species were *A. rectangular*, *C. spherecus*, *B. longirostris* and immature cladocerans. At the third site, *C. piger*, *D. crassa* and *B. coregoni*. The results obtained are consistent with earlier studies conducted on other Iraqi waters. *B. longirostris*, *B. coregoni* and *C. rigaudi* were the most constant species in the Samarra Impoundment[48]. *A. rectangular*, *B. longirostris*, *C. rigaudi*, and *D. brachyurum* were the largest constant Cladocerans in the Tigris water[18]. Generally, habitats that have similar structures tend to support similar compositions of cladocerans[49].

4. Discussion

The study is consistent with the previous research carried out by[39], which identified 25 Cladoceran species in Samarra Reservoir and Tigris River. The study aligns with previous research conducted on the Dam and Alwand Rivers, which identified six species of Cladocerans belonging to four different families[16]. The results also agree with different global studies. In the Kardzhaly Reservoir, thirteen Cladoceran species were identified[50]. In the Valle de Bravo Reservoir seven Cladoceran species were detected[51]. In the Medik Reservoir, 8 Cladoceran species were recorded[52]. Also, in the Barragem da Pedra Reservoir, 4 Cladoceran species were detected[44]. In the Kayalıköy Reservoir, 24 Cladoceran species were identified[53].

These findings are consistent with a previous study implemented in the Samarra Impoundment and the Tigris River[48]. This earlier research found that the density of Cladocerans fluctuated between 1,300 and 7,000 individuals per cubic meter in the impoundment. In contrast, the density downstream of the impoundment doubled.

Spatial fluctuations indicated that the highest density was 1954.7 Ind./m^3 recorded at site 2, while the lowest value was 66.6 Ind./m^3 at site 3 (**Figure 2**). These differences can be attributed to variations in habitats, particularly hydrodynamic conditions and the distance of each site from the dam openings. Site 2 is considered a more stable environment than site 3, which likely contributes to the increased density observed there. Seasonal fluctuations showed the highest densities recorded in winter at 1954.7 Ind./m^3 and the lowest densities in spring at 66.6 Ind./m^3 (**Figure 2**). One study found that the density of Cladocerans increased during winter due to rising dissolved oxygen levels, while the lowest densities were observed in summer due to higher temperatures[54]. Another study explained how temporal variations impact limnological factors, which subsequently affect the Cladocerans communities over time[44]. Contrarily, the maximum density of Cladocera occurred during spring season, gradually decreasing during July and September within the Samarra Impoundment[48]. As well, in the Alwand River and Alwand Dam, the density of Cladocerans increased significantly during the summer season[16]. The peak density of Cladocerans during spring correlated with an increase in phytoplankton and favorable environmental conditions[18]. A positive correlation was observed between water temperature and species composition in the Medik Reservoir[52].

The results also showed that the genera *Alona*, *Bosmina* and *Chydorus* were the most abundant cladoceran identified in the impoundment while the rest appeared sporadically **(Figure 3).** This indicates that these species are tolerant to a wide range of environmental factors. Moreover, produce a large number of eggs[55]. Bosmina spp. is the most dominant Cladoceran in Garças Reservoir, comprising 95% of the total Cladoceran population[56]. This dominance is related to cyanobacterial blooms, which negatively impact larger Cladoceran species such Daphnia, leading to their replacement by smaller organisms such as Bosmina sp. Another reason for the successful presence of Bosmina spp. in this environment is the ability to resist various harmful environmental effects[56]. Also, *B. longirostris*, *C. sphaericus*, and *D. laevis* were the most dominant cladoceran species in the Valle de Bravo Reservoir[51]. In the Kayalıköy Reservoir *B. longirostris* was the most prevalent Cladoceran species observed over a twelve-month period[53]. Generally, all Cladoceran species recorded in the Samarra Impoundment are widely distributed in the Tigris River [18, 38, 42, 48].

In terms of spatial fluctuations, the values of the richness index fluctuated among different sites, as we show in **Figure 4**. This is probably due to the differences in hydrodynamic conditions between the two sites. The most significant factors affecting microcrustacean species richness in both natural and artificial lakes in Brazil were morphometric conditions and water residence time[57]. Seasonally, the minimum values of this index were observed in summer. Whereas the maximum value was seen in the spring season (**Figure 4**). The richness index rose during spring, likely due to increased sunlight intensity and improved photosynthesis, which support phytoplankton blooms and subsequently enhance microcrustacean diversity[18, 43]. The results agreed with previous study conducted in the Tigris River northern Baghdad City which observed an increase the Cladoceran richness index during the spring season[18]. Similar findings reported in Medik Reservoir, indicating the highest value in the spring (6.35) and the lowest in summer (2.85)[52].

For spatial variations of the *J* index, the lowest value was in site 2 (J = 0.511) while the highest value was in site 3 (J =1). This may be linked to the difference in the nature of hydrodynamic conditions between the two sites is considered the most important factor affecting the homogeneity of species[18, 58, 59, 60].

For Seasonal variations, the value varied between 0.511 in summer and 1 in spring. The peak value in spring is probably due to the favorable conditions. Similar results in the Sarno Dam, indicating a strong distribution of Cladocera with population values ranging from 0.84 to 0.92 in the rain season and from 0.79 to 0.81 in the low precipitation season[61].

For spatial variations of the diversity index, the lowest value was in site 2, recorded as 0.35 and the highest value was in site 2, recorded as 2.09 bits/individuals. (**Figure 6**). This variation may be attributed to the differing hydrodynamic conditions between the two sites, which are considered the most significant factor affecting Cladocerian diversity. Another study found a direct relationship between Cladoceran diversity and macrophytes in different reservoirs[62].

For seasonal variations, the lowest value was recorded in summer (0.35 bits/Ind.) and the largest value was recorded in the winter season (2.09 bits/Ind). The variations in diversity may be related to seasonal changes in water temperature (**Figure 6**). We can explain that although the influence of temperature alone has a positive effect, it can also act as an antagonist effect on cyanobacteria growth and reduce Cladoceran diversity[63]. In this respect, low diversity in Garças Reservoir was attributed to the predominance of a few species[56].

5. Conclusion

We identified nineteen taxa, belonging to five families: *A. gutata*, *A. affinis*, *A. excise*, *A. intermedia*, *A. rectangular*, *B. longirostris*, *B. coregoni*, *C. rigaudi*, *C. spherecus*, *C. piger*, *D. pulex*, *D. brachyurum*, *D. crassa*, *M. affinis*, and *S. vetulus* were the most abundant species in the water. In addition, the genera Alona, Bosmina, Chydorus, Diaphanosoma, and Moina showed a high degree of consistency. The study showed that Cladoceran density varied spatially and temporally due to changes in limnological and hydrodynamic conditions, which were considered the most significant factors affecting Cladoceran density. Also, the average values of ecological indices, such as diversity, evenness, and richness, varied by site and time. Finally, this study established baseline knowledge regarding Cladoceran densities and diversity in Samarra Impoundment water.

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Conflict of Interest

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Ethical Clearance

The study does not require any ethics committee approval.

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