Biological and Applied Environmental Research

Vol. 6(2): 121-143, 2022

https://doi.org/10.51304/baer.2022.6.2.121

ISSN: 2002-6153
Biol. Appl. Environ. Res.
www.baerj.com
editor@baerj.com

Impact of Hindiya Dam on Copepoda Diversity in Euphrates River, North of Babylon Province, Iraq

Muhanned R. Nashaat[1*] & Idrees A. A. Al-Bahathy[2]

[1]Agricultural Research Directorate, Ministry of Science & Technology, Baghdad, Iraq
[2]Directorate of Education at Al-Qadisya, Ministry of Education, Baghdad, Iraq

*Corresponding author: muhanned_nashaat@yahoo.com

Abstract: The study was the first trial to evaluate the effect of the Hindiya Dam on the Euphrates copepods diversity during January to December 2019. The copepod density average was decreased clearly at downstream the dam compared with dam site. Nauplii showed the highest percentages relative abundance while *Macrocyclops albidus albidus* was the lowest. Thirty-eight taxa were recorded, including 9, 4, 2, 1 and 22 taxa of Calanoida, Harpacticoida, parasitic cyclops, nauplii, and Cyclopoda, respectively. The average values of species richness index declined from 0.83 at site 1 to 0.62 at dam downstream. Copepods were considered as a distributed richness. Site 4 with 5 had the lowest similarity (49.99%), whereas the highest Jaccard index percentage (92.5%) was between sites 1 and 4. The average values of Shannon-Weiner index ranged from 0.788- 0.96 bit/ind at up and downstream dam, respectively. The dam is considered as moderate to unbalance according to uniformity index. Constant taxa decreased from 6 on upstream to 4 downstream dam. It was concluded that the change in hydrological conditions from current water in site 1 to limnetic basins in site 2, then back to current water at sites 3, 4 and 5 downstream dam had a significant impact on the spatial composition of the copepod community.

Keywords: Biodiversity, Copepoda, Invertebrates, Regulated River, Iraq

Introduction

Rivers and lakes are important to global biodiversity and highly sensitive to environmental stresses (Vorosmarty et al., 2010). Biodiversity is maintained globally by the habitats of freshwater (Poff et al., 2007). Dams significantly changed aquatic ecosystems such as rivers more than other human activities (Lees et al., 2016), therefore induce alterations in sediment regimes, river flow regimes, geomorphology and wetland morphology (Donohue & Molinos, 2009).

Zooplankton communities (Rotifera, Cladocera and Copepoda) are impacted by abiotic factors (e.g. light, precipitation, hydrology and turbidity) in addition to biotic factors (e.g. parasitism, competition, predation and diseases (Dejen et al., 2004). The importance of these factors to zooplankton communities differs according to seasons and species (Jones et al., 2015). So, it is increasingly used in aquatic environments as bioindicators (Okorafor et al., 2013) as well as having high

Received Dec. 15, 2021, accepted Feb. 28, 2022

sensitivity and reaction to environmental variation (Shah & Pandit, 2013). Therefore, several local studies are dealing with a zooplankton group as indicative of environmental stress, such as those of Al-Lami et al. (2004), Radi et al. (2005), Nashaat (2010), Nashaat et al. (2013), Hassan et al. (2014), Ala Allah et al. (2015), Nashaat et al. (2015, 2016), Rasheed et al. (2016), Merhoon et al. (2017), Abbas et al. (2017), Abed & Nashaat (2018), Al-Bahathy & Nashaat (2021) and Nashaat et al. (2021). The present study is considered as the first trial to evaluate the effect of Hindiya Dam on the Euphrates copepod community, in Babylon Province, which can be considered as the main objectives by investigating these impacts on Euphrates copepod diversity.

Material and Methods

Study Area Description

Hindiya Dam is situated on the Euphrates River in the south of Musayyib City in the north of Babylon Province, Iraq. The dam length is 250 m and has 36 dams' spillways, 5 m width of each one (Mutin, 2003). It was designed for treating sediment matter of the one of the two major branches of the Euphrates River in this area called Hilla River.

Sampling Sites

Five sites for collection of study samples on the Euphrates River near Hindiya Dam were chosen (Map 1).

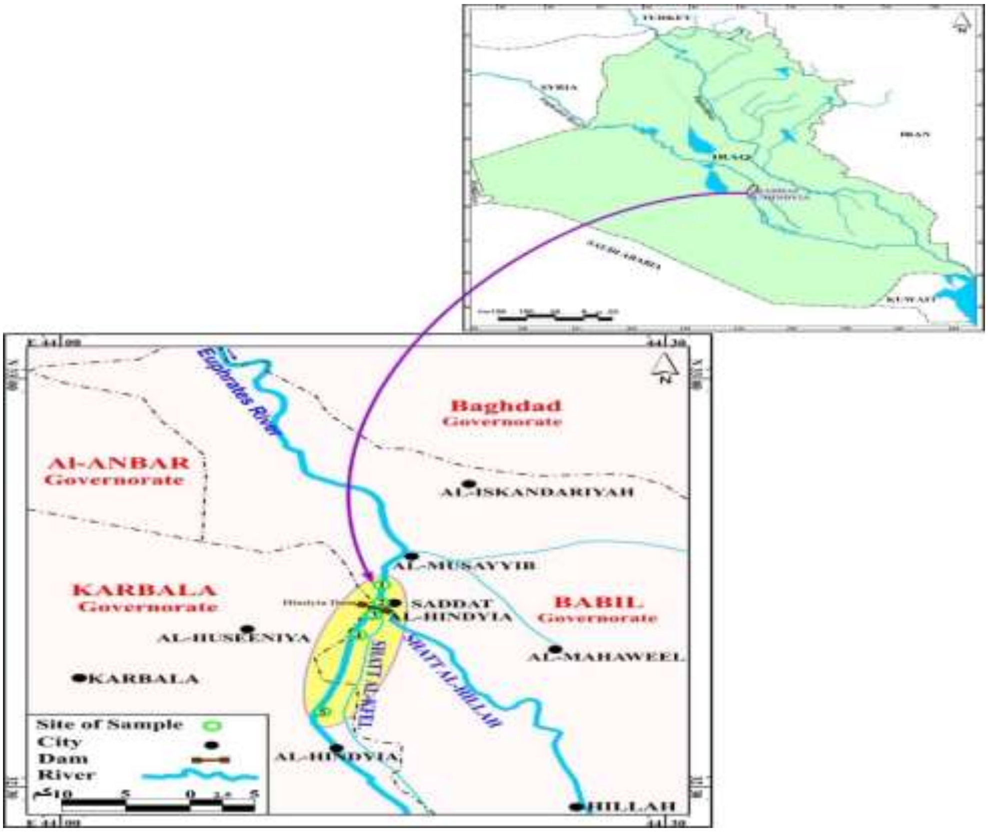
Site 1: This site is located before the Babylon Cement Factory, south of the Musayyib City, about 1 km upstream the Hindiya Dam at 44° 16' 05"N, 32° 44' 18"E and Euphrates River was 328 m wide.

Site 2: It represents the Hindiya Dam site which is wider than other sites, it is about 366 m wide at 44° 16' 07" N, 32° 43' 42"E.

Site 3: It is located at about 400 m down Hindiya Dam with 235 m wide at 44° 16' 06"N, 32° 43' 29"E.

Site 4: It is located at about 5 km down Hindiya Dam at 44° 15' 16"N, 32° 41' 24"E, and has 293 m wide.

Site 5: It is located at about 10 km downstream site 4, and about 15 km downstream the Hindiya Dam at 44° 13' 12"N, 32° 35' 50"E, and has 231 m wide.



Map 1**:** The study area with sites of samples collected. (Source: Ministry of Water Resources, Baghdad, 2017 personal communication).

Copepod Collection and Identification

Samples were collected monthly from January to December 2019 at a depth of 0.5 m. Forty liters of water were filtered through net with mesh size of 55 µm by using a graduated bucket (10 l). A copepod sample was transferred from the net collector to a 500 ml vial. After that, the sample was concentrated to 10 ml for counting by using the same size mesh (Tranter et al., 1981). The specimens were preserved in 4% formalin (Edmondson, 1959). The samples were examined under a compound microscope and the species were identified according to the diagnostic keys: Edmondson (1959) and Smith (2001). The results were expressed for individual/m^3.

Ecological Indexes

The following ecological indices were counted: Relative Abundance Index (Ra) was calculated depending on the formula used by Odum (1971). The Species Richness Index (D) was calculated monthly according to Margalef (1968). Jaccard Presence-Community was calculated according to Jaccard (1908). Shannon-Weiner Diversity Index (H) of copepod communities was calculated monthly by using the formula of Shannon & Weiner (1949). The Species Uniformity Index (E) was measured as stated in Neves et al. (2003). Uniformity is in appearance if the value of the index is higher than 0.5 according to Pielou (1977). Constancy Index (S) was calculated according to Serafim et al. (2003).

Results and Discussion

Copepoda Density

The density values of Copepoda ranged from 450 ind/m^3 to 10175.5 ind/m^3 at site 1 (upstream the dam) during February and November (Figure 1).

On the other hand, the values of the dam site were raised so, they ranged from 666.64 ind/m^3 to 10766.4 ind/m^3. The lowest values were in January, whereas the higher values were in November. The copepod density at site 3 decreased in relation to the dam site, then increased in sites 4 and 5, ranging from 226 ind/m^3 to 24199.86 ind/m^3, respectively. The lower value was recorded in February at site 3, while the higher value was recorded in December at site 5.

As for spatial variations, density values reduced on site 3 (below the dam) compared with the site 2 because copepod species which have large size, made it exposed to damage when passing the dam and exposure to predation risk in site 3, downstream the dam (Grabowska et al., 2013).

Hindiya Dam site 2 had a high density of a copepods. This may be related to open water zones, longer water retention time and lower current velocity (Czerniawski & Sługocki, 2017).

For the same reasons, one can attributed the higher density values of copepods in site 5 compared with other sites. This could be either owing to the occurrence of copepods in the river with suitable features, such as, longer water retention time in open water zones, current velocity of less than 0.1 m/s, and to intense of macrophytes (Czerniawski & Sługocki, 2017), and all these conditions which were presented in site 5.

As for temporal variations, copepods density values showed that two peaks were detected at the end of spring and autumn, which coincided with suitable water temperature for egg hatching and development as well as phytoplankton growth increment (Vadstein et al., 2004; Haberman & Haldna, 2017), or due to an increase in nutrients and the absence of vertebrate and invertebrate predators that may be selective for large sizes (Ibrahim, 2005; Al-Keriawy, 2014). The lower copepod densities in winter and the beginning of spring could be due to high turbidity in winter, which reduced feeding rates of copepods (Zhao et al., 2017), or owing to its predation by both fish larvae and macroinvertebrates at the beginning of spring (Gayosso-Morales et al., 2019).

The result of the current study agrees with some local and international studies such as Al-Nimrawee (2002), Zhou et al. (2008), Havel et al. (2009), Sharma et al. (2010), Grabowska et al. (2013), Salman (2015) and Portinho et al. (2016).

Conversely, the findings of this study disagreed with other studies which have detected lower density values of copepods in the dam site compared with downstream the dam such as Sabri et al. (1993) when discussed effect of Samarra Dam on zooplankton of the Tigris River as well as Al-Shamy (2016) who carried out a number of investigations on Al-Kut Dam's impacts on zooplankton.

The disagreed studies recorded values of copepod density in downstream the dam higher than the dam site. This could be either due to the high discharge from the impoundment, which may increase the populations in the river site downstream the dam by flushing the small backwaters in which copepods were abundant (Sabri et al., 1993), or owing to dam reservoir which was exposed to environmental stress such as predation or sewage effluents (Gayosso-Morales et al., 2017).

The present results agreed with those obtained by some studies such as Ibrahim (2005) and Al-Keriawy (2014), who observed that increment in the copepods density was in autumn, which was associated with an increase in nutrients and the absence of vertebrate and invertebrate predators that they may be selective for large sizes. Similarly, Salman (2015), recorded the highest density during the spring in Gharaf River in Wasit Province. The present findings agreed with the Sharma et al. (2010) who recorded the highest density of copepods during spring in the Narmada River in India.

In contrast, the findings of this study disagreed with Kushawaha & Agrahari (2014) when they examined zooplankton in the Rapti River in India who recorded the highest density of copepods (499.8 ind/l) during the summer season, while the lowest was 75 ind/l during the rainy season.

Finally, it was shown that the dam had an effect on copepod densities, particularly on site 3 (downstream the dam), which was lower than the dam site, based on the results of this study and some previous studies. This may be due to the copepods' large size, which exposed them to damage while going through the dam, or predation in site 3 (downstream the dam) as explained by Grabowska et al. (2013).

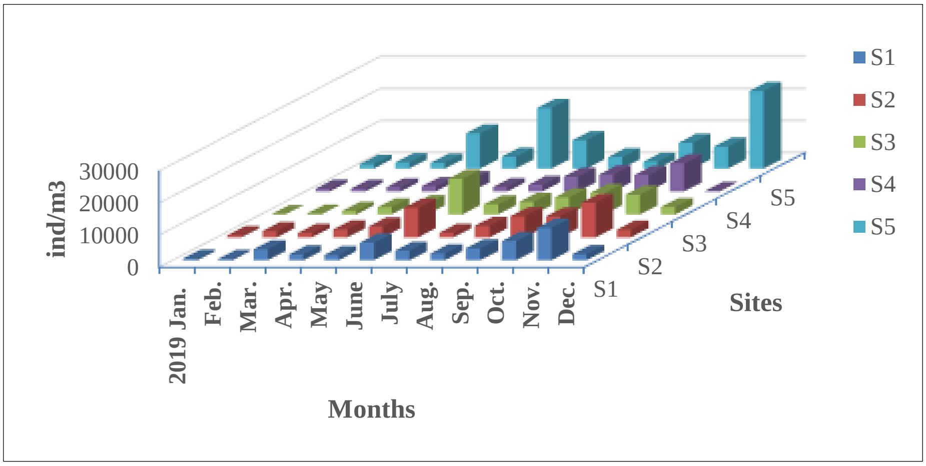


Figure 1: Monthly variations of copepod densities (ind/m^3) at five sites of the Euphrates River, north of Babylon Province during January to December 2019.

Ecological Indexes

Figure 2 and Table 1 represent values of relative abundance index of copepod taxa which showed that nauplii had the highest percentages ratio followed by immature cyclops, *Cyclops* (♂), *Cyclops* sp., *Paracyclops fimbriatus* (Fischer, 1853), immature calanoids, *Halicyclops* sp. and *Paracyclops affinis* (Sars, 1863), respectively at all sites of the study area.

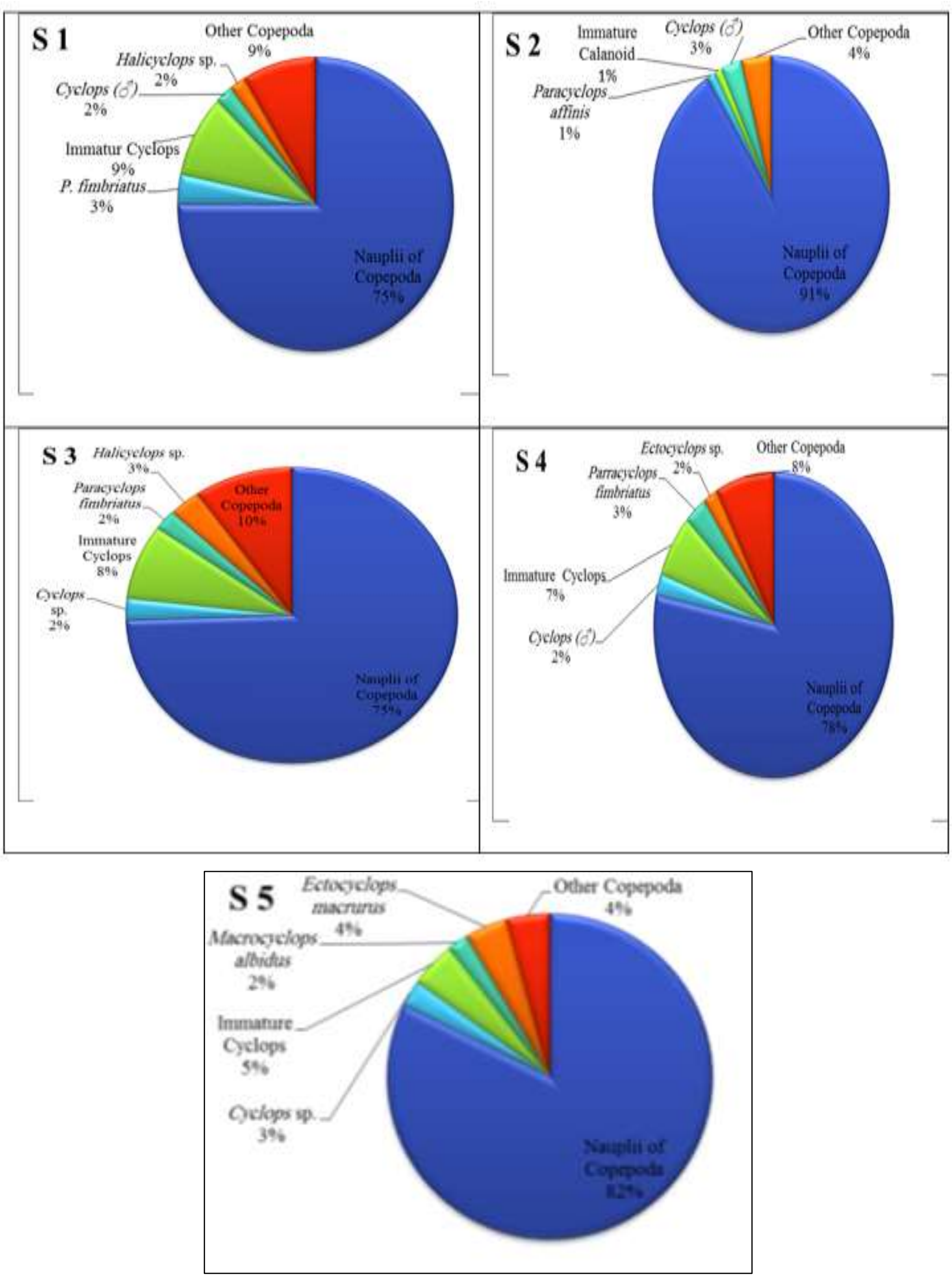


Figure 2: Dominant copepod species at five sites of the Euphrates River, north of Babylon Province during January to December 2019.

Table 1: List of the copepod taxa with Copepod's relative abundance and constancy index in the five studied sites.

Taxa		Relative abundance*					Constancy**				
		Sites					Sites				
		1	2	3	4	5	1	2	3	4	5
Calanoida											
1	*Diaptomus amatitlanensis* Wilson M.S., 1941	R			R	R	A			A	A
2	*Diaptomus arapahoensis* Dodds, 1915			R		R			A		A
3	*Diaptomus floridanus* Marsh, 1926		R	R					A		
4	*Diaptomus gracilis* Sars, 1863	R				R	A				A
5	*Diaptomus novemdecimus* Wilson, 1953		R			R		A			A
6	*Diaptomus sarsi* Rylov, 1923	R				R	A				A
7	*Diaptomus* sp.	R	R				A	A			
8	*Hesperodiaptomus franciscanus* (Lilljeborg, 1889)	R			R		A			A	
9	Immature Calanoida	R	R	R	R	R	A	Ac	Ac	Ac	Ac
Cyclopoida											
10	*Cyclops capillatus* Sars G.O., 1863		R					A			
11	*Cyclops exilis* Coker, 1934	R		R	R	R	Ac		Ac	A	A
12	*Cyclops jeanne*li Chappuis 1929	R	R	R		R	A	A	A		A
13	*Cyclops venustoides* Coker, 1934			R					A		
14	*Cyclops vernalis* Fisher, 1853	R			R		A			A	
15	*Ectocyclops phaleratus* (Koch, 1838)	R	R			R	A	A			Ac
16	*Ectocyclops* sp.	R	R	R	R	R	Ac	C	Ac	Ac	A
17	*Eucyclops agilis* Koch, 1838	R	R	R	R		Ac	A	A	Ac	
18	*Eucyclops macrurus* (Sars, 1863)	R				R	A				A
19	*Halicyclops* sp.	R	R	R	R	R	C	C	Ac	Ac	A
20	*Macrocyclops albidus albidus* (Jurine, 1820)	R			R	R	A			A	C
21	*Mesocyclops albicanus* (Smith G. W., 1909)	R					A				
22	*Mesocyclops hylalinus* (Rehberg, 1880)	R	R	R	R	R	A	A	A	A	A
23	*Mesocyclops leuckarti* (Claus, 1857)	R		R			A		A		
24	*Paracyclops affinis* (Sars, 1863)	R	R	R	R		Ac	Ac	Ac	A	
25	*Paracyclops fimbriatus* (Fischer, 1853)	R	R	R	R	R	Ac	C	C	Ac	A
26	*Paracyclops poppei* (Rehberg, 1880)	R					A				
27	*Pesceus reggiae* (Wilson M. S., 1958)					R					A
28	*Tropocyclops prasinus* (Fischer, 1860)		R	R		R		A	A		Ac
29	*Cyclops* (♂)	R	R	R	R		C	C	C	C	
30	*Cyclops* sp.	R	R	R	R	R	Ac	Ac	C	Ac	C
31	Immature cyclops	R	R	R	R	R	C	C	Ac	C	C
Harpacticoida											
32	*Nitokra lacustris* (Schmankevitch, 1875)	R	R		R		Ac	Ac		A	
33	*Nitokra spinipes* Boeck, 1865					R					A
34	*Nitokra* sp.					R					A
35	Immature Harpacticoida	R	R		R	R	Ac	Ac	Ac	A	A

36	Nauplii of Copepoda	D	D	D	D	D	C	C	C	C	C
	Parasitic cyclops								A		
37	*Ergasilus* von Nordmann, 1832	R		R	R		A	A	A	A	
38	*Lernaea* Linnaeus, 1758		R					A			A

*Relative abundance: > 70%: Dominant species (D), 40%-70%: Abundant species (A), 10%-40%: Less abundant species (La). < 10%: Rare species (R).

**Constancy index: Frequencies calculated from % occurrence in samples. Accidental species (A) zooplankton occur in 1%-25%, Accessory species (Ac) occur in 25%-50% of samples and constant species (C) occur in more than 50%.

Site 1 (upstream the dam) showed more abundant copepod species, nauplii, immature cyclops, *Paracyclops fimbriatus*, *Cyclops* (♂) and *Halicyclops* sp. which recorded percentages of 75%, 9%, 3%, 2% and 2%, respectively.

Hindiya Dam (site 2) showed that nauplii, *Cyclops* (♂), immature calanoids and *Paracyclops affinis* had recorded percentages of 91%, 3%, 1% and 1%, respectively.

Site 3 (downstream the dam) showed that nauplii, immature cyclops, *Halicyclops* sp., *Cyclops* sp. and *Paracyclops fimbriatus* recorded percentages of 75%, 8%, 3%, 2% and 2%, respectively.

In site 4, nauplii, immature cyclops, *Paracyclops fimbriatus*, *Cyclops* sp. (♂) and *Ectocyclops* sp. recorded percentages of 78%, 7%, 3%, 2% and 2%, respectively.

In site 5, nauplii, immature cyclops, *Eucyclops macrurus*, *Cyclops* sp. and *Macrocyclops albidus albidus* recorded percentages of 82%, 5%, 4%, 3% and 2%, respectively.

In the Euphrates River, the dominance of nauplii had greater densities compared with adult copepods, which could be due to their similarity to the rotifers which can drift passively farther than adult copepods for the small size and weight of nauplii, or due to having the tolerance to wide environmental conditions (Thorp & Rogers, 2014), or because of predation intensity which was higher to adult forms, especially in reservoir water as a result of lack of macrophytes (Czerniawski et al., 2017) which caused a higher relative abundance in the Hindiya Dam site compared with other sites.

In view of all that has been mentioned so far, the present observations, as well as with previously known studies, it has been shown that the dam has an effect on the relative abundance of copepod species. This could be due to the reservoirs, even with short water retention times, led to higher densities of nauplii followed by immature copepods compared with adult copepods because predation intensity was higher to adult forms, especially in water of Hindiya reservoir as a result of lack of macrophytes (Czerniawski et al., 2017).

Figure 3 showed the temporal and spatial variations of copepod richness values during the study period, site 1 (upstream the dam) values were ranged from 0.391 to 1.474, during August and March, respectively.

On the other hand, the recorded values at Hindiya Dam (site 2) ranged from 0.391 to 1.103 during January and October, respectively. The values of this index of copepods were declined at sites downstream of the dam (sites 3 and 4) compared with the dam site that ranged from zero to 1.14. The lower values were at site 4 in December, whereas the higher value was at site 3 in November.

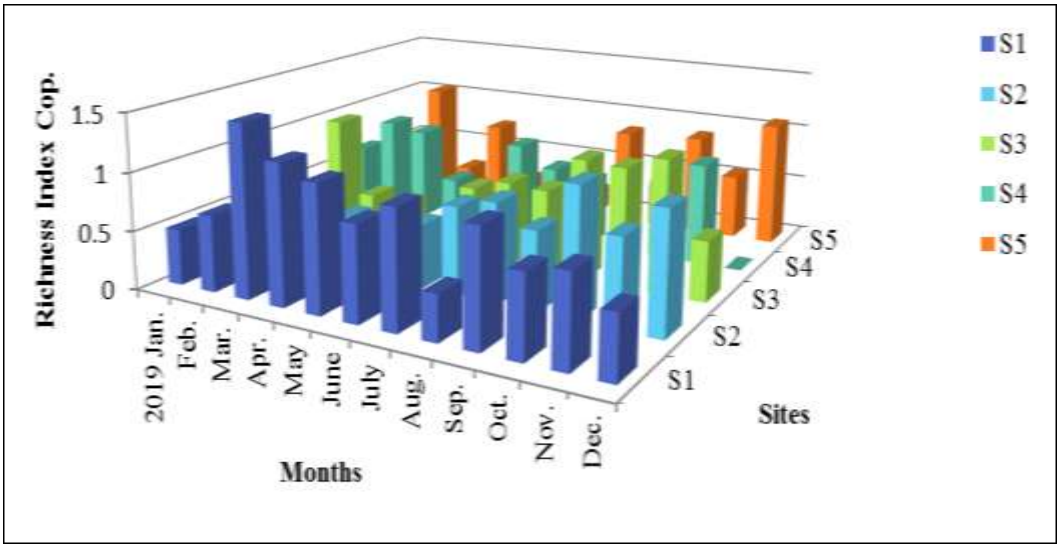


Figure 3: Temporal and spatial variations of the richness index of copepods during the study period.

As for spatial variations, in site 4 the lowest values in richness were recorded. This may be due to its location faraway from the dam reservoir, which was the river's main source of cladocerans and copepods (Havel et al., 2009).

As for temporal variations, copepod richness was higher in spring and autumn. Its richness increment may be due to suitable water temperature (Haberman & Haldna, 2017), or due to increment of phytoplankton growth, which are considered as major food to grazers of zooplankton (Wu et al., 2014) in spring and autumn months as well as due to, the high organic matter as a food source for zooplankton (Dražina et al., 2017). In addition, zooplankton richness had high values, which might be due to its coincidence with high water discharge in June and July (Branco et al., 2018). All mentioned reasons (suitable water temperature, phytoplankton growth, organic matter and high water discharge) are considered as important causes for zooplankton richness increment in spring, summer and autumn. If richness value was ≥ 5, it would be classified as perfect. If it was from 3 to 5, then classified as moderate and if the index value was ≤ 2, then they classified as distributed (Hussain, 2014). Euphrates River copepods were considered as of distributed richness during 2019 in the study area according to Hussain (2014). In addition, the decline of total zooplankton richness values in the sites below the dam compared with the dam site agrees with some other studies such as those of Sabri et al. (1993), Czerniawski & Domagala (2014), Czerniawski et al. (2017) and Zhao et al. (2017).

Czerniawski & Sługocki (2017) observed an increment of richness values with a higher current velocity (>0.1 m/s). This is consistent with downstream the dam site in the current study, while richness values are reduced with a less water current velocity (<0.1 m/s) which are consistent with the dam site in the current study.

Conversely, these findings disagreed with some local and global studies that found that zooplankton richness raised in the site below the dam compared with the dam site, such as Zhou et al. (2008), Grabowska et al. (2013) and Al-Shamy (2016).

The current study recorded the highest richness of copepods in spring and autumn, which is in agreement with some local and global studies such as Ajeel et al. (2005), Ali (2010), Rabee (2010), Nashaat (2010), Akbar (2013), Mwagona et al. (2018) and Pinto (2018).

The disagreed studies with the spatial variations findings recorded values of zooplankton richness in downstream the dam, which were higher than the dam site. This could be either owing to the slower water current in reservoirs, which provides a less number of zooplankton taxa compared with the streams and rivers (Czerniawski & Sługocki, 2017), or their study site downstream the dam was further than this study downstream the dam site, which made it far from the negative dam effect on the density and richness of zooplankton.

In view of all that has been mentioned so far from the present findings and the previous agreed studies, it was proved that the dam affected zooplankton richness, especially on site 3 (downstream the dam), which was lower compared with the dam. This might be related to the effect of current velocity on chlorophyll a content and physicochemical conditions. The zooplankton densities and richness are clearly correlated with the concentration of chlorophyll a, which is associated with better nutritional conditions for filter-feeding zooplanktons. This is more frequently occurred in lentic waters (Lévesque et al., 2010).

Thirty-eight taxa of copepod species were recorded during the study period, including nine taxa of Calanoida, four taxa of Harpacticoida, two taxa of parasitic cyclops, one taxa of Nauplii and 22 taxa of Cyclopoda (Table 1).

The present findings showed that copepods included cyclops which occurred with eight taxa, while *Diaptomus* with seven taxa. *Mesocyclops*, *Nitocra* and *Paracyclops* included three taxa each. *Ectocyclops* and *Eucyclops* included two taxa each. The rest of the genera have one taxa each (Table 1). In comparison with some local studies, Nashaat (2010), through a study of Tigris River near Al-Durah Power Plant in Baghdad, showed that richness range was 1.23-6.17 and recorded 147 taxonomic taxa belonging to zooplankton, including 44 taxa of copepods: genera *Diaptomus* and *Leptodiaptomus* with four species each and also the genera *Onychodiaptomus*, *Cyclops* and *Skistodiaptomus* with three species each. Abdul-Wahab & Rabee (2015) recorded richness range from 1.05-12, and recorded 106 taxonomic units of zooplankton, including 25 taxa of copepods. Al-Shamy (2016) observed through study of Al-Kut Dam that richness range was 0.37-4.35, with 79 taxa of zooplankton that included 17 taxa of copepods. Copepods included the genus *Cyclops* which occurred with species as well as *Ectocyclops* and *Paracyclops* which occurred with two species each.

In comparison with some global studies, Sleem & Hassan (2010) reported species richness range from 1.8-2.4 through study of zooplankton in Nile River. Long et al. (2014) recorded, in Bakun in Malaysia, richness range from 0.23-0.24.

As for similarity index, site 3 had low copepods similarity values (Table 2, Figure 4). This could be due to the poor water quality and more polluted site compared with other sites which affected by Hindiya Dam.

Table 2: Jaccard presence coefficient matrix between sites for copepods.

1	4	7.49165	92.50835	1	4
2	3	13.79156	86.20844	1	2
3	2	14.51889	85.48111	1	3
4	1	37.78501	62.21499	1	5
Similarity Matrix					
	S 1	S 2	S 3	S 4	S 5
S 1	*	86.2084	85.4811	92.5083	54.1563
S 2	*	*	77.5225	81.3452	62.215
S 3	*	*	*	84.9216	50.4989
S 4	*	*	*	*	49.9904
S 5	*	*	*	*	*

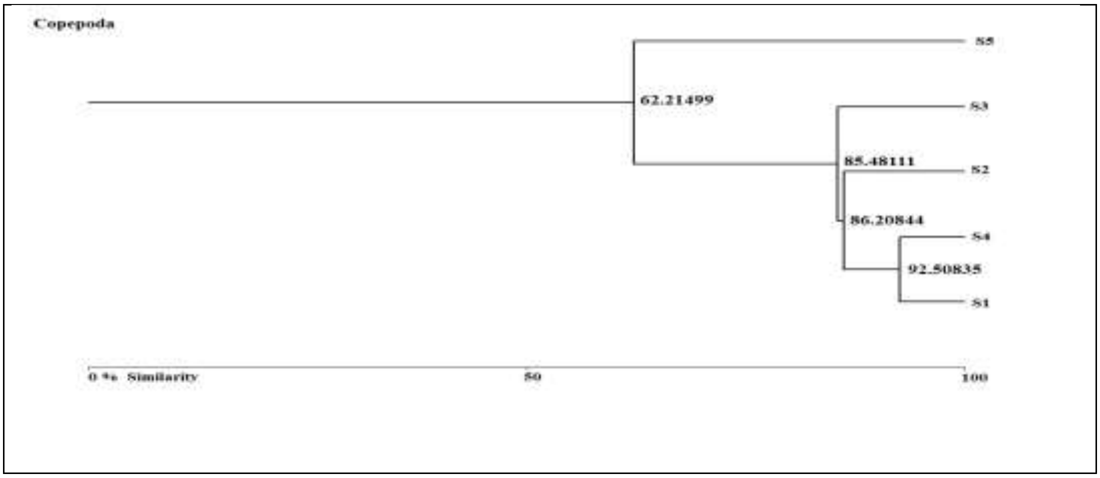


Figure 4: Dendrogram of Jaccards index percentages of copepods.

These local and global studies found that less similarity index value in site below the dam compared with other sites. For example, Al-Shamy (2016) on the effect of Al-Kut Dam on zooplankton. Similarly, Zhou et al. (2008) on zooplankton in a small dam on Xiangxi River in China, as well as Czerniawski et al. (2013) on zooplankton communities of River Oder in Poland.

Conversely, findings of the present study disagreed with Grabowska et al. (2013) in the Narew River in Poland which recorded less similarity index values in the last downstream site which was a riverine site further distance from the dam.

In view of all that has been so far mentioned from the present findings and the previous similar studies, it was proved that the dam was affected by decrease similarity value on site 3 which became more polluted site compared with other sites.

Figure 5 showed that Shannon Weiner diversity values of copepods in the study area ranged at site 1 (upstream the dam), from 0.59 to 1.6 bit/ind in November and March, respectively, while the values of the Hindiya Dam site (site 2) were decreased, ranged from 0.18 to 1.33 bit/ind in October and December, respectively. However, such values increased at site 3 compared to site 2, then decreased in sites 4 and 5 which ranged from zero to 1.84 bit/ind. The lowest value was at site 4 in December, whereas the higher value was at site 3 in February.

Euphrates River copepods were considered as poorly diversified because this index value ranged from 0.5 to 1 bit/ind in all study sites during the study period (Hussain, 2014).

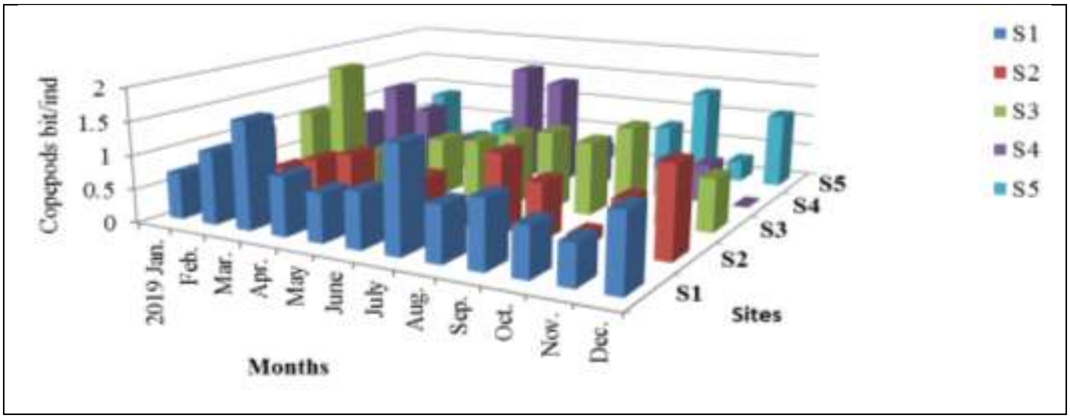


Figure 5: Variation of Shannon Weiner Diversity Index for copepods in the Euphrates River.

The spatial variation in Shannon values of copepods showed higher values in the Hindiya Dam site 2 compared with other sites. This might be due to the fact that crustaceans prefer lentic water bodies such as reservoirs or lakes because they have longer life cycles, and they are larger in size than rotifers (Błędzki & Rybak, 2016). Also, Shannon values of copepods declined gradually as the distance from the dam reservoir increased in site 3, 4 and 5 (Figure 5) as the reservoir provides optimal conditions for their growth (Havel et al., 2009).

Temporal variations of copepods showed that increment of Shannon index values coincided with suitable water temperature (Haberman & Haldna, 2017) and increment of phytoplankton growth at spring, which is considered as a major food for zooplankton grazers (Sharma et al., 2010). Also, Shannon index values' peak coincided with high water discharge during summer (Branco et al., 2018).

The current study agrees with some local and global studies that outlined the higher diversity values of copepods in the dam reservoir compared with the site (below the dam) such as indicated by Al-Nimrawee (2002), Zhou et al. (2008), Havel et al. (2009) and Portinho et al. (2016). In contrast, other local and global studies disagreed with this findings such as Sabri et al. (1993) and Al-Shamy (2016).

The disagreed studies were recorded less diversity values of crustaceans in the dame site compared with site (below the dam). This could be either due to the high discharge from the impoundment may flush the small backwaters in which crustaceans were abundant, thus increasing species of the populations in the river site below the dam (Sabri et al., 1993), or due to dam reservoir exposed to environmental stress (e.g. predation, sewage effluents) which made it of less suitability to crustacean growth compared with the site below the dam (Gayosso-Morales et al., 2017).

In view of all that has been mentioned so far from the present findings and the previous agreed studies it has been proven that the dam affected on Shannon index values of crustaceans especially on Hindiya Dam site which were higher diversity values compared with site 3 (below the dam). This might be due to crustaceans prefer lentic water bodies such reservoirs or lakes because crustaceans have a longer life cycles, and they are of larger size than rotifers (Błędzki & Rybak, 2016), or owing to the reservoir provide optimal conditions for its growth and it was the major source of the river crustaceans (Havel, 2015).

Figure 6 showed that uniformity index values of copepods at site 1 (upstream the dam) ranged from 0.28 to 0.70 in November and July, respectively. The values of the Hindiya Dam site 2 declined from 0.07 to 0.62 during October and January, respectively. The values of this index of copepods at sites (downstream the dam) were increased compared with the dam site which ranged from zero to 0.96. The lower value was at site 4 in December, whereas the higher value was at site 3 in January.

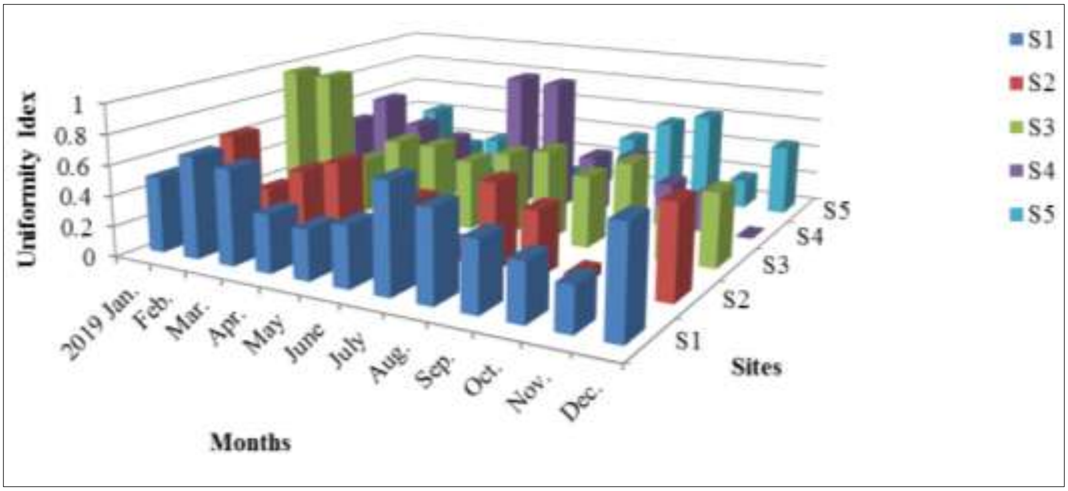


Figure 6: Uniformity Index values of copepods in the Euphrates River during the study period.

The spatial variation for copepods of Hindiya Dam site had high uniformity index values of crustaceans in this site compared with site 1 and other sites. This could be due to crustaceans prefer lentic water bodies such lakes or reservoirs because of it have a longer development cycle. Also, they are heavier and larger in size than rotifers (Błędzki & Rybak, 2016), whereas, uniformity index values of crustaceans gradually declined as the distance from the dam reservoir increased at site 3, 4 and 5 as showed in Figure 6 owing due to the reservoir provide optimal conditions for its growth which was the major source of the crustaceans of the river sites (Havel et al., 2009).

As for temporal variations of Uniformity Index values, increment on copepods coincided with increment of phytoplankton growth at spring and autumn, which are considered as major food to grazers of crustaceans (Sharma et al., 2010). Also, other increment of uniformity index values coincided with high water discharge at summer (Branco et al., 2018).

If uniformity index value is 0.8- ≥0.9, it would be classified as highly balanced. If it is from 0.6 to 0.7, then it is classified as moderate balanced and if this index ≤ 5, then it is classified as unbalanced (Hussain, 2014). So, copepods of Euphrates River are generally considered from moderate to unbalance during 2019 in this study area.

Local and global studies highlighted that uniformity index values of crustaceans were higher in the dam reservoir compared with the site (below the dam). Such as the study of Al-Nimrawi (2002) on the impact of the Qadisiyah Dam on the Euphrates River. Similarly, Zhou et al. (2008) discussed impacts of Small Dam in Xiangxi River in China. Also, Havel et al. (2009) carried similar study to demonstrate the effect of main-stem dams on zooplankton communities of the Missouri River in USA. Portinho et al. (2016) found that crustacean uniformity values were higher in Itaipu Reservoir on the Paraná River in Brazil compared with site below the dam.

In contrast, Sabri et al. (1993) and Al-Shamy (2016) recorded less uniformity values of crustaceans in the dam site, compared with the site below the dam during the higher river discharge months in Samarra Dam on the Tigris River and in Al-Kut Dam, respectively.

The disagreed studies recorded lower uniformity values of crustaceans in the dame site. This could be due to the fact that dam reservoir was more exposed to environmental stresses (e.g. predation, sewage effluents) which made it less suitable to crustaceans growth compared with the site below the dam (Gayosso-Morales et al., 2019).

Finally, according to present findings and some previous studies, it was proved that the dam affected on uniformity values of crustaceans in Hindiya Dam site which had higher values compared with other sites. This might be due to the fact that crustaceans prefer lentic water bodies such reservoirs or lakes as they have longer life cycles, and they are of larger size than rotifers (Błędzki & Rybak, 2016).

Table 1 showed that nauplii, immature cyclops, *Cyclops* (♂), *Cyclops* sp., *Paracyclops fimbriatus* and *Halicyclops* sp. recorded the highest occurrence of copepods species at most or all sites which occurred in more than 50% of samples collected from Euphrates River in Hindiya Dam area during the study period.

The constant species of copepods were six at the dam site, while, they decreased to four constant species at site of downstream the dam

Simões et al. (2015) studied the impact of reservoirs on constancy of species and compared them with natural lakes in Brazil. They found that constant species occurred in lakes more than in reservoirs and only rotifer species were notable in the reservoirs, while rotifers and crustaceans were recorded in natural lakes. This result could be related to the contribution of littoral zone and sediment with the pelagic zone of lakes. Accessory species were expected to be more influenced to environmental changes. In contrast, the constant species were more resistant to environmental changes in the dam.

Zhou et al. (2008) referred to the increment of occurrence and abundance of some zooplankton species positively in reservoir with number of constructed dams on the river. The existence of small reservoirs, even with a short water retention times, leads to more presence of pelagic zooplankton in rivers and lead to drift them from the upstream impoundments which agreed with the present results, especially with existence of several upstream reservoirs as Haditha Dam, Ramadi Barrage and Fallujah Barrage) that would influence abundance of pelagic zooplankton in Hindiya Dam sites.

It was found that all of nauplii, immature cyclops, *Cyclops* (♂), *Paracyclops fimbriatus* and *Halicyclops* sp. were more frequent and formed constant taxonomic units during the study period.

Thorp & Rogers (2014) observed that the dominance of nauplii (Figure 7) in rivers with greater densities frequently compared with adult copepod forms owing to its similarity to the rotifers which can drift passively farther than copepod adults for the small size and weight of nauplii, or may be due to its tolerance to a wide range of environmental conditions.

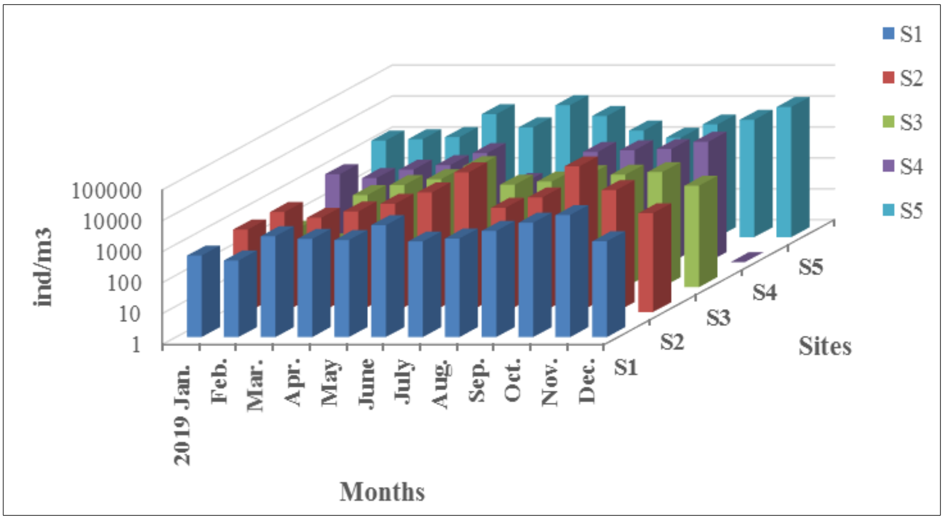


Figure 7: Densities of nauplii during the study period.

Czerniawski & Domagała (2014) observed that nauplii, followed by immature copepods (Figure 8), have greater occurrence compared with adult copepod forms as a result of the predation intensity which was higher to adult forms. This is in agreement with their higher occurrence in sites of the present study area.

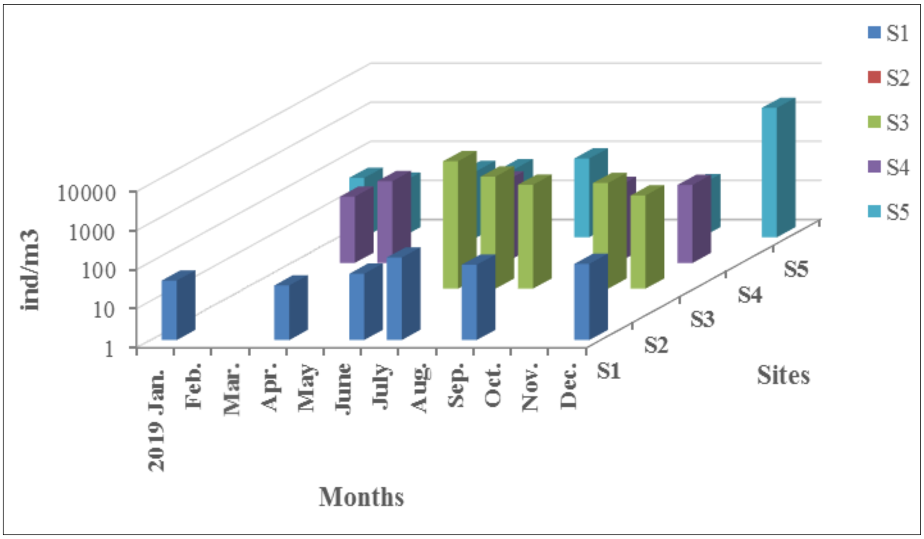


Figure 8: Densities of immature cyclops at the study sites.

Brandl & Prazakova (2002) found that most cyclopoid species, such as cyclops, prefer to live in brackish water as they feed on all common species of rotifers, as well as nauplii and immature cladocerans (Figure 9).

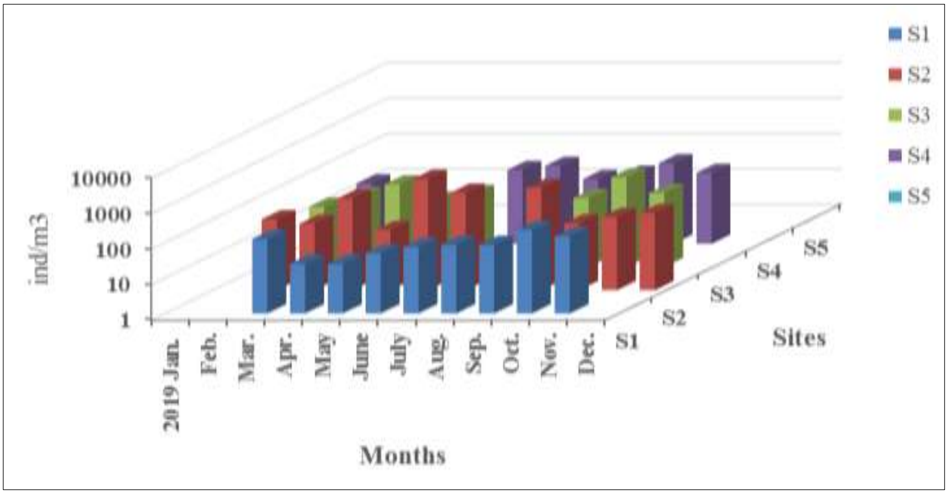


Figure 9: Densities of *Cyclops* (♂) during the study period.

Błędzki & Rybak (2016) referred that *Paracyclops fimbriatus* (Figure 10) occurred frequently in the study area because it has a cosmopolitan distribution and thrive in total dissolved solids (TDS) rich water for river and lakes which agreed with water nature of the present study area.

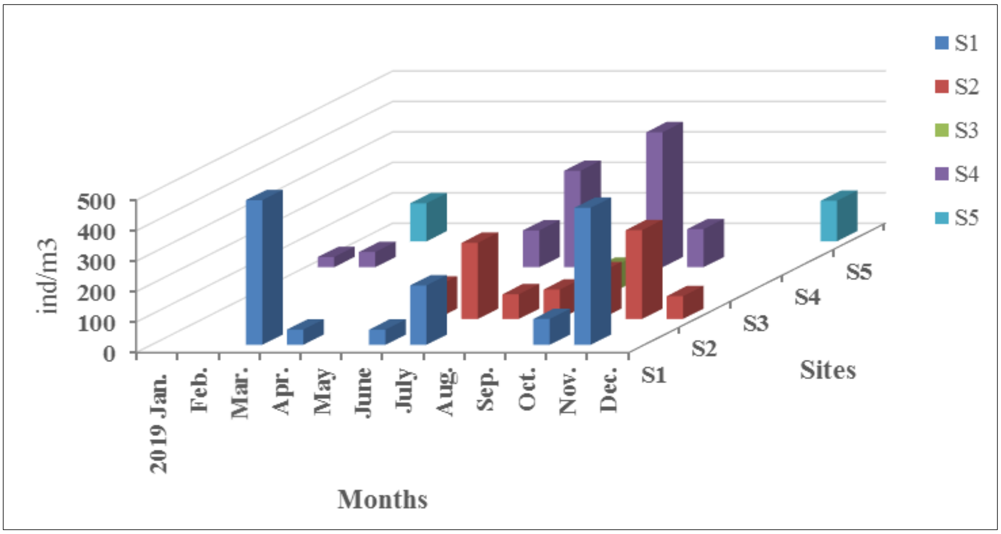


Figure 10: Densities of *Paracyclops fimbriatus* during the study period.

Fuentes-Reinés et al. (2013) reported that the frequent occurrence of *Halicyclops* sp. (Figure 11) which occurred frequently in study area may be due to its cosmopolitan distribution and its favor to brackish waters in rivers, ponds and lakes.

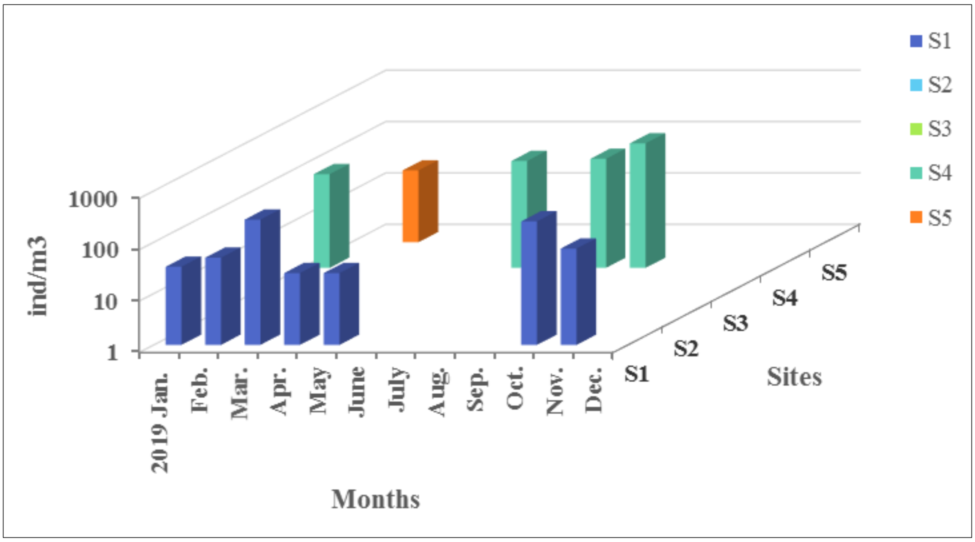


Figure 11: Densities of *Halicyclops* sp. during the study period.

In view of all that has been so far mentioned from the present investigation and the previous concerned studies, it is clear that the dam has affected on occurrence and constancy of most zooplankton species. This could be due to the reservoirs, even with short water retention times, which led to high presence of pelagic zooplanktons. Also, reservoirs provide a place for drifting pelagic zooplanktons and to proliferate in sites downstream the dam (Czerniawski & Kowalska-Góralska, 2018).

It was concluded that the changes in hydrological conditions from the current water in site 1 to limnetic basins in site 2 (the dam reservoir), then back to current water at sites 3, 4 and 5 downstream dam, had a significant impact on the spatial composition of the copepod community.

Acknowledgement

The authors appreciated the support of staff of Fish Environment and Diseases Laboratory, Department of Fisheries, Agricultural Research Directorate, Ministry of Science and Technology, Iraq to accomplish this research.

References

Abbas, E.K.; Nashaat, M.R.; Moftin, F.S. & Ali, E.H. (2017). Distribution and occurrence of Copepoda in Tigris River, and effect of Diyala River on its bodiversity. Eur. Acad. Res., 4(10): 8561-8580.

Abdul-Wahab, S. & Rabee, A.M. (2015). Ecological factors affecting the distribution of the zooplankton community in the Tigris River at Baghdad region, Iraq. Egypt. J. Aquat. Res., 41(2): 187-196.

Abed, I.F. & Nashaat, M.R. (2018). Species composition, abundance, biodiversity and temporal variations of Rotifera in the Dejiala River, Southern Iraq. Biochem. Cell. Arch., 18(2): 1877-1886.

Ajeel, S.G.; Abdulla, S.B. & Mohammad, H. (2005). Abundance and distribution of the zooplankton in the Garmat-Ali River. Basrah J. Agric. Sci., 17(1): 167-178.

Akbar, M.M. (2013). Ecological survey of Al-Gharaf Canal at Thi Qar Province, Iraq. Marsh Bull., 8(1): 1-17.

Ala Allah, S.K.; Rasheed, K.A. & Nashaat, M.R. (2015). Study of cladocera invertebrates diversity in Al-Shamyia River- Iraq. J. Al-Qadisiyah Pure Sci., 20(1): 53-61.

Al-Bahathy, I.A. & Nashaat, M.R. (2021). Impact of Hindiya Dam on Rotifera community of Euphrates River on the Northern of Babil Governorate, Iraq. Iraqi J. Sci., 62(9): 2872-2886. DOI:10.24996/ijs.2021.62.9.4. .

Ali, L.A. (2010). Seasonal variation in physico-chemical properties and zooplankton biomass in Greater Zab River, Iraq. Jordan J. Biol. Sci., 3(3): 115-120.

Al-Keriawy, H.A. (2014). A study of biodiversity indices to assessment the zooplankton community in the Kuffa River- Iraq. Ph. D. Thesis, Coll. Educ., Univ. Qadisiya: 174 pp. (In Arabic).

Al-Lami, A.; Bassat, S.F. & Nashaat, M.R. (2004). Comparative ecological study of zooplankton in different salinity aquatic ecosystems mid of Iraq. Ibn Al-Haitham J. Pure Appl. Sci., 17(1): 1-16. (In Arabic).

Al-Nimrawee, A.M.R. (2002). Effect of Al-Qadisia Dam on some ecological factors downstream Euphrates River with refernce to zooplankton and benthic invertebrates. M. Sc. Thesis, Coll. Sci., Univ. Baghdad: 83 pp. (In Arabic).

Al-Shamy, N.J. (2016). Ecological study on zooplankton community and the impact of Kut Dam on its biodiversity in Tigris River, Iraq. M. Sc. Thesis, Coll. Sci., Univ. Wasit: 157 pp. (In Arabic).

Błędzki, L.A. & Rybak, J.I. (2016). Freshwater crustacean zooplankton of Europe: Cladocera and Copepoda (Calanoida, Cyclopoida) key to species identification, with notes on ecology, distribution, methods and introduction to data analysis. Springer Int. Publ., Switzerland: 918 pp. DOI:10.1007/978-3-319-29871-9.

Branco, C.W.; Silveira, R.D. & Marinho, M.M. (2018). Flood pulse acting on a zooplankton community in a tropical river (Upper Paraguay River, Northern Pantanal, Brazil). Fundam. Appl. Limnol., 192(1): 23-42.

Brandl, Z. & Prazakova, M. (2002). Impact of predation by cyclopoides copepods (Copepoda: Cyclopoida) on zooplankton in a carp pond in Czech Republic. Acta Soc. Zool. Bohem., 66: 169-175.

Czerniawski, R. & Domagała, J. (2014). Small dams profoundly alter the spatial and temporal composition of zooplankton communities in running waters. Int. Rev. Hydrobiol., 99(4): 300-311.

Czerniawski, R. & Kowalska-Góralska, M. (2018). Spatial changes in zooplankton communities in a strong human-mediated river ecosystem. Peer J., 6: e5087. DOI:10.7717/peerj.5087.

Czerniawski, R. & Sługocki, Ł. (2017). Analysis of zooplankton assemblages from man-made ditches in relation to current velocity. Oceanol. Hydrobiol. Stud., 46(2): 199-211.

Czerniawski, R.; Pilecka-Rapacz, M. & Domagała, J. (2013). Zooplankton communities of inter-connected sections of Lower River Oder (NW Poland). Open Life Sci., 8(1): 18-29.

Czerniawski, R.; Sługocki, L. & Kowalska-Góralska, M. (2017). Effects of beaver dams on the zooplankton assemblages in four temperate lowland streams (NW Poland). Biologia, 72(4): 417-430.

Dejen, E.; Vijverberg, J.; Nagelkerke, L. & Sibbing, F. (2004). Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in a large tropical lake (L. Tana, Ethiopia). Hydrobiologia, 513: 39-49.

Donohue, I. & Molinos, J.G. (2009). Impacts of increased sediment loads on the ecology of lakes. Biol. Rev., 84(4): 517-531.

Dražina, T.; Špoljar, M.; Primc, B. & Habdija, I. (2017). Distribution of rotifers and other meiofauna in the bryophytes and hyporheic zone of a karst hydrosystem- an example of a nested community. Mar. Freshw. Res., 68(1): 43-52.

Edmondson, W. (1959). Freshwater biology, 2nd edition. John Wiley and Sons, New York: 1248 pp.

Fuentes-Reinés, J.M.; Zoppi de Roa, E. & Torres, R. (2013). Calanoida and Cyclopoida (Copepoda: Crustacea) from Ciénaga Grande de Santa Marta, Colombia. Métodos Ecol. Sist., 8(2): 54-103.

Gayosso-Morales, M.A.; Nandini, S.; Martínez-Jeronimo, F.F. & Sarma, S.S. (2017). Effect of organic and inorganic turbidity on the zooplankton community structure of a shallow waterbody in Central Mexico (Lake Xochimilco, Mexico). J. Environ. Biol., 38(6): 1183-1196.

Gayosso-Morales, M.A.; Nandini, S.; Martínez-Jeronimo, F.F. & Sarma, S.S. (2019). Fish-mediated zooplankton community structure in shallow turbid waters: A mesocosm study. Wetlands Ecol. Manag., 27(5-6): 651-661.

Grabowska, M.; Ejsmont-Karabin, J. & Karpowicz, M. (2013). Reservoir-river relationships in lowland, shallow, eutrophic systems: An impact of zooplankton from hypertrophic reservoir on river zooplankton. Pol. J. Ecol., 61(4): 759-768.

Haberman, J. & Haldna, M. (2017). How are spring zooplankton and autumn zooplankton influenced by water temperature in a polymictic lake? Proc. Est. Acad. Sci., 66(3): 264-278. DOI:10.3176/proc.2017.3.03.

Hassan, H.A.; Nashaat, M.R. & Rasheed, K.A. (2014). Study biodiversity of Cladocera in the Kuffa River-Iraq. J. Al-Qadisiyah Pure Sci., 19(4): 105-117.

Havel, J.E.; Medley, K.A.; Dickerson, K.D.; Angradi, T.R.; Bolgrien, D.W.; Bukaveckas, P.A. & Jicha, T.M. (2009). Effect of main-stem dams on zooplankton communities of the Missouri River (USA). Hydrobiologia, 628(1): 121-135.

Hussain, N.A. (2014). Biotopes of Iraqi marshlands. Difaf Publ., Basrah: 432 pp. (In Arabic).

Ibrahim, S.S. (2005). Biological and diversity of Invertebrates in Al-Dagara and Al-Diwaniya Rivers/ Iraq. Ph. D. Thesis, Coll. Educ., Al-Qadisiya Univ.: 177 pp. (In Arabic).

Jaccard, P. (1908). Nouvelles researches sur la distribution florale. Bull. Soc. Vaud. Sci. Nat., 44: 223-270.

Jones, S.; Carrasco, N. & Perissinotto, R. (2015). Turbidity effects on the feeding, respiration and mortality of the copepod *Pseudodiaptomus stuhlmanni* in the St. Lucia Estuary, South Africa. J. Exp. Mar. Biol. Ecol., 469: 63-68.

Kushawaha, V.B. & Agrahari, M. (2014). Effect of domestic sewage on zooplankton community in River Rapti at Gorakhpur, Indian J. Zool., 9(2): 86-92.

Lees, A.C.; Peres, C.A.; Fearnside, P.M.; Schneider, M. & Zuanon, J.A. (2016). Hydropower and the future of Amazonian biodiversity. Biodivers. Conserv., 25(3): 451-466.

Lévesque, S.; Beisner, B.E. & Peres-Neto, P.R. (2010). Meso-scale distributions of lake zooplankton reveal spatially and temporally varying trophic cascades. J. Plankton Res., 32(10): 1369-1384.

Long, S.M.; Ismail, N. & Chukong, L.N. (2014). Freshwater zooplankton of Bakun Dam Sarawak. Malaysia. Asian J. Biol. Life Sci., 3(2): 120-124.

Margalef, R. (1968). Perspectives in ecological theory. Univ. Chicago Press, Chicago, III: 11 pp. DOI:10.4319/lo.1969.14.2.0313.

Merhoon, K.; Nashaat, M.R. & Alkam, F.M. (2017). Environmental and vertical distribution study of zooplankton in Al-Diwaniyah River/ Iraq. J. Biodivers. Environ. Sci., 10(6): 2017-228.

Mutin, G. (2003). Le Tigre et l'Euphrate de la discorde. Vertigo, 4(3): 59-70. (In French). DOI:10.4000/vertigo.3869.

Mwagona, P.C.; Chengxue, M. & Hongxian, Y. (2018). Seasonal dynamics of zooplankton functional groups in relation to environmental variables in Xiquanyan Reservoir, Northeast China. Ann. Limnol. - Int. J. Limnol., 54(33): 1-13. DOI:10.1051/limn/2018024.

Nashaat, M.R. (2010). Impact of Al-Durah Power Plant effluents on physical, chemical and invertebrates biodiversity in Tigris River, Southern Baghdad. Ph. D. Thesis, Coll. Sci., Univ. Baghdad: 183 pp.

Nashaat, M.R.; Rasheed, K.A. & Hassan, H.A. (2016). Rotifera abundance and species diversity in Al-Kufa River, Iraq. Global J. Sci. Front. Res., 16(5) Version I: 49-58.

Nashaat, M.R.; Abbas, E.K.; Ali, E.H., & Moftin, F.S. (2015). Impact of Al-Rasheed Power Plant effluents on Cladocera fauna biodiversity in Tigris River, Southern Baghdad. lraqi J. Biotechnol., 14(2): 243-254.

Nashaat, M.R.; Ali, E.H.; Abbas, E.K. & Moftin, F.S. (2013). Impact of Al-Rasheed Power Plant effluents on Rotifera biodiversity at Tigris River, Southern Baghdad. Proc. 6th Natl. Conf. Environ. Nat. Res, October 29-31 for the Environ. Dept., Coll. Sci., Univ. Basrah: 122-135.

Nashaat, M.R.; Moftin, F.S.; Abbas, E.K. & Ali, E.H. (2021). Occurrence and composition of copepodes in Tigris River, Southern Baghdad, and impact of Al-Rasheed Power Plant on its Biodiversity. Ibn Al-Haitham Int. Conf. Pure Appl. Sci. (IHICPS). IOP Publ., J. Physics: Conf. Ser., 1879, 022022. DOI:10.1088/1742-6596/1879/2/022022.

Neves, I.F.; Rocha, O.; Roche, K.F. & Pinto, A. (2003). Zooplankton community structure of two marginal lakes of the River Cuibá (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. Braz. J. Biol., 63: 329-343.

Odum, E.P. (1971). Fundamentals of Ecology. 3rd edition, W.B. Saunders Co., Philadelphia: 574 pp.

Okorafor, K.A.; Andem, A.B.; Mowang, D.A. & Akpan, U.U. (2013). Diversity and spatial distribution of zooplankton in the intertidal regions of Calabar River, Cross River State, Nigeria. Adv. Appl. Sci. Res., 4(4): 224-231.

Pielou, E.C. (1977). Mathematical ecology. John Wiley and Sons, New York: 385 pp.

Pinto, J.F. (2018). Zooplankton dynamics and water quality of the reservoirs from the Alqueva Irrigation System. M. Sc. Thesis, Ciênc. Univ.: 44 pp. (In Portuguese).

Poff, N.L.; Olden, J.; Merritt, D. & Pepin, D. (2007). Homogenization of regional river dynamics by dams and global biodiversity implications. Proc. Natl. Acad. Sci., 104(14): 5732-5737.

Portinho, J.L.; Perbiche- Neves, G. & Nogueira, M.G. (2016). Zooplankton community and tributary effects in free- flowing section downstream a large tropical reservoir. Int. Rev. Hydrobiol., 101(1-2): 48-56.

Rabee, A.M. (2010). The effect of Al-Tharthar-Euphrates Canal on the quantitative and qualitative composition of zooplankton in Euphrates River. J. Al-Nahrain Univ., 13(3): 120-128.

Radi, A.; Al-Lami, A.A.; Al-Rudainy, A.M. & Nashaat, M.R. (2005). Distribution and composition of zooplankton in Euprates River near Al-Musaib Power Station. Iraqi J. Aquac., 2: 143-154. (In Arabic).

Rasheed, K.; Nashaat, M.R. & Ala Allah, S.K. (2016). Studies of rotifers community structure in Al-Shamiah River- Hilla/ Iraq. Global J. Sci. Front. Res., 16(5) Version I: 68-77.

Sabri, A.W.; Ali, Z.H.; Shawkat, S.F.; Thejar, L.A.; Kassim, T.I. & Rasheed, K.A. (1993). Zooplankton population in the River Tigris: Effects of Samarra Impoundment. Regul. Rivers: Res. Manag., 8(3): 237-250.

Salman, R.S. (2015). Ecology and diversity study of zooplankton in Al-Gharraf River, Wasit- Iraq. M. Sc. Thesis, Coll. Sci., Univ. Wasit: 155 pp. (In Arabic).

Serafim Jr. M.; Lansac-Tôha, F.A.; Paggi, J.C.; Velho, L.F.M. & Robertson, B. (2003). Cladocera fauna composition in a river-lagoon system of the upper Paraná River floodplain, with a new record for Brazil. Braz. J. Biol., 63(2): 349-356.

Shah, J. & Pandit, A.K. (2013). Diversity and abundance of cladoceran zooplankton in Wular Lake, Kashmir Himalaya. Res. J. Environ. Earth Sci., 5(7): 410-417. DOI:10.19026/rjees.5.5668.

Shannon, C.E. & Weaver, W. (1949). The mathematical theory of communication. Univ. Illions Press, Urbana: 125 pp.

Sharma, S.S.; Vyas, A.; Solnki, C.M.; Sharma, D.; Nair, S. & Sengupta, T. (2010). Population dynamics and seasonal abundance of zooplankton community in Narmada River (India). Researcher, 2(9): 1-9.

Simões, N.R.; Nunes, A.H.; Dias, J.D.; Lansac-Tôha, F.A.; Velho, L.F. & Bonecker, C.C. (2015). Impact of reservoirs on zooplankton diversity and implications for the conservation of natural aquatic environments. Hydrobiologia, 758(1): 3-17.

Sleem, S. & Hassan, M.M. (2010). Impact of pollution on invertebrates biodiversity in the River Nile associated with Dahab and El-Warrak islands, Egypt. Egypt. Int. J. Environ. Sci. Eng., 1: 15-25.

Smith, D.G. (2001). Pennaks freshwater invertebrates of the United States. 4th edition, John Wiley and Sons Inc., New York: 664 pp.

Thorp, J.H. & Rogers, D.C. (2014). Ecology and general biology, Thorp and Covich's freshwater invertebrates, 4th edition. Acad. Press, New York: 1118 pp.

Tranter, D.J.; Bulleid, N.C.; Campbell, R.; Higgins, H.W.; Rowe, F.; Tranter, H.A. & Smith, D.F. (1981). Nocturnal movements of phototactic zooplankton in shallow waters. Mar. Biol., 61(4): 317-326.

Vadstein, O.S.; Lippert, B.; Løseth, K.; Roederer, W.; Sundt-Hansen, L. & Olsen, Y. (2004). Moderate increase in the biomass of omnivorous copepods may ease grazing control of planktonic algae. Mar. Ecol. Prog. Ser., 270: 199-207.

Vorosmarty, C.; McIntyre, P.; Gessner, M.; Dudgeon, D.; Prusevich, A.; Green, P.; Glidden, S.; Bunn, S.E.; Sullivan, C.A.; Liermann, C.R. & Davies, P. (2010). Global threats to human water security and river biodiversity. Nature, 467(7315): 555-556.

Wu, X.; He, D.; Yang, G.; Ye, L.; Zhu, J.H. & Hu, J. (2014). Seasonal variability of water quality and metazooplankton community structure in Xiaowan Reservoir of the upper Mekong River. J. Limnol., 73(1): 167-176.

Zhao, K.; Song, K.; Pan, Y.; Wang, L.; Da, L. & Wang, Q. (2017). Metacommunity structure of zooplankton in river networks: Roles of environmental and spatial factors. Ecol. Indic., 73: 96-104.

Zhou, S.; Tang, T.; Wu, N.; Fu, X. & Cai, Q. (2008). Impacts of a small dam on riverine zooplankton. Int. Rev. Hydrobiol., 93(3): 297-311.