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IMPACT OF THARTHAR ARM WATER ON COMPOSITION AND DIVERSITY OF COPEPODA IN TIGRIS RIVER, NORTH OF BAGHDAD CITY, IRAQ

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ABSTRACT

This study is considered to be the first on this sector of Tigris River after 2003, to evaluate the effect of Tharthar Arm on the composition and diversity of Copepoda in Tigris River. Six sampling sites were selected; two on the Tharthar Arm and four sites along the Tigris River, one before the confluence as a control site and the others downstream the confluence; thirty-five copepod taxa were recorded, 34 taxa in the Tigris River and 25 taxa in the Tharthar Arm.

The highest density of Copepoda was 265584.2 Ind./m^3 in the site 2 at Tharthar Arm lead to an increasing in Copepoda density in the Tigris River from 63878.2 Ind./m3 in site 1 before the confluence to 127198.3 Ind./m3 in site 4 immediately downstream the confluence. Also, the mean values of richness index and diversity index increased from 1.71 and 0.98 bit/Ind. in site 1 before the confluence to 2.08 and 1.00 bit/Ind. in site 4 below the confluence, respectively. Moreover, the highest similarity percentage was between sites 3 and 4 reached 87.83% while, the lowest percentage was between the sites 1 and 2 recorded 65.41%. For constancy index the highest value was 9 at the site 6 whereas the lowest value was 2 at site3.

Key words: Biodiversity, Copepoda, River Confluences, Tharthar Arm, Tigris River.

INRODUCTION

River channel confluences play a major role in the dynamics of all fluvial systems and are ubiquitous, fundamental elements of natural drainage networks (Parsons *et al*., 2008; Sukhodolov *et al*., 2010). Rivers at channel confluences produces a complex hydrodynamic and morphodynamic environment within fluvial systems; inside the confluence the tributaries flows mutually deflect each other, this deflection outcome from pressure gradients created by the spatial pattern of water-surface elevations that steers the confluent flows into the receiving channel. The portion of the river system which is affected by merging of flows at a junction is defined as Confluence Hydrodynamic Zone (CHZ). The four common factors that influence CHZ, the symmetry of the junction, the junction angle, the momentum flux ratio of the incoming flows, and channel bed morphology (Rhoads, 2020).

The name of subclass Copepoda comes from Greek words kope for oar and podos for foot, and refers to the flat, paddle-like swimming legs (Støttrup, 2003). Copepods are one of the most abundant metazoans on aquatic ecosystems, with over 14,000 known species, but approximately 3000 species inhabit freshwater (Turner, 2004 ; Suárez-Morales *et al*., 2020). Copepods are found in a wide variety of aquatic environments, ranging from the benthic, littoral, and pelagic waters of lakes and oceans, to swamps, wetlands, marshes, large rivers, and temporary ponds (Reid and Williamson, 2010 ; Suárez-Morales *et al*., 2020).

The copepods also formed one of the most components of the crustaceans community in the Iraqi waters; AL-Keriawy *et al*. (2017) recorded 9 taxa of copepods in the Hilla River, the highest number was 850 Ind./m^3 recorded in summer whereas the lowest number was 100 Ind./m^3 in winter. Abbas *et al*. (2017) recorded 40 Copepoda taxa in both Tigris and Diyala Rivers, including 17 taxa for Cyclopoida, 13 taxa for Calanoida, 8 taxa for Harpacticoida, 2 taxa for parasitic copepods and 1 for Copepoda larvae. Abed (2018) found that Copepoda density in the Dejiala River more than other zooplankton groups, it reached 46% flowed by Rotifera 42% and Cladocera 12%, related that to high density of immature stages represented six naupliar stages and five Copepodite stages. Also, Maytham *et al*. (2019) mentioned that copepods were the major component of zooplankton in Shatt Al-Arab River with a percentage of 81% after that Rotifers 18% and Cladocerans 1%. In addition, Ajeel *et al*. (2019) showed that Copepoda was dominant in the Tigris River Northern of Basrah, constituted about 43.8% of the total microcrustaceans.

Copepods play an important role in aquatic food webs as primary and secondary consumers. Most are omnivorous or herbivorous, consuming foods such as detritus, pollen, bacteria, and microalgae, but some groups (especially cyclopoids) are raptorial predators on other invertebrates such as protozoa, rotifers, nematodes, insect larvae; some large copepods can attack and eat small larval fish (Reid and Williamson, 2010; Suárez-Morales, 2015). Copepoda are used as live food for the early larval stages of many kinds of fishes in aquaculture throughout the world (Barroso *et al*., 2015) and they considered as the main food source for several planktophagous fishes and benthic invertebrates.

The aim of this study is to investigate the effect of Tharthar Arm on the density and diversity of Copepoda in Tigris River, northern of Baghdad City during 2020. Therefore, this study can be considered the first of its kind after 2003 in this sector of the Tigris River.

MATERIALS AND METHODS

Study Area

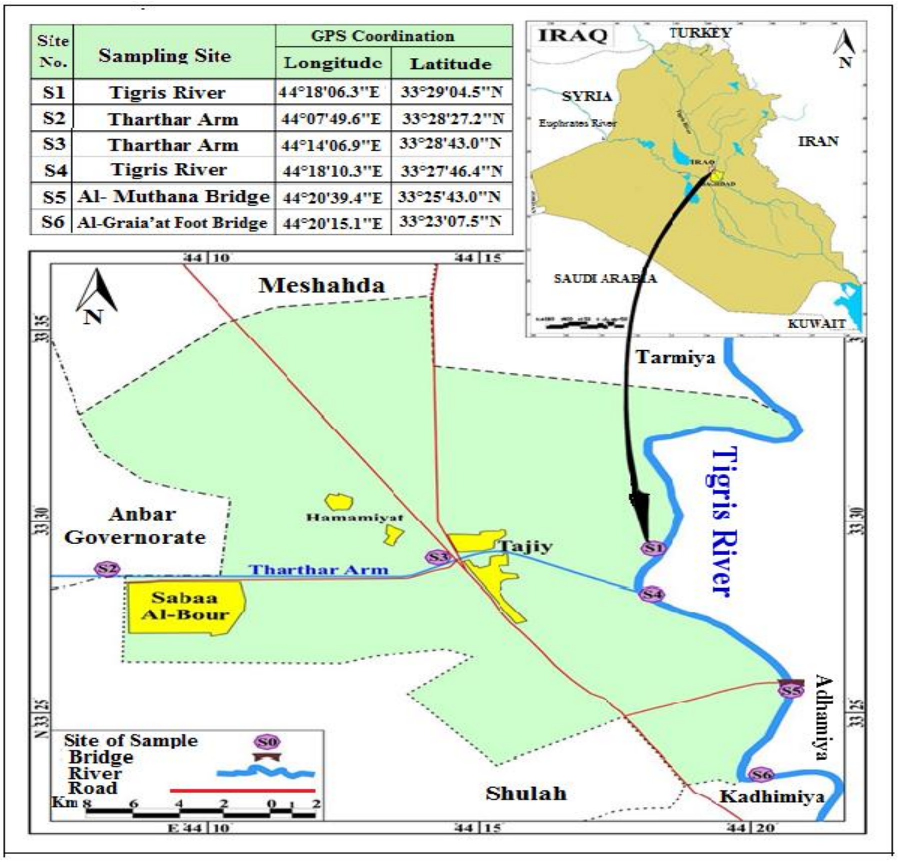
Tigris is one of the largest rivers in the western Asia; also it is considered one of the two most important twin rivers in Iraq. It rises in the southeastern parts of Turkey on the southern slopes of Taurus Mountains. It crosses Iraqi border 4 kilometers north of Fieshkhabur close Zakho City (Al-Ansari *et al*., 2018). Tigris River enters the Baghdad at a distance of 5 km north of Al-Muthana Bridge (Ali *et al*., 2012). The river's length from Al-Muthana Bridge to the confluence with the Diyala River is 49 km in Baghdad City (Nama, 2015).

Tharthar Arm or "Tharthar-Tigris Canal" is human-mediated river obtains it's characteristics from Tharthar Lake. It is diverted from the left side of division regulator which is located on Tharthar-Euphrates Canal; then it continues to the east for 65 km until confluence with Tigris River northern of Baghdad City. It is designed to discharge water up to 600 m^3/s to the Tigris River directly (Abdullah *et al*., 2019).

Study sites description

Six sites have been selected from which specimens were taken, as seen in Map (1). The first site located along the main stream of the Tigris River about 2.4 km before the confluence Tharthar Arm with Tigris River at 33°29'04.5"N latitude and 44°18'06.3"E longitude. This site was considered as reference station known as upstream Confluence Hydrodynamic Zone (CHZ). The second site located on Tharthar Arm above the entrance of Sabaa Al-Bour City at 33°28'27.2"N, 44°07'49.6"E about 20 km downstream the drop regulator on the arm. The third site located on Tharthar Arm before the entrance to main street leading up Sabaa Al-Bour City (33°28'43.0"N, 44°14'06.9"E) about 7.5 km before the confluence Tharthar Arm with Tigris. The fourth site located on Tigris River, about 300 meters from the joining of Tharthar Arm with Tigris River, known as immediately downstream the Confluence Hydrodynamic Zone (CHZ) at 33°27'46.4"N and 44°18'10.3"E. The fifth site lies in Al-Tajiy, near Al-Muthana Bridge area at 33°25'43.0"N, 44°20'39.4"E about 6 km below the confluence of Tharthar Arm with Tigris River. The sixth site located on Tigris River near Al-Graia'at Floating Bridge in Al-Kadhimiya City (33°23'07.5"N, 44°20'15.1"E) about 12.6 km downstream the confluence of Tharthar Arm with Tigris River. "Sites 5 and 6 known as downstream CHZ".

The rates of discharged water ranges from 474 m^3/s in April to 681 m^3/s in July for Tigris River. Whereas, in Tharthar Arm ranges from 83 m^3/s in August to 250 m^3/s in January (Diag.1) (The data obtained from Ministry of Water Resources, 2021. personal communication).



Site No.	Sampling Site	GPS Coordination	
		Longitude	Latitude
S1	Tigris River	44°18'06.3"E	33°29'04.5"N
S2	Tharthar Arm	44°07'49.6"E	33°28'27.2"N
S3	Tharthar Arm	44°14'06.9"E	33°28'43.0"N
S4	Tigris River	44°18'10.3"E	33°27'46.4"N
S5	Al- Muthana Bridge	44°20'39.4"E	33°25'43.0"N
S6	Al-Graia'at Foot Bridge	44°20'15.1"E	33°23'07.5"N

Map (1): Study sites on Tigris River and Tharthar Arm. (Map scale 1\100000. Source: Ministry of water Resources\ General Authority of Survey 2020).

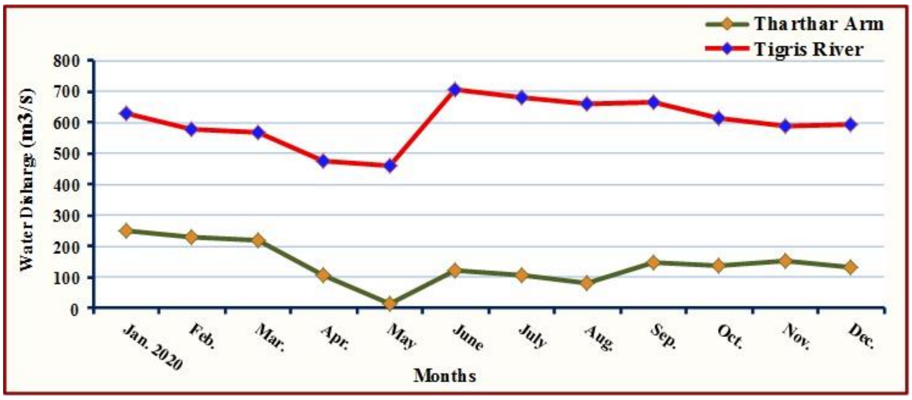


Diagram (1): Seasonal variation of water discharges in Tigris River and Tharthar Arm during 2020.

Sampling method

Samples were collected monthly from January to December 2020, by passing 45 liters of surface water through vertical planktonic net with a mesh size of 55 µm, mouth diameter 25 cm. All samples were preserved in 4% formalin; following sample condensation, the zooplankton was identified under a compound microscope (Type Kruss MBL 2100) to the lowest possible taxonomic unite by using Sedgewick-Rafter chamber: the rectangular cavity slide contains (50 mm long x 20 mm wide x 1 mm deep) exactly 1 ml of water sample (Baird *et al*., 2017). The sample was shaken well and 1 ml of it was transferred instantly to the cavity by using a graduated pipette. The coverslip was adjusted correctly to ensure that no air bubbles remained within.

$$\text{Copepods Ind. /L} = \frac{n}{\text{Volume of sample}} \text{ X } 1000$$

Where: n = No. of Copepods.

The method of species identification depended on differences in structures of the antennules and the fifth and sixth legs, number of urosomal segments, the large size of females against the males. Male copepod antennules are geniculate and modified for clutching the female during copulation, in male harpacticoids, cyclopoids, and gelyelloids, both first antennae are geniculate; while in male calanoids, usually, only the right antenna is geniculate. Second antennae of calanoids, harpacticoids, and gelyelloids are a biramous appendage (Støttrup, 2003; Reid and Williamson, 2010; Suárez-Morales, 2015; Suárez-Morales *et al*., 2020). Additionally, the keys of Edmondson (1959), Smith (2001) and Lee and Lee (2019) have been used for identification of taxa and the results expressed by the number of individuals in a cubic meter.

Some physicochemical characteristics conducted in the study sites directly, such as water temperature, salinity, pH and turbidity (Tab. 1). Water temperature, salinity and pH measured by HANA (HI9811). Turbidity was measured by the turbidity meter Jenwaw Company Model-6035. Dissolved oxygen and biological oxygen demand were measured by using Azide modification of Winkler titration method; Total Suspended Solids (TSS), total hardness, reactive phosphate and nitrate determined as described in standard methods (Baird *et al*., 2017).

Table (1): Physicochemical characteristics for Tigris River and Tharthar Arm during 2020. Minimum and maximum (First Line) mean and standard error (Second Line).

Parameters	Tigris River	Tharthar Arm		Tigris River			LSD Value
	S1	S2	S3	S4	S5	S6	
Water Tempe.(˚C)	10-27 18.90±1.717	12.1-28.2 21±1.8078	12.4-28.4 21.34±1.837	10.7-28.7 20.916±1.838	10.3 - 28.5 20.23±1.78	10.6 - 28.5 20.35±1.819	2.72 NS
Turbidity (NTU)	8.16-131 34.75±9.603 a	6.2-18.37 11.53±1.300 b	3.68-22.33 13.503±1.71 b	10.9-114 28.65± 8.094 a	11.73-118 32.49±8.238 a	12.2-137 34.26±9.636 a	8.55 *
Salinity (‰)	0.339-0.710 0.504±0.031	0.4224-1.324 0.718±0.074	0.4224-1.286 0.7382±0.07	0.4224-0.704 0.603 ± 0.027	0.4352-0.6208 0.531 ± 0.015	0.396-0.6144 0.519 ± 0.01	0.281 NS
pH	7.38-7.91 7.642 ± 0.049	7.35-7.88 7.66 ± 0.055	7.34-7.93 7.68 ± 0.061	7.44-7.89 7.692 ±0.051	7.51-7.91 7.69 ± 0.425	7.41-7.84 7. 63]±0.044	0.944 NS
DO (mg/L)	8 - 13.1 9.891 ± 0.49	7.7 - 13.6 10.35 ± 0.499	7.8 - 11.9 9.691 ± 0.428	7.5 - 12.8 9.96 ± 0.468	7 - 11 9.1 ± 0.38	6.5 - 11.3 9.35 ± 0.44	1.26 NS
POS (%)	93.61-122.3 104.82±2.49	91.44-131.74 114.88±3.44	94.43-124.70 107.96±2.58	94.10-123.68 110.20±2.67	90.90-110.54 100.20±1.67	84.41-131.85 102.75 ±3.94	13.94 NS
BOD_5 (mg/L)	1.4-3.6 2.35 ± 0.23	0.9-3.5 2.4 ± 0.197	1-2.9 2.108 ± 0.21	1.5-3.6 2.38 ± 0.193	0.9 -4.1 2.18 ±0.228	1.1-4.3 2.2083±0.239	0.579 NS
Total Hardness ($mgCaCO_3/L$)	284-440 354.66±13.2 b	304-800 516.66±42.96 a	288-960 518.33±51.40 a	300-556 431.33±27.16 ab	288-468 369.33 ±13.45 b	320-380 358.25±5.57 b	142.3 *
NO_3^- (mg/L)	0.6817-1.074 0.9654±0.038	0.317-1.293 0.588±0.0865	0.2698-1.226 0.533±0.082	0.2913-0.93 0.497±0.055	0.49-0.911 0.6577±0.033	0.58-0.998 0.7704±0.033	0.366 NS
PO_4^{2-} (mg/L)	0.00337-0.02 0.0115±0.001	0.0002-0.0193 0.0061±0.004	0.0002-0.016 0.0070±0.001	0.0015-0.019 0.0064±0.001	0.0015-0.0237 0.0099±0.001	0.00025-0.022 0.0125±0.001	0.0109 NS
TSS (mg/L)	1-118 34.25±8.615 a	4-22 12.25±1.557 b	6-29 15.16±1.650 b	2-102 25.91±7.753 a	4-109 34.91±8.056 a	1-125 34±8.934 a	9.516 *
Means having with the different letters in same column differed significantly. * (P≤0.05), NS: Non-Significant.							

Ecological Indices were counted as follows: Relative Abundance Index (Ra): This index calculated depending the equitation found in Omori and Ikeda (1984).

$$Ra = N/Ns \text{ X } 100$$

Where:

N = Total number of individuals of each taxon in sample.

Ns = Total number of individuals in the sample.

The results expressed as percentage, dominant species (D), more than 70%, abundant species 40- 70% (A), less abundant 10-39% (La), rare species less (R) than 10%.

Constancy index (S): the presence and frequency of each species, calculate depending the formula found in Serafim *et al*. (2003).

$$S = n/N \times 100$$

Where:

n = Number of samples in which the species occurred.

N = Total number of the samples.

The results expressed as percentage, constant species (C) more than 50%, accessory species (Ac) 26%-50%, accidental species (A) 1-25%.

Jaccard Presence-community index: This index was calculated according to the formula found in Mueller-Dombois and Ellemberg (1974). Species richness index (D): This index was calculated monthly by using the formula present in Margalef (1968). Species evenness index (J): was measured based on the equitation found in Neves *et al*. (2003). Shannon-Weiner diversity index (H): the values of this index were calculated monthly according to the formula stated in Shannon and Weaver (1949). Also, the result is represented as the unit bit/Ind. as a bit equal one piece of information. Low diversity is indicated by values less than 1 bit/Ind. whereas, high diversity is indicated by values more than 3 bits/Ind. (Proto-Neto, 2003).

RESULTS AND DISCUSSION

Species composition

Thirty-five taxa of Copepoda were recorded 34 taxa in Tigris River and 25 taxa in Tharthar Arm (Tab.2). In Tigris River results showed that the genus *Acanthocyclops* included 5 species *Acanthocyclops* sp., *Acanthocyclops capillatus* (Sars, 1863), *Acanthocyclops exilis* (Coker, 1934), *Acanthocyclops venustoides* (Coker, 1934) and *Acanthocyclops vernalis* (Fischer, 1853). *Paracyclops* included 4 species *Paracyclops* sp., *P. affinis* (Sars, 1863), *P. fimbriatus* (Fischer, 1853) and *P. phaleratus* (Koch, 1838). *Eucyclops* included 3 species *Eucyclops agilis* (Koch, 1838), *E. speratus* (Lilljeborg, 1901) and *E. macrurus* (Sars,1863). *Aglaodiaptomus* included 2 species *Aglaodiaptomus lintoni* (Forbes, 1893) and *Aglaodiaptomus marshianus* Wilson, 1953. *Megacyclops* included 2 species *Megacyclops latipes* (Lowndes, 1927) and *Megacyclops magnus* (Marsh, 1920) and other identified genera occurred with one species. While, in the Tharthar Arm the genus *Paracyclops* included 4 species *Paracyclops* sp., *P. affinis* (Sars, 1863), *P. fimbriatus* (Fischer, 1853) and *P. phaleratus* (Koch, 1838). *Acanthocyclops* included 3 species *Acanthocyclops capillatus* (Sars, 1863), *Acanthocyclops exilis* (Coker, 1934) and *Acanthocyclops vernalis* (Fischer, 1853). *Eucyclops* included 2 species, *Eucyclops agilis* (Koch, 1838) and *E. speratus* (Lilljeborg, 1901) and other identified genera occurred with one species.

As well as, Copepoda dominated in the Tharthar Arm in terms of individual abundance, not in terms of species abundance. The large numbers of immature stages for different copepod species led to the dominance of copepod in the Tharthar Arm.

Table (2): Copepods distribution, Relative abundance (Ra) and Constancy index (S) in the Tharthar Arm and Tigris River during 2020.

	Taxa \ Sites	Relative abundance						Constancy					
		1	2	3	4	5	6	1	2	3	4	5	6
	Calanoida												
1	*Acanthodiaptomus denticornis* (Wierzejski, 1887)	R	-	R	R	R	-	A	-	A	A	A	-
2	*Aglaodiaptomus* sp.	-	-	-	R	-	-	-	-	-	A	-	-
3	*Aglaodiaptomus forbesi* Light, 1938	-	R	-	-	-	-	-	A	-	-	-	-
4	*Aglaodiaptomus lintoni* (Forbes, 1893)	-	-	-	R	-	-	-	-	-	A	-	-
5	*Aglaodiaptomus marshianus* Wilson, 1953	-	-	-	R	-	-	-	-	-	A	-	-
6	*Hesperodiaptomus franciscanus* (Lilljeborg, 1889)	-	R	R	R	R	R	-	Ac	A	Ac	A	A
7	*Sinodiaptomus sarsi* (Rylov, 1923)	R	R	R	R	R	R	A	A	A	A	A	A
8	Immature Calanoida	-	R	R	R	R	R	-	Ac	Ac	Ac	Ac	C
	Cyclopoida												
9	*Acanthocyclops* sp.	R	-	-	-	-	-	A	-	-	-	-	-
10	*A. capillatus* (Sars, 1863)	R	R	R	R	R	R	A	A	A	A	A	-
11	*A. exilis* (Coker, 1934)	R	R	R	R	R	R	Ac	Ac	A	Ac	Ac	C
12	*A. venustoides* (Coker, 1934)	R	-	-	-	R	R	A	-	-	-	A	A
13	*A. vernalis* (Fischer,1853)	R	R	R	-	-	R	A	A	A	-	-	A
14	*Eucyclops agilis* (Koch, 1838)	R	-	-	-	-	-	A	-	-	-	-	-
15	*Ectocyclops* sp.	R	R	R	R	R	R	Ac	C	Ac	Ac	Ac	Ac
16	*Eucyclops agilis* (Koch, 1838)	R	R	-	-	R	R	Ac	A	-	-	A	A
17	*E. speratus* (Lilljeborg, 1901)	-	-	-	R	-	-	-	-	-	A	-	-
18	*E.macrurus* (Sars,1863)	-	-	R	R	R	-	-	-	A	A	A	-
19	*Halicyclops* sp.	R	R	R	R	R	R	Ac	A	A	Ac	Ac	C
20	*Macrocyclops albdius* (Jurine, 1820)	-	-	-	R	-	-	-	-	-	A	-	-

21	*Megacyclops latipes* (Lowndes, 1927)	-	-	R	R	-	-	-	-	A	A	-	-
22	*Megacyclops magnus* (Marsh, 1920)	-	-	-	-	R	-	-	-	-	-	A	-
23	*Mesocyclops leuckarti* (Claus, 1857)	R	R	R	R	R	R	A	A	A	A	A	Ac
24	*Paracyclops* sp.	-	-	R	R	-	-	-	-	A	A	-	-
25	*P. affinis* (Sars, 1863)	-	-	R	R	R	R	-	-	A	Ac	A	A
26	*P. fimbriatus* (Fischer, 1853)	R	R	R	R	R	R	C	Ac	Ac	C	C	C
27	*P. phaleratus* (Koch, 1838)	R	R	R	R	-	-	A	A	Ac	A	-	-
28	*Thermocyclops hyalinus* (Rehberg, 1880)	-	-	-	R	-	R	-	-	-	A	-	A
29	*Cyclops* sp. (♂)	R	R	R	R	R	R	C	C	A	Ac	Ac	C
30	*Cyclops* sp.	R	R	R	R	R	R	Ac	A	C	C	C	Ac
31	Immature Cyclopodia	R	La	R	R	R	La	C	C	Ac	Ac	Ac	C
Harpacticoida													
32	*Nitokra lacustris* (Schmankevich, 1875)	R	R	R	R	R	R	Ac	Ac	Ac	C	Ac	C
33	Harpacticoida (♂)	R	-	-	-	-	-	A	-	-	-	-	-
34	Immature Harpacticoida	R	R	R	R	R	R	Ac	Ac	Ac	C	Ac	C
35	Nauplii of Copepoda	D	D	D	D	A	A	C	C	C	C	C	C
Parasitic Cyclopoida													
36	*Ergasilus* sp.	-	R	R	R	R	R	-	C	Ac	C	Ac	A

Where (D) dominant species, more than 70%, (A) abundant species 40-70 %, (La) less abundant 10-39 %, (R) rare species less than 10 %. Whereas, for constancy, (C) constant species more than 50%, (Ac) accessory species 26%-50%, (A) accidental species 1-25%.

Total Density and Relative Abundance Index (Ra) of Copepods

Diagram (2) shows the values of Copepoda density. At site 1 upstream CHZ, the values ranged from 444.3 to 12408.4 Ind./m3 in February and October, respectively. In the arm the density ranged from 817.7 in December to 173643 Ind./m3 in August. Whereas, the minimum and maximum values were 950 and 30879.6 Ind./m3 in March and February, respectively in site 4 at immediately downstream CHZ. While downstream CHZ, the lowest value was 793.2 Ind./m3 in February and the highest value was 22110 Ind./m3 in October. Moreover, high density of Copepoda in Thartar Arm increased the mean value of Copepoda density in Tigris River from 63878.2 Ind./m3 before the confluence to 127198.3 Ind./m3 at immediately downstream the confluence (Tab.3).

As for spatial variations, the highest density of Copepoda recorded at site 2 in the arm; while, the lowest value was at site1 (Diag. 2). This case may be related to the salinity which is increased in site 2 and decreased in site1. This view is confirmed by Hedayti *et al*. (2017) and Nguyen *et al*. (2020) found that the density of Copepoda increased with the increasing the salinity. Another reason behind the increasing of copepods in site 2. It its transported from lake (standing water regime) which is considered suitable environment for increasing this microcrustaceans (Wahl *et al*., 2008, Napiórkowski *et al*., 2019). Or due to large numbers of nauplii as shown in Diagram (3). Furthermore, low flow rates and residence of water in the arm and lake may be the cause behind the increasing of density in site 2 (Czerniawski and Domagała, 2012; Czerniawski *et al*., 2013).

Whereas, the lowest copepod density recorded at site 1, may be related to the high discharge rate (Diag. 2). Led to increasing the turbidity and suspended solids (Tab.1) which have a negative impact on copepods, blocked respiration and locomotive organs, as well reduced the light penetration which in turn decline in phytoplankton populations which are used as food source for Copepoda (Mitsuka and Henry, 2002). Also, we can see a longitudinal change in the density of Copepoda along the Tharthar Arm depending on the distance away from the Tharthar Lake. For this, the density was highest in site 2, compare with site 3.

Seasonally, the highest Copepoda densities noticed in summer followed by autumn were 173643 and 33017 Ind./m^3, respectively. While, the lowest density recorded in winter was 444.3 Ind./m^3 (Diag. 2). The highest copepods density in the summer may be attributed to the increasing of water temperature which in turn decline the rates of egg hatching times and development period of naupliar and copepodite stage. Furthermore; increased the rate of phytoplankton growth; the minimum densities for Copepoda in winter may be return to the decreased in water temperature below the optimal temperature this led to reduced metabolic rates of immature stages and the abundant of phytoplankton (Cook *et al*., 2007).

These results agreed with other studies conducted on Tigris River; Nashaat (2010) and Abdulwahab and Rabee (2015) found that Copepoda density in Tigris River increased during autumn and decreased in winter. Also, Czerniawski *et al*. (2013) showed that Copepoda density increased downstream the confluence of Western Oder Canal with the Eastern Oder Canal, and contributed 65% of total zooplankton. Related that to the low depth and slow current which suitable to increase copepod.

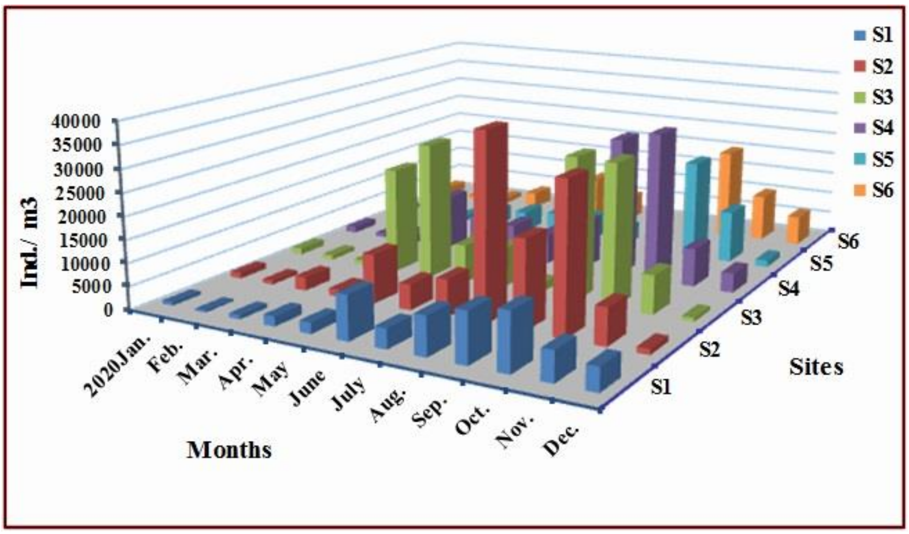


Diagram (2): Total densities of copepods in Tigris River and Tharthar Arm during 2020.

Diagram (3) and Table (2) detected the relative abundance index of most common Copepoda taxa in all studied sites during 2020. For Tigris River were nauplii had the highest percentages ratio followed by immature *Cyclops*, *Cyclops* sp. (♂), *Ectocyclops* sp., immature Calanoida, *Hesperodiaptomus franciscanus* (Lilljeborg, 1889), *Halicyclops* sp., *Nitocra lacustris* (Shmankevich, 1875), *Sinodiaptomus sarsi* (Rylov, 1923) and *Acanthocyclops exilis* (Coker, 1934). While, in the Tharthar Arm were nuplii followed by immature *Cyclops* and *H. franciscanus*, *Halicyclops* sp., *N. lacustris*, immature Calanoida and *Cyclops* sp.

The highest ratios of Copepoda taxa in site 1 upstream CHZ were nauplii followed by Immature *Cyclops*, *Cyclops* (♂), *Ectocyclops* sp., *Halicyclops* sp., *Acanthocyclops exilis* and *Cyclops* sp., with percentage 71%, 7%, 5% 4%, 2%, 2% and 1%, respectively. While, at site 2 were nauplii, immature *Cyclops*, immature Calanoid, *Paracyclops fimbriatus* and *Halicyclops* sp. with percentages 79%, 12%, 1%, 1% and 1%, respectively. At site 3 were nauplii, immature *Cyclops*, immature Calanoid, *Cyclops* sp. and *Ectocyclops* sp. with percentages 77%, 4%, 4%, 2% and 1%, respectively. Also, nauplii, immature *Cyclops*, immature Calanoid, *Sinodiaptomus sarsi*, *H. franciscanus*, *N. lacustris* and *Cyclops* sp. in site 4 with percentages 71%, 5%, 4%, 3%, 2%, 2% and 2%, respectively. At site 5 were nauplii, *Ectocyclops* sp., immature *Cyclops*, *Cyclops* (♂), *N. lacustris*, *P. fimbriatus* and *H. franciscanus* with percentages 61%, 11%, 7%, 4%, 3%, 2% and 1%, respectively. Whereas, the highest percentages in site 6 were 64%, 10%, 4%, 3%, 2%, 2%, 2% and 2% for nauplii, immature *Cyclops*, *Cyclops* (♂), *Halicyclops* sp., *N. lacustris*, *Cyclops* sp., *Ectocyclops* sp. and *Aglaodiaptomus forbesi*, respectively (Diag. 3).

These results agree with Al-Lami (1998) recorded that nuaplii of copepods were the most abundant in Tharthar Arm and Tigris River from October 1996 to December 1997, followed by *Cyclops* sp. *Halicyclops* sp., *Nitocra* sp., and *Ectocyclops* sp. Also, Al-Lami *et al*. (2005)

found that *Halicyclops* sp., *N. lacustris*, *P. fimbriatus* the most taxa abundant in Lower Zab Tributary and Tigris River. Also Rabee (2010) found that nauplii of Copepoda dominated in Al-Tharthar-Euphrates Canal and Euphrates River during 2009, followed by *Diaptomus* sp., *Cyclops* sp. and *Halicyclops* sp. Furthermore, Abdulwahab and Rabee (2015) indicated that *P. fimbriatus*, *P. affinis, Nitocra* sp., *Halicyclops* sp. and *Ectocyclops* sp. were the most abundant Copepoda taxa in Tigris River with high percentage of nuaplii related that to their ability to tolerate different environmental factors. Abbas *et al*. (2017) indicated that nuaplii of copepods were the most abundant in Tigris River and Diyala River followed by *P. fimbriatus*, *P. affinis*, *N. lacustris* and *Ectocyclops* sp.

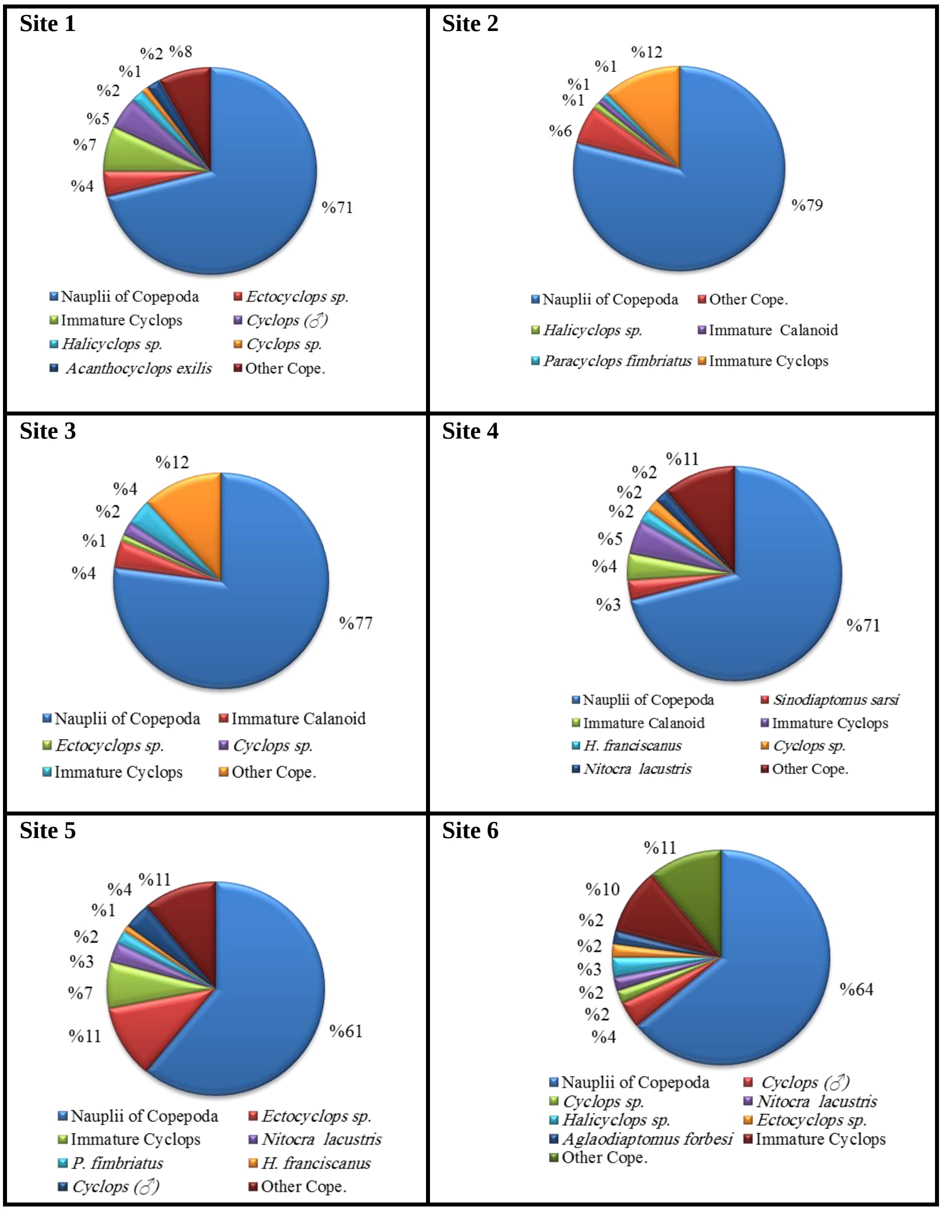


Diagram (3): The most dominant copepods in Tigris River and Tharthar Arm during 2020.

Ecological Indices

Species Richness Index (D)

Diagram (4) shows the values of species richness index for copepods during the study period. At site 1 upstream CHZ, the values were ranged from 0.81 to 3.22 in December and

September, respectively. In the arm the value ranged from 0.32 in December to 3.07 in July. Whereas, the minimum and maximum values were 0.31 in January and 3.05 in May at immediately downstream CHZ. While downstream CHZ, the lowest value was 0.35 in January and the highest value was 3.25 in October. In other terms, the average value of species richness index of Copepoda in Tigris River increased from 1.71 upstream the confluence to 2.08 at immediately downstream the confluence zone (Tab.3).

As for spatial variations, the lowest values of species richness index were on the Tharthar Arm; while, the highest values were at sites 1 upstream the main river (Diag. 4). This may be related to heterogeneity between the habitats of two rivers. This fact is proved by Karpowicz (2017) showed that heterogeneous habitats of the lowland river had higher crustacean species richness and vice versa. In this respect, Gao *et al*. (2013) observed that differences in ecological factors between habitats in the Lianjiang River determined the spatial distribution of crustacean species richness.

As for temporal variations, the lowest values of Copepoda recorded in winter; whereas, the highest values were in spring and autumn (Diag. 4). Low value of this index in winter may be related to the decreasing of water temperature which is the main reason for reduction of egg production and number of immature stages; as well as, reduced the density of phytoplankton. These findings corresponded with Hedayati *et al*. (2017) indicated that the values of species index for copepod decreased with the decreasing of water temperatures.

On the other hand, the values of this index raised in spring, this may be returned to the increasing of sunlight intensity and photosynthesis rates this in turn increases phytoplankton production which is subsequently increased Copepoda diversity (Hedayati *et al*., 2017).

Our results agreed with Abbas *et al*. (2017) found that unfavorable conditions in Diyala River reduced the values of Copepoda richness index. This in turn, decline this index in Tigris River downstream the confluence of two rivers.

Table (3): The averages values of species index, evenness index and Shannon -Weiner index with total density of Copepoda.

Copepoda						
Site / Index	**1**	**2**	**3**	**4**	**5**	**6**
D	1.71	1.60	1.37	2.08	1.78	2.02
J	0.52	0.46	0.49	0.47	0.52	0.52
H	0.98	0.85	0.87	1.00	1.01	1.10
Total Copepoda	63878.2	265584.2	147204.3	127198.3	93004.5	78376.6

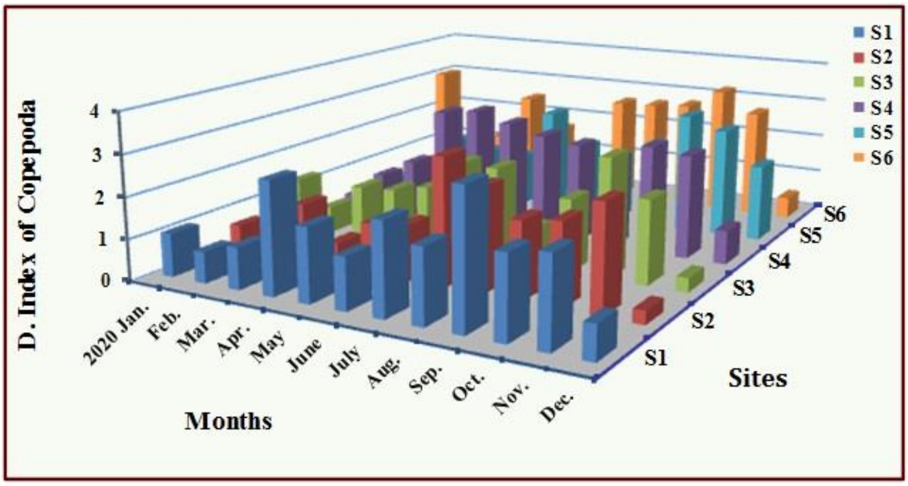


Diagram (4): Seasonal variations of richness index (D) of copepods in Tigris River and Tharthar Arm during 2020.

Species Evenness Index (J)

Diagram (5) presents the values of evenness index of Copepoda. At site 1 upstream CHZ it was ranged from 0.33 in August to 0.67 in February. In the Tharthar Arm, the lowest value was 0.18 in May and the highest value was 0.81 in December. Whereas, the minimum and maximum value of E index were ranged from 0.26 to 0.67 in January and November, respectively at immediately downstream CHZ. While, it was ranged from 0.15 in January to 0.82 in June downstream CHZ.

In another perspective, the low mean value of evenness index of Copepoda in the arm reduces their mean values in the Tigris River from 0.52 upstream CHZ to 0.47 in site 4 at immediately downstream CHZ. Then it returned to the first state reached 0.52 at site 6 after remove the effect of Tharthar water (Tab. 3).

For spatial variation, the lowest value was in site 2 on the arm, and the highest value was at site 6 near Graia'at Floating Bridge (Diag. 5). This may be returned to the effect of salinity which is increased in Tharhar Arm (0.7382‰) and decreased in the main river (0.504‰). This view is supported by Nguyen *et al*. (2020) indicated that salinity decreased evenness index of Copepoda. Other possible explanation is the differences in hydrological regimes and physicochemical parameters between two rivers (Vadadi-Fülöp, 2009; Gao *et al*., 2013; Karpowicz, 2017). For seasonal variation, the highest values were in winter recorded 0.82 and 0.81 in January and December, respectively. Whereas, the lowest value was in summer recorded 0.18 in May (Diag. 5). This might be related to the fact that solubility of oxygen in water increased with the decrease in temperature and vice versa with the increase of temperature. This view supported be Lee *et al*. (2021) stated that evenness index of copepod in Danshuei River in northwestern Taiwan increased during winter than other seasons.

Similar results were obtained by many Iraqi studies such as Rabee (2010) showed that evenness values of Copepoda ranged from 0.49 to 0.80 in Tharthar Euphrates Canal. Whereas, ranged from 0.53 to 0.71 in Euphrates River. Also, Abdulwahab and Rabee (2015) pointed that evenness values of Copepoda ranged from 0.36 to 1 in Tigris River depending on environmental conditions. Abbas *et al*. (2017) found the limited values of evenness index of Copepoda in Diyala River reduce their values in the Tigris River from 1.4 before the confluence to 0.9 below the confluence, related that to low concentration of DO and high amount of nutrient and organic matter which responsible for resident of few species with great densities.

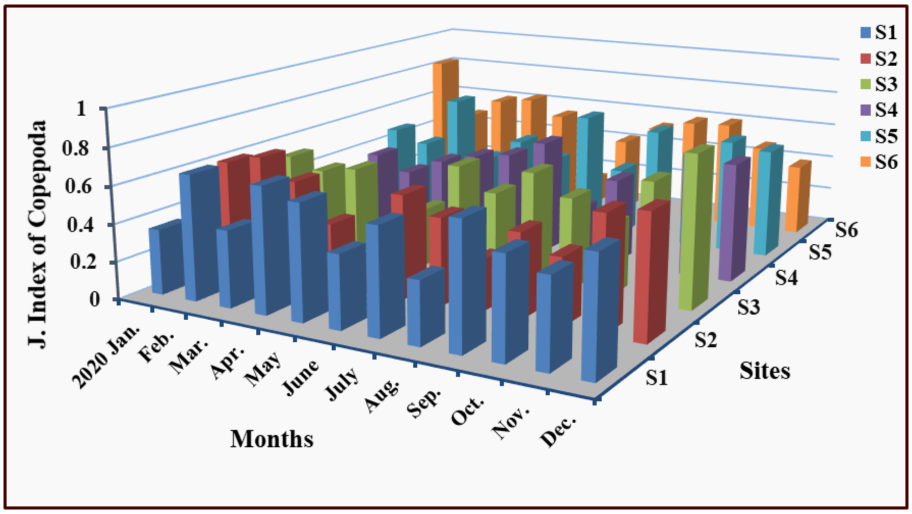


Diagram (5): Seasonal variations of Evenness Index (J) of Copepoda in Tigris River and Tharthar Arm, during 2020.

Shannon-Wiener Diversity Index (H')

Diagram (6) shows the values of Shannon-Weiner diversity index for copepods during the study period. At site 1 upstream CHZ, the value ranged from 0.48 to 1.73 bit/Ind. in January and September, respectively. In the arm the values were ranged from 0.32 bit/Ind. in May to 1.46 bit/Ind. in November. Whereas, the minimum and maximum values were 0.18 bit/Ind. in January and 1.61 bit/Ind. in November at immediately downstream CHZ. While, the lowest value was 0.17 bit/Ind. in June and the highest value was 1.97 bit/Ind. in January downstream CHZ. In other words, copepods diversity in the Tigris River more than in Tharthar Arm; the lowest average value in Tigris was 0.98 bit/Ind., while the highest average in the arm was 0.85 bit/Ind. (Tab.3).

For, spatial variation the highest values observed in the Tigris River at sites 1 and 6, whereas the lowest values were in the Tharthar Arm (Diag. 6). This may be related to heterogeneity among habitats (Karpowicz, 2017).

Seasonally, the maximum values were in winter while, the minimum values were in summer (Diag. 6). The reasoning for this may be due to the rising of DO in winter. These results coincided with the results of Abbas *et al*. (2017) and Li *et al*. (2020) they observed that the diversity index of copepods increased in winter and decreased summer related that to the rising of dissolved oxygen in winter and decline in summer.

Current study agree with other studies, Al-Lami *et al.* (2005) mentioned that low copepods diversity in Lower Zab Tributary decreased the diversity in Tigris River from 1.175 above the confluence to 1.085 bit/Ind. below the confluence. Abbas *et al*. (2017) they showed low Copepoda diversity in Diyala River decreased the diversity of Copepoda in Tigris River after the confluence of two rivers, related that to the bad water quality. Furthermore, Rabee (2010) observed Copepoda diversity of Euphrates River increased slightly after the confluence with Al-Tharthar-Euphrates Canal.

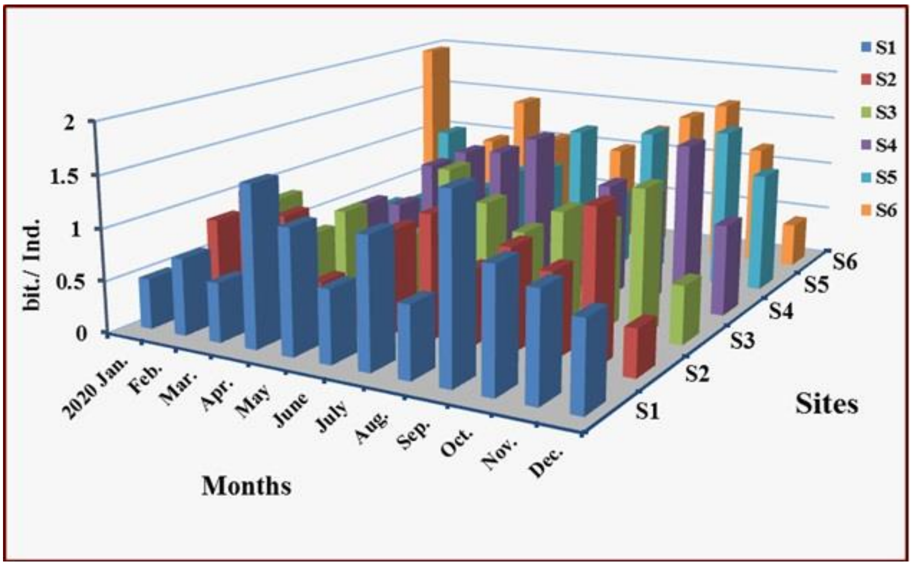


Diagram (6): Seasonal variation of Shannon-Weiner diversity index for copepods in Tigris River and Tharthar Arm.

Copepoda in Tigris River and Tharthar Arm classified according to Hussain (2014). It was ranged from moderate to disturbed for richness index. While, from unbalanced to the highly balanced for evenness index, and from very poor to poor class for Shannon Weiner diversity index.

Jaccard Presence-Community Index

The highest value of similarity index was 87.83% between sites 3 in Tharthar Arm and site 4 on Tigris River (Diag.7). This may be resulted from the effect of Tharthar Arm on Tigris River by increasing the density of Copepoda at immediately downstream the CHZ as we have previously discussed.

Whereas, the lowest similarity value was found between site 1 and 2 with percentages 65.41%. This is probably returned to the fact that each site located on different river, and every river characterized with distinct hydrological, morphological and geological features. This view is supported by Czerniawski *et al*. (2013) found that variations in environmental factors declined the rate of similarity index of zooplankton communities along the lower reaches of Oder River.

Similarly, Abed (2018) showed that the highest percentage of similarity index for copepods in Dejiala River was 71.42% between the sites located before and after of Wafidea District area attributed that to the similarity in physicochemical characteristics in both sites on the river. Also, Al-Bahathy (2021) showed that the highest similarity value for copepods in Euphrates River was 92.50% between the site near AL-Musayyib City and the site downstream Hindiya Dam, related that to similar environmental variable between two sites.

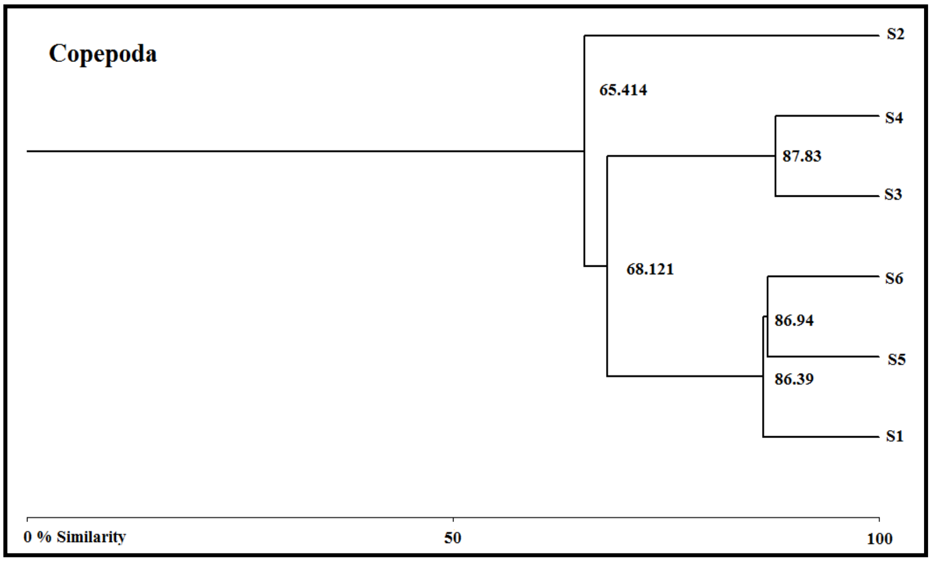


Diagram (7): Dendrogram of Jaccard's index percentages of copepods.

CONCLUSIONS

In view of all that has been mentioned from our findings we can be concluded that, Tharthar Arm increased the density of Copepoda immediately downstream the confluence, then the density decreased with the increasing of distance downstream the main river. Spatio-temporal variations of copepod density in the Tharthar Arm and Tigris River depends on the changes of environmental conditions and hydrological regimes such as sources of water, flow rates, salinity, water temperatures, turbidity, DO, TSS and total hardness. Longitudinal change in the density of Copepoda along Tharthar Arm depending on the distance away from the Tharthar Lake, for this the Copepoda density was highest in site 2, compare with site 3. Also, linear relationship between Copepoda density with salinity, and conversely with discharge rate. Tharthar Arm increased the mean values of richness index and diversity index immediately downstream the confluence. According to ecological indices, it was ranged from moderate to disturbed for richness index, and from unbalanced to the highly balanced for evenness index, and from very poor to poor class for Shannon Weiner diversity index.

CONFLICT OF INTEREST STATEMENT

No conflicts of interest, the current results are part of the requirements of Ph.D. thesis in Ecology, Department of Biology/ College of Science-University of Baghdad.

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تأثير ذراع الثرثار في تركيب وتنوع مجذافيات الأرجل في نهر دجلة، شمال مدينة بغداد، العراق

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الخلاصة

تعد هذه الدراسة الأولى من نوعها في هذا الجزء من نهر دجلة بعد عام 2003، التي هدفت الى تقييم تأثير مياه ذراع الثرثار على تركيب وتنوع مجذافيات الأرجل في نهر دجلة. اختيرت ست محطات للدراسة اثنتان على ذراع الثرثار وأربعة على نهر دجلة احداهما قبل التقاء الذراع بالنهر حددت كمحطة سيطرة والثلاث الاخريات بعد الالتقاء. أُخذت العينات شهريا للفترة من كانون الثاني الى كانون الأول 2020. شخص 35 وحدة تصنيفية من مجافية الاقدام 34 وحدة في نهر دجلة و25 وحدة في الذراع؛ وكما بينت النتائج ايضاً ان الكثافة العالية في الذراع أدت الى زيادة الكثافة الكلية في نهر دجلة من 63878.2 فرد/م^3 في الموقع رقم 1 قبل الالتقاء الى 127198.3 فرد/ م^3 في الموقع رقم 4 بعد الاتقاء مباشرة. كذلك متوسط القيم لكل من دليل الغنى والتنوع ازدادت من 1.71 و 0.98 بت/فرد في الموقع رقم 1 قبل الالتقاء الى 2.08 و1.00 بت/فرد في الموقع رقم 4 بعد الالتقاء مباشرةً وعلى التوالي.

بيَّنَ دليل جاكرد للتشابه ان اعلى نسبة تشابه كانت بين الموقع الثالث والرابع بلغت 87.83% ؛ في حين ان اقل نسبة كانت بين الموقع الأول والثاني حيث وصلت 65.41%؛ و وفقا لمؤشر الثباتية للأنواع فان اعلى عدد كان 9 عند الموقع السادس واقل عدد كان 2 عند الموقع الثالث.