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Impact of Tharthar Arm on the Composition and Diversity of Rotifera in Tigris River North of Baghdad, Iraq

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Abstract

This study was conducted to evaluate the effects of Tharthar Arm on the composition and diversity of Rotifera in Tigris River. Six sampling sites were selected, two on Tharthar Arm and four along the Tigris River, one before the confluence as a control site and the others downstream of the confluence. Seventy-seven species of Rotifera were identified in Tigris, whereas, 60 in the arm. The results showed that low density of Rotifera in Tharthr Arm decreased the density in Tigris from 239812.4 Ind./m^3 upstream of the confluence to 223315.5 Ind./m^3 at immediate downstream of the confluence. It also declined the mean values of richness, evenness and Shannon diversity indices from 5.19, 0.69 and 2.14 bit/Ind., before the confluence to 3.97, 0.73 and 2.00 bit/Ind. below the confluence, respectively. Moreover, the highest similarity value was between sites 1 and 6 reached 83.27%, while the lowest value was between sites 1 and 2 recorded as 60.52%. For constancy index, the highest value was 14 in site 1 and the lowest was 8 in site 2.

Keywords: Biodiversity, River Confluences, Rotifera, Tharthr Arm, Tigris River.

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

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الخلاصة

هدفت هذه الدراسة الى تقييم تأثير ذراع الثرثار على تركيب وتنوع الدولابيات في نهر دجلة. تم اختيار ست محطات للدراسة اثنتان على الذراع وأربعة على النهر احداهما قبل التقاء الذراع بالنهر كمحطة سيطرة والثلاث الاخريات بعدالالتقاء. أُخذت العينات شهريا من كانون الثاني الى كانون الأول 2020. تم تشخيص 77 نوعاً في نهر دجلة و61 نوعاً في الذراع. وبينت النتائج ان انخفاض الكثافة الكلية للذراع أدت الى نقص تلك الكثافة في نهر دجلة من 239812.4 فرد/م^3 قبل الالتقاء الى 223315.5 فرد/م^3 بعد الالتقاء مباشرة وكذلك قلل من متوسط القيم لكل من دليل الغنى والتساوي وشانون للتنوع من5.19، 0.69 و2.14 بت/فرد قبل الالتقاء الى 3.97، 0.73 و2.00 بت/فرد بعد الالتقاء مباشرةً وعلى التوالي. وبين دليل جاكرد للتشابه ان اعلى نسبة تشابه كانت بين الموقع الأول والسادس اذ بلغت 83.27 % بينما اقل نسبة كانت بين الموقع الأول والثاني حيث

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وصلت الى 60.52 %. وفقا لمؤشر الثباتية للأنواع فان اعلى عدد كان 19 عند الموقع الاول واقله كان 12 عند الموقع الثاني.

الكلمات المفتاحية: تنوع احيائي، التقاءات الأنهار، الدولابيات، ذراع الثرثار، نهر دجلة.

1. Introduction

Riverine confluences play an important role in the dynamics of all fluvial systems and are ubiquitous and fundamental elements of natural drainage networks [1, 2]. Rivers at channel confluences create a complex hydrodynamic and morphodynamic environment. Inside the confluence, the tributaries flow mutually deflect each other. This deflection is the outcome of pressure gradients created by the spatial pattern of water-surface elevations that steers the confluent flows into the receiving channel [3]. Quite often two incoming flows have different water properties, such as temperature, conductivity, pH, hardness, or if they are transporting various types of suspended materials [3].

The term zooplankton comes from the Greek, zoon meaning living organism, and planktons meaning wanderer or drifter that floats and drifts passively at the mercy of currents, waves, and tides. Zooplankton (Rotifera, Cladocera and Copepoda) are tiny, often microscopic, water-suspended species. They are present in both freshwater and marine ecosystems and form a vital link in the aquatic food chains, grazing on phytoplankton, bacteria and non-living organic matter, and in turn being eaten by secondary consumers like fish [4]. These animals groups, especially Rotifera, provide a complete picture about the status of the water ecosystem because they are bioindicators for pollution and eutrophication [5, 6].

Rotifera, also known as wheel animals, are so-named because of the ciliated corona on their head [7,8]. Rotifers are considered to be the smallest animals amongst the Metazoa. It's mostly of microscopic size. The adult rangefrom about 40-2,000 μm in length. They are made up of about a thousand cells, unsegmented, bilaterally symmetrical, pseudocoelomates [7, 8, 9]. Based on Segers [10], rotifers are widely distributed geographically and contain about 2,030 species divided into three classes, the Monogononta composed of 1,570 species, Bdelloidea with 461 species and the marine Seisonida involved only 3 species. Though, most rotifers live in freshwater out of 1,948 species some species are also able to inhabit in saline waters [11, 12]. The objective of this study is to investigate the effect of Tharthar Arm on the density and diversity of Rotifera in Tigris River north of Baghdad City during the 2020.

2. Material and Methods

2.1 Study Area

Tigris is one of the largest rivers in the western Asia, also considered as one of the two most important twin rivers in Iraq. It rises from the south-eastern parts of Turkey on the southern slopes of Touros mountains. It drains an area of 473103 Km^2 which is shared by Turkey, Syria and Iraq. It forms the Turkish-Syrian border for about 47 Km, before crossing Iraqi border 4 Km north of Faysh Khabur near Zakho City [13].

Tharthar Arm or Tharthar-Tigris Canal is a human-mediated river that 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 the confluence with Tigris River northern of Baghdad City. It is designed to discharge water up to $600m^3/s$ into the Tigris River directly [14].

2.2 Study Sites Description

Six sites were selected for sample collection (Figure 1). The first site was 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 a reference site, known as upstream Confluence Hydrodynamic Zone (CHZ). The second site was 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 was located on Tharthar Arm before the entrance to the mainstream, leading up to Sabaa Al-Bour City (33°28'43.0"N, 44°14'06.9"E) about 7.5 km before the confluence of the arm with Tigris. The fourth was 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. Fifth site lied 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. Sixth site was 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 were known as downstream CHZ.

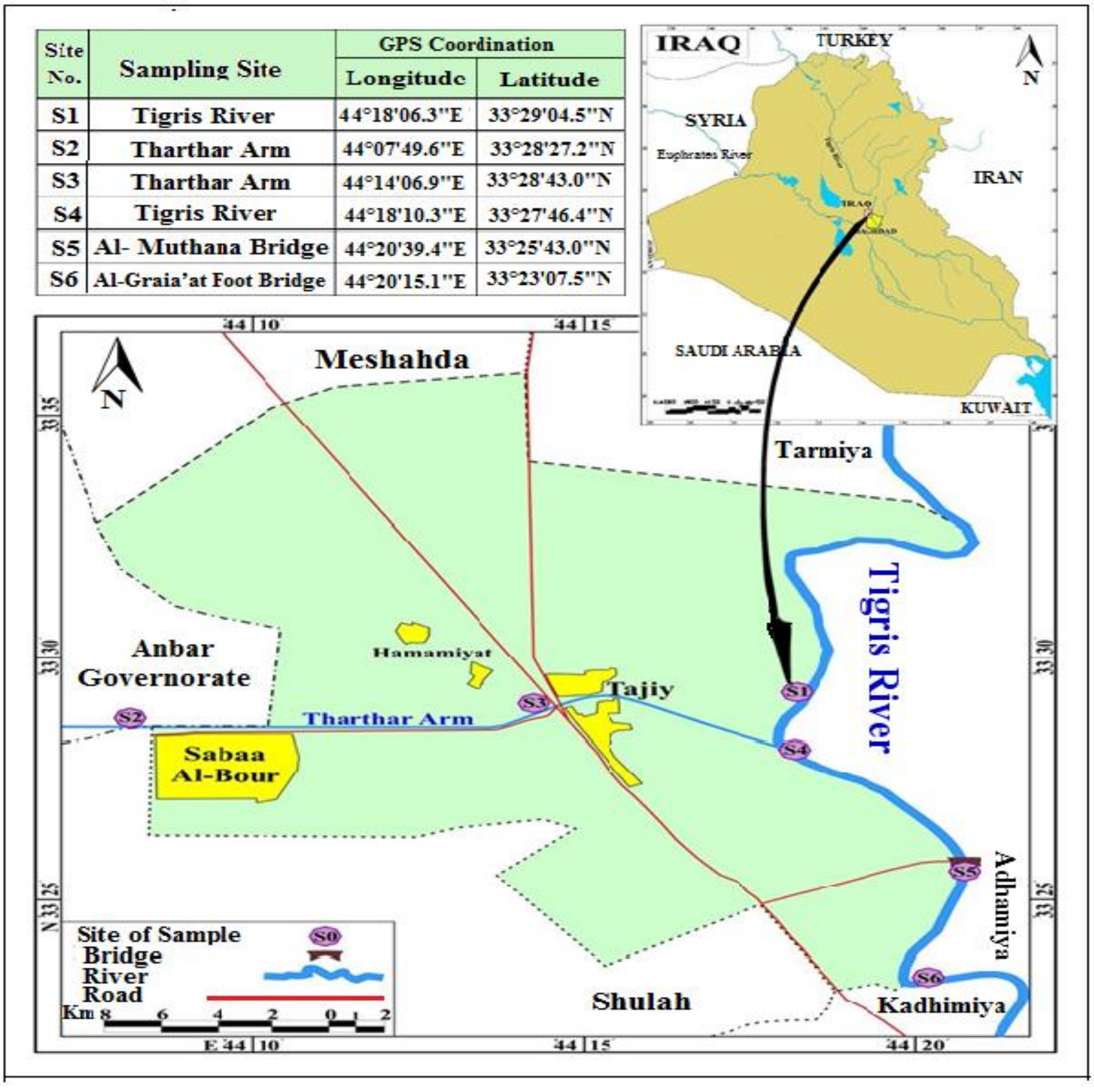

Figure 1 - Iraq map showing the study sites on Tigris River and Tharthar Arm. Map Scale 1/10000.

The rates of water discharge ranged from 474 m^3/s in April to 681 m^3/s in July for Tigris River. Whereas in Tharthar Arm the flow ranged from 83 m^3/s in August to 250 m^3/s in January (Figure 2). The data was obtained from the Ministry of Water Resources, 2020 personal communication.

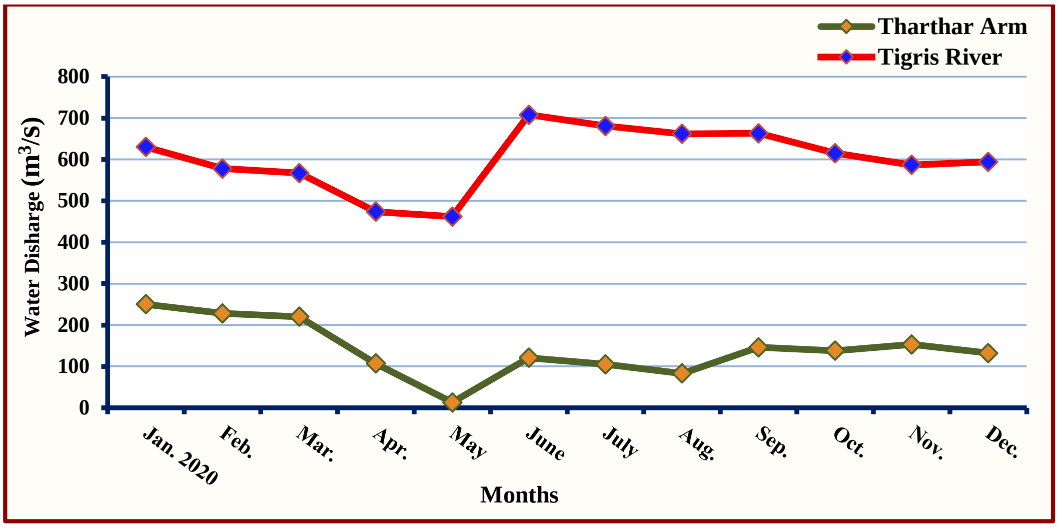

Figure 2- Seasonal variation of water discharges in Tigris River and Tharthar Arm during 2020.

2.2 *Sampling Method*

Samples were collected monthly from January to December 2020. Samples collected by passing 45 litres of surface water through vertical planktonic net with a mesh size of 55 microns, mouth diameter 25 cm. All samples were preserved in 4% formalin. Following sample condensation, the zooplankton was identified under a compound microscope to the lowest possible taxonomic unit by using Sedgewick-Rafter chamber. The rectangular cavity slide contained (50 mm long x 20 mm wide x 1 mm deep) exactly 1 ml of water sample [15]. The sample was shaken well and was instantly transferred to the cavity by using a graduated pipette. The coverslip was adjusted correctly to ensure that no air bubbles remained within.
The density was calculated depending on the formula contained in Baird *et al*. [15].

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

Where: n = No. of Rotifera.

Following diagnostic keys were used for identification, Edmondson [16], Pontin [17] and Smith [18], and the results were expressed by the number of individuals in a cubic meter.
Ecological Indices were counted as follow:
Relative Abundance Index (Ra): This index calculated depending on the equation found in Omori and Ikeda[19]: Ra% = (N/Ns) χ100
N: Number of individuals in each taxonomic unit in the sample;
Ns: Total number in the sample.
Constancy Index (S): Calculate the presence and frequency of each species, the formula found in Serafim *et al* [20]: S = (n/N) χ 100 where n = positive sample number; N = total sample number.

The Species Richness Index (D): This index was calculated monthly, using the formula in Margalef's book [21]: D = (S-1)/ log N
S: Species number; N: Individuals total numbers.
Species Evenness Index (J): was measured based on the equation found in Neves *et al*. [22]:
E = H/Ln S
Ln S: Diversity largest theoretical value; H: Shannon Weiner value; S: Taxonomic unit number in each site.
Shannon-Weiner Diversity Index (H): The values of this index were calculated monthly according to the formula stated in Shannon and Weaver [23]: H =-$\sum$ ni/n χ Ln (ni/n)
Where ni: Number of individuals per taxonomic unit; n: Total summation of individuals. The results were expressed by a bit/individual unit.

The results are also 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. [24].

Some physicochemical characteristics, such as water temperature, salinity, pH and turbidity, were conducted in the study sites directly. Water temperature, salinity and pH were measured by HANA (HI9811). Turbidity was measured by the turbidity meter, Jenwaw company Model-6035. Dissolved and biological oxygen demands were measured by using Azide modification of Winkler titration method [15]. Total Suspended Solids (TSS), total hardness, reactive phosphate and nitrate were determined as described in standard methods [15].

Table 1- Some physical and chemical characteristics for Tigris River and Tharthar Arm during 2020. Minimum and maximum (First Line) mean and standard error (Second Line).

Site / Parameter	TigrisRiver	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 7.64 ± 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 (mg $CaCO_3$/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 0.965±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 0.011±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.**

3. Results and Discussion

Our results showed that Rotifera density varied spatially and temporally. At site 1 upstream CHZ, the values of rotifers densities ranged from 3407.5 Ind./m^3 to 54879.2 Ind./m^3 in May and December respectively. In Tharthr Arm, the values varied from 2367.9 Ind./m^3 in May to 37360.4 Ind./m^3 in March. Whereas, the minimum density was 2080 Ind./m^3 in July and the maximum density recorded was 71675.2 Ind./m^3 in March at immediately downstream CHZ. As well as, it ranged from 4332 to 92271.3 Ind./m^3 in January and December, respectively downstream CHZ (Figure 3).

In general, the low density of Rotifera in Tharthar Arm decreased its total density in Tigris River from 239812.4 Ind./m^3 upstream CHZ down to 223315.5 Ind./m^3 at immediately downstream the CHZ (Table 3). This finding agreed with Rabee [25], pointed that low density of rotifers in Tharthar-Euphrates Canal also reduced its density in Euphrates River downstream the confluence zone. Conversely, with Czerniawski and Domagała [26], they found out that the high density of Rotifera in Stary Potok Tributary increased its density in Drawa River after the confluence of two rivers.

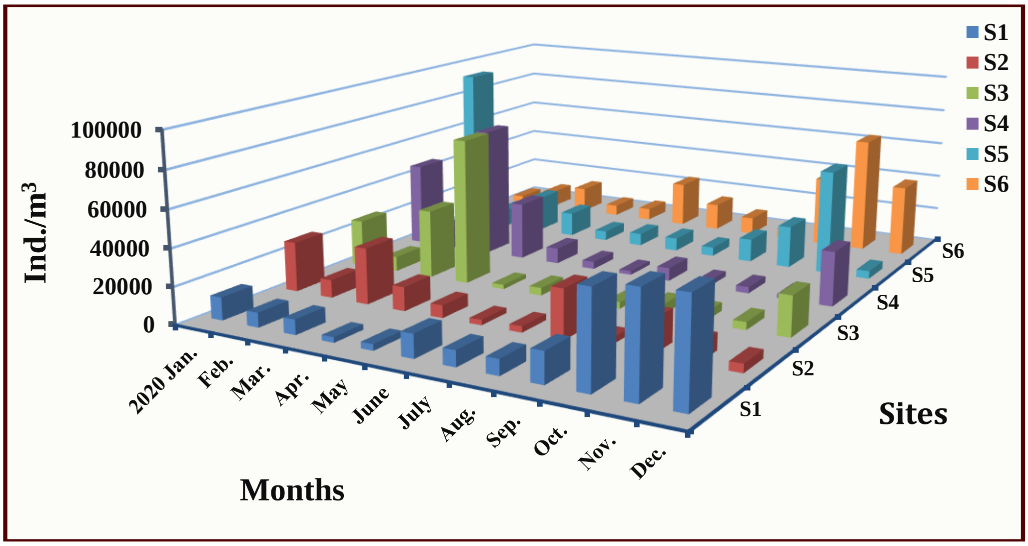

Figure 3 -Total densities of Rotifera in Tigris River and Tharthar Arm during 2020.

In the spatial aspect, the minimum value of Rotifera density recorded at site 2 on Tharthar Arm, whereas the maximum value was recorded on site 5. Low density in the arm could return to the high level because of low salinity. This fact is supported by Czerniawski and Sługocki [27], Yuan *et al*. [28] and Nguyen *et al*. [29] they found that Rotifera density decreases with increasing the salinity. Whereas, the high density in site 5 may be related to several favorable conditions for rotifers growth such as low values of salinity, high percentage of oxygen saturated (Table 1) [30], high discharge rate and the presence of macrophytes [27].

In the temporal aspect, Figure 3 shows that two peaks of rotifers density recorded during spring and autumn. This case may coincide with suitable environmental conditions such as the nutrients and water temperature which have an essential supporting role for increasing microalgae as an important feeding resource. This consequently increased the density of Rotifera in the river [31].

The relative abundance index of rotifers indicated that *Brachionus angularis* followed were: *Syncheta oblonga*, *Polyarthra dolicoptera*, *Keratella cochlearis*, *K. valga*, *K. tropica* and *B. plicatlus* were the most abundant species in Tigris River. Whereas, *S. oblonga*, *B. angularis*, *K. cochlearis*, *Trichocerca similis*, *Rotaria neptunia* and *Polyarthra dolicoptera* were the most abundant species in the arm as shown in Table 2 and Figure 4.

As well as, the higher abundance of Rotifera in site 1 upstream CHZ, were *B. angularis* 36%, *K. tropica* 9%, *K. valga* 5%, *B. urceolaris* 5%. Whereas, on the arm at site 2, *B. angularis*, *E.*

delatata, *K. cochlearis*, *R. neptunia*, *P. dolicoptera*, were recorded, 14%, 9%, 9%, 7% and 6%, respectively. At site 3, *S. oblonga*, *K. cochlearis*, *T. similis*, *K. valga*, *P. dolicoptera* were recorded 42%, 11%, 7%, 6% and 5%, respectively. While in site 4, the relative abundance distributed as follows: *P. dolicoptera* 25%, *S. oblonga* 22%, *K. cochlearis* 11% and *B. angularis* 10%. Also, at site 5 downstream CHZ, the values of relative abundance of *S. oblonga*, *B. angularis*, *K. cochlearis*, *K. valga* and *B. plicatlus* were recorded 31%, 20%, 10%, 7%, and 5%, respectively. Furthermore, that on site 6 *B. angularis*, *B. plicatlus*, *K. valga*, *K. tropica* and *R. neptunia* were recorded as 31%, 14%, 9%, 8% and 7%, respectively.

In the present study seventy-eight species of Rotifera were identified, 77 species in Tigris River and 60 species in Tharthar Arm (Table 2). Our results contrasted with other previous studies implemented in the river Tigris and Tharthar water [25, 32, 33]. These differences could be related to several reasons such as the level of classification, size of planktonic net, sampling sites and nature of environmental conditions.

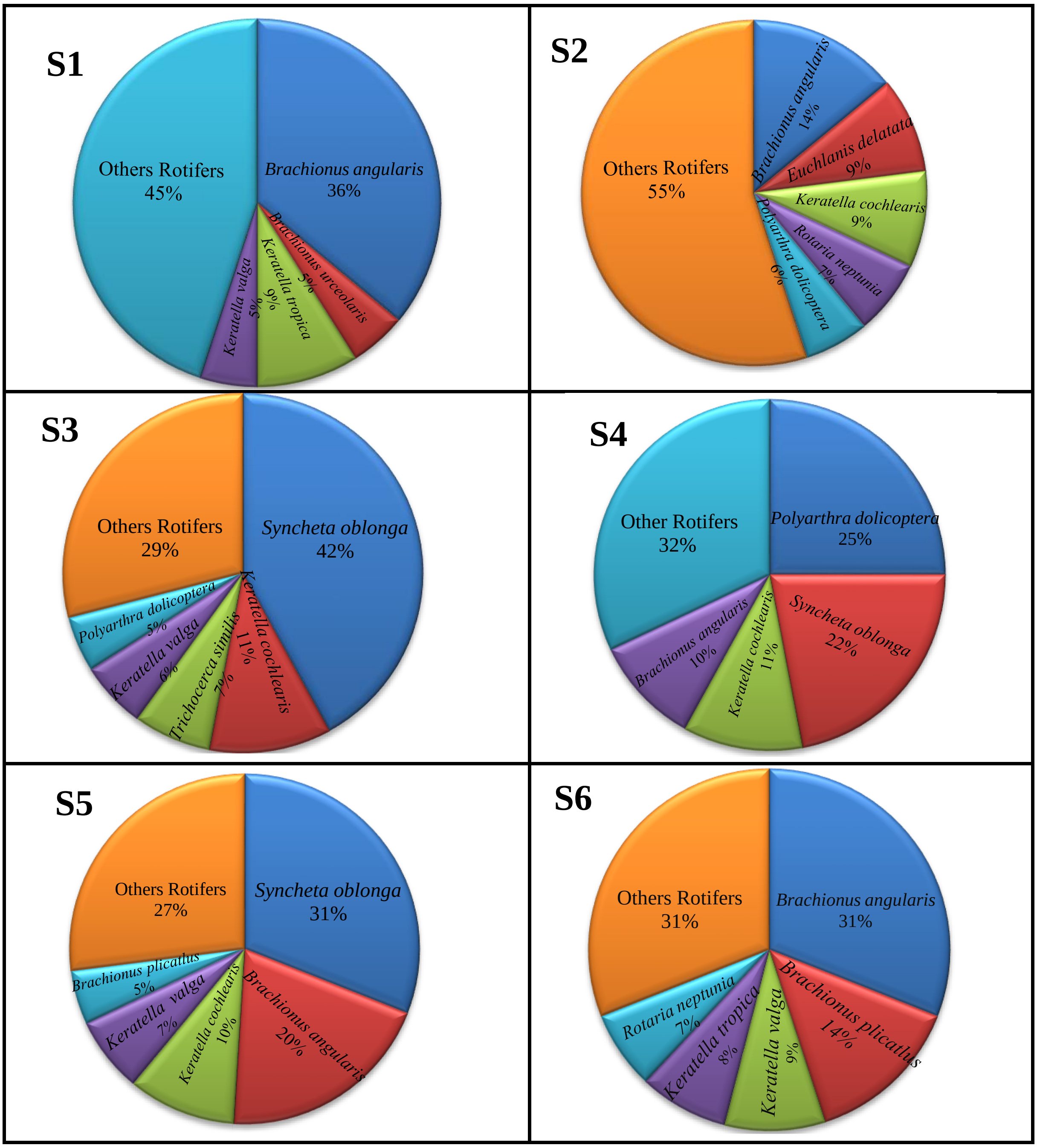

Figure 4 - The most dominant Rotifera in Tigris River and Tharthar Arm during 2020.

Table 2 - Rotifers distribution, Relative abundance (Ra) and Constancy index (S) in Tharthar Arm and Tigris River

	Sites Taxa	Relative abundance						Constancy					
		1	2	3	4	5	6	1	2	3	4	5	6
1	*Anuroaeopsis fissa* (Gosse, 1851)	R	R	R	R	R	R	C	Ac	A	A	Ac	A
2	*Asplanecna brightwelli* (Gosse, 1850)	-	-	-	-	-	R	-	-	-	-	-	Ac
3	*A. priodonta* (Gosse, 1850)	R	R	R	R	R	R	Ac	Ac	Ac	Ac	C	
4	*Ascomorpha* sp..Perty, 1850	-	R	-	-	-	R	-	A	-	-	-	A
5	*Ascomorpha saltans* Bartsch, 1870	-	R	R	R	R	-	-	A	A	A	A	-
6	*Aspelta bidentate* (Wulfert, 1961)	R	R	R	R	R	-	A	-	A	A	A	-
7	*Brachionus angularis* (Gosse, 1851)	La	La	R	R	La	R	C	C	C	C	C	C
8	*B. bennini* (Pallas, 1766)	-	-	-	-	-	R	-	-	-	-	-	A
9	*B. calcyflorus calcyflorus* (Pallas, 1766)	R	R	R	R	R	R	C	Ac	Ac	A	C	C
10	*B. calcyflorus amphecerus* (long spin) (Ehrenberg 1838)	R	-	R	R	R	R	C	-	A	A	A	A
11	*B. calcyflorus amphecerus* (short spin) (Ehrenberg 1838)	R	R	R	R	R	R	C	A	A	A	Ac	C
12	*B. falcatus* (Zacharias, 1898)	R	R	R	R	R	R	Ac	A	A	A	Ac	A
13	*B. forficula* (Pallas, 1766)	R	R	R	R	R	R	Ac	A	A	A	C	Ac
14	*B. havanaensis* (Rousselet, 1913)	R	-	R	R	R	R	A	-	A	A	Ac	A
15	*B. quadridentatus* (Hermann,1783)	R	R	R	R	R	R	Ac	Ac	A	A	Ac	Ac
16	*B. quadridentatus* (long spin) (Hermann,1783)	-	-	-	R	-	R	-	-	-	A	-	A
17	*B. quadridenta Gtus* (short spin) (Hermann,1783)	R	-	R	R	R	-	A	-	A	A	A	-
18	*B. plicatlus* (Müller,1786)	La	R	R	R	R	La	C	Ac	C	Ac	C	C
19	*B. rubens* (Ehrenberg, 1838)	R	R	-	-	-	-	A	A	-	-	-	-
20	*B. urceolaris*(Müller, 1773)	R	R	R	R	R	R	C	C	A	C	C	C
21	*Cephalodella aureculata* (Wulfert, 1938)	R	R	R	R	R	-	A	Ac	A	A	A	-
22	*C. forficula* (Wulfert, 1938)	-	-	-	-	R	R	-	-	-	-	A	A
23	*C. gibba* (Wulfert, 1938)	R	R	R	R	R	R	Ac	Ac	A	Ac	A	Ac
24	*Colurella obtuse* (Gosse, 1886)	-	-	-	-	R	-	-	-	-	-	A	-
25	*Colurella adriatica* (Ehrenberg, 1831)	R	R	R	R	R	R	Ac	A	C	Ac	A	C
26	*Dipleuchlanis propatula* (Gosse, 1886)	R	R	R	R	R	R	A	A	A	A	A	A
27	*Euchlanis delatat* (Ehrenberg, 1832)	R	R	R	R	R	R	C	C	C	C	Ac	Ac
28	*Filinia longiseta* (Ehrenberg, 1834)	R	R	R	-	R	R	Ac	A	A	-	A	Ac
29	*F. opliensis* (Zacharias, 1898)	R	R	R	-	R	R	Ac	A	A	-	A	A
30	*F. brachiate* (Rousselet, 1901)	-	-	-	-	-	R	-	-	-	-	-	A
31	*Hexarethra mera* (Hudson,1871)	R	R	R	R	R	R	Ac	Ac	Ac	A	Ac	Ac
32	*Keratella cochlearis* (Gosse, 1851)	R	R	La	La	La	R	C	Ac	C	C	Ac	C

33	*K. tropica* (Apstein, 1907)	R	R	R	R	R	R	C	Ac	C	Ac	Ac	Ac
34	*K. quadrata* (Müller, 1786)	-	-	-	-	R	R	-	-	-	-	A	A
35	*K. quadrata* (logn spin) (Müller,1786)	R	R	R	R	R	R	Ac	Ac	Ac	Ac	C	Ac
36	*K. quadrata* (short spin) (Müller,1786)	R	R	R	R	R	R	Ac	A	A	Ac	Ac	C
37	*K. valga* (Ehrenberg, 1834)	R	R	R	R	R	R	C	C	C	C	C	C
38	*K. testudo* (Ehrenberg, 1832)	R	-	-	-	R	-	A	-	-	-	A	-
39	*L. ovallus* (Müller, 1786)	R	-	-	R	R	-	A	-	-	A	A	-
40	*L. salpina* (Donner, 1943)	R	R	R	R	R	R	Ac	Ac	Ac	Ac	A	A
41	*Lecane donneri* (Chengalath & Mulamoottil, 1974)	R	R	R	-	-	-	A	A	A	-	-	-
42	*L. depressa* (Bryce, 1891)	-	-	-	R	-	-	-	-	-	A	-	-
43	*L. elasma* (Harring & Myers, 1926)	R	R	R	R	R	R	A	Ac	A	Ac	Ac	A
44	*L. luna* (Müller, 1776)	R	R	R	R	R	R	Ac	Ac	Ac	C	Ac	Ac
45	*L. leudg* (Eckstein, 1883)	-	-	-	R	-	-	-	-	-	A	-	-
46	*L. stichaea* (Harring, 1913)	R	R	-	-	-	R	A	A	-	-	-	A
47	*L. crepida* (Harring, 1914)	-	-	R	-	-	-	-	-	A	-	-	-
48	*Macrochaetus subquadratus* (Perty, 1850)	-	R	-	R	-	R	-	A	-	A	-	A
49	*Macrotrachela quadri cornifera* (Milne, 1886)	R	-	-	-	-	-	A	-	-	-	-	-
50	*Manfredium eudactylotum* (Gosse, 1886)	-	-	R	R	R	-	-	-	A	A	A	-
51	*Mikrodades chlaena* (Gosse,1886)	-	R	-	-	-	-	-	A	-	-	-	-
52	*Monostyla bulla* (Gosse, 1851)	R	R	R	R	R	R	C	A	Ac	C	C	C
53	*M. closterocerca* (Schmarda, 1859)	R	R	R	-	R	R	Ac	A	A	-	Ac	Ac
54	*M. hamata* (Stokes, 1896)	R	R	-	R	R	R	A	A	-	A	A	A
55	*M. quadridentata* (Ehrenberg, 1832)	R	R	R	R	-	R	A	A	A	A	-	A
56	*M. lunaris* (Ehrenberg, 1832)	R	R	R	R	R	R	A	A	A	A	Ac	A
57	*M. stenroosi* (Meissner, 1906)	R	R	R	R	R	R	Ac	A	Ac	Ac	C	A
58	*M. thalera* (Harring & Myers, 1926)	-	R	-	-	R	R	-	A	-	-	A	A
59	*M. thionemanni* (Hauer, 1938)	-	R	R	R	R	R	-	A	A	A	A	A
60	*M. scutata* (Harring & Myers, 1926)	R	R	-	-	-	-	Ac	A	-	-	-	-
61	*Mytilina nucronata* (Müller, 1773)	-	-	-	R	-	-	-	-	-	A	-	-
62	*Notholca acuminate* (Ehrenberg, 1832)	R	-	-	-	R	-	A	-	-	-	A	-
63	*N. squamula* (Müller, 1786)	R	R	R	R	R	R	A	A	A	A	A	A
64	*Philodina paradoxus* (Murray, 1905)	-	-	-	-	R	R	-	-	-	-	A	A
65	*Polyarthra dolicoptera* (Idelson,1925)	R	R	R	La	R	R	C	C	C	C	C	Ac
66	*P. vulgaris* (Carlin, 1943)	R	R	R	R	R	R	A	Ac	Ac	Ac	Ac	Ac
67	*Pomopholyx sulcate* (Gosse, 1851)	R	R	R	R	R	R	A	A	A	Ac	A	Ac
68	*Platyias quadricornis* (Ehrenberg, 1832)	-	-	R	-	R	R	-	-	A	-	A	A

69	*P. patulus* (Müller, 1786)	R	-	-	R	R	R	A	-	-	A	A	A
70	*Rotaria neptunia* (Ehreberg,1830)	R	R	R	R	R	R	C	C	C	C	C	C
71	*Syncheta oblonga* (Ehrenberg,1831)	R	La	A	La	La	R	Ac	C	C	Ac	C	Ac
72	*S. pectinata* (Ehrenberg,1832)	R	R	-	-	R	-	A	A	-	-	A	-
73	*Testudinella patina* (Hermann, 1783)	R	-	R	R	R	R	A	-	A	A	A	A
74	*Trichotria tetractis* (Ehrenberg, 1830)	R	R	R	R	R	R	Ac	C	Ac	C	A	C
75	*Trichocerca bicristata* (Gosse, 1887)	R	R	R	R	R	R	Ac	Ac	A	A	A	A
76	*T. capucina* (Wierzejski&Zacharias,1893)	-	-	-	R	-	-	-	-	-	A	-	-
77	*T. rousseleti* (Voigt, 1901)	R	R	R	R	R	R	A	Ac	Ac	Ac	Ac	A
78	*T. similis* (Wierzejski, 1893)	-	R	R	R	R	R	-	A	A	A	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%.

3.1 *Ecological indices*

3.1.1 *Richness index (D)*

Figure 5 depicted the value richness index of Rotifera during the study period. At site 1 upstream CHZ, the values ranged from 3.58 to 7.58 in December and January, respectively. In the arm, the value ranged from 1.94 in April to 5.67 in July. Whereas at the immediate downstream of CHZ, the minimum and maximum values were 2.41 and 6.74 in July and August, respectively. While downstream of CHZ, the lowest value of 3.01 was recorded in February and the highest value of 7.03 was recorded in August.

In other words, the low mean values of species richness index in Tharthar Arm reduced the richness of Rotifera in Tigris River from 5.19 in site 1 upstream CHZ to 3.97 in site 4 at immediately downstream CHZ, as can be seen in Table 3.

For spatial variations, the highest values of richness index were recorded in Tigris River at sites 1 and 6. While, the lowest value was recorded on the Tharthar Arm. The high values of this index in Tigris River could be related to the high water discharge rates [27]. Whereas, low values in Tharthar Arm could be attributed to the high amount of salinity (Table 1) [28].

Seasonally, the minimum value of species richness index of Rotifera was reported during the spring season. While, the maximum value was recorded during winter season (Figure 5). The increase in this value in winter could be associated to the increase of dissolved oxygen in cold months which in turn increased the value of species richness of Rotifera. This finding is corresponded with [25, 32]. Whereas, Rasheed *et al*. [35] showed that the value of richness index for Rotifera in Al-Shamyiah River, increased during spring and autumn seasons. It was related that to the increase of phytoplankton in these seasons. While, Abed and Nashaat [36] found that the lowest values of richness index for total Zooplankton and Rotifera in Dejiala River in winter was related that to the low density of phytoplankton.

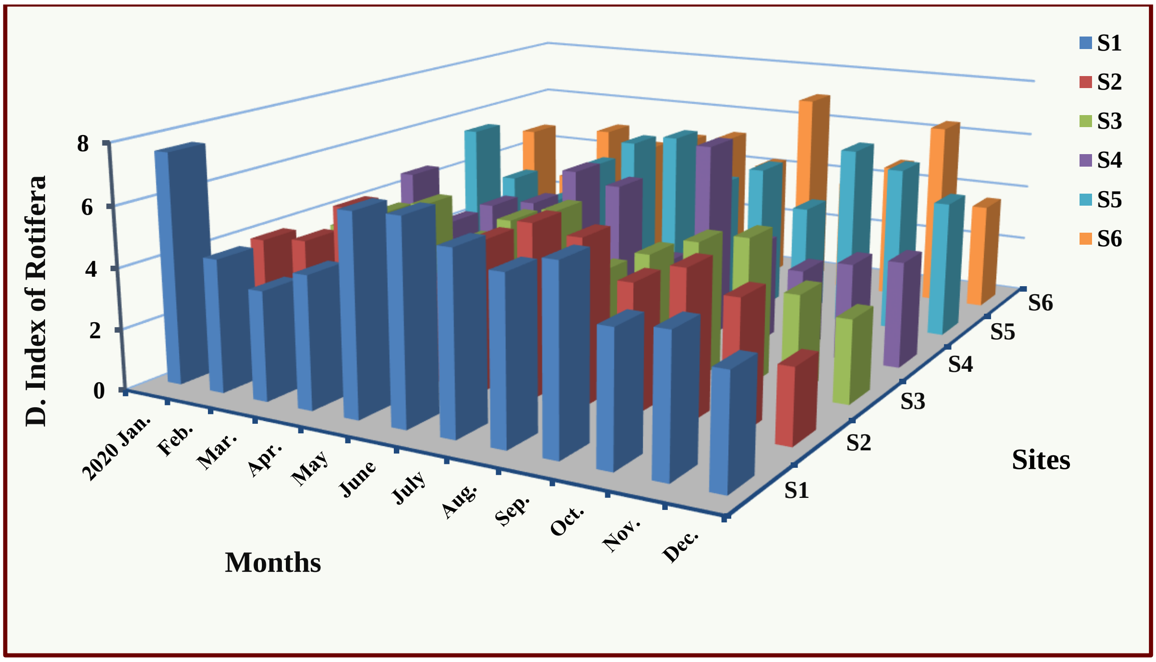

Figure 5 - Seasonal variations of richness index of rotifers in Tigris River and Tharthar Arm during 2020.

3.1.2 *Species Evenness Index (J)*

At site 1 upstream CHZ, the values of evenness index ranged from 0.52 in November to 0.90 in May. In the Tharthar Arm, the lowest value was 0.24 in April and the highest value was 0.93 in December. Whereas the minimum and maximum values of this index ranged from 0.38 to 0.95 in January and November respectively at immediately downstream of CHZ. While it ranged from 0.22 in January 0.86 in April, downstream of CHZ (Figure 6).

In other terms, the mean value of Rotifera homogeneity in Tigris River increased slightly from 0.69 upstream of CHZ to 0.73 at immediately downstream of CHZ, due to the lower of evenness index in Tharthar Arm as can be seen in Table 3.

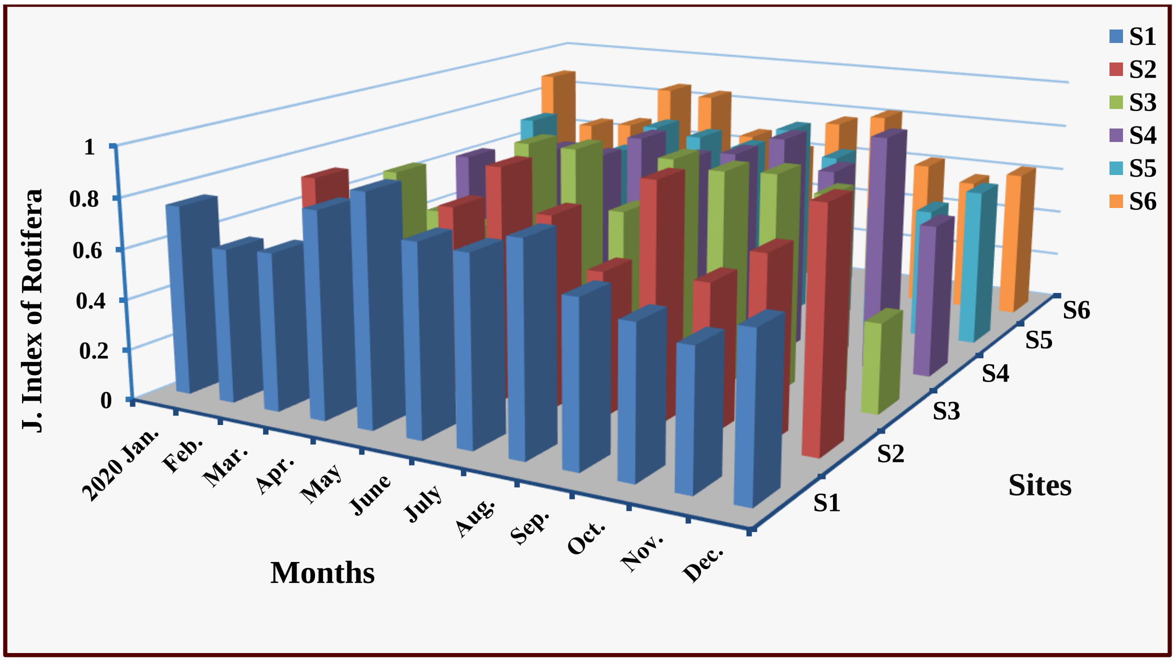

Figure 6 - Seasonal variations of Evenness index of rotifers in Tigris River and Tharthar Arm during 2020.

Seasonally, the highest values were recorded in spring and summer seasons while, the lowest values were reported in winter (Figure 6). This could be related to the favorable temperatures and phytoplankton abundance [37]. In addition to the increasing of nutrients and Chlorophyll-A during summer and spring seasons [38]. These results are consistent with Abdulwahab and Rabee [32] that showed the evenness values of Rotifera in Tigris River ranged from 0.41 to 0.93.

3.1.3 *Shannon Wiener Diversity Index (H')*

The values of this index ranged from 1.63 bit/Ind. in November to 2.60 bit/Ind. in January at site 1 upstream of CHZ. While, in the arm the values ranged from 0.53 to 2.65 bit/Ind. in April and June respectively. Whereas, the minimum and maximum values were 1.17 bit/Ind. in January and 2.71 bit/Ind. in August at immediately downstream of CHZ. While, the lowest value was 0.76 bit/Ind. in January and the highest value recorded was 2.62 bit/Ind. in August downstream of CHZ (Figure-7).

In other words, the diversity of Rotifera slightly impacted by Tharthar Arm and the average values reduced from 2.1 bit/Ind. before the confluence to 1.99 bit/Ind. at immediately downstream of CHZ. Then it returned to its first state (Table 3).

For seasonal variations, the highest values of diversity index were reported during summer. While, the lowest values were during winter (Figure 7). This could be associated to increase in temperature, transparency and Chlorophyll-A, These factors are important for the availability of phytoplankton as a food for zooplankton [39]. Whereas, the values of this index decreased in winter probably due to the higher amount of turbidity and suspended matter which effects the diversity of rotifers as mentioned by [32].

For spatial variation, the highest values were in Tigris River at sites 1 and 6 recorded 2.6 bit/Ind. for each site. Whereas, the lowest value recorded was 0.53 in the Tharthar Arm (Figure 7). The high values of this index in Tigris River could be related to the high discharge rates (Figure 1). This view is supported by Czerniawski and Sługocki [27]. The low values in Tharthar Arm could be attributed to high amount of salinity, as shown in Table 1. This fact was proved by Yuan *et al*. [28].

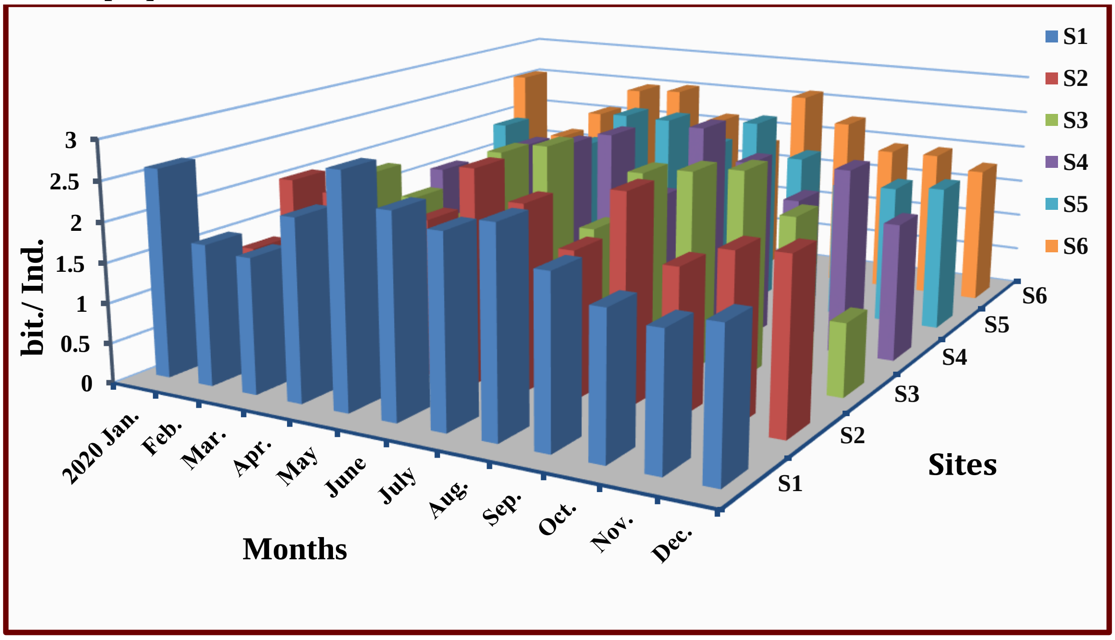

Figure 7 - Seasonal variations of Shannon-Weiner diversity index of rotifers in Tigris River and Tharthar Arm during 2020.

The results of present study were confirmed by other previous studies. Rabee [25] observed that Al-Tharthar-Euphrates Canal impacts the diversity index of rotifer in Euphrates River that decreased the diversity values downstream the confluence of two rivers. Also, Bolotov *et al*. [40] mentioned that the diversity index of Rotifera in the Savala tributary declined after junction with Khoper River, related that to the differences in hydrological and physiochemical characteristic as velocity of current, salinity and water temperature between the two sites.

According to Hussain classification [41], species richness index ranged from moderate to the perfect. Whereas that for the evenness index, values ranged from unbalanced to high. Shannon index fluctuated between very poor and moderate both in Tharthar Arm and the river Tigris.

Table 3 - The average values of species index, evenness index and Shannon-Weiner index with total density of Rotifera.

	Sites					
Index	**1**	**2**	**3**	**4**	**5**	6
D	**5.19**	**4.20**	**3.96**	**3.97**	**4.86**	**4.81**
J	**0.69**	**0.68**	**0.71**	**0.73**	**0.63**	**0.72**
H	**2.14**	**1.95**	**1.99**	**2.00**	**1.91**	**2.17**
Total Rot.	**239812.4**	**154757**	**200136**	**223315.5**	**258572**	**239115**

3.2 Jaccard Presence-Community Index

The highest similarity index value for Rotifera between sites 1 and 6 reached 83.27% (Figure 8). This could be attributed to the fact that the two sites were located on river Tigris and were away from the influence of Tharthar Arm. Site1 was placed about 2.4 km before the confluence of Tharthar Arm with Tigris River while, site 6 was placed around 12.6 Km away from the confluence of two rivers. While, the lowest similarity index value of Rotifera was between sites 1 and 2 recorded 60.52% (Figure 8). This is probably was due to the fact that each site was located on a different river, and each river was characterized with distinct hydrological, morphological and geological features (Table 1). Similar results were reported by Abed and Nashaat [36] which showed that the highest percentage of similarity for Rotifera in Dejiala River was 60% between Wafidea District and the last stretch of river. They attributed to the similar environmental and hydrological factors for both sites. Also, Al-Bahathy and Nashaat [42] found that the highest percentage value of similarity index for Rotifera in the Euphrates River, was 76.27 between the sites upstream and downstream of the Hindiya Dam. It was attributed to the similarity of physicochemical characteristics of Euphrates River for these sites. Whereas Mirza and Nashaat [43] showed that the lowest percentage of this index for Mollusca groups in the Gharaf River was 33.17% between the sites located near Al-Kut Barrage 10 Km down to Al-Moafaqya. It was related to the differences in the waste discharge between the sites that generates different environmental conditions in each site.

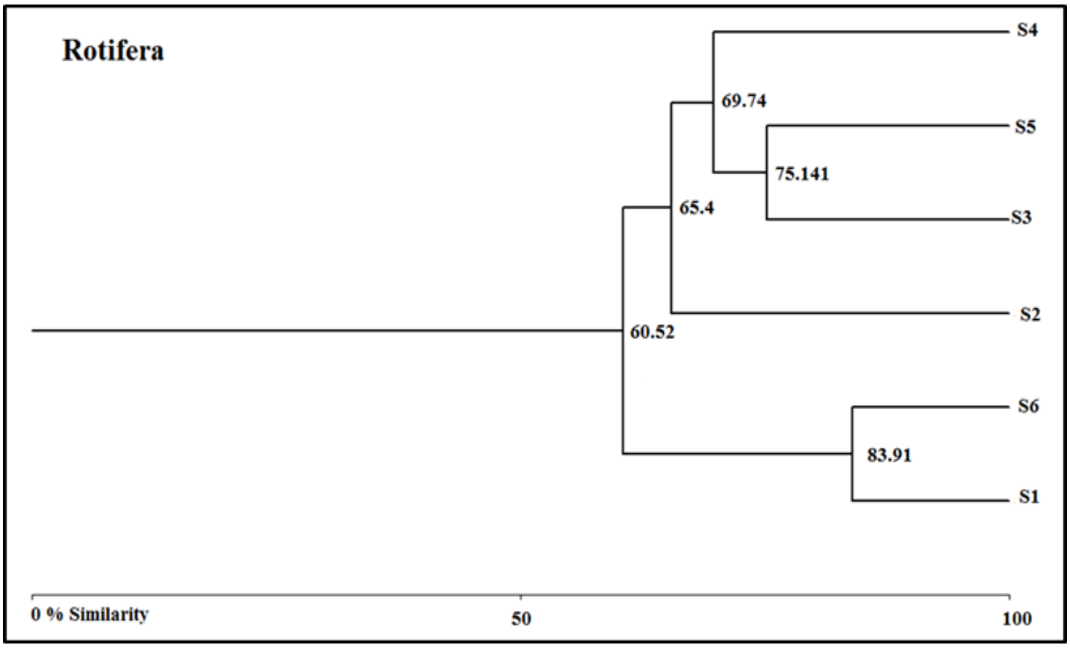

Figure 8- Dendrogram of Jaccard's index percentages of Rotifer.

In view of all that has been mentioned from our findings and other previous agreed studies we can conclude that

- Tharthar Arm reduced the density and diversity of Rotifera immediately downstream of the confluence. The values then raised with the increase in the distance downstream of the main river. Also, the density fluctuated seasonally depending on climatic change and the composition of Rotifera in both rivers didn't change since a long time.
- Environmental conditions and hydrological regimes were the most important factors which affected Rotifera density.

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