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The Effect of AL-Tharthar Canal on the Zooplankton Composition and Diversity in the Tigris River

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ABSTRACT

This study is considered the first in this sector of Tigris River after 2003, to evaluate the effect of Tharthar Canal on the composition and diversity of zooplankton in Tigris River. Six sampling sites were selected; two on the Tharthar canal and four sites along the Tigris River, one before the confluence as a control site and the others downstream the confluence. One hundred thirty-four taxa of zooplankton were recorded in this study, 129 taxa in Tigris River ,76 taxa in Tharthar Canal as well and 96 taxa shared between river and canal. The high value of zooplankton density in Tharthar Canal increased the density of Tigris River from 307989 Ind./m^3 in site 1 upstream the confluence to 371427 Ind./m^3 in site 4 immediately downstream the confluence. Also, the mean values of richness index, evenness index and diversity index decreased from 7.46, 0.69 and 2.40 bit/Ind. before the confluence to 6.46, 0.61 and 2.08 bit/Ind. after the confluence, respectively. Furthermore, the highest similarity percentage was between sites 1 and 6 reached 84.28% while, the lowest percentage was between sites 1 and 2 reached 65.97%. The highest value for the constancy index was 24 in site 6.

KEYWORDS: Ecological Indices; Tharthar Canal; Tigris River; Spatial and temporal variations; Zooplankton.

الخلاصة

تعتبر هذه الدراسة الأولى من نوعها في هذا الجزء من نهر دجلة بعد عام 2003. التي هدفت الى تقييم تأثير مياه قناة الثرثار على تركيب وتنوع الهائمات الحيوانية في نهر دجلة. اختيرت ست محطات للدراسة اثنتان على قناة الثرثار وأربعة على نهر دجلة احداهما قبل التقاء النهر بالقناة حددت كمحطة سيطرة والثلاث الاخريات بعد الالتقاء. شخصت في هذه الدراسة مائة وأربعة وثلاثون وحدة تصنيفية، 129 وحدة تصنيفية في نهر دجلة و76 وحدة في القناة وكذلك وجد 96 وحدة تصنيفية مشتركة بين النهروالقناة. كما بينت النتائج ان الكثافة االعالية للهائمات في القناة زادت من من كثافتها في نهر دجلة من 307989 فرد/م^3 في الموقع رقم 1 قبل الالتقاء الى371427 فرد/م^3 في الموقع رقم 4 بعد الالتقاء مباشرة. ايضا متوسط القيم لكل من دليل الغنى ودليل التساوي ودليل التنوع تناقصت من 7.46 و 0.69 و 0.240 بت/فرد الى 6.46 و 0.61 و 2.08 بت/فرد في الموقع رقم 4 بعد الالتقاء مباشرة وعلى التوالي. وبين دليل جاكرد للتشابه ان اعلى نسبة تشابه كانت بين الموقع الأول والسادس اذ بلغت %84.28 بينما اقل نسبة كانت بين الموقع الأول والثاني حيث وصلت الى %65.97. كما ان اعلى نسبة لدليل الثباتية كانت 24 في موقع رقم 6.

INTRODUCTION

The term zooplankton is derived from the Greek zoon meaning living organism, and planktons meaning wanderer or drifter. Which passively float and drift at the mercy of water currents, tides and waves. Zooplankton are tiny, often microscopic, water-suspended species. They are found in both marine and freshwater and form a vital link in the aquatic food chains, grazing on phytoplankton, bacteria and non-living organic matter, and then being eaten by secondary consumers like fish [1]. These animals' groups provide a complete picture of the status of the water ecosystem because they are bioindicators for pollution and eutrophication [2, 3]. It is important in the cycling of organic matter in an aquatic ecosystem [4, 5]. Zooplankton plays a vital role in conserving energy conservation from the primary producer (phytoplankton) to higher trophic levels of the food chain, particularly fish larvae [6]. Although it's found in lentic water, they are found in all most lotic systems, from intermittent streams [7] to great rivers [8, 9,10]. Zooplankton in riverine systems is often dominated by rotifers, cladocera, and copepods [11,12, 13,14].

In lotic water, zooplankton is found at low densities than in lentic water because of the flow of water, which has a mechanical advective effect on zooplanktonic populations [15]. The flow velocity of the water can also restrict food availability and make it impossible for many groups of plankton to reproduce [15, 16]. A significant inverse relationship between current velocity and zooplankton abundance has been found [10, 15]. The study aimed to (1) quantify Zooplankton densities in Tigris River and Tharthar Canal (2) Spatial and temporal variations (3) Measure the impact of the Tharthar Canal on the composition and diversity of Zooplankton in Tigris, within 2020.

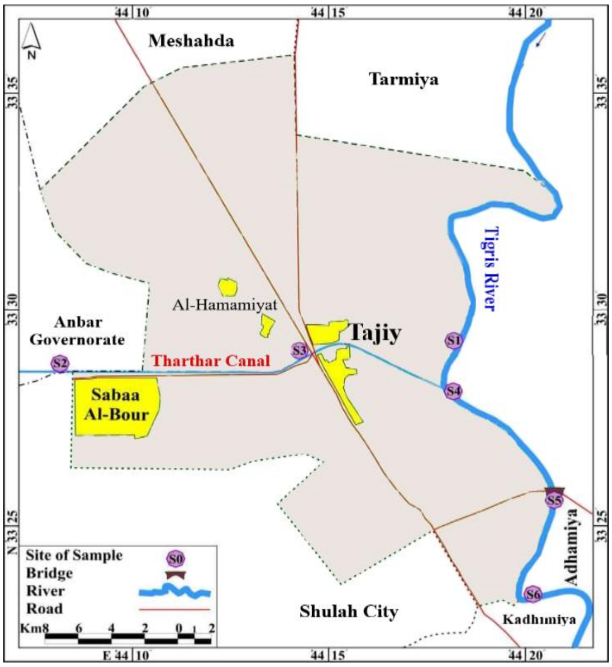
MATERIALSAND METHODOLOGIES

Study Area

Tharthar Depression is one of the biggest natural closed depressions in the area, it was changed in 1956 to an artificial reservoir to compile the over flooded water of the Tigris River during flood seasons and to recharge water to the Euphrates and Tigris Rivers in the dry seasons. Therefore, was named Tharthar Lake. At the lower edge of the lake, from the outlet regulator. Tharthar-Euphrates Canal starts in a linear path for 26.8 km until the division regulator, from the left side of this regulator. Tharthar-Tigris Canal or "Dhira'a Dijla" starts and continues to the east for 65 km until the confluence with Tigris River north of Baghdad Discharge rate reached about 600 m^3/s directly to the Tigris River [17, 18, 19].

Study sites description

As seen in Map 1, six sites were chosen from which samples were taken. The first site lies on Tigris River at 33°29'04.5"N, 44°18'06.3"E upstream the confluence as a reference site termed as upstream Confluence Hydrodynamic Zone (CHZ). Second and third sites occurring on the Tharthar Canal at 33°28'27.2"N, 44°07'49.6"E and 33°28'43.0 N " 44°14'06.9"E, respectively. Fourth site located at 33°27'46.4"N and 44°18'10.3"E, approximately 300 m below the confluence called as immediately downstream the Confluence Hydrodynamic Zone (CHZ). Fifth site located about 6.5 kilometers downstream the confluence nearby Al-Muthana Bridge area (33°25'43.0"N, 44°20'39.4"E). Sixth site placed near Al Graia'at Foot Bridge in Al-Kadhimiya City at 33°23'07.5"N, 44°20'15.1"E, about 13 kilometers downstream the confluence zone.



Map 1. Shows the study area northern Baghdad City. Map scale of 1/100000

The discharge rates of Tigris River ranged from 474 to 681 m^3/s in April and July respectively. While, in Tharthar Canal ranged from 83 to 250 m^3/s in August and January respectively (Figure 1) (Ministry of Water Resources, 2020. Personal connections).

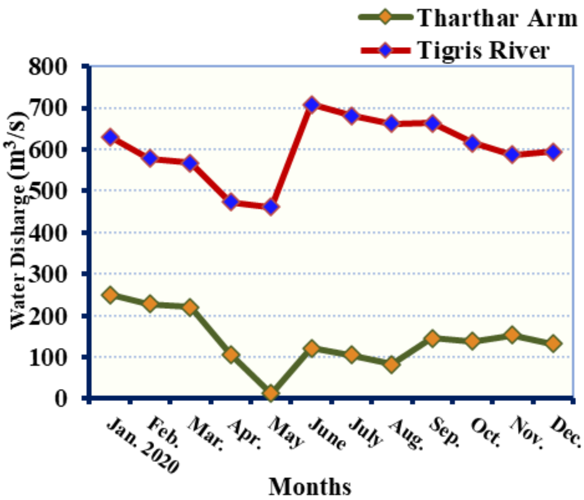


Figure 1. Monthly variation of water discharges in both Tigris and Tharthar Canal from January to December 2020.

Sampling Method

From January to December 2020, samples were collected monthly. Collected by filtering 45 L of subsurface water using a 55-μm mesh-sized plankton net. The samples were preserved in the filed in formalin solution 4%. In the laboratory, the

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concentrated samples were identified and counted under a compound microscope to the lowest possible taxonomic level, using special counting slide [20]. The sample was well mixed, after that a drop of 1 ml was taken by calibrated pipette.

$$\text{Plankton Ind./L} = \text{n}/(\text{Volume of sample}) \times 1000 \quad (1)$$

Where: n = Number of Plankton.

Some physicochemical factors conducted in this study (Table 1), salinity, pH, water temperature, and turbidity, were measured directly in situ. Temperature, pH and salinity analyzed by Hana Portable Meter model HI-9811. A turbidity meter, Jenwaw Company model 6035, was used to determine turbidity. Dissolved oxygen (DO) and biological oxygen demand (BOD_5) were determined by using the modified Winkler method; Total Suspended Solids (TSS), total hardness, reactive phosphate (PO_4^{2-}) and nitrate (NO_3^-) were measured according to the procedures explained in standard methods [20].

Ecological Indices

Jaccard similarity coefficient was calculated according to the equitation present in Mueller-Dombois and Ellemberg [21]. Species Richness Index (D) was measured based on the equitation found in Margalef [22]. Species Evenness Index (J) This index calculated depending on equitation found in Neves *et al*. [23]. Shannon's Diversity Index (H'): the value of diversity index calculated monthly depending on equation found in Shannon and Weaver [24]. In addition, the result is expressed as the unit bit/Ind. as a bit equal to one piece of data. Values less than 1 bit/Ind. indicate low diversity, whereas values more than 3 bits/Ind. indicate high diversity [25].

Additionally, several diagnostic keys were used for identification [26, 27, 28, 29, 30, 31].

The species' number counted as one per cubic meter.

Table 1. Physicochemical parameters of the water in the study area. First line represents minimum and maximum values, the second line represent Means and Standard Errors.

Parameters	Tigris River	Tharthar Canal		Tigris River			LSD Value
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	
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 *
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 *
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 ($CaCO_3$ mg/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

Notes: Means followed by different letters in same column differed significantly.
* p-value ≤ 0.05. NS: Not Significant.

RESULTS AND DISCUSSION

Species Composition

One hundred thirty-four taxa of zooplankton were identified in this study, 78 species of rotifera, 35 Copepoda and 21 Cladocera. In Tigris River 129 taxa were identified and distributed between 76 taxa belong to Rotifera, 34 taxa for Copepada and 19 taxa for Cladocera. While, in Tharthar Canal were 102 including 61 taxa for Rotifera, 25 taxa for Copepada and 16 taxa for Cladocera. Comparatively, we can also see 96 zooplankton taxa shared between Tigris River and Tharthar Canal, 59 taxa Rotifera, 14 taxa Cladocera and 23 taxa Copepod (Table 3).

From another point of view, Tharthar Canal caused a slightly increase in taxonomic units of zooplankton in Tigris River, the taxa numbers of total zooplankton, Cladocera and Copepoda were increased from 88, 12 and 20 upstream CHZ to 91, 14 and 21 immediately downstream CHZ, respectively (Table 2).

These results are parallel with the previous studies conducted in Tigris River and its tributaries. Al-Lami *et al*. [32] identified 88 Zooplankton taxa in Tigris River and 82 taxa in Tharthar Arm with 49 taxa shared between two rivers, and the taxonomic units increased below the confluence. Also, Al-Lami [33] who recorded 38 zooplankton taxa in both Tigris River and Al-Adaim River, included 26 taxa for Rotifera, 6 taxa for Cladocera and 6 taxa for Copepod. Also, they found 26 taxa shared between two rivers. Al-Lami *et al*. [34] identified 3l Cladocerans taxa in both Tigris River and Lower Zab Tributary, 19 taxa in Tigris and 26 taxa in the Lower Zab. Also, showed that tributary increased cladocerans taxa downstream the confluence of two rivers. Rabee [12] who reported 52 Zooplankton taxa in Euphrates River and Al-Tharthar-Euphrates Canal, 51 taxa for the river and 43 taxa for the canal. Abdulwahab and Rabee [35] indicated that 106 Zooplankton taxa along Tigris River within

Baghdad City, 65 taxa for Rotifera,16 taxa for Cladocera and 25 taxa for Copepods.

The differences and changes in the number of zooplankton species of the current study compared with the other previous studies conducted in Tigris River and Tharthar Canal, maybe related to the level of classification, size of planktonic net, sampling sites and nature of environmental conditions.

Globally, Deksne and Škute [36] revealed that abiotic environmental factors influence zooplankton populations, they also indicated 144 zooplankton taxa in the middle Daugava River, 86 taxa for Rotifera, 39 taxa for Cladocera, and 19 taxa for Copepoda. Also, Gaygusuz and Dorak [37] pointed those environmental changes are the most important factors affecting Zooplankton diversity index. As well as, they identified 39 taxonomic units of zooplankton in Darlık Stream, 25 taxa of Rotifera, 7 taxa of Copepoda and 7 taxa of Cladocera.

Table 2. Numbers of zooplankton taxa in Tigris River and Tharthar-Tigris Canal during study period from January to December 2020.

Sites	Tigris River	Tharthar Canal		Tigris River		
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Rotifera	56	56	52	56	60	58
Cladocera	12	12	13	14	11	12
Copepod	20	20	23	21	20	20
Total Zoo.	88	88	88	91	91	90

Total Density of Zooplankton in Tigris River and Tharthar-Tigris Canal

Zooplankton density is a measurement of the number of organisms in a given volume [38]. Figure 2 showed the density values of total zooplankton within 2020. In site 1 above the confluence, it was ranged between 5421.1 Ind./m^3 and 62807.4 Ind./m^3 during April and October 2020, respectively. On the canal, the minimum value was 6132.7 Ind./m^3 in December and the maximum value was 202214.7 Ind./m^3 in August. Whereas, in site 4, at immediately downstream of the confluence it was ranged from 74124.9 to 11820.8 Ind./m^3 in March and November, respectively. Whereas, it was ranged between 5931.7 Ind./m^3 in December and 93004.5 Ind./m^3 in January downstream CHZ. Furthermore, the high value of total zooplankton density in Tharthar Canal increased the density of Tigris River from 307989 Ind./m^3 upstream CHZ to 371427 Ind./m^3 immediately downstream CHZ (Table 4).

As for spatial variation, the highest total zooplankton density recorded on Tharthar Canal especially at site 2. While, the lowest value was at site 1 upstream CHZ. There are several possible reasons for these results

1. Sources of water, both rivers come from different hydrological regimes. Tharthar Canal takes its water from a lentic ecosystem (Tharthar Lake), characterized by a higher zooplankton density than the river. This fact indicated by Wahl *et al*. [39] found that zooplankton assemblage in Illinois River similarly to that in backwater lake due to of flushing from the backwater lake into the river.

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2. The retention time of water in the canal and lake also affects the abundance and composition of the zooplankton species [15, 40].
3. Variations in discharge rates of Tigris River higher than of Tharthar Canal (Figure 1). An inverse relationship between water discharge and zooplankton density [41]. High discharge rates restrict food availability for many groups of zooplankton and make it impossible to reproduce. As well as, high discharge rates increased the amounts of turbidity and suspended solids which in turn affect planktonic organisms [15, 42].
4. The high density in the canal compared with Tigris before the confluence may be related to the differences in water qualities between the two rivers as we explained in Table 1.

Table 3. Zooplankton taxa identified in the Tigris River and Tharthar Canal during 2020.

Rotifera	*K. valga*	*S. pectinate*	*marshianus*
Anuroaeopsis fissa	*K. testudo*	*Testudinella patina*	*Hesperodiaptomus*
Asplanecna brightwelli	*Lepadella ovallus*	*Trichotria tetractis*	*franciscanus*
A. priodonta	*L. salpina*	*Trichocerca bicristata*	*Sinodiaptomus sarsi*
Ascomorpha sp.	*Lecane depressa*	*T. capucina*	Immature Calanoid
Ascomorpha saltans	*L. donneri*	*T. rousseleti*	**Cyclopoida**
Aspelta bidentate	*L. elasma*	*T. similis*	*Acanthocyclops* sp.
Brachionus angularis	*L. luna*	**Cladocera**	*A. capillatus*
B. bennini	*L. leudg*	*Alona affinis*	*A. exilis*
B. calcyflorus calcyflorus	*L. stichaea*	*A. costata*	*A. venustoides*
B. calcyflorus amphecerus	*L. crepida*	*A. gutata*	*A. vernalis*
B. calcyflorus amphecerus	*Macrochaetus*	*A. rectangula*	*Eucyclops agilis*
B. falcatus	*subquadratus*	*Alonella excise*	*Ectocyclops* sp.
B. forficula	*Macrotrachela*	*A. intermedia*	*Eucyclops agilis*
B. havanaensis	*quadricornifera*	*Bosmina coregoni*	*E. speratus*
B. quadridentatus	*Manfredium*	*B. longirostris*	*E.macrurus*
B. quadridentatus (long spin)	*eudactylotum*	*Ceriodaphienia rigaudi*	*Halicyclops* sp.
B. quadridenta Gtus (short spin)	*Mikrodades chlaena*	*Camptocercus macrurus*	*Macrocyclops albdius*
B. plicatlus	*Monostyla bulla*	*Chydorus piger*	*Megacyclops latipes*
B. rubens	*M. closterocerca*	*Daphnia pulex*	*Megacyclops magnus*
B. urceolaris	*M. hamata*	*Diaphanosoma*	*Mesocyclops leuckarti*
Cephalodella aureculata	*M. quadridentata*	*brachyurum*	*Paracyclops* sp.
C. forficula	*M. lunaris*	*D. longiremis*	*P. affinis*
C. gibba	*M. stenroosi*	*Dunhridia serrata*	*P. fimbriatus*
Colurella obtuse	*M. thalera*	*Ilyocryptus*	*P. phaleratus*
Colurella adriatica	*M. thionemanni*	*sordidusMacrothrix*	*Thermocyclops hyalinus*
Dipleuchlanis propalula	*M. scutata*	*montana*	*Cyclops* sp(♂) .
Euchlanis delatat	*Mytilina nucronata*	*Moina affinis*	*Cyclops* sp.
Filinia longiseta	*Notholca acuminate*	*Scapholebrus kigni*	Immature Cyclopodia
F. opliensis	*N. squamula*	*Simocephalus vetulus*	**Harpacticoida**
F. brachiata	*Philodina paradoxus*	Immatur Cladocera	*Nitocra lacustris*
Hexarethra mera	*Polyarthra dolicoptera*	**Copepoda Calanoida**	Harbactecoida (♂)
Keratella cochlearis	*P. vulgaris*	*Acanthodiaptomus*	Immature Harpacticoida
K. tropica	*Pomopholyx sulcate*	*denticornis*	Nauplii of Copepoda
K. quadrata	*Platyias quadricornis*	*Aglaodiaptomus* sp.	**Paracitic Cyclopoida**
K. quadrata (long spin)	*P. patulus*	*Aglaodiaptomus forbesi*	*Ergasilus* sp.
K. quadrata (short spin)	*Rotaria neptunia*	*Aglaodiaptomus lintoni*	
	Syncheta oblonga	*Aglaodiaptomus*	

As for temporal variations, there are two peaks recorded in spring and summer. This case may be related to raising in water temperature which is beneficial for zooplankton, especially for growth and reproduction [43]. As well as, it may be associated with the increasing of phytoplankton and aquatic plants due to rinsing in water temperature and solar intensity [44].

The results agreed with Al-Lami [33] who showed that zooplankton density of Al-Adaim River higher than in Tigris River. Also, Al-Lami [45] recorded zooplankton density in Tigris River decreased from 524017 Ind./m^3 north of Baghdad to 127307 Ind./

m³ south of Baghdad, due to the effect of Baghdad City. In global studies, Viroux [46] pointed that zooplankton density in Moselle River northeast of France often influenced by lateral inputs, they showed the density of river increased downstream the confluence with its tributaries that loaded with high density. Scherwass *et al*. [47] showed that the high density of phytoplankton in Moselle River increase the density of zooplankton, this in turn, raised zooplankton density in Rhine River downstream the confluence. Also, Czerniawski and Domagała [48] they found the high density of zooplankton of Stary Potok and Drawica Tributaries increased zooplankton density in Drawa River after the confluence with the river.

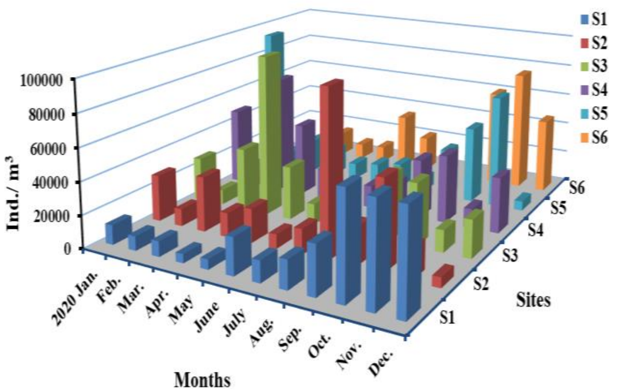

Figure 2. Total zooplankton densities in Tigris River and Tharthar Canal.

Species Richness Index (D)

In site 1 upstream the confluence, the values of this index ranged between 4.81 in December and 9.92 in January. On the canal, the lowest and highest values were 3.16 and 8.83 in December and July, respectively. While, in site 4 immediately downstream CHZ, the values fluctuated between 4.55 in February and 8.89 August. Whereas the minimum and maximum values were 4.84 and 10.51 March and August, respectively downstream CHZ (Figure 3). From another point, Tharthar Canal reduced the mean values of zooplankton richness index in main river from 7.46 above CHZ to 6.46 in site 4 immediately downstream CHZ (Table 4).

Spatially, the highest values of zooplankton richness index recorded in sites 1 and 6 along the river. While the lowest value was on the canal. The high values of species richness index in Tigris River might be related to the high water-discharge rates (Figure 1). Strong current washout numerous zooplankton species from the substrate and aquatic plants. This view was confirmed by Czerniawski and Sługocki [49]. They reported a direct relationship between current velocity and the number of species.

Whereas the low values of this index for zooplankton in Tharthar Canal could be attributed to the high amount of salinity. This finding was confirmed by Paturej and Gutkowska [50] and Yuan *et al*. [51]. They found that zooplankton species richness decreased with increasing salinity level.

Seasonally, the lowest and highest values for total zooplankton were in winter and summer, respectively. The increasing value in summer probably due to the increasing of water temperature and intensity of light which in turn increased phytoplankton. This could be increased zooplankton species richness. This finding in agreement with Lu *et al*. [52], found that the increasing of water temperature increased the value of species richness in Yangtze River.

Our result is parallel with Abbas and Talib [53] they reported that zooplankton richness index increased during spring flowed by autumn and summer. Attributed the availability of nutrients and phytoplankton. While, Ajeel *et al*. [54] recorded low values of species index for total zooplankton in Tigris River Northern of Basraha. It was varied between 1.66 in summer and autumn and 0.91 in winter, attributed that to pollution and environmental stresses. Moreover, Abed and Nashaat [55] found that the lowest values of richness index for total zooplankton and rotifera in Dejiala River were in winter related that to the low density of phytoplankton.

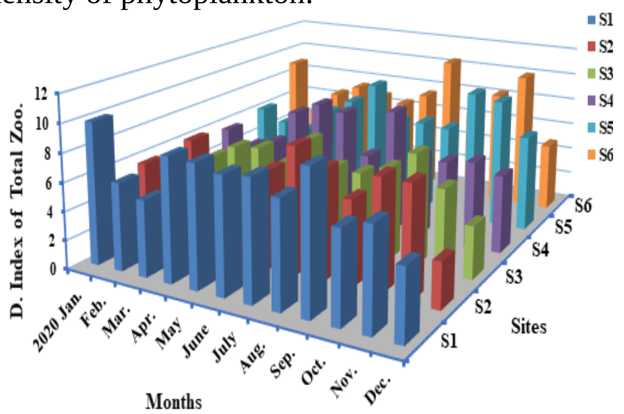

Figure 3. Monthly variations of richness Index (D) for the total zooplankton.

Our findings supported by several global studies, like Jafari *et al*. [56] showed that the values of richness index in the Haraz River fluctuated between 1.821 and 3.012 which related to the variation in water quality along the river. Also, Imoobe [57] found that the richness index of

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zooplankton was higher during the rainy season and decreased during the dry season. Moreover, Shayebi *et al*. [58] found poor species richness values for total zooplankton along Opobo River which varied between 1.04 and 1.2, attributed that to the presence of different chemical compounds in water. Ko *et al*. [59] found that the dredging process increased the number of species in the Korean Guemho River after two years of constructing a suitable ecosystem.

Shannon-Weiner Diversity Index (H')

Figure 4 represent the values of zooplankton diversity index during 2020. At site 1 upstream CHZ, the numbers were ranged between 1.95 bit/Ind. in November and 2.80 bit/Ind. in January and April. On the canal, the values were fluctuated between 0.98 and 2.65 bit/Ind. in April and August, respectively. While, the lowest and highest values were 1.32 and 2.64 bit/Ind. in January and April, respectively in site 4 directly below the confluence. Whereas, the lowest value was 0.80 bit/Ind. in January and the highest value was 2.90 bit/Ind. in August downstream CHZ.

In other terms, Tharthar Canal has a slight impact on the diversity of zooplankton in Tigris River and the average value decreased from 2.4 bit/Ind. at upstream CHZ to 2.08 bit/Ind. in site 4 immediately downstream CHZ. After that, it is return to the first state away from the influence of confluence zone and recorded 2.51 bit/Ind. in site 6 (Table 4).

For spatial variation, the highest values were recorded in Tigris River at sites 1 and 6. While, the lowest values were in the Tharthar Canal (Figure 4). This may be related to variation in hydrodynamic and physicochemical characteristics in each river [54, 60, 61].

As well as, the variation of water discharge between two rivers (Figure 1) may be the most significant variable affecting zooplankton diversity. This fact is indicated by Czerniawski and Sługocki [49] because they pointed that a linear relationship between discharge and diversity.

For temporal variations, the highest values of diversity index were recorded in summer, especially in August while, the lowest values were recorded during winter (Figure 4). These changes in diversity might be linked to the variations in water temperature between the seasons. The increasing of water temperatures and sunlight intensity in summer causes the rate of photosynthesis to increase and subsequently the amount of phytoplankton production which can lead to an increase in zooplankton diversity [53]. Whereas, the diversity lowered in winter which may be due to increase the current of water which is washing out the Copepoda away [62] and increased the turbidity and suspended matter which affect the diversity of Copepoda [35]. Also, it may be related to the decreasing of water temperature which is the main reason for the reduction of egg production and the number of immature stages. As well as, the reduction of the density of phytoplankton. This found is agree with Hedayati *et al*. [63].

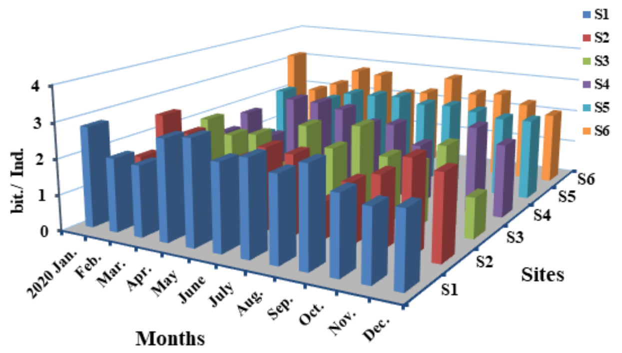

Figure 4. Monthly variations of Shannon Weiner diversity index for the total zooplankton.

Species Evenness Index (J)

Figure 5 shows the values of zooplankton evenness index during the study period. In site 1 upstream the confluence which ranged from 0.55 in November to 0.80 in April. In Tharthr Canal, the minimum and maximum values were 0.31 and 0.92 in April and December, respectively. While, the lowest and highest values were fluctuated between 0.40 in January to 0.75 in November, in site 4 immediately below the confluence. Whereas, it was ranged between 0.23 in January and 0.83 in April downstream CHZ.

In other words, the low mean values of total zooplankton in Tharthr Canal decreased the evenness index in Tigris River form 0.69 upstream CHZ to 0.61 at immediately downstream CHZ (Table 4).

Seasonally, the highest values were recorded in the spring and summer seasons while, the lowest values were recorded in winter. This may be due to the favorable summer temperature, and phytoplankton abundance because increasing the evenness of zooplankton. This view which is supported by Ajeel *et al*. [54] stated that evenness values of zooplankton in Tigris River were decreased in winter and increased in summer due to increasing in water temperature.

Another possible explanation, during winter the rain water increased the currents of this washout zooplankton and phytoplankton. This consequently reduced the evenness of zooplankton. This fact proved by Suresh *et al*. [62] which found that the depletion of phytoplankton naturally affects the evenness of zooplankton. Additionally, may be associated with the increasing of nutrients and chlorophyll-a during summer and spring seasons, which are the most important factors to increase phytoplankton. This consequently increased evenness values of zooplankton [52].

For spatial variation, the lowest values were on the Tharthar Canal while, the highest values were at site1 upstream CHZ and at site 6 near Graia'at Foot Bridge area. This could be attributed to differences in hydrological regimes and physicochemical parameters between two rivers (flow rate, water temperature, DO, turbidity and salinity) which may be affected the heterogeneity of zooplankton [43, 64].

As well as, Yuan *et al*. [51] showed that the evenness index of zooplankton in Pearl River decreased with increasing of salinity level. Abbas and Talib [53] mentioned that evenness index of total zooplankton in Tigris River ranged from 0.435 to 0.911 depending on the water level and concentration of nitrate. Sarkar and Pal [65] pointed those high values of zooplankton evenness in Torsa River ranged from 0.9 to 1. They related that to good water quality. Whereas, Wu *et al*. [43] indicated that this index increased in autumn in Nanfei River due to low levels of pollutions. Shayebi *et al*. [58] also showed zooplankton evenness index is varied between 0.73 and 0.84 in Opobo River.

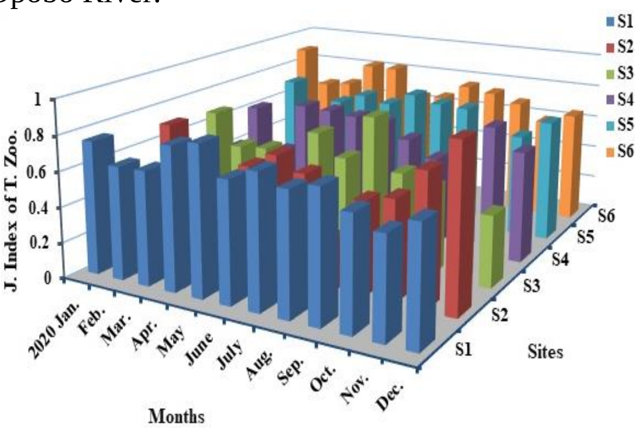

Figure 5. Monthly variations of evenness index (J) for the total zooplankton.

Table 4. Mean values of richness, evenness Shannon-Weiner index and total Zooplankton density.

	Total Zooplankton					
Index	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
D	7.46	6.36	5.90	6.46	7.13	7.47
J	0.69	0.59	0.58	0.61	0.64	0.72
H'	2.40	1.98	1.92	2.08	2.20	2.51
Total Zoo.	307989	436741	369174	371427	345837	324886

Jaccard Presence-Community Index

The highest value of similarity index was between sites 1 with 6 which reached to 84.28% (Figure 6). This could be attributed those two sites located on same river and away from the influence of Tharthar Canal, site 1 placed above the confluence of canal with river while, site 6 placed away about 12.6 km from the confluence of two rivers (Figure 1). Furthermore, the physicochemical characteristics for both sites were very similar such as water temperature, turbidity, salinity, pH, DO, BOD_5, POS, $NO_3^-$and PO_4^3 (Table 1).

In other terms, the influence of Tharthar water in site 6 was disappeared. Thus, the community structure of zooplanktons was recovered and returned to the first state.

Whereas, the lowest similarity index values for total zooplankton were recorded between sites 1 with 2, 65.97%. This is maybe returned to the fact that each site is located on a different river, and every river is characterized with distinct hydrological, morphological and geological features. Moreover, significant differences in physicochemical factors and hydrological regimes between two sites such as discharge rate, turbidity, salinity, total hardness and TSS (Table 1). In addition to the sources of water, all these factors played a key role in abundance and diversity of zooplankton in both rivers.

Ekwu and Sikoki [66] showed low index of similarity for total zooplankton between the upper and lower reach of Cross River estuary recorded 25% attributed that to the differences in salinity concentration between the sites on the river. Also, Ostojic´ *et al*. [67] showed that variations in physicochemical characteristics reduced the value of zooplankton similarity index in the Sava River. In this respect, Majeed *et al*. [68] found that the highest value of the similarity index for Rotifera reached 83.27% between two different sites along the Tigris River northern Baghdad City, attributing that to the similarity between the physicochemical factors of both sites.

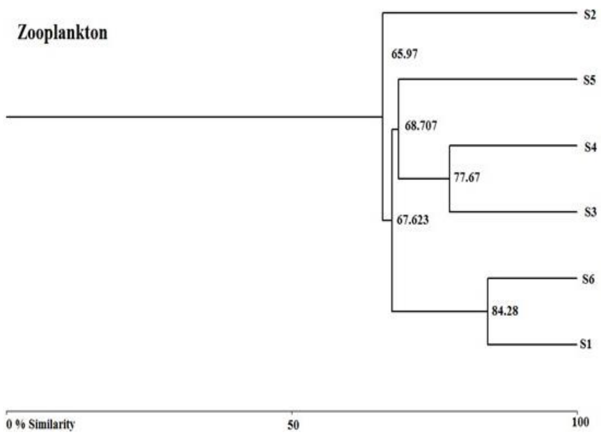

Figure 6. Dendrogram of Jaccard Index percentages for the total zooplankton.

According to the constancy index, 19 species were in site 1 upstream the confluence. On the canal, it was 16 and 12 at site 2 and 3, respectively. While, the values decreased to 18 at immediately downstream CHZ. Whereas, in sites 5 and 6 were 17 and 24, respectively.

Brachionus angularis, *B. calcyflorus amphecerus* (short spin), *B. plicatlus*, *B. urceolaris*, *Euchlanis delatata Keratella cochlearis*, *K. valga*, *Monostyla bulla*, *Polyarthra dolicoptera*, *Rotaria neptunia*, *Alona rectangular*, *Bosmina longirostris*, *Paracyclop fimbriatus*, *Cyclops* (♂), *Cyclops* sp., Immatur Cyclopdia, *Nitocra lacustris*, Immature Harpacticoida and Nauplii of Copepoda were the most constant in Tigris River.
Whereas, *B. angularis*, *E. delatata*, *K. valga*, *K. cochlearis*, *R. neptunia*, *P. dolicoptera*, *Syncheta oblonga*, *B. longirostris*, *Diaphanosoma brachyuru* and Nauplii of Copepoda were the most constant species in the Tharthar Canal. The other taxonomic units ranged between accessory species and accidental species.
From a different view, nine constant species in Tigris River dropped into accessory or accidental species after the confluence with Tharthar Canal, represented by *Anuroaeopsis fissa*, *B. calcyflorus calcyflorus*, *B. calcyflorus amphecerus* (long spin), *B. calcyflorus amphecerus* (short spin) *B. plicatlus*, *K. tropica*, *Alona rectangula*, *Cyclops* (♂) and Immatur Cyclopodia.
For spatial variation, the most constant zooplankton species were recorded at site 6 whereas, the lowest value was at site 3 on the arm. This might be related to differences in ecological conditions between two rivers like sources of water, flow rates, turbidity, salinity and total hardness as we have explained previously in Figure 1 and Table 1.
Our findings are in agreement with previous studies implemented on Tigris River, Nashaat *et al.* [69] showed that the thermal effluent from Al-Rasheed Power Plant reduced the constancy index of rotifera in Tigris River. Also, they indicated that *B. calcyflorus calcyflorus*, *K. valga* and *E. delatat* were the most constant species. Abbas *et al*. [70] mentioned that Diyala River reduced the constancy index of copepods in Tigris River. Also, they indicated that *Halicyclops* sp., *P. fimpriatus*, *Ectocyclops* sp., *Cyclops* ♂, Imature *Cyclops* and nauplii were the most constant copepods in Tigris River. Rabee [12] observed that *Brachionus* sp., *Cephalodella* sp., and *Keratella* sp., were the most constant taxa in Tharthar-Euphrates canal and Euphrates River.

CONCLUSIONS

Overall, these results indicate that environmental conditions and hydrological regimes were the most important factors which affected zooplankton density. Tharthar Canal reduced the density of rotifera immediately downstream the confluence and increased cladocera and copepoda densities. The low mean values of species richness index, species evenness index and Shannon-Wiener diversity index for total zooplankton in Tharthar Canal declined these indices in Tigris River downstream the confluence. In other terms, Tharthar Canal declined the diversity of the Tigris River immediately downstream the confluence. The highest percentage of similarity index for total zooplankton were between sites 1 and 6 whereas the lowest percentage was between site sites 1 and 2.

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Informed Consent: All patients gave their written informed consents before inclusion.

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