DOI: 10.24996/ijs.2021.62.9.4

ISSN: 0067-2904

Impact of Hindiya Dam on Rotifera Community of Euphrates River on the Northern of Babil Governorate, Iraq

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Received: 27/10/2020 Accepted: 18/12/2020

Abstract
This study was the first of its kind on the Hindiya Dam, which is considered one of the important dams in Euphrates River. Five sites were chosen on the north of Babil Governorate in order to know the rotifers biodiversity features and the impact of the Hindiya Dam on it's during the 2019. Site2(S2) was located near the dam to reflect the rotifers diversity of this site, whereas , S1 was located at the upstream of the dam as a control site, and S3, S4 and S5 were located down the dam. Rotifers showed higher density average at Hindiya Dam site compared with sites downstream the dam which was 9164 Ind./m^3, whereas density average at the site downstream the dam was 5540 Ind./m^3, site (downstream the dam) decreased clearly compared with the dam site. It was showing the relative abundance index of rotifers: *Keratella cochlearis* was with the highest percentages followed by *Rotaria neplunia*, *Syncheta oblonga* and *K. valga* at the sites of study area. The study confirmed that the dam reservoir was the source of pelagic rotifers for the outflowing river which led to increase species numbers about 104 species of rotifers. The average values of species richness index of rotifers declined from 1.64 at Hindiya Dam site to 1.58 at site below the dam. Euphrates River rotifers were considered generally from moderate richness to disturbed during 2019 in study area. Site 3(downstream the dam) had the lowest similarity values with site 5 which was 47.5% in rotifers group. Whereas, the highest Jaccard similarity index percentage was between sites 1 with 4 which reached to 76.2%. The Shanon- Weiner index of rotifers reported average values at the dam site 1.7 and 1.8 bit/Ind. at site below the dam. Also, the average values uniformity index of rotifers increased from 0.6 at Hindiya Dam site to 0.7 at site downstream the dam. Euphrates River rotifers were considered generally as little diversified because of index value was ranged from 1 to 2 during 2019 in study area. According to uniformity index values, Euphrates River rotifers were considered generally from unbalanced to moderate balanced in study area. The constant species of rotifers showed that constant species were 8 at the dam site. While, it decreased to 7 constant species at site (downstream the dam). It was concluded that Hindiya Dam had a great effect on the spatial composition of the rotifers community related to the change in the hydrological conditions from current water in site1 to limnetic basins in site 2 (the dam reservoir) then again to current water at site 3, 4 and 5 downstream the dam.

Keywords: Invertebrate; Biodiversity; Regulated River.

تأثيـر سـدة الهنديـة في مجتمع دولابيات نهر الفرات شمـال محافظة بابـل، العـراق

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الخلاصة

هذه الدراسة هي الأولى من نوعها على سدة الهندية والتي تعّد احدى أهم السدود في نهر الفرات. تم اختيار خمسة مواقع في شمال محافظة بابل لمعرفة التنوع الاحيائي لدولابيات نهر الفرات وتأثير سد الهندية عليها خلال عام 2019. اذ يقع الموقع الثانيS2 بالقرب من السد لتعكس تنوعها الاحيائي، في حين أن المواقع الأخرى، S1 يقع عند اعلى السد كموقع مرجعي. علاوة على ذلك، تم تحديد الموقعين الآخرين S3 وS4وS5 تحت تأثير السد. اظهرت الدولابيات متوسط كثافة أعلى في موقع سد الهندية مقارنة بالمواقع الواقعة بعد السد والتي كانت 13961 فرد/ م^3، بينما كان متوسط الكثافة في موقع بعد السد 9470 فرد/ م^3، وانخفض في الموقع بعد السد بشكل واضح مقارنة مع موقع السد. وكان مؤشر الوفرة النسبية للدولابيات الاعلى لنوع *Keratella cochlearis* يليه *Rotaria neplunia* و *Syncheta oblonga* و *K. valga* على التوالي في مواقع منطقة الدراسة. اكدت الدراسة أن خزان السد كان مصدر الدولابيات المتخصصة بمياه المنطقة المفتوحة للنهر (البعيدة عن ضفاف النهر) مما أدى الى زيادة ظهورها وتسجيل 104نوع. انخفض متوسط قيم مؤشر ثراء الأنواع الدولابيات من 1.64 في موقع سد الهندية إلى 1.58 في الموقع بعد السد. اعتبرت الدولابيات في نهر الفرات بشكل عام من مضطربة الى متوسطة الثراء خلال عام 2019 في منطقة الدراسة. كان للموقع 3 بعد السد مع الموقع 5 أقل قيم تشابه 48.25٪ في مجموعات الدولابيات ، بينما كانت أعلى قيم مؤشر جاكارد بين الموقع 1 مع 4 والتي وصلت إلى 79.71٪. سجل مؤشر Shanon– Weiner للدولابيات قيمًا متوسطة 1.8 بت/فرد في موقع السد و 1.8 بت/ فرد. في الموقع أسفل السد. كما ارتفع متوسط مؤشر تجانس الدولابيات من 0.6 في موقع سد الهندية إلى 0.7 في الموقع بعد السد. اعتبرت جودة نهر الفرات بشكل عام معتدلة التلوث حسب مؤشر شانون خلال عام 2019 في منطقة الدراسة. علاوة على هذا فقد عدّت الدولابيات في نهر الفرات بشكل عام فقيرة التنوع نظراً لأن قيمة المؤشر تراوحت بين2-1. ووفقًا لقيم مؤشر تجانس ظهور الانواع، تم اعتبار الدولابيات لنهر الفرات بشكل عام من غير متوازنة إلى معتدلة التوازن. أظهرت الدراسة ان الأنواع الثابتة من الدولابيات كانت 8 في موقع السد. بينما انخفضت إلى 7 نوعًا ثابتًا في الموقع بعد السد. استنتج من خلال الدراسة الحالية أن سد الهندية كان له تأثير كبير في تغيير مجتمعات الدولابيات مكانيا مرتبطة ذلك بالتغير في الظروف الهيدرولوجية من مياه جارية في الموقع 1 إلى مياه ساكنة في الموقع 2 (خزان السد) ثم مرة أخرى إلى مياه جارية في الموقع 3 و4 و5 بعد السد.

Introduction

Dams were built for a variety of reasons, including water supply, sediment control, agriculture, and around 48% for other purposes [1]. These sediment-control and irrigation dams, such as Hindiya Dam, are smaller than reservoir dams. [2].

The impacts of dam are either direct or indirect on river ecosystems by altering the structure of aquatic habitats and fluctuating flow pattern for river, loss biodiversity, population displacement, and ecosystem services [3], water discharge, sedimentation, and changes of water quality are the important factors in changing of ecological conditions in river ecosystems [4].

The zooplankton (Rotifera, Cladocera, Copepoda) reacts in various ways to different types of environmental stresses, so it is increasingly used in aquatic environments as a bioindicator [5] , as well as having a high sensitivity and reaction to environmental variation [6]. Therewith several local studies are dealing with a zooplankton group to indicative of environmental stress, such as [7-18] while this study considered as the first of its kind due to it included the study of the impact of Hindiya Dam on Euphrates rotifers assemblage, in Babil Governorate. Which we can include it’s the main objectives by investigating these impact on Euphrates rotifers biodiversity and identification.

Material and Methods

Study area Description

Hindiya Dam is situated on the Euphrates River in the south of Musayyib City in the north Babil Governorate, Iraq. The Dam length is 250 m and has 36 dams spillways, 5m wide of each one. It was designed for treating sediment matter of the one of two major branches of the Euphrates in this area called Hilla River.

We choose five sites for collection of study samples on Euphrates River near Hindiya Dam (Figure- 1). **1. Site 1:** This site was located before the Babylon Cement Factory south of the Musayyib City about 1Km upstream the Hindiya Dam at 44° 16' 05"N, 32° 44'18"E. Euphrates River was 328m wide. **Site 2:** It represents the Hindiya Dam site which characterized wider among other sites about 366m width at 44°16' 07" N, 32° 43' 42"E. **Site 3**: It was located about 400m down Hindiya Dam with 235m width at 44°16' 06"N, 32° 43' 29"E. **Site 4:** This site was 293m wide and located about 5Km down Hindiya Dam at 44°15' 16"N, 32°41' 24"E**. Site 5:** It was 231 m wide and located about 10Km downstream site 4, and about 15Km downstream the Hindiya Dam at 44°13' 12"N, 32° 35' 50"E.

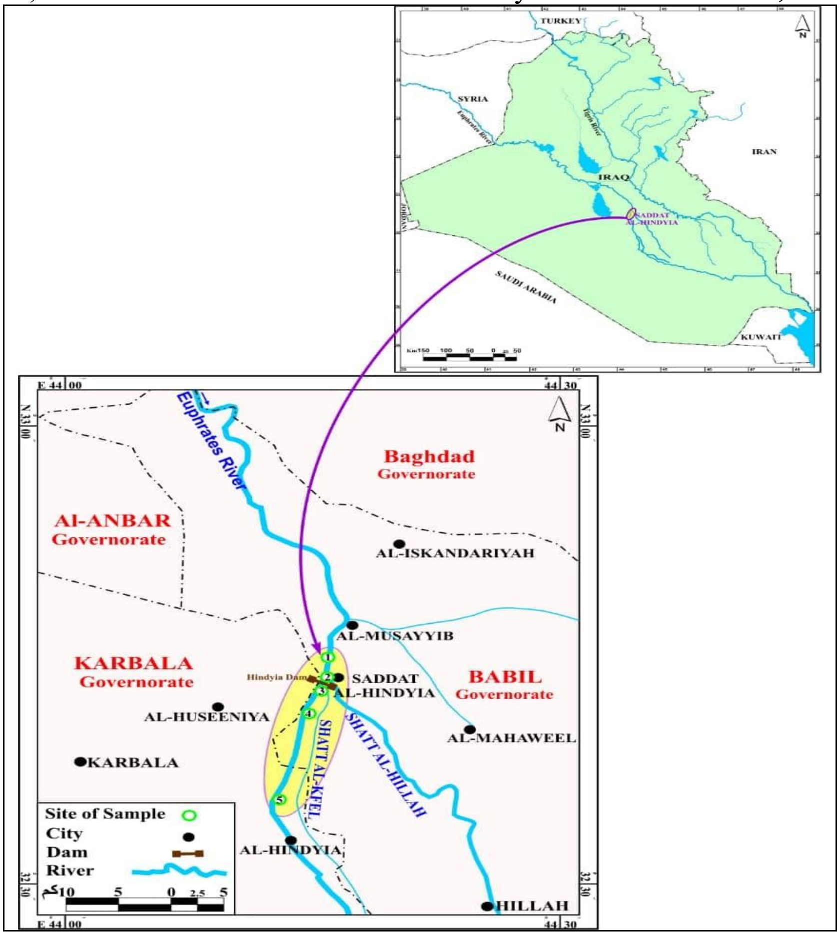

Figure 1- A map of Hindya Dam with locations of the studied sites**.** Source: (Ministry of Water Resources, 2017 personal communication).

Water discharges were in the range between the lower value of 116.92 m^3/sec. in February 2019 while the greatest value was 409.89 m^3/sec. in July2019 (Ministry of Water Resources, 2019 personal communication). Water velocity of Euphrates River study sites during study period was in the range between the lower value of 0.46 m/sec. in February 2019 while the greatest value was 0.64 m/sec at November 2019 (Ministry of Water Resources, 2019 personal communication) (Figure- 2).

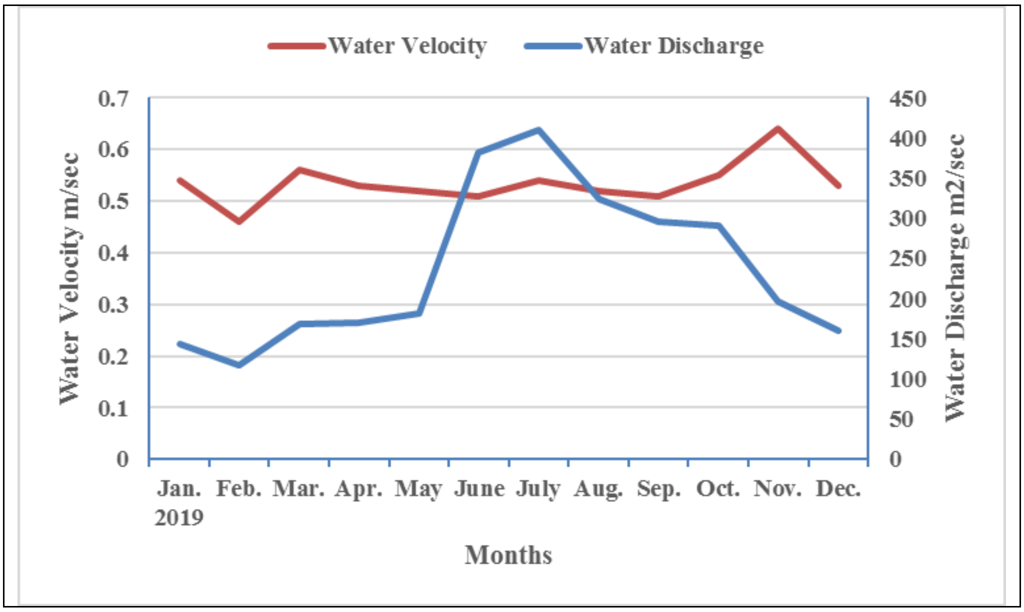

Figure 2-Water discharges and velocity of Euphrates River during period study.

Sample Collection

Samples were collected monthly from January to December 2019 at depth 0.5m with a volume of 40 L . Forty liters of water were filtered through net with mesh size 55 µ by using a graduated bucket (10 L). Rotifers were captured in a vial at the net bottom, and then it can be put the sample water into a bottle (500ml) for counting after concentrating to 10 ml. [19]. The biological material (Rotifers) was preserved in 4% formalin [20].

Ecological Indices

The following Ecological Indices were accountable**:** Relative Abundance Index (Ra) was calculated depending on the formula used by Odum [21]**.** The Species Richness Index (D) was calculated monthly according formula for Margalefe [22]. Jaccard Presence – Community was calculated according to the formula of Jaccard [23]. Shannon – Weiner Diversity Index (H) of rotifers communities were calculated monthly by using the formula of Shannon and Weiner [24]. The Species Uniformity Index (E) was measured by the formula of Neves *et al*.[25]. Uniformity is in appearance if value of index is higher than 0.5 according to Pielou [26]. Constancy Index (S) was calculated according the equation used by Seraphim *et al*. [27].

Results and Discussion

It was shown that the rotifers density values of Hindiya Dam site were 1743 Ind./m^3 to 26220 Ind./m^3, the lowest values were in September, whereas the highest values were in December. For sites downstream the dam, the numbers of rotifers decreased in site 3 compared with site the dam, then increased in sites 4 and 5 which ranged from 166.65 Ind./m^3 to 47150 Ind./m^3. The lowest values were at sites 4 in January, whereas the highest value was at site 5 in June (Figure-3).

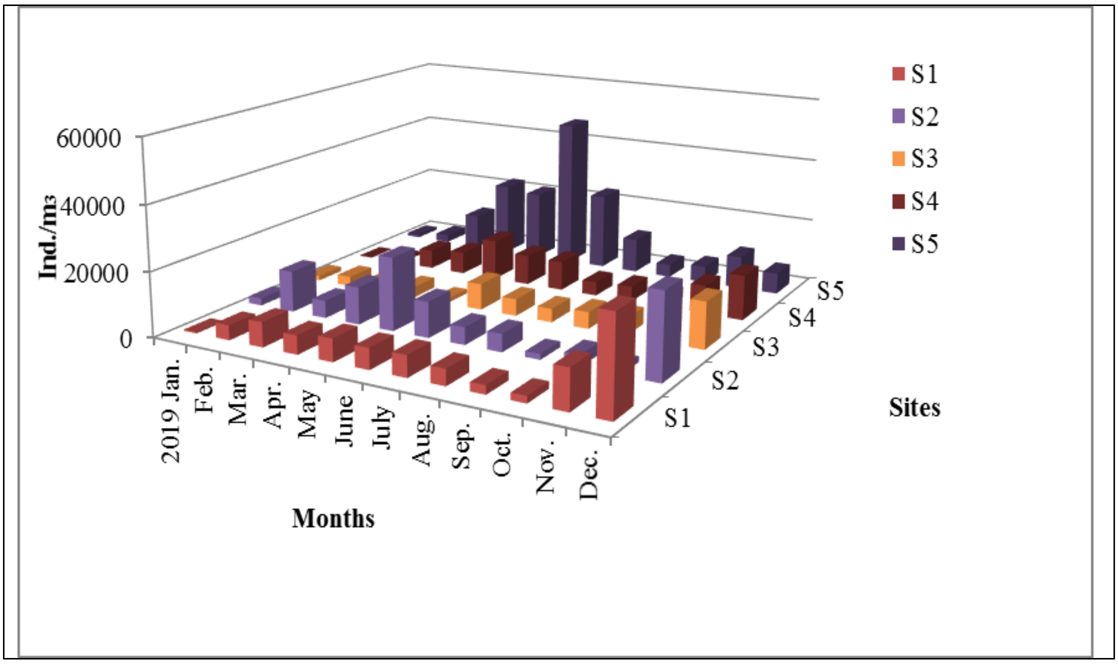

Figure 3- Rotifers densities of Euphrates River during January to December 2019**.**

As for spatial variation, site 5 had high density may due to it had favorable conditions for rotifers growth such as higher value percentage oxygen saturated [28], and the presence of macrophytes [29].

Whereas, the density values in site 3 (below the dam) decreased compared with the dam site. This could be either due to the effect of the dam as a barrier which caused a reduction in rotifers densities compared with the dam site [30]. Or the low water quality in site 3 compared with the dam site which effect negatively on rotifer density[31].

A number of studies have found that rotifers density values in site (below the dam) decreased compared with the dam site such Portinho *et al*.[32] pointed out that rotifers density on the Paraná River site downstream was less than the Itaipu Reservoir in Brazil. Likewise, Zhao *et al* .[30] when they compared dam effect on the Ying River which is tributary of the Huaihe River in China.

In view of all that has been mentioned so far from our findings and the previous agreed studies, it was proved that the dam affected on rotifers densities, especially on site 3 downstream the dam compared with the dam may due to the effect of the dam as a barrier which decreased rotifers densities .Or due to the lower quality in site 3 as explained above.

The relative abundance index of rotifers which indicated that *Keratella cochlearis* with highest species percentages followed by *Rotaria neplunia, Syncheta oblonga, K. valga, Trichocerca bicristata, Polyarthra dolicoptera, Euchlanis deltata* then *Polyarthra vulgaris* at all sites of the study area Figure-4 and Table-1.

Also, the relative abundance index of rotifer on site 1 (upstream the dam) which *Keratella cochlearis, Euchlanis deltata, K. valga, Polyarthra dolicoptera, Monostyla bulla* were recorded, 26%, 7%, 6%, 4% and 3%, respectively.

Whereas, the values of relative abundance index of rotifers at Hindiya Dam site showed that *Keratella cochlearis, Polyarthra dolicoptera, K. valga, Polyarthra vulgaris* and *Euchlanis deltata* were recorded 18%, 8%, 6%, 4% and 3%, respectively.

Whereas, the values of relative abundance index of rotifers at site 3 (downstream the dam) showed that *Keratella cochlearis, Rotaria neplunia, K. valga, Trichocerca bicristata* and *Syncheta oblonga* were recorded 17%, 16%, 7%, 7% and 5%, respectively. Site 4 had the values of relative abundance index of rotifers showed that *Keratella cochlearis, Syncheta oblonga, Rotaria neplunia, K. valga, Polyarthra dolicoptera* were recorded 19%, 14%, 12%, 8% and 8%, respectively. Site 5 had the values of relative abundance index of rotifers showed *Rotaria neplunia, Keratella cochlearis, Syncheta oblonga, Euchlanis deltata* and *Polyarthra dolicoptera* were recorded 17%, 10%, 9%, 9% and 8%, respectively.

Sabri *et al*.[33] recorded pelagic rotifers taxa through study of Samarra Dam on Tigris River , which contributed to river plankton was influenced by many factors such as the seasonal pattern of lentic plankton, reservoir levels and outflow characteristics in the impoundment.

Czerniawski and Kowalska-Góralska [34] when they studied the effects the impoundments of carp ponds on zooplankton in Poland. They referred to the domination of pelagic rotifers (e.g., *Keratella cochlearis* ,*Rotaria neplunia*, *Syncheta oblonga*, *K. valga* ,*Trichocerca bicristata*, *Polyarthra dolicoptera*, *Euchlanis deltata* and *polyarthra vulgaris*) as shown in this study results at all sites because of sites of dams on Barycz River considered a suitable place for drifting pelagic rotifers to proliferate, and reproduce in rivers.

Czerniawski *et al*.[35] point out the abundance of most the benthic rotifers which correlated positively with the current velocity. However, abundance of some benthic Rotifers, such as *Euchlanis* sp and other taxa , in contrast pelagic rotifers, was negatively correlated with the current velocity, and they were most abundant in the dam site than sites downstream the dam.

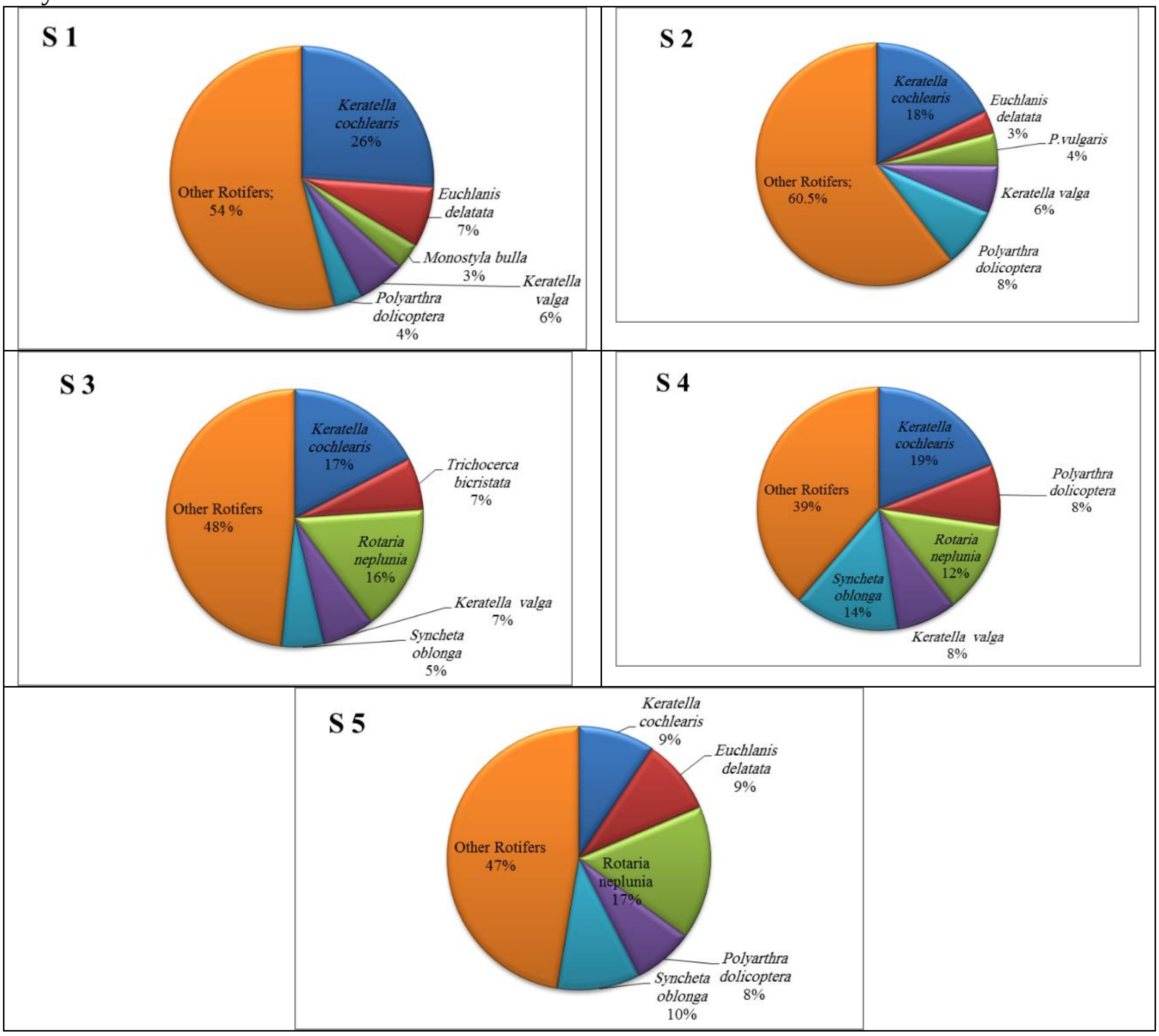

Figure 4-The dominating of rotifer species in Euphrates River during 2019.

In view of all that has been mentioned so far from our findings and the previous agreed studies, it was proved that the dam affected on relative abundance of a mentioned rotifers species may be the reservoirs, even with short water retention times, led to high presence of pelagic rotifers in rivers because the dams sites considered suitable place for drifting pelagic rotifers to proliferate, and reproduce in sites of rivers downstream the dam [34] as explained above.

Table 1-Rotifers distribution, relative abundance frequencies and constancy index

	Sites / Taxa	Relative abundance 1	2	3	4	5	Constancy 1	2	3	4	5
1	*Anuroaeopsis fissa*	R	R	R	R	R	A	Ac	A	Ac	Ac
2	*Ascomorpha saltans*	R	R	R	R	R	A	A	A	A	A
3	*Asplanecna priodonta*	R	R	R	R	R	Ac	Ac	Ac	Ac	C
4	*Ascomorphus* sp.	R	R	R				A	A	A	
5	*Aspelta bidentata*			R	R					A	A
6	*Brachionus angularis*	R	R	R	R	R	Ac	Ac	Ac	Ac	Ac
7	*B.bennini*	R					A				
8	*B.diversicornis*	R		R	R	R	A		A	A	A
9	*B.calcyflorus calcyflorus*	R	R	R	R		A	A	A	A	
10	*B.calcyflorus amphecerus (*long spin*)*	R		R	R		A		A	A	
11	*B.calcyflorus amphecerus (*short spin*)*	R	R	R	R	R	A	Ac	Ac	A	Ac
12	*B. falcatus*			R		R			A		A
13	*B. forficula*	R	R	R		R	A	A	A		A
14	*B.havanaensis*	R	R			R	A	A			A
15	*B.quadridentatus*	R	R	R	R	R	Ac	Ac	Ac	Ac	Ac
16	*B.quadridentatus* (long spin)	R							A		
17	*B.quadridenta* (short spin)	R	R	R				A	A	A	
18	*B.pterodinoides*	R	R	R			A	A	A		
19	*B.plicatlus*		R	R	R	R		A	A	A	A
20	*B.rubens*		R	R	R	R		A	A	A	A
21	*B.varidbilis*	R					A				
22	*Brachionus urceolaris*	R	R	R	R	R	Ac	A	A	Ac	A
23	*Brachionus* sp.	R	R	R	R	R	A	A		A	A
24	*Dipleuchlanis propalula*	R	R	R	R	R	A	A		A	Ac
25	*Cephalodella aureculata*	R			R			A			A
26	*C.intuta*	R				R			A	A	
27	*Cephalodella gibba*	R	R	R	R	R	A				A
28	*Cephalodella lepida*				R		Ac	Ac	Ac	Ac	C
29	*Collothec pelagica*				R						A
30	*Colurella adriatica*	R	R	R	R	R					A
31	*Conochilus hippocreptis*	R					C	A	A	Ac	Ac
32	*Dipleuchlanuis propatula*		R				A				
33	*Epiphanus brachionus*			R						A	
34	*Epiphanus seata*				R						A
35	*Euchlanis delatata*	R	R	R	R	R					A
36	*Filina longiseta*	R	R	R	R	R	C	C	C	C	C
37	*F.opliensis*	R	R	R	R	R	Ac		A	A	A
38	*Gastropus hyptopus*	R					A	A	Ac	Ac	A
39	*Hexarethra mera*	R	R	R	R	R	A				
40	*Hexarethra vulgaris*				R		C	Ac	Ac	Ac	Ac
41	*Keratella cochlearis*	La	La	La	La	R					A
42	*K.tropica*	R	R	R	R	R	C	C	C	C	C
43	*K. tropica f. asymmetrica*	R		R			A	A	A	Ac	Ac
44	*K.quadrata*	R						A		A	

45	*K.quadrata* (logn spin)	R	R	R	R	R		A			
46	*K.quadrata* (short spin)	R	R	R	R	R	A	A	Ac	A	A
47	*K. valga*	R	R	R	R	R	Ac	A	Ac	Ac	Ac
48	*Lepadella depressa*	R					C	C	C	C	C
49	*L. salpina*	R	R	R	R	R		A			
50	*L. ovallus*	R	R	R		R	A	A	A	A	Ac
51	*L. patella*			R		R	Ac	A	A		Ac
52	*L.crepida*			R		R			A		A
53	*Lecan donneri*	R	R			R			A		A
54	*L.elasma*		R	R			A	A			A
55	*L. qadridentata*	R						A	A		
56	*L. luna*	R	R	R	R	R	A				
57	*L.tenuiseta*				R		C	Ac	A	Ac	C
58	*L.undulata*					R					A
59	*L. tichaea*					R					A
60	*L.ludwigii*	R									A
61	*L.grandis*	R					A				
62	*Lophocharis salpina*				R		A				
63	*Macrochaetus subquadratus*	R			R	R					A
64	*Macrotrachela quadricornifera*	R					A			A	A
65	*Manfredium eudactylotura*	R	R	R	R	R			A	A	
66	*Monostyla bulla*	R	R	R	R	R	A	A	A	A	Ac
67	*M. closterocerca*	R		R		R	C	C	C	C	C
68	*M.hamata*	R		R	R	R	A		A		A
69	*M.grandis*	R					Ac		A	Ac	Ac
70	*M.quadridentata*	R			R		A				
71	*M.lunaris*				R	R		A			A
72	*M. scutata*					R				A	Ac
73	*M.stenroosi*	R	R	R	R	R					A
74	*M.thalera*	R					A	A	A	Ac	A
75	*M. thionemanni*	R	R				A				
76	*Monostyla* sp.	R					A	A			
77	*Mytilina nucronata*	R		R		R	A				
78	*Notholca acuminata*	R	R	R	R	R	A		A		A
79	*Notholca squamula*	R	R	R	R	R	A	Ac	A	Ac	A
80	*Notomata usedocerberus*	R					A	A	A	A	A
81	*Philodinavus paradoxus*	R	R	R	R	R			A		
82	*Polyarthra dolicoptera*	R	R	R	R	R	A	A	A	A	Ac
83	*P.vulgaris*	R	R	R	R	R	Ac	C	C	C	C
84	*Pomopholyx sulcata*	R		R	R		A	A	A	A	A
85	*Platyias quadricornis*	R	R	R	R		A	A	A	A	
86	*P. patulus*	R	R			R	A				A
87	*Rotaria citrinus*	R		R		R	A		A		A
88	*R.neplunia*	R	R	R	La	La	C	C	C	C	C
89	*Stephanoceros fimbriatus*			R							A
90	*Syncheta oblonga*	La	La	R	La	La	C	C	Ac	C	C
91	*Syncheta pectinata*	R	R	R			A	A	A		
92	*Testudinella patina*	R	R	R	R	R	Ac	A	A	Ac	Ac
93	*Trichotria tetractis.*	R	R	R	R	R	C	Ac	Ac	Ac	C
94	*Trichocerca bicristata*	R	R	R	R	R	C	C	C	C	C
95	*T.elongata*	R	R	R	R	R	A	A	A	A	Ac

96	*T.longseta*		R	R	R				A		A
97	*T.inemis*		R			R		A			Ac
98	*T.porcellus*	R	R	R	R	R	Ac	Ac	A	A	A
99	*T.pucillus*		R					A			
100	*T.rousseleti*	R	R	R	R	R	Ac	Ac	Ac	Ac	Ac
101	*Trichocerca* sp.	R	R		R	R	A	A		A	A
102	*T.stylata*	R			R	R	A			A	A
103	*T.multicrinus*	R	R	R			A	A	A		
104	*Tripleuchlanis plicata*		R	R					A	A	

*Relative abundance :- > 70%: Dominant Species (D) , 40%-70%: Abundant species (A), 10%-40%: Less abundant species (La). < 10%: Rare species (R).
*Constancy index :- Frequencies calculated from% occurrence in samples. Accidental species (A) zooplankton occur in 1%-25%, Accessory species (Ac) occur in 25%-50% of samples and constant species (C) occur in more than 50% .

It was shown that the values of species richness index for rotifers ranged from 0.67 to 4.1 at site 1(upstream the dam), during January and June, respectively.

On the other hand, the recorded values of Hindiya Dam site ranged from 0.4 to 2.4, the results indicated that the lower values were in November, whereas the higher values were in June. The richness index values of rotifers at sites downstream of the dam ranged from 0.55 to 3.25. It was declined in site 3 to the lowest level in May compared with other sites. Whereas, site 5 raised to the highest level in June (Figure -5).

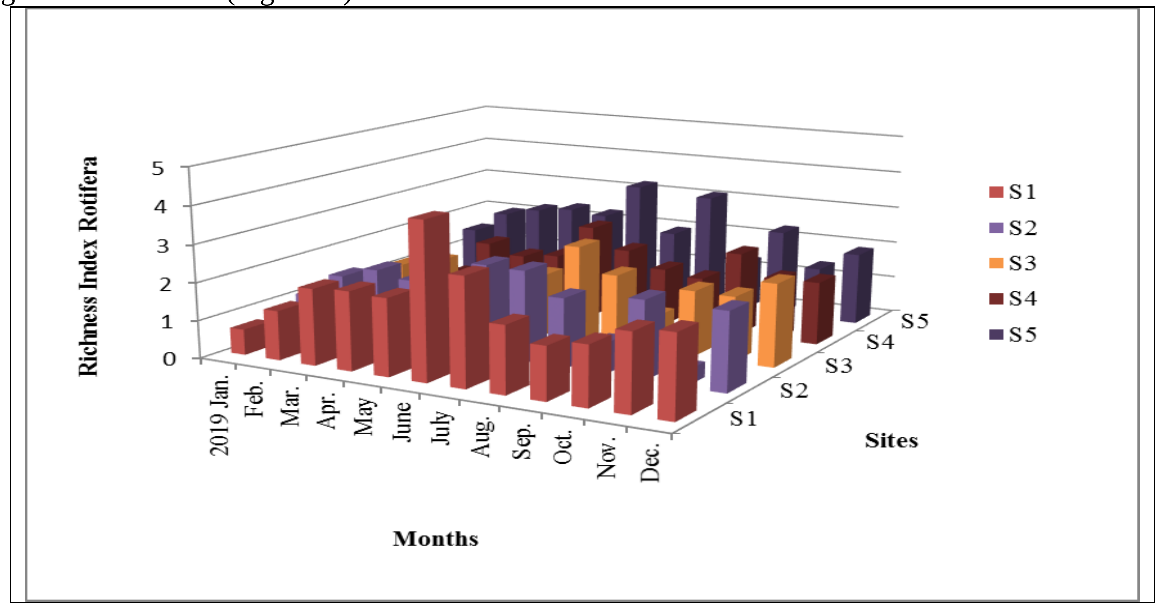

Figure 5- Temporal variations of richness index of rotifers on Euphrates River during January to December 2019.

As for spatial variations, site 3 (below the dam) had lower richness values for rotifers compared with the dam site. This might be related to the effect of current velocity on chlorophyll a content and physicochemical conditions. The rotifers densities and richness clearly correlated with the concentration of chlorophyll a, which is associated with better nutritional conditions for filter-feeding rotifers that is more frequently occurred in lentic waters [36].

However, site 5 had the highest values of richness index for rotifers. This could be owing to the more diversity of washed out rotifers from other habitats in this site compared with other sites[37]. Or with higher water quality for aquatic life compared with other sites which had a positive effect on rotifers richness [31; 38].

If richness value was (≥ 5). It would be classified as perfect. If it was from 3 to 5 classified as moderate and if index value was (≤ 2) classified as distributed [39]. So, Euphrates River rotifers was considered generally from distributed to moderate richness during 2019 in study area.

Overall, these local and global studies highlighted on decline of rotifers richness values in site below the dam compared with the dam site such as Sabri *et al*.[33] when they examined the effect of Samarra Dam on rotifers during the low water discharge period in River Tigris. As well as, Zhao *et al*. [30] when they studied the Ying River which is tributary of the Huaihe River in China.

In view of all that has been mentioned so far from our findings and the previous agreed studies it was proved that the dam affected on rotifers richness especially on site 3 (downstream the dam) which was lower compared with the dam. This might be related to the effect of current velocity on chlorophyll a content and physicochemical conditions. The rotifers densities and richness clearly correlated with the concentration of chlorophyll a, which is associated with best nutritional conditions for filter-feeding rotifers which is more frequently occurred in lentic waters [36] as explained above.

Table-1 showed that 104 species of rotifers occurred at 2019 . The genus *Brachionus* included 17 species, *Monostyla* included 11 species, *Trichocerca* included 10 species, *Lecan* included 9 species and *Keratella* included 7 species, *Lepadella* included 5 species *Cephalodella* included 4 species as well as other genus occurred with more than one species.

In general, Figure-6 showed that the higher Jaccard similarity index value was noted between sites 1 with 4 could be attributed to values of physical chemical characteristics of Euphrates River at these sites .

While, site 5 with site 4 was less similarity value compared with other sites may be related with water quality of site5 which had the higher quality compared with site4 and other sites.

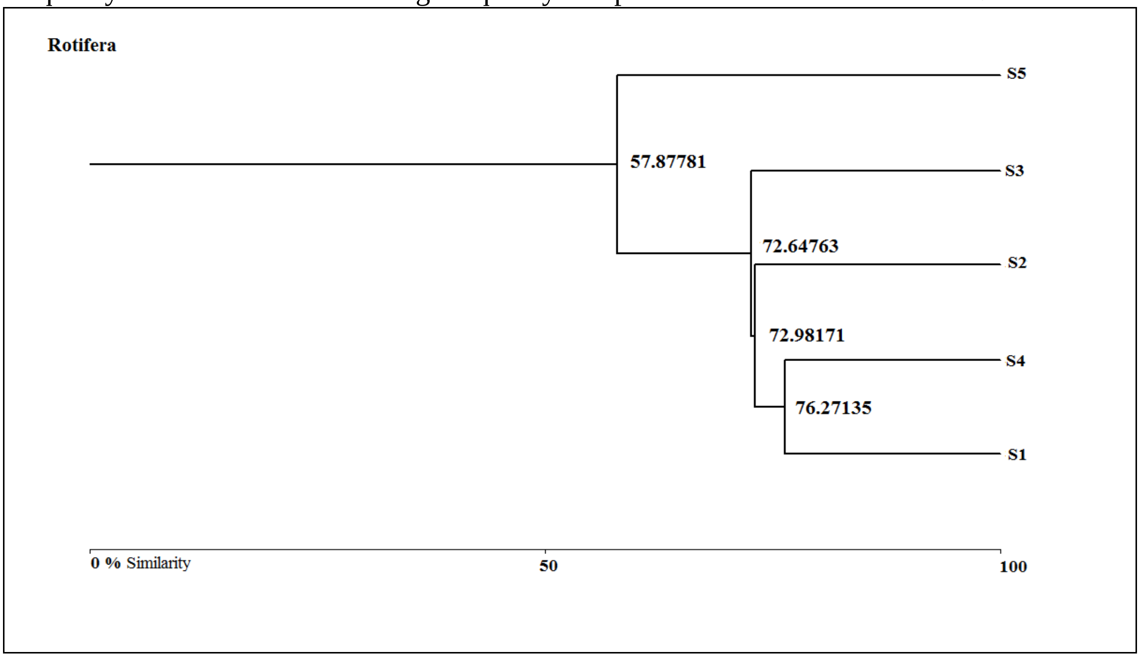

Figure 6- Dendrogram of Jaccard similarity index percentages of rotifers on Euphrates River.

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

Regarding to Shannon Weiner diversity values of rotifers at site 1 (upstream the dam) declined which ranged from 1.46 to 2.79 bit/Ind.. The lowest value was in December, whereas the higher value was in June and July. The values of Hindiya Dam site ranged from 0.43 to 2.70 bit/Ind. which were recorded in November and June, respectively. The index values of rotifers at sites (downstream of the dam) increased compared with the dam site which ranged from 0.85 to 2.81 bit/Ind.. The lowest values were at sites 3 in May, whereas the higher value was at site 5 in June Figure-7.

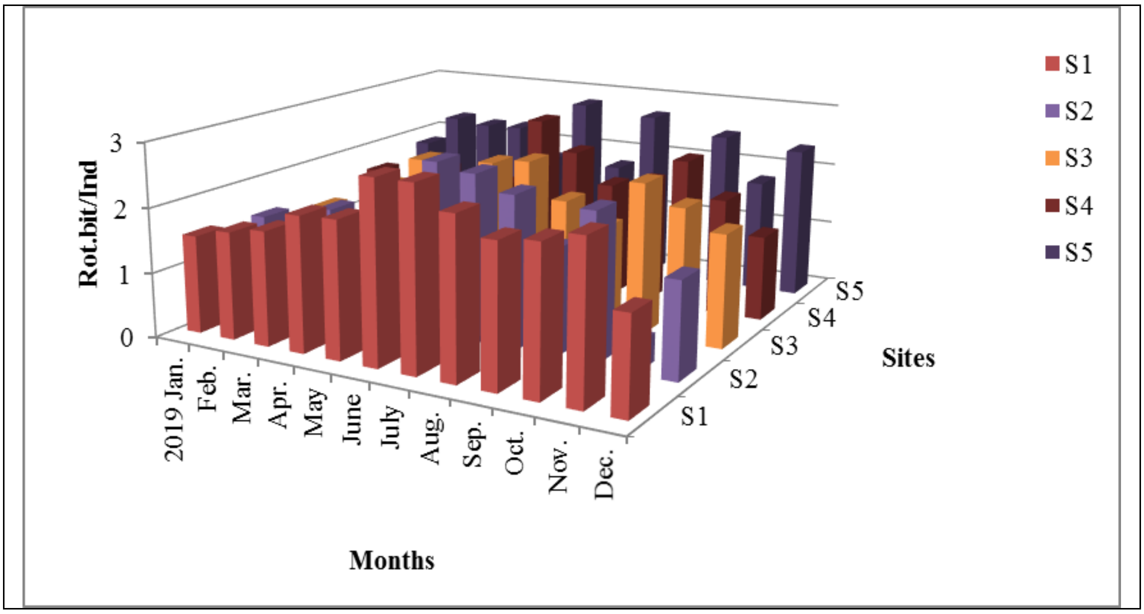

Figure 7- Variation of Shannon Weiner Diversity Index for rotifers on Euphrates River during January to December 2019.

The spatial variation for rotifers showed that Hindiya Dame site had the lower Shannon index values of rotifers. Although it had high richness at the dam site but it was found that it had less evenness as consequence rotifers had less diversity which considered the major group of zooplankton in the study area. This could be either due to their diversity in the reservoir zone were declined by internal processes, such as predators or food whereas rotifers were dominated in the river particularly in the channelized zone [40]. Or owing to the slower water current in reservoirs provide less diversity of rotifers compared with the streams and rivers. This phenomenon is caused by the washout of numerous benthic taxa by higher velocity flow from macrophytes or the substrate, and by the water retention time, which is too short and hinders the development of dominant planktonic forms[35].

If Shannon Index value was more than 4 bit/Ind. It would be classified as most highly diversified. If it was from 3 to 4 bit/Ind. classified as highly diversified and if index value was from 2 to 3 bit/Ind. classified as moderately diversified. If index value was from 1 to 2 classified as little diversified and if index value was less than 1 bit/Ind. classified as very poor [38]. So, Euphrates River was considered generally little diversified during 2019 in study area.

A number of studies have found that Shannon index values declined in the dam site compared with site (below the dam) for example Al-Shamy [41] who discussed effect of Kut Dam site on zooplankton. Similarly, Czerniawski & Sługocki [29] when recorded an increment of Shannon's index values with a higher current velocity >0.1 m s/L. While, Shannon's index values were reduced with a less water current velocity <0.1 m s/L, when discussed man-made ditch in the Drawa catchment (Poland) which are similar with influence of artificial dams. As well as, Czerniawski *et al*.[28] when studied Barycz River and its tributaries which are outlets of carp ponds (in Poland).

In view of all that has been mentioned so far from our findings and the previous agreed studies it was proved that the dam affected on Shannon index values of rotifers especially on the dam site which caused decline of Shannon index values in this site. This could be either due to rotifers diversity in the reservoir zone were declined by internal processes, such as predators or food whereas rotifers were dominated in the river particularly in the channelized zone[40]. Or owing to the slower water current in reservoirs provide less diversity of rotifers compared with the streams and rivers. This phenomenon is caused by the washout of numerous benthic taxa by higher water current from macrophytes or the substrate, and by the water retention time, which is too short would to hinder the development of dominant planktonic forms [35]as explained above.

The results in Figure-8 showed uniformity index values of rotifers at site 1 (upstream the dam) which ranged from 0.46 to 0.94, the lower value was in December, whereas the higher value was in January. The values of Hindiya Dam site declined which ranged from 0.31 to 0.84 that was recorded in October and July, respectively. The values of this index on rotifers at sites (downstream the dam) raised compared with the dam site which ranged from 0.46 to 1. The lowest values were at site 4 in December, whereas the higher value was at the same site in January.

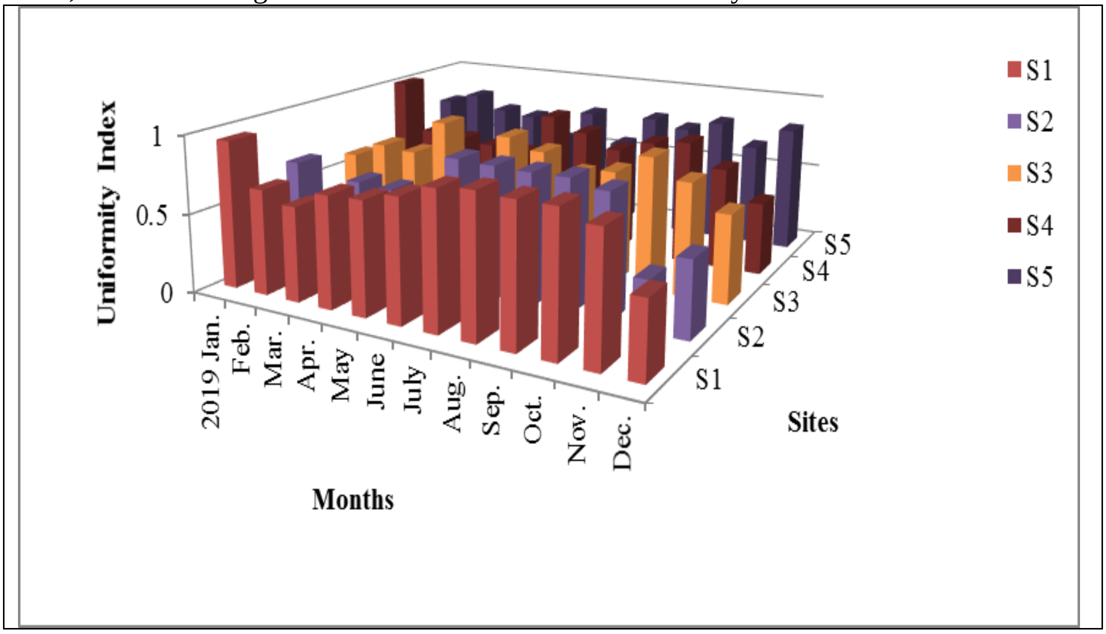

Figure 8-Uniformity Index values (E) of rotifers in Euphrates River.

The spatial variation for rotifers showed that Hindiya Dam site had lower uniformity index values of rotifers compared with other sites. This could be due to the slower water current in reservoirs provides less evenness with more taxa dominance of rotifers compared with the streams and rivers [35].

If uniformity index value was (0.8- ≥0.9), it would be classified as highly balanced. If it was from 0.6 to 0.7 classified as moderate balanced and if index value was (≤ 0.5) classified as unbalanced or under stress [39]. So, Euphrates River zooplankton was considered generally from moderate balanced to highly balanced during 2019 in study area.

Together, these local and global studies found that uniformity index values for rotifers were lower in the dam site compared with the site (below the dam) for example Al Shamy [41] when discussed effect of Al-Kut dam on zooplankton. Similarly, Czerniawski *et al.*[35] when studied beaver impoundments on lowland streams (Poland).

In view of all that has been mentioned so far from our findings and the previous agreed studies it was proved that the dam affected on uniformity index values of rotifers especially in Hindiya Dam site which caused decrease Uniformity Index values of rotifers in this site owing to the slower water current in reservoirs provide more taxa dominance of rotifers compared to the streams and rivers [29], as explained above.

The constant species were 9 at site 1 (upstream the dam). While, it dropped to 7 constant species at site 3 (below the dam), whereas appeared 8 constant species at site 4 and finally the number of constant species increased to 12 constant species after removal the effect of Hindiya Dam on site 5. While, the constant species of the Hindiya Dam represented by 8 constant species (Table- 1).

Keratella cochlearis, *Euchlanis deltata*, *Rotaria neplunia*, *Monostyla bulla*,*Keratella valga*, *Trichocerca bicristata*, *Syncheta oblonga*, *polyarthra dolicoptera* recorded the highest occurrence of rotifers species at most or all sites which occurred in more 50% of samples collected from Euphrates River in Hindiya Dam area during study period (Table- 1).

The spatial variation of constant species of rotifers showed that site 5 was more constant species compared with other sites might be related with its water quality which had higher quality resulted from the far distance from pollution city sources.

While, site 4 had less constant species compared with other sites could be related to the poor water quality as a consequence to the exposure to discharge of city sewage effluents in the river [31].

Our findings agreed with Zhou *et al.* [42] referred to the increment of occurrence and abundance positively of some pelagic rotifer species (e.g., *Keratella cochlearis*, *Rotaria neplunia*, *Syncheta* *oblonga*, *K. valga*, *Trichocerca bicristata*, *polyarthra dolicoptera* and *polyarthra vulgaris*) in the reservoir of the number of dams built on the river. The existence of small reservoirs, even with a short water retention times, lead to more presence of these species in rivers, and lead to drift them from the upstream impoundments, especially with existence of several upstream reservoirs as (Haditha Dam, Ramadi Barrage, Fallujah Barrage) that would influence abundance of pelagic rotifers in Hindiya Dam sites.

Similarly, Czerniawski and Kowalska-Góralska [34] found that the dam reservoir provide a place for drifting pelagic rotifers to proliferate in the dam site and sites (downstream the dam) owing to the ability to colonize new habitats by reproduce through cyclical parthenogenesis, short life span, production the resting eggs that are easily transferred as well as, the small size.

In view of all that has been mentioned so far from our findings and the previous agreed studies it was proved that the dam affected on occurrence and constancy of most rotifers species. This could be due to the reservoirs, even with short water retention times, led to high presence of pelagic rotifers (e.g., *Keratella cochlearis*, *Rotaria neplunia*, *Syncheta oblonga*, *Trichocerca bicristata*, *polyarthra dolicoptera*). Also, reservoirs provide a place for drifting pelagic rotifers and to proliferate in sites downstream the dam [34].

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