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Diversity and seasonal changes of zooplankton communities in the Shatt Al-Arab River, Basrah, Iraq, with a special reference to Cladocera

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Abstract - Zooplankton abundance and distribution were studied at four stations in the northern sector of Shatt Al-Arab from September 2008 to August 2009. Monthly zooplankton samples were collected. Oblique hauls were taken at each station using a 0.120 mm mesh-sized net with 40 cm mouth opening. Air and water temperatures, salinity, pH, dissolved oxygen, turbidity, chlorophyll-a, total suspended solids and total soluble solids were measured at each station and at each sampling event and were correlated with the density of Cladocera. Like Shannon index, Jaccard's similarity index, measures of richness and evenness were calculated. Water temperature ranged from 10 to 28 °C. Salinity values changed from 0.7 to 4.1 psu with a decline in the summer and an increase in the autumn. pH values were >7, dissolved oxygen varied from 4.9 in the summer to 12.3 mg/l in the winter. Chlorophyll-a values fluctuated between 2.3 in the autumn and winter and 21.4 mg/m^3 in Summer. Zooplankton density was the least at station 1 (79-10074 ind/m^3) and the most at station 2 (174-65170 ind/m^3). Cirripede larvae dominated the zooplankton community at all the stations. Cladocera was second in number, followed by Copepoda. The maximum diversity index (2.11), richness (64.45) and evenness (0.47) were obtained at station 1. The highest similarity was obtained between stations 3 and 4 and the lowest between stations 1 and 2.

Keywords: Diversity, Seasonal changes, Zooplankton, Shatt Al-Arab River, Cladocera.

Introduction

Zooplankton comprises a major group of animals in aquatic habitats, for it transfers organic matter from phytoplankton and detritus to higher trophic levels. This group is an important food for many fishes especially juveniles (Green, 1967), and for many other animals.

Jones and Kaly (1996) noted that the zooplankton are useful for monitoring the aquatic ecosystem, because of their morphological, physiological and genetic rapid plasticity according to environmental changes. However the use of zooplankton in environmental monitoring is not common. Phytoplankton, on the other hand, because of their rapid turnover ratio, quick response to the changes in the environment, and ease of identification, are more commonly used for that purpose (Jones and Kaly, 1996).

Studies on zooplankton of southern Mesopotamia goes back to more than 90 years (Gurney, 1921), and was followed by recent studies like those of (Mohammed, 1980; Al-Saboonchi *et al*., 1986; Salman *et al*., 1986), (Abdul-Hussain *et al*., 1989; Hammadi, 2010; Salman *et al*., 2014) for Rotifera, (Ajeel *et al*., 2004; Salman *et al*., 2014) for Cladocera, and (Khalaf, 1991; Mohammed, 1999) for Copepoda. A detailed review on the work that has been done in the region on zooplankton can be found in Abbas (2010) and Hammadi (2010).

This study investigates the distribution and abundance of zooplankton in general and Cladocera in particular in the northern area of the Shatt Al-Arab River, an area where these organisms were not previously studied.

Study area:

The two large rivers of Mesopotamia; Tigris and Euphrates meet at Al-Gurna town to form Shatt Al-Arab River, which is of about 195 km long and 0.4-2 km wide. The depth of the River ranges from 4-15 m. The Shatt Al-Arab River has 3 tributaries; the Al-Sowaeb River coming from the Al-Hawaizah Marshes, the Garmat Ali River flowing from the Al-Hammar Marshes and the Karun River entering Shatt Al-Arab River at about 35 km south of Basrah City although, it has been cut off from the Shatt Al-Arab few years ago. The Shatt Al-Arab River is influenced by the semidiurnal tidal rhythm of the Arabian Gulf (Al-Ramadan and Pasteur, 1987).

Four stations were selected (Fig. 1). Station 1 was located at Al-Gurna town near the confluence of Tigris and Euphrates Rivers, an area affected by untreated waste from local populations. Water depth ranged between 4-8m at station 1. Station 2 was located close to a paper mill at a depth ranging between 8 and 10 m. Station 3 was located at the confluence of Shatt Al-Arab with Garmat Ali Rivers, near Al-Sindbad Island. Station 3 receives waste waters from development and the power station of Al-Najeebiah. Water depth at Station 3 fluctuates between 4 and 23 m. Station 4 was at Al-Ashar an area heavily affected by waste from development, near Basrah and Al-Tanomma. Station 3 is also characterized by heavy boat and ship traffic, and has a water depth ranging between 10 and 12 m.

Materials and Methods

Air and water temperatures were measured with a thermometer. Salinity was estimated with a Salinometer, WTW Condo 315i/set. pH was recorded with a pH meter model WTW pH 315i/set. The Winkler method was used for the estimation of dissolved oxygen concentration (Lind, 1979). Turbidity was measured with a HACH 2100 p Turbidity meter. TDS and TSS were estimated according to the method in APHA (2006). Chlorophyll-a was measured according to Lind (1979).

Monthly zooplankton samples were collected from the 4 stations between September 2008 and August 2009, with a plankton net with a mouth opening of 40 cm and a mesh-size of 0.120 mm. The net was lowered to near the bottom, using a weight fixed to the net, and pulled to the surface. Water depth was recorded during samplings.Samples were poured into a plastic container, labeled and fixed with 4% formalin. In the laboratory a 10ml sub - sample was taken and placed in a Bogorov chamber, where identification and counting of zooplankton using a dissecting microscope were done. The process was repeated 3 times and the average was taken. The whole sample was examined for the rare species.

To assess diversity, we used the Shannon-Weiner index (1949), evenness estimators according to Pielou (1966), richness estimators according to Margalef (1968) and the Jaccard's index (1908). Data for physical, chemical and biological parameters were associated with the density data for Cladocera using multivariate analysis.

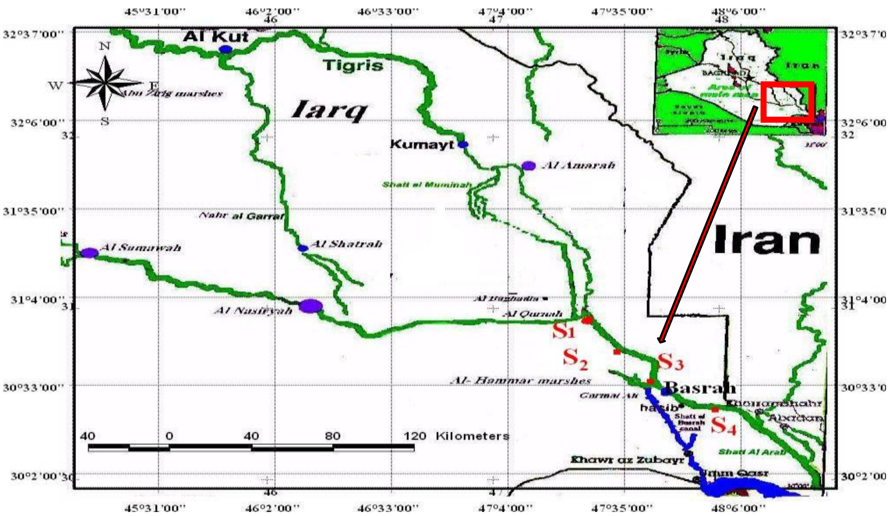

Figure 1. Map of the study area showing sampling locations.

Results

Abiotic factors:

Air and water temperatures tracked each other (Fig. 2). Air temperature varied from 8 (December, 2009) to 33 °C (August, 2009). Water temperatures varied from 10 (December, 2009) to 28 °C (August, 2009). Salinity varied from 0.7 (August 2009) to 2.8 psu (September 2008) (Fig. 3). An exceptionally high reading was recorded at station 4 in August (4.1 psu).

pH values varied from 7.8 in April to 8.65 in September 2008 (Fig. 4). Dissolved oxygen concentration varied from 4.9 mg/l (September 2008) to 12.3 mg/l (December 2009) (Fig. 5). Turbidity fluctuated between 2.0 NTU (December) and 25.1 NTU (July 2009) (Fig. 6). Abnormally high values (47.1 and 53.0 NTU) were recorded in July at stations 1 and 2.

Monthly values of Chlorophyll-a were 2.3 mg/l in July, 12.1 mg/l in April at station 1 (Fig. 7); 3.1 mg/l in September, 15.3 mg/l in April at station 2; 2.9 mg/l in August, 21.1 mg/l in April at station 3; and 1.7 mg/l in August and 10.1 mg/l in April at station 4.

Statistical analysis showed no significant differences (p>0.05) in chlorophyll-a values between the different stations, values of TDS fluctuated between 1168 mg/l (August) and 3940 mg/l (September) at station 1; between 1250 mg/l (August) and 4096 mg/l (September) at station 2; between 1718 mg/l (July) and 4240 mg/l (September) at station 3; and between 2320 mg/l (July) and 5070 mg/l (August) at station 4 (Fig. 8).

TSS values ranged from 4 mg/l (April) to 94 mg/l (July) at station 1 (Fig. 9); from 14 mg/l (October) to 67 mg/l (July) at station 2; from 10 mg/l (February) to 50 mg/l (June) at station 3; and from 10 mg/l (November and May) to 38 mg/l (October) at station 4.

Statistical analysis indicated no significant differences (p>0.05) between the stations. Significant statistical difference (p<0.05) was found between stations 1 and 4 only.

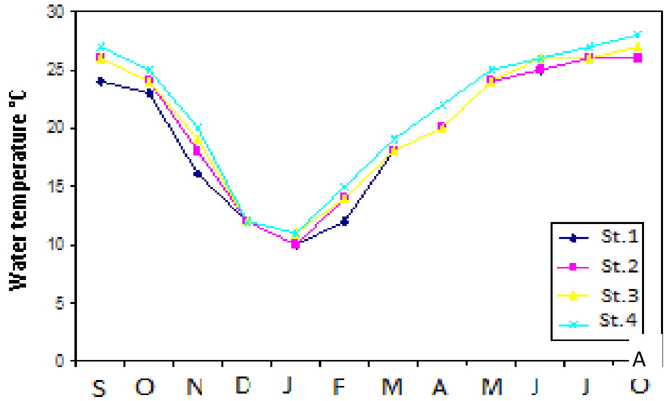

Figure 2. Monthly variations in the water temperature at the 4 stations of the Shatt Al-Arab River.

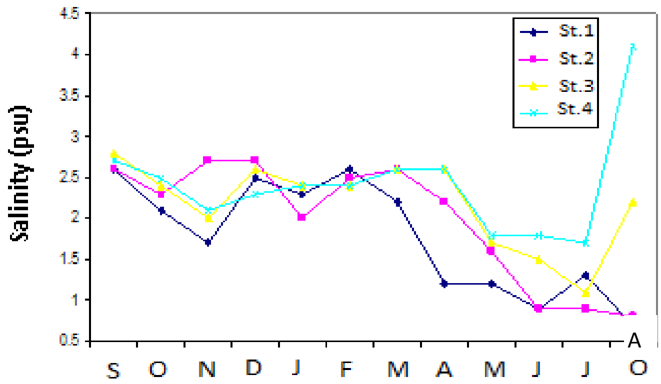

Figure 3. Monthly variations in the salinity at the 4 stations of the Shatt Al-Arab River.

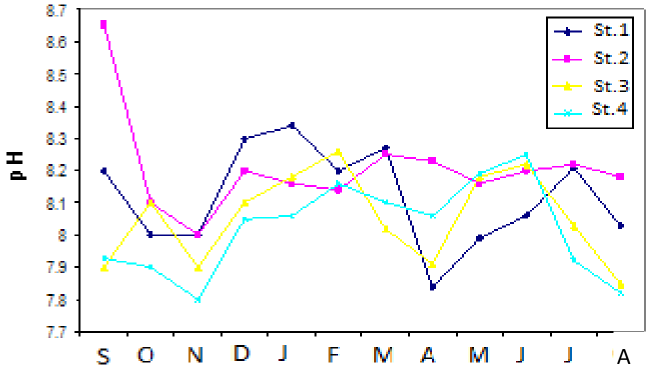

Figure 4. Monthly variations in the pH at the 4 stations of the Shatt Al-Arab River.

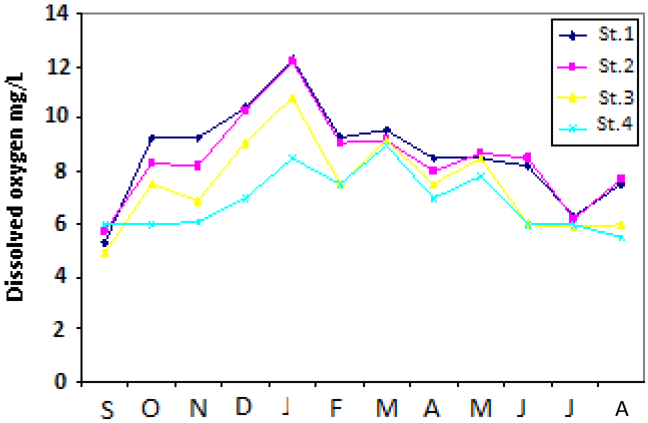

Figure 5. Monthly variations in the dissolved oxygen at the 4 stations of the Shatt Al-Arab River.

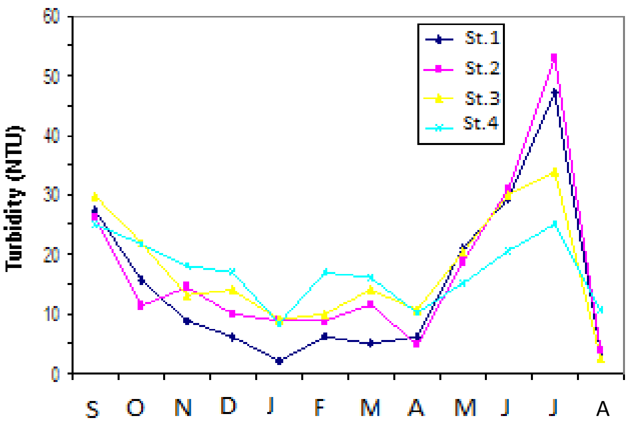

Figure 6. Monthly variations in the turbidity at the 4 stations of the Shatt Al-Arab River.

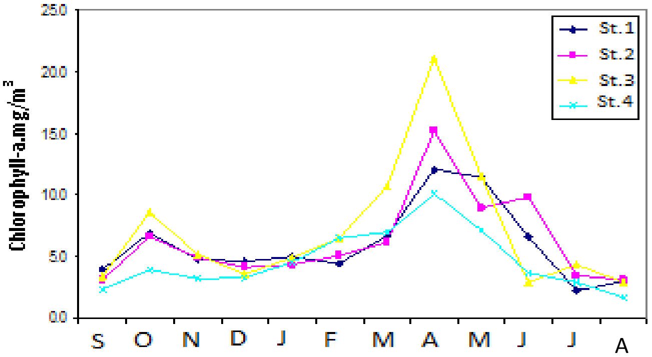

Figure 7. Monthly variations in the Chlorophyll-a at the 4 stations of the Shatt Al-Arab River.

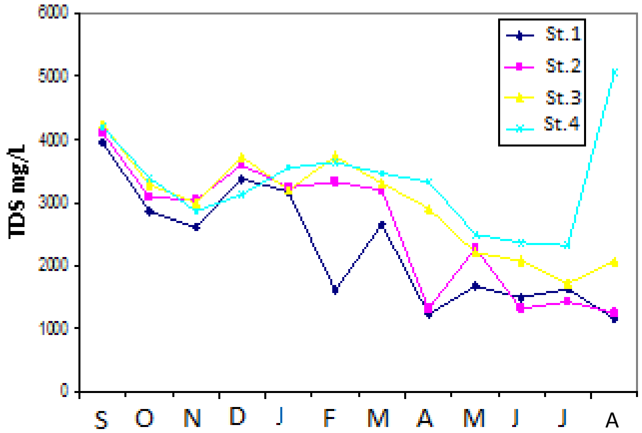

Figure 8. Monthly variations in the TDS at the 4 stations of the Shatt Al-Arab River.

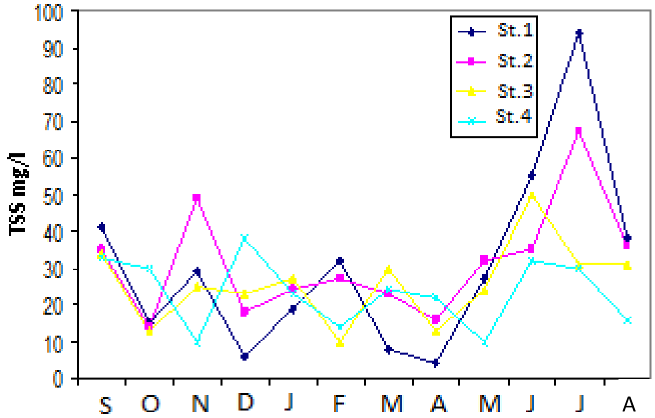

Figure 9. Monthly variations in the TSS at the 4 stations of the Shatt Al-Arab River.

Zooplankton:

Cirripede larvae were the most abundant group of zooplankton in our samples, with abundance ranging from 27 (June) to 9891 ind/m^3 (October) at station 1 (none sampled in August, Table 1); from 27 (January)-48,000 ind/m^3 (April) at station 2 (Table 2); from 5 (June)-25395 ind/m^3 (April) at station 3 (Table 3); and from 12 (January)-36017 ind/m^3 (April) at station 4 (Table 4).

Cladocera was the second most important group, fluctuating in number from 2 (January)-4062 ind/m^3 (September) at station 1 (Table 1); from 2 (April)-59769 ind/m^3 (July) at station 2 (Table 2); from 4 (February)-18280 ind/m^3 (May) at station 3; and from 0.33 (January)-35004 ind/m^3 (May) at station 4 (Table 4).

Copepoda was the third group in dominance. It ranged from 14 (December) to 1015 ind/m^3 (February) at station 1 (Table 1); from 20 (April) to 375 ind/m^3 (September) at station2 (Table 2); from 11 (May) to 438 ind/m^3 (March) at station 3 (Table 3); and from 35 (May) to 810 ind/m^3 (February) at station 4 (Table 4).

Ostracoda were next in abundance, represented by few individuals at station1 (Table 1), reached maximum number (253 ind/m^3) in September at station 2 (Table 2), attained 430 ind/m^3 in April at station 3, (Table 3) and 640 ind/m^3 at station 4 (Table 4). Although zoeas of crabs and shrimps occurred occasionally, sometimes they were highly abundant (Tables 1-4).

Cyclopoda dominated copepods in the Shatt Al-Arab River. The first rise in cyclopod density occurred in September 2008 (669 ind/m^3), the second and major peak (898 ind/m^3) came in February 2009. Harpacticoida rose in January and March 2009, with a second peak in July (105 ind/m^3). Density of Calanoida was very low during the entire sampling period (Tables 1-4).

Cladocera:

Station 1 produced all species sampled in all other stations with a higher frequency of species observations, with the exception of *Moina affinis*, which was observed every month at station 3, and in 10 months at stations 2 and 4 (Tables 1-4).

Twenty three species of Cladocera were recorded. There was an apparent difference in the number of species reported at each station (Table 1). Seven species were present at Station 1: *Alonella diaphana*, *Daphnia lumholtzi*, *Ilyocryptus agilis*, *Leydigia acanthocercoides*, *L. macrodonta macrodonta*, *Leydigia sp.* and *Scapholeberis kingi*. At station 2, 11 species were reported throughout the sampling period (Table 2); *Alona costata*, *Alona rustica rustica*, *Bosmina meridionalis*, *Ceriodaphnia rigaudi*, *Chydorus sphaericus sphaericus*, *Daphnia exilis*, *Daphnia hyalina*, *Diaphanosoma brachyurum, Moina affinis, Pleuroxus paraplesius and Simocephalus vetuloides*. At Station 3, six species were observed (Table 3): *Alona costata, Ceriodaphnia rigaudi, Daphnia hyaline, Diaphanosoma brachyurum, Moina affinis and Simocephalus (Simocephalus) vetuloides*. Six species were also reported at station 4 (Table 4): *Daphnia hyalina, Diaphanosoma brachyurum, Latonopsis fasciulata, Moina affinis* and*Simocephalus vetuloides*. The most common species at all the stations were *Alona costata, Ceriodaphnia rigaudi, Chydorus sphaericus sphaericus, Daphnia hyalina,* *Diaphanosoma brachyurum, Moina affinis and Simocephalus vetuloides.*

Monthly variations in the numbers of Cladocera at each station (Fig. 10) indicated that 12 species were encountered in January, 11 species in February and April, and one in November at Station 1. At station 2, six were recorded in January, five in February and March, and one in September and October. Station 3 had four species in January, and one species for September, October, November and May 2009. Finally, at station 4, ...species were observed in September and only one in October 2008, January 2009 and in May 2009.

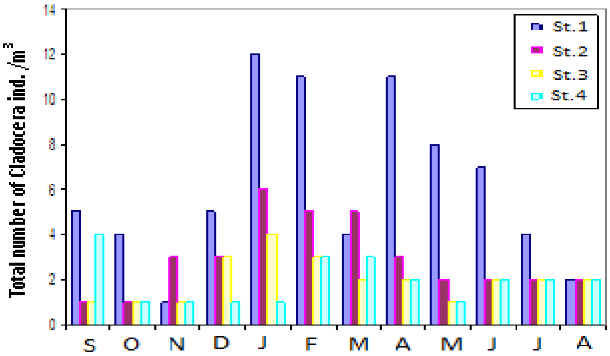

Figure 10. Monthly variations in the density of Cladocera.

Seasonal variation in density of the common species of Cladocera:

Moina affinis, was the most abundant species of Cladocera in the region (Table 1). At station 1, this species peaked in September, with a density of 3913 ind/m^3, disappeared in the winter and spring and reappeared in May (1638 ind/m^3) and declined towards August of the same year. At station 2, *M. affinis* was present throughout most of year, with the highest density in July 2009 (52326 ind/m^3), so was the case at stations 3 and 4, with the peak in May 2009 (18280 and 35004 ind/m^3, at the two stations, respectively).

Diaphanosoma brachyurum, was noticeably present in fewer numbers at station 1 (Table 1) than the rest of stations, with a peak (438ind/m^3) in July, and in June (9950 ind/m^3) at station 2 (Table 2), July at station 3 (12250 ind/m^3) (Table 3) and in June (9699 ind/m^3) at station 4 (Table 4).

Chydorus sphaericus sphaericus, was observed at station 1 (Table 1), from January-June 2009, but in rather few individuals, with maximum number (165 ind/m^3) in February, and the density rose again in April (130 ind/m^3). This species was represented by very few individuals at station 2 (Table 2) and was totally absent at stations 3 and 4 (Tables 3 and 4). Although *Simocephalus vetuloides*was present in rather low densities at all the stations, it was observed in 7 months at station 1 (with 120 ind/m^3 in February) (Table 1), in 6 months at station 2 (Table 2), and in five months at stations 3 and 4 (Tables 3 and 4). *Alona costata*, was recorded in high numbers at station 1 in February (200 ind/m^3) and April (80 ind/m^3) (Table 1), whereas at stations 2 and 3, it was present by few individuals in one or two occasions (Tables 2 and 3). *A. costata* was totally absent at station 4 (Table 4).

Bosmina meridionalis, was sampled in four occasions at station 1 (Table 1), with a rise (195 ind/m^3) in February, while at station 2 (Table 2), it was represented by single specimen in January 2009 and was absent at stations 3 and 4 (Tables 3 and 4). Station 1 produced all 23 species recorded in the present study.

Alona rustica rustica, *Camptocercus rectirostris* and *Daphnia exilis* were found at station 2 and were absent at stations 3 and 4. *Bosmina meridionalis* and *Pleuroxus paraplesius* were sampled at station 3, but not at station 4. *Latonopsis fasciulata* was observed at station 4, but not found at stations 2 and 3.

Ecological Indices:

The highest diversity index (Shannon-Weiner, Ĥ) was recorded at station 1 in January 2.11 (Fig. 11).

Seasonal changes in Ĥ indicated that the highest value was in spring (1.18) and the lowest value (0.25) was in autumn. Significant negative correlation (r = -0.540) was obtained between the Ĥ value and temperature. Mean annual Evenness value showed that the highest value (0.47) was at station 1, followed by station 2 (0.45), station 3 (0.32) and the lowest value was at station 4 (0.29).

Seasonal changes in Evenness showed spring to have the maximum value (0.96), followed by winter (0.50), summer (0.34) and autumn (0.17).

Monthly changes in species richness were quite evident (Fig. 12). Richness peaked at station 1 in February (63) and reached the minimum (1.08) in November. At station 2, zero richness was found in September and October and a maximum value of 15.6 was obtained in January. At station 3, zero richness was observed in November, and a value of 9.7 was recorded in July. At station 4, richness of zero was observed in October-January and May and a value of 18 was estimated for September.

Seasonal changes in species richness were pronounced (Fig. 12), with the maximum value in the spring (20) and the minimum (1.3) in autumn. The Jaccard's similarity index, was greatest between stations 3 and 4 (66%) and lowest between stations 1 and 2 (37.5%) (Fig. 13).

Zooplankton communities and environmental factors:

Significant negative correlations were found between density of zooplankton and salinity (r = -0.363) and TDS (r = -0.402) and positive relations were obtained between zooplankton density and temperature (r = 0.29) and TSS (r = 0.389).

Density of zooplankton showed a positive non-significant correlation with chlorophyll-a (r = 0.099) and turbidity (r = 0.095), whereas dissolved oxygen had a negative correlation with density of zooplankton (r = - 0.014).

There was significant negative relation between diversity index (Ĥ) and temperature (r = - 0.474) and turbidity (r = 0.446), while non-significant negative correlations were obtained between evenness and temperature (r = - 0.373) and turbidity (r = - 0.256).

Principal component analysis (PCA) was used to detect the relationships between various species of Cladocera and environmental variables.

Table 1. Monthly density of zooplankton at station 1 for the period Sept. 2008 - Aug.2009.

Cladocera	Sept. 2008	Oct.	Nov.	Dec.	Jan. 2009	Feb.	Mar.	Apr.	May	June	July	Aug.
Alona costata	1	0	0	0	4	200	1	80	2	0	0	0
Alona rustica rustica	0	0	0	0	1	78	1	6	1	0	0	0
Alonella diaphana	0	0	0	0	0	0	0	0.33	0	0	0	0
Bosmina meridionalis	0	0	0	0	1	195	19	6	0	0	0	0
Camptocercus rectirostris	0	0	0	1	3	20	0	20	11	1	0	0
Ceriodaphnia rigaudi	41	1	0	1	1	0	0	0	0	0	0	0
Chydorus sphaericus sphaericus	0	0	0	0	1	165	2	130	1	6	0	0
Daphnia exilis	0	0	0	0	1	12	0	0	0	0	0	0
Daphnia hyalina	0	0	0	0	3	40	0	0	0	0	0	0
Daphnia lumholtzi	0	0	0	0	0	1	0	0.33	0	0	0	0
Diaphanosoma brachyurum	104	1	0	0	1	0	0	0	0	64	438	72
Dunhevedia crassa	0	1	0	0	0	0	0	0	0	1	0	0
Ilyocryptus agilis	0	0	0	0	0	0	0	0	0	6	3	0
Latonopsis fasciulata	3	0	0	0	0	0	0	0	0	0	0	0
Leydigia acanthocercoides	0	0	0	1	0	0	0	0	0	0	1	0
Leydigia macrodonta macrodonta	0	0	0	0	0	0	0	0	0.5	0	0	0
Leydigia sp.	0	0	0	0	0	0	0	0	0.5	0	0	0
Macrothrix spinosa	0	0	0	0	0	0	0	1	0	0	0	0
Moina affinis	3913	2	0	1	0	0	0	0	1638	1541	893	24
Pleuroxus paraplesius	0	0	0	0	1	10	0	0	0	0	0	0
Scapholeberis kingi	0	0	0	0	0	0	0	0.33	0	0	0	0
Simocephalus (Echinocaudus) exspinosus	0	0	0	0	1	8	0	2	0	0	0	0
Simocephalus (Simocephalus) vetuloides	0	0	2	1	9	120	0	58	2	0.15	0	0
Total of Cladocera	4062	5	2	5	27	849	23	304	1656	1619	1335	96
Copepoda												
Calanoida	10	0	1	1	10	27	2	61	1	0	0	0
Cyclopoida	669	103	60	8	37	898	197	65	278	194	368	48
Harpacticoida	41	23	48	3	80	50	81	40	60	62	105	1
Nauplii larvae	31	1	92	2	50	40	51	50	2	0	0	0
Total of copepoda	751	127	201	14	177	1015	331	216	341	256	473	49
Cirripedia larvae	733	9891	338	55	71	40	3022	2285	163	27	87	0
Others												
Fish larvae	0	0	0	0	0	1	0	0	0	0	0	0
Foraminifera	0	0	0	0	1	0	0	0	8	1	37	0
Amphipoda	0	0	0	1	1	0	0	0	2	0	0	0
Isopoda	13	12	0	0	0	0	0	0	0	0.3	0	1
Ostracoda	2	3	0	1	0	0	1	40	0	0	0	0
Rotifera	83	17	1	3	12	155	32	15	1	1	0	0
Zoea of crab	10	18	1	0	0	0	0	0	13	190	53	2
Zoea of shrimp	13	1	0	0	0	0	0	1	42	166	105	24
Total of others	121	51	2	5	14	156	33	56	66	358.3	195	27
Total of all	5667	10074	543	79	289	2060	3409	2861	2226	2260	2090	172

Table 2. Monthly density of zooplankton at station 2 for the period Sept. 2008 - Aug.2009.

Cladocera	Sept. 2008	Oct.	Nov.	Dec.	Jan. 2009	Feb.	Mar.	Apr.	May	June	July	Aug.
Alona costata	0	0	0	0	1	3	0	0	0	0	0	0
Alona rustica rustica	0	0	0	0	0	1	0	0	0	0	0	0
Alonella diaphana	0	0	0	0	0	0	0	0	0	0	0	0
Bosmina meridionalis	0	0	0	0	1	0	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0	0	0	0	0	0	0
Ceriodaphnia rigaudi	0	0	0	0	0	0	2	0	0	0	0	0
Chydorus sphaericus sphaericus	0	0	0	0	1	0	4	0.33	0	0	0	0
Daphnia exilis	0	0	0	0	0	1	5	0	0	0	0	0
Daphnia hyalina	0	0	0	0	1	3	15	0	0	0	0	0
Daphnia lumholtzi	0	0	0	0	0	0	0	0	0	0	0	0
Diaphanosoma brachyurum	0	0	1	0	0	0	0	0	64	9950	7443	395
Dunhevedia crassa	0	0	0	0	0	0	0	0	0	0	0	0
Ilyocryptus agilis	0	0	0	0	0	0	0	0	0	0	0	0
Latonopsis fasciulata	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia acanthocercoides	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia macrodonta macrodonta	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia sp.	0	0	0	0	0	0	0	0	0	0	0	0
Macrothrix spinosa	0	0	0	0	0	0	0	0	0	0	0	0
Moina affinis	4332	67	3	5	0.33	0	0	1	1770	8050	5236	9948
Pleuroxus paraplesius	0	0	0	1	0	0	0	0	0	0	0	0
Scapholeberis kingi	0	0	0	0	0	0	0	0	0	0	0	0
Simocephalus (Echinocaudus) exspinosus	0	0	0	0	0	0	0	0	0	0	0	0
Simocephalus (Simocephalus) vetuloides	0	0	1	5	3	1	5	0.33	0	0	0	0
Total of Cladocera	4332	67	5	11	7	9	31	2	1834	18000	59769	10343
Copepoda												
Calanoida	12		5	2	12	6	0	0	0	0	0	0
Cyclopoida	290	138	255	13	64	87	75	20	13	60	165	120
Harpacticoida	25	19	25	10	6	4	16	0.33	50	65	0	0
Nauplii larvae	48	29	10		55	9	0	0	0	30	0	0
Total of copepoda	375	186	295	25	137	106	91	20	63	155	165	120
Cirripedia larvae	18332	12018	3365	296	27	59	18915	48000	18291	15050	4426	779
Others												
Fish larvae	0	0	0	0	0	1	2	0	0	0	0	0
Foraminifera	0	0	0	0	0	1	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0	0	90	70	0
Isopoda	1	0	0	0	0	0	0	0	2	0	0	0
Ostracoda	253	167	6	1	0	0	1	40	34	10	0	0
Rotifera	0	103	15	0	3	0	436	0	30	600	0	0
Zoea of crab	28	104	12	0	0	0	0	0	37	60	668	26
Zoea of shrimp	1	6	0	0	0	0	0	0.33	10	50	72	132
Total of others	283	380	33	1	3	2	439	40.33	113	810	810	158
Total of all	23322	12651	3698	333	174	176	19476	48062	20301	34015	65170	11400

Table 3. Monthly density of zooplankton at station 3 for the period Sept. 2008 - Aug.2009.

Cladocera	Sept. 2008	Oct.	Nov.	Dec.	Jan. 2009	Feb.	Mar.	Apr.	May	June	July	Aug.
Alona costata	0	0	0	0	1	0	0	0	0	0	0	0
Alona rustica rustica	0	0	0	0	0	0	0	0	0	0	0	0
Alonella diaphana	0	0	0	0	0	0	0	0	0	0	0	0
Bosmina meridionalis	0	0	0	0	0	0	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0	0	0	0	0	0	0
Ceriodaphnia rigaudi	0	0	0	0	2	1	0	0	0	0	0	0
Chydorus sphaericus sphaericus	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia exilis	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia hyaline	0	0	0	0	0	2	0	0	0	0	0	0
Daphnia lumholtzi	0	0	0	0	0	0	0	0	0	0	0	0
Diaphanosoma brachyurum	0	0	0	0	0	0	0	0	0	7040	12250	4410
Dunhevedia crassa	0	0	0	0	0	0	0	0	0	0	0	0
Ilyocryptus agilis	0	0	0	0	0	0	0	0	0	0	0	0
Latonopsis fasciulata	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia acanthocercoides	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia macrodonta macrodonta	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia sp.	0	0	0	0	0	0	0	0	0	0	0	0
Macrothrix spinosa	0	0	0	0	0	0	0	0	0	0	0	0
Moina affinis	1360	478	424	112	1	0	5	4421	18280	1115	3115	3375
Pleuroxus paraplesius	0	0	0	0	0	0	0	0	0	0	0	0
Scapholeberis kingi	0	0	0	0	0	0	0	0	0	0	0	0
Simocephalus (Echinocaudus) exspinosus	0	0	0	0	0	0	0	0	0	0	0	0
Simocephalus (Simocephalus) vetuloides	0	0	0	5	1	1	1	4	0	0	0	0
Total of cladocera	1360	478	424	118	5	4	6	4425	18280	8155	15365	7785
Copepoda												
Calanoida	0	0	0	0	5	8	0	1	0.33	0	53	135
Cyclopoida	105	19	61	50	35	24	362	259	1	65	25	135
Harpacticoida	121	53	6	27	6	0	41	12	10	0.33	0	1
Nauplii larvae	0	18	0	8	25	0	35	0	0	0	3	30
Total of copepoda	226	90	67	85	71	32	438	272	11	65	81	301
Cirripedia larvae	4507	5922	4265	1152	17	7	8707	25395	6950	5	963	14550
Others												
Fish larvae	0	0	0	0	0	0	0	0	0	0	0	0
Foraminifera	0	0	0	0	0	0	0	0	0	30	0	0
Amphipoda	0	0	1	1	0	0	0	4	15	26	0	0
Isopoda	0	0	0	0	0	0	0	0	0	1	0	0
Ostracoda	67	42	1	7	0	0	0	430	5	0	0	150
Rotifera	27	248	18	3	3	0	0	0	5	0	53	0
Zoea of crab	27	47	11	1	0	0	0	0.33	285	90	153	34
Zoea of shrimp	0	0	0	0	0	0	0	30	175	120	53	15
Total of others	121	337	31	12	3	0	0	464.3	485	267	259	199
Total of all	6214	6827	4787	1367	96	43	9151	30556	25726	8492	16668	22835

Table 4. Monthly density of zooplankton in station 4 for the period Sept. 2008 - Aug.2009.

Cladocera	Sept. 2008	Oct.	Nov.	Dec.	Jan. 2009	Feb.	Mar.	Apr.	May	June	July	Aug.
Alona costata	0	0	0	0	0	0	0	0	0	0	0	0
Alona rustica rustica	0	0	0	0	0	0	0	0	0	0	0	0
Alonella diaphana	0	0	0	0	0	0	0	0	0	0	0	0
Bosmina meridionalis	0	0	0	0	0	0	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0	0	0	0	0	0	0
Ceriodaphnia rigaudi	0	0	0	0	0	3	0	0	0	0	0	0
Chydorus sphaericus sphaericus	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia exilis	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia hyaline	0	0	0	0	0	4	1	0	0	0	0	0
Daphnia lumholtzi	0	0	0	0	0	0	0	0	0	0	0	0
Diaphanosoma brachyurum	36	0	0	0	0	0	0	0	0	9699	2050	705
Dunhevedia crassa	0	0	0	0	0	0	0	0	0	0	0	0
Ilyocryptus agilis	0	0	0	0	0	0	0	0	0	0	0	0
Latonopsis fasciulata	1	0	0	0	0	0	0	0	0	0	0	0
Leydigia acanthocercoides	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia macrodonta macrodonta	0	0	0	0	0	0	0	0	0	0	0	0
Leydigia sp.	0	0	0	0	0	0	0	0	0	0	0	0
Macrothrix spinosa	0	0	0	0	0	0	0	0	0	0	0	0
Moina affinis	2996	3326	186	127	0	0	1	94	35004	238	5688	2192
Pleuroxus paraplesius	0	0	0	0	0	0	0	0	0	0	0	0
Scapholeberis kingi	0	0	0	0	0	0	0	0	0	0	0	0
Simocephalus (Echinocaudus) exspinosus	0	0	0	0	0	0	0	0	0	0	0	0
Simocephalus (Simocephalus) vetuloides	1	0	0	0	0.33	3	1	0.33	0	0	0	0
Total of cladocera	3034	3326	186	127	0.33	10	3	94.33	35004	9937	7738	2897
Copepoda												
Calanoida	0	0	0	1	0.33	0	1	76	0	12	88	283
Cyclopoida	218	106	41	15	60	473	179	59	29	24	107	246
Harpacticoida	15	71	9	22	5	17	4	15	6		13	22
Nauplii larvae	0	35	0	3	27	320	36	0	0	0	0	0
Total of copepoda	233	212	50	41	92.33	810	220	150	35	36	208	551
Cirripedia larvae	14833	7449	1244	1206	12	840	7177	36017	1744	1547	2644	20355
Others												
Fish larvae	0	0	0	0	0	0	0	0	0	0	0	0
Foraminifera	0	0	0	0	0	0	0	0	15	0	0	0
Amphipoda	0	0	1	0	0.33	0	0	0	6	1	1	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	150	265	38	0	0	0	0	55	0	0	1	640
Rotifera	26	106	0	0	131	0	0	0	387	417	13	0
Zoea of crab	46	141	3	1	0	0	0	5	72	595	401	327
Zoea of shrimp	1	18	0	0	0	0	0	27	84	274	38	3
Total of others	223	530	42	1	131.3	0	0	87	564	1287	454	970
Total of all	18323	11517	1522	1375	236	1660	7400	36348	37347	12807	11044	24773

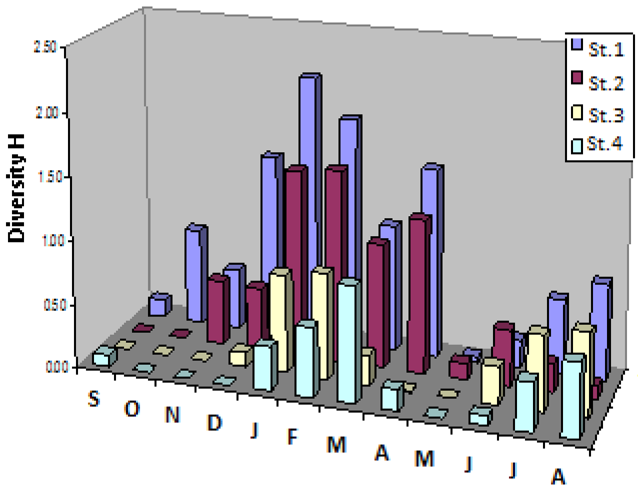

Figure 11. Monthly variation in the Diversity index (H) of Cladocera.

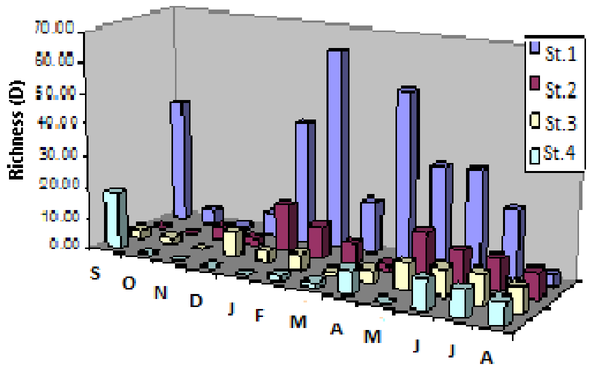

Figure 12. Monthly variations in the Richness (D) of Cladocera.

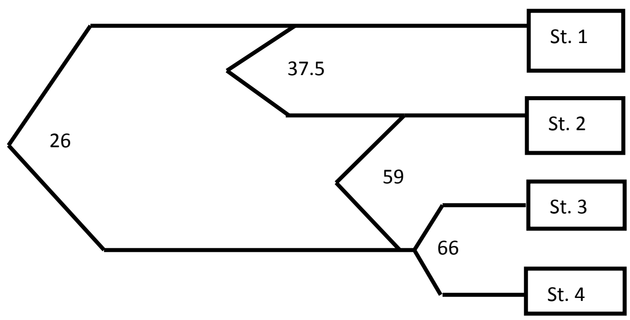

Figure 13. Cluster of the similarity index (Jaccards) of the 4 stations in the Shatt Al-Arab River.

Figure (14) showed that the abundance of *M. affinis* was significantly correlated with water temperature (r = 0.332) and turbidity (r = 0.448), and weakly positively correlated with TSS, pH and chlorophyll-a (r = 0.211, 0.136, 0.026, respectively), whereas negative correlations were obtained with DO (r = -0.098), TDS (r = - 0.278) and a significant negative correlation was found with salinity (r = -0.337). *A. costata* had negative correlations with most ecological variables, except with chlorophyll a, which had a weak positive correlation (r = 0.1).

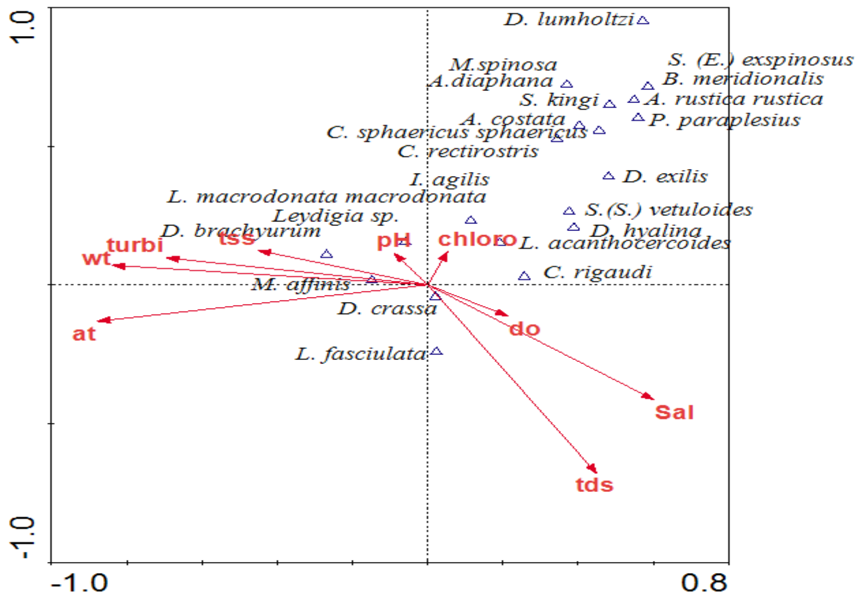

Figure 14. Canonical Correspondence Analysis of the correlation coefficients between some species of Cladocera and the environmental factors at the Shatt Al-Arab River.

Discussion

The present investigation showed that there were differences between the four stations in density of zooplankton, caused entirely by the changes in densities of Cladocera. Density of Cladocera was significantly higher at station 1 compared with the rest of stations. This was due to the fact that in station 1 water had a lower salinity than the rest of stations, as the station 1 is near the confluence of the two Rivers, Tigris and Euphrates and is far from the influence of the Arabian Gulf. This is supported by salinity values which were higher at station 4 and by the lowest number of species of Cladocera at this same station. Moreover, station 1 receives less waste effluents than the rest of stations (Hussain *et al.*, 1991).

The present results emphasize that species of Cladocera increased in the spring more than in the winter, summer and autumn at all stations. This coincides with the results of Ajeel (1998) and with the index of diversity estimated herein, which indicated higher values in the spring and winter and lower values in the summer and autumn.

Moina affinis was recorded at most sampling events and at all the stations. That trend was repeated to a lesser extent by *Siomcephalus vetuloides* and *Diaphanosoma brachyurum*. This was possibly due to these species becoming adapted to a wide spectrum of environmental conditions. Contrary *Alonella diaphana, Leydigia macrodonta macrodonta, Leydigia sp*. and *Macrothrix spinosa*, which were observed in a very short period and in limited numbers. These species apparently have a very narrow limit of tolerance to different environmental conditions. Most species of Cladocera showed positive correlation with chlorophyll-a and this is an indication to their close relation with phytoplankton. It is important to note that phytoplankton is the most important constituents of food of Cladocera, in particular and zooplankton in general. This is supported by the results of Lampert (1987) and Sommer *et al*. (1986) in lakes indicating that there were signification top-down effects on phytoplankton, including order-of-magnitude reductions of phytoplankton biomass after the spring bloom "clear water phase" by the zooplankton dominated by the Cladoceran *Daphnia spp*. The northern section of Shatt Al-Arab River is poorly known in terms of zooplankton taxa. This study indicated that that section has less species of Cladocera (23 species) compared to the Marshes (41 species; Salman *et al*., 2014). Al-Qarooni (2005) reported only 14 species from the southern Marshes, Ajeel (1998) found 23 species in Shatt Al-Arab River. Al-Saboonchi *et al*. (1986) observed 7 species only in Garmat-Ali and Mohammed (1986) found 13 species in the Tigris and 18 species in the Euphrates River. Al-Lami (1998) recorded only 16 species of Cladocera in the Tigris River whereas; Sabri *et al*. (1993) recorded 25 species in the Tigris River. Generally, the differences in numbers of species of Cladocera may be due to local differences. Moreover, enclosed areas like ponds, swamps and lakes are considered species-poor, but have high numbers of individuals (Ajeel, 1998). Temperature plays a large role in determining distribution of plankton in the surface waters, especially, in shallow waters (Kinnesh, 1986). The present results indicate that there was a signification positive correlation of temperature with the density of zooplankton. This result is in support of the findings of Khalaf and Shihab (1977), Ajeel *et al*. (2001) and Al-Qarooni (2005). Salinity is considered as one of the most important factor affecting the zooplankton (Madhupatap, 1979). Significant negative correlation was found between density of zooplankton and salinity and TDS. These results concur with those of Mangalo and Akbar (1986) on the Tigris River. Moreover, Al-Qarooni (2005) and Ajeel *et al*. (2006) also reported negative correlations of zooplankton with salinity at Al-Chibayesh and Southern Iraqi Marshes, respectively. A negative correlation was found between density of zooplankton and DO at all stations, and this is in accordance with the results of Al-Qarooni (2005) on Al-Chibayesh and Al-Hammar Marshes. There was a significant positive correlation of turbidity with density of zooplankton and a positive correlation of the latter with TSS at all the stations. However, Al-Lami (1998) found a negative correlation of zooplankton density and turbidity at Tigris River, but he recorded exceptionally higher values (average 188 NTU) due to the effect of the Al-Tharthar Reservoir arm on the Tigris River, whereas turbidity values recorded in the present study were mostly lower at all stations, except in

July when they varied between 25 and 53 NTU, at stations 4 and 2, respectively. Cressey (1963) concluded that the Tigris and Euphrates rivers lay about 90% of their sediment loads at their middle and southern sectors and only 10% of their loads reached Shatt Al-Arab River. A positive non-significant correlation was found here between chlorophyll-a values and density of zooplankton, and this is in support of the findings of Al-Lami (1998) at the Tigris River. This is not surprising, as the Ctenopoda and Anomopoda live on bacteria, algae, yeasts, Protista and detritus (Dumont and Negrea, 2001), they add that the bulk of the diet of most anomopod species, consisted of small-sized, living or dead particles that were filtered from suspension, or scraped or brushed from a substratum. Zooplankton density greatly varied at the four stations, with the highest at station 2 and the lowest at station 1. However, stations 4 and 3 came second and third, respectively, in density of zooplankton. Raymont (1983) noted that comparison of zooplankton from various localities was not easy to accomplished, as the plankton is rapidly affected by changes in the environment, both locally and spatially. Although, his conclusions applied to marine zooplankton, it can be transferred to this study. Richness and evenness of Cladocera indicate that they are higher at station 1 than the rest of stations, with the least values recorded at station 4. This may be due to the fact that the northern sector of the River in less affected by pollution than the southern sector. This is supported by the conclusion of Al-Jizani (2005) that pollution tends to reduce diversity. Statistical analysis showed that there were significant negative correlations between evenness and turbidity. This concurs with the observation of Al-Jizani (2005) that diversity is positively correlated with transparency. Moreover, the present study showed that there were negative significant correlations of the diversity index and evenness with water temperature. On the other hand, water temperature was positively correlated with density, suggesting that temperature was having a vital role in increasing density, possibly affecting one or a few species at the expense of others, hence reducing diversity. This is supported by the Jaccards, similarity index which indicated that station 1 was less similar to the other stations, due to it having higher diversity and lower densities compared to the other stations. Jonge (1995) suggested that during normal conditions, water quality enhanced diversity, whereas during abnormal conditions a reduction in diversity would enable other species to take over. We showed that cirripede larvae were the most dominant group of zooplankton community in the Shatt Al-Arab River, comprising 53 and 59% of the zooplankton at stations 1 and 2, respectively. Cladocera ranked second (31 and 42%) at stations 1 and 3. Copepoda were 13% at station 1 and 1% at each of the other 3 stations. The only species of Cirripedia present in the region is *Balanus amphitrite amphitrite*, which is an invasive species not present in the upper reaches of Shatt Al-Arab River before the 1980s (Salman *et al.*, 1986). It was first observed in the 1990s in the region (Salman, personal observations; see also Abdul-Sahib *et al.*, 2003). This species is now spreading out to the Southern Iraqi Marshes of Al-Hammar (Jaweir and Al-Kenzawi, 2009) and Al-Chibayish Garmat-Bani-Seed (Salman personal observation). The abundance of this meroplanktonic larvae made the Cladocera to the second dominant group, after being the first in the Shatt Al-Arab River in the 1980s (Salman *et al*., 1986). However, throughout the course of vertical haul sampling, horizontal tows were also conducted at each station and at each sampling event. During these events, Cladocera comprised of 29%, 70%, 43%, and 52% at the four sampling stations, respectively, whereas cirripede larvae comprised of 52, 29, 55 and 49% at the four stations, respectively. Such increase in number of Cladocera may be an artifact of sampling caused by patchiness.

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التنوع والتغيرات الفصلية في مجتمعات الهائمات الحيوانية في شط العرب، البصرة، العراق، مع إشارة خاصة لمتفرعة اللوامس

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المستخلص - اختيرت أربع محطات في القسم الشمالي من شط العرب، الأولى في القرنة، والثانية في الهارثة والثالثة قرب جزيرة السندباد والرابعة في العشار. جمعت عينات شهرية من الهائمات الحيوانية للمدة من أيلول 2008 إلى أب 2009. سحبت شبكة الهائمات الحيوانية في كل محطة من القاع إلى السطح وكانت فتحات الشبكة 0.120 ملم وقطر فوهتها 40 سم. سجلت درجة حرارة الهواء والماء والملوحة والأس الهيدروجيني والأوكسجين المذاب والعكارة والكلوروفيل-أ والمواد الصلبة العالقة الكلية والمواد الصلبة الذائبة عند كل محطة وسجلت علاقتها مع كثافة متفرعة اللوامس. حسب دليل شانون ودليل التشابه والغنى والتكافؤ. تراوحت درجات حرارة الماء بين 10-28 ºم، وتراوحت قيم الملوحة بين 0.7 و 4.1 جزء بالألف فكان هناك تدني في الصيف وزيادة القيم في الخريف. كانت قيم الأس الهيدروجيني قاعدية، وتراوحت قيم الأوكسجين الذائب بين 4.9 في الصيف و 12.3 ملغم/لتر في الشتاء. وتراوحت قيم كلوروفيل - أ بين 2.3 في الخريف و 21.4 ملغم/م^3 في الصيف. كانت اقل قيم كثافة الهائمات الحيوانية في المحطة 1 (79-10074 فرد/م^3) وأعلاها في الحطة 2 (174-65170 فرد/م^3). سادت يرقات ذؤابية الأقدام مجتمع الهائمات الحيوانية في جميع المحطات، وجاءت متفرعة اللوامس ثانية تبعتها مجذافية الأقدام. بلغت أعلى قيمة دليل شانون للتنوع 2.11 والغنى 64.45 والتكافؤ 0.4 وكانت جميعها في المحطة 1. لقد كان أعلى تشابه بين المحطتين 3 و 4 وأدنى تشابه بين المحطتين 1 و 2.