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Ecological Study of Zooplankton in South Shatt Al-Arab River, Southern Iraq

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Abstract

The ecology of zooplankton in general and Copepoda in particular has been studied in this study. The samples were collected monthly, during the period from December 2011 to November 2012, in south Shatt Al-Arab River at Al-Siba and Al-Faw by using plankton net of 85 μm mesh sized and a mouth aperture of 30 cm, by vertical collection method. Physical and chemical parameters were studied such as: water temperatures were ranging from (13 – 28 °C), pH values (7 – 8.8), the salinity (0.5 – 41.5 ppt) in station 1 and 2 respectively. The highest oxygen concentration (12 mg/l) was recorded at station 2 during December 2011, whereas the lowest concentration was (6 mg/l) at station 1 during August 2012. The highest value of chlorophyll – a was (19.9 mg/m3) at station 2 during November 2012, while the lowest value was (2.8 mg/m^3) at station 1 during December 2011. The highest density of zooplankton reached (53211 ind.//m^3) at station 2 during May 2012, whereas the lowest density was (21 ind.//m^3) at station 1 during December 2011, where the highest density of copepods was (48966 ind.//m^3) at station 2 during May 2012, and the lowest density was (7 ind.//m^3) at station 1 during December 2011. Fifty-three taxa of zooplankton were identified through the present study, 34 taxa belong to Copepoda, and 19 taxa belong to the other zooplankton. Copepoda dominated among the other zooplankton. The species *Acartia (Odontacartia) ohtsukai* was new record in Iraqi water.
Keywords: Zooplankton, Shatt Al-Arab, ecology

1 Introduction

Zooplankton is a diverse group of heterotrophic organisms ranging in size from unicellular flagellates to multi-cellular crustaceans that serve an important function by grazing on phytoplankton and thus to transfer energy to higher trophic levels (e.g. Shrimps and fishes) exploitable by humans

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(Steinberg and Condon, 2009). Furthermore, they are present in the water column of all aquatic ecosystems, the pelagic and littoral zones in oceans, seas, ponds, lakes and rivers. The zooplankton can be grouped into many different ways including size, habitat, depth distribution, length of planktonic life and feeding mode (Lynn, 2007).

The zooplankton community is composed of both primary consumers, which graze on phytoplankton and secondary consumers, which feed on other zooplankton. Since herbivorous zooplankton feeds on phytoplankton, an increase in the size of phytoplankton productivity generally leads to an increase in the size of the grazing zooplankton community (Kiørboe, 1993; Legendre and Michaud, 1998). Most fishes and other aquatic organisms depend on zooplankton for food during their larval stages, and some fish continue to eat zooplankton in their entire life (Madin et al., 2001).

Zooplankton are used as indicators of changes in the environment due to their sensitivity to biotic and abiotic variables. Despite variable salinity, many species usually linked to inland waters can colonize estuarine systems by being tolerant to a wide range of salinity and temperatures or by possessing life cycle stages that are resilient or remain dormant (encystment) under unfavorable condition (Steinberg & Condon, 2009). In addition, zooplankton serves as an indicator for pollution of the marine and freshwater environments by different types of pollutants.

The Shatt Al-Arab River is the major fresh water discharge to the Arabian Gulf. Consequently, some of the previous oceanographic studies showed a direct effect of water discharged from the Shatt Al-Arab River upon the physic-chemical characters of the water, particularly in NW Arabian Gulf (Brewer et al., 1978; Saad and Antoine, 1978). The fluctuation in salinity, in particular, is often the dominant feature of the estuarine environment. A salinity gradient exist in each estuary, but the pattern of the gradient varies with the topography of the estuary, the tidal regime and the river flow (Nybakken, 1982). Consequently, several studies considered salinity as the most important environmental variable determining geographical distribution of zooplankton in estuaries (Goswami and Selvakumar, 1977; Laprise and Dodson, 1994).

The objectives of this study to evaluation the study area of zooplankton, as it is a major food source for fish. Therefore, its fertility is considered evidence of the fertility of the area for fishing, and they are considered as environmental guides to know the changes in the environment, as they are sensitive to environmental conditions; also, they are used as biological indicators of pollutants in the aquatic environment.

2 Materials and Methods

Study area

The Shatt Al-Arab River forms the outlet of the two main rivers of Iraq. The Tigris and Euphrates Rivers that are meeting at Al-Qurna. The river flows in a Southeasterly direction and downstream of Al-Faw discharges into the Arabian Gulf. The length of Shatt Al-Arab River from the meeting site at Al-Qurna to Al-Faw is about 195 Km and the width varies at different regions ranging from 0.2 km at south Karoon confluence to 2.25 km at the mouth. The water depth increases, in general, in the direction of the Gulf, varying from 8-15 m (Al-Wahili, 2009). The major tributary connected to the Shatt Al-Arab River is Al-Karun River, which connected to it at 33 km south of Basrah. Two stations were selected for sampling, station 1 is located at Al-Siba, i.e. at mid distance between Basrah and Al-Faw towns with coordinates 29°59’23.28"N, 48°27’51.94"E , the 2nd station is located in Al-Faw town at coordinates 30°20’20.94"N, 48°15’43.82"E.

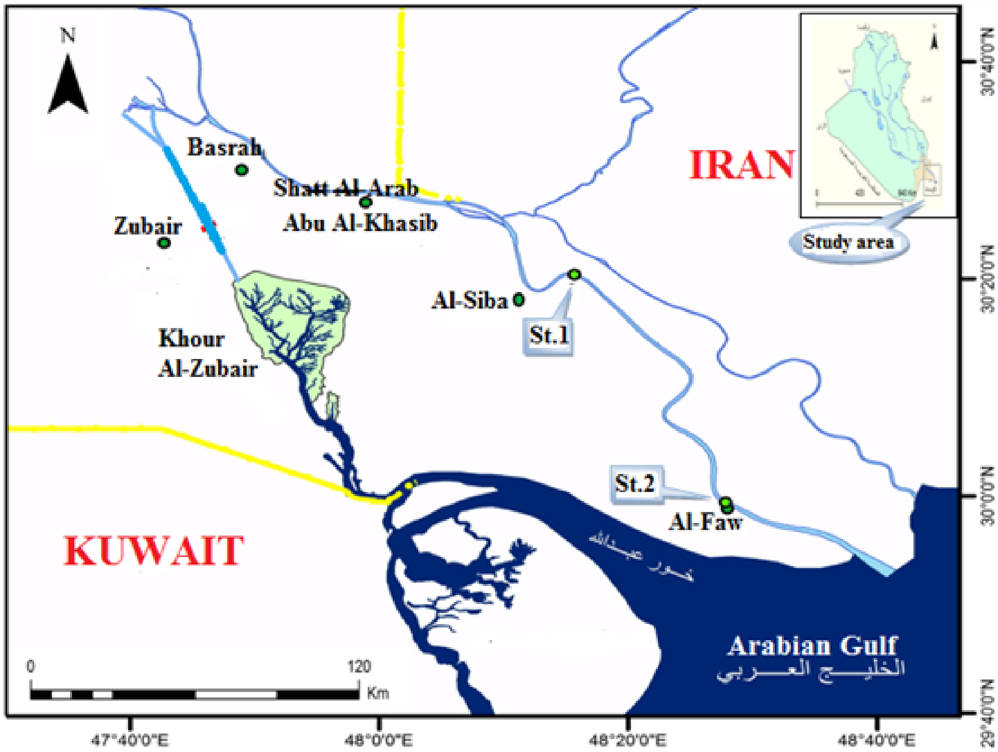

Figure 1. Map of lower Mesopotamia showing the sampling stations.

Samples collection

Zooplankton samples were collected monthly from the two stations during the period from December 2011 to November 2012 (Fig. 1). Collection was made vertically from near the bottom to the surface layer of the water column during daytime, by using a plankton net, 30 cm in diameter of mouth aperture and 85-μm mesh-size, by using wooden medium-sized boat. The samples were immediately preserved in 5% buffered formaldehyde.

Identification of some unidentified species was made with the aid of the following guides, keys and references: Khalaf (1988.1991, 1992, and 2008 a, b); Zheng Zhong (1989); Al-Yamani & Prusova (2003); Al-Yamani et al. (2011). Water volume which was filtered through the plankton net towed vertically represented by the volume of cylinder which was calculated by the formula:

V = $r^2 \pi h$

Where

V = the volume of cylinder (i.e. the water volume filtered through the net)

r = diameter of the mouth aperture of the plankton net

π = (3.14)

h = the height of the cylinder, i.e. the depth from which the net are towed to the surface of the water.

Environmental measurements

Water temperatures, salinity, pH and dissolved oxygen (DO) were measured in field; by a digital multi meter, YSI incorporated 556 MPS. Chlorophyll-a was measured at laboratory (Lind, 1979). The results of the environmental measurements have been analysed using Spearman's-Rank Correlation Coefficient (Al-Qahtani, 2014).

Ecological indices

Diversity index (H) (Shannon and Weaver, 1949), Evenness index (J) (Pielou, 1977), Richness index (D) (Margalefe, 1968) and Jacard similarity index (Jaccard, 1908) were used in our analysis work. In addition, the program SPSS and Canonical correspondence analysis (CCA) were used in statistical analysis.

3 Results

Hydrographic parameters

The maximum value of water temperature recorded was 28°C in August 2012, while the minimum temperature was 13 °C in December 2011 at stations 1 and 2 (Fig. 2). Statistical analysis showed the absence of significant differences ($P > 0.05$) between the study sites. The monthly variations in salinity values were extremely pronounced, where the lowest value of salinity was 0.5 ppt reported in November 2012 at station 1, and the highest value was 41.5 ppt in July at station 2. (Fig. 3). The results of statistical analysis showed presence of significant differences ($P < 0.05$), between studied stations.

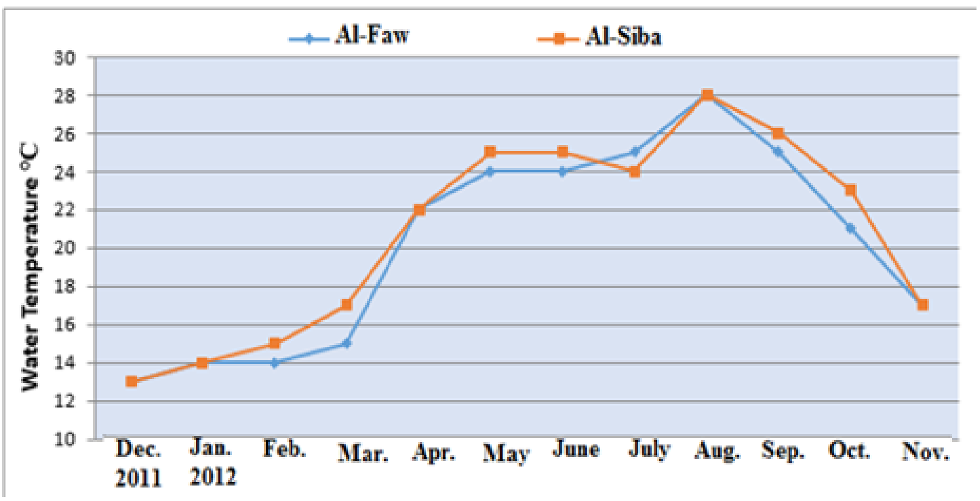

Figure 2. Water temperature °C in the study area during the study period.

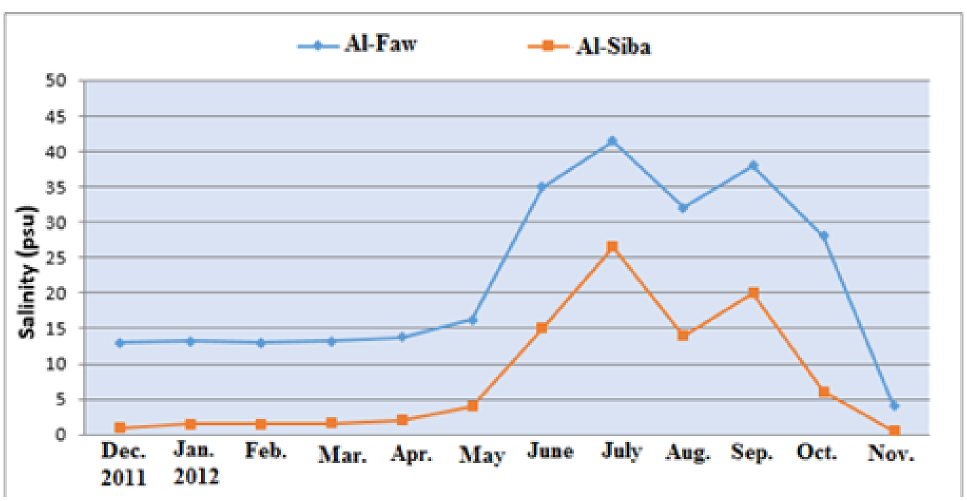

Figure 3. Salinity concentration (ppt) in the study area during the study period.

Monthly variations in the pH values were observed during the study period ranging between 7 at station1 in November 2011 and 8.8 at station 2 in June 2012 (Fig. 4). Statistical analysis showed significant differences ($P < 0.05$) in pH between all stations of studying area.
The highest values of DO were 12 mg/L at stations 2 in December 2012, while the lowest value was 6 mg/L at station 1 in August (Fig. 5). A significant difference ($P < 0.05$) was found between stations. The monthly variation in the values of chlorophyll-a ranging between the highest value 19.9 mg/m^3 in October 2012 at stations 2 and the lowest value of 2 mg/m^3 at station 1 in December 2011 (Fig. 6). No significant differences ($P > 0.05$) were observed between the studying stations.

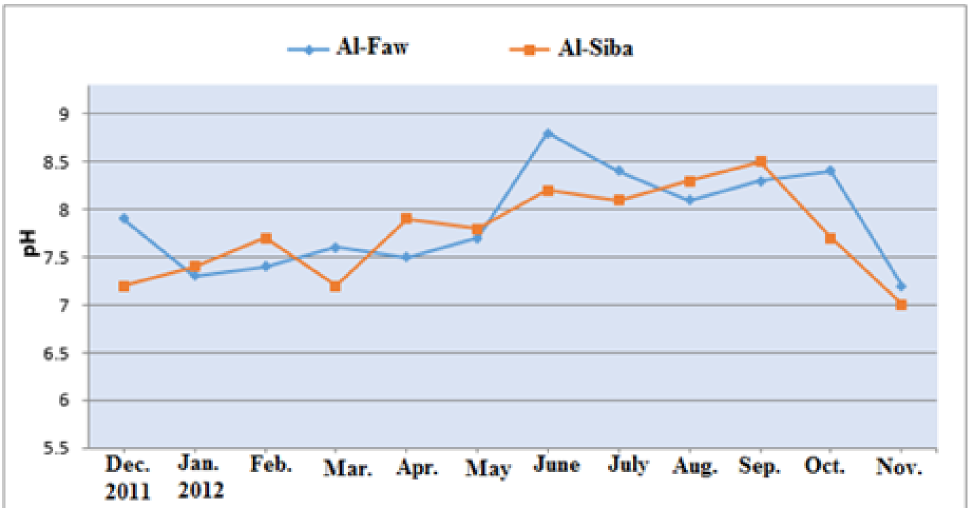

Figure 4. Hydrogen ion concentration (pH) in the study area during the study period.

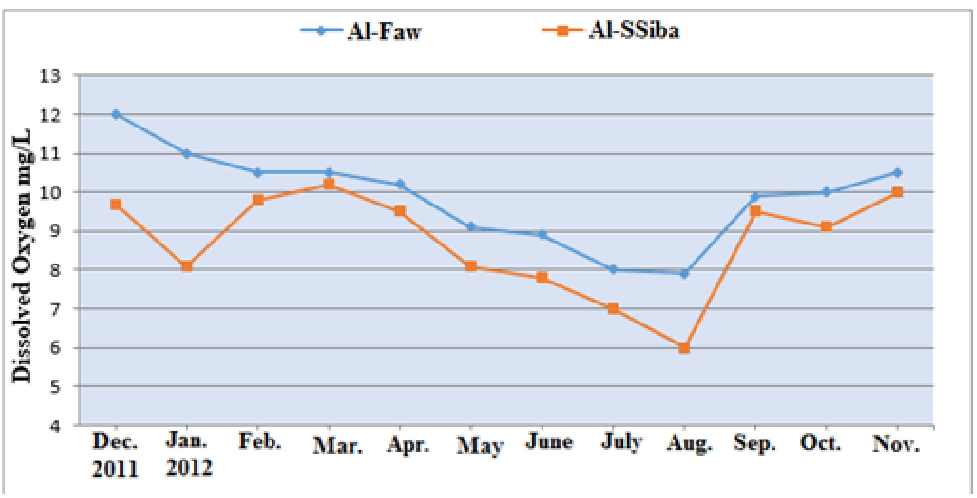

Figure 5. Dissolved Oxygen concentration (mg/L) in the study area during the study period.

Zooplankton composition

Zooplankton communities in Shatt Al-Arab River consisted of 53 taxa. Copepods were the most diverse group containing the highest number of species (34) species belonging to 26 genera. The taxa of other than copepods zooplankton which were not identified to generic or species levels included, Cirripede larvae; polychaets larvae and adults; planktonic gastropods; Ostracoda; Cladocera; Tintinnida; Crab Larvae; Sergistidae; shrimp larvae; Nematoda; Fish larvae; Jelly fish and Isopoda in addition to eggs; Nauplii and copepodite stages of copepod. Two species of other than copepods zooplankton were identified to generic levels; these are *Sagitta* sp.; *Lucifer* sp. and one to species level *Acetes japonicas*.

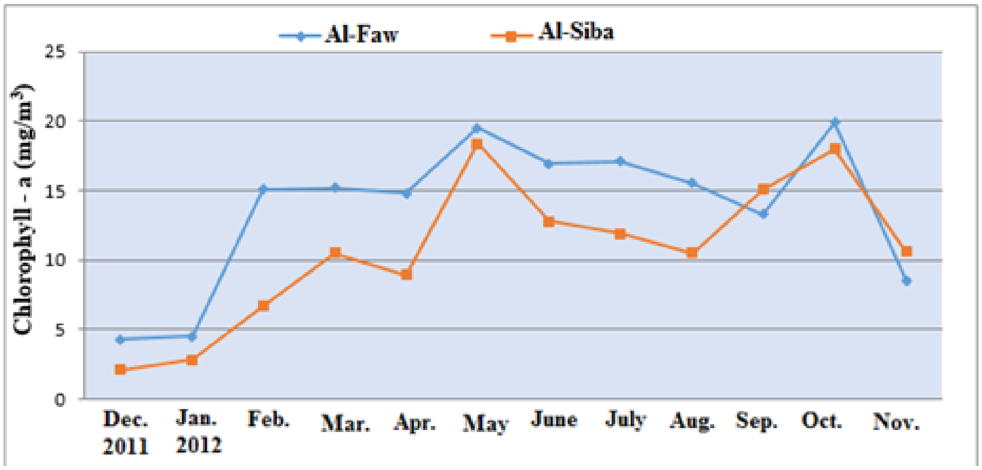

Figure 6. Chlorophyll - a concentration (mg/m3) in the study area during the study period.

The most abundant of copepods in the two studied stations was Calanoida with 18 species belonging to 14 genera, then the order Cyclopoida with 7 species belong to 5 genera, the 3rd. and 4th. Orders were Harpacticoida which recorded six species and six genera, and Poecilostomatoida with three species belong to one genus, which occurred in the two stations (Table 1). Statistical analysis showed significant differences in the number of species ($P < 0.05$) between the studied stations.

The highest number of Copepoda 32 species, belonging to 24 genera was recorded in the station 2 (Al-Faw); while 17 species of 16 genera were recorded in station 1 (Al-Siba)

Quantitative study The density of zooplankton significantly varied during the study period. At Al-Siba station, the density of zooplankton ranged between (21 - 13883 ind./m^3) during December and June respectively (Table 1), and the annual density reached 57867 ind./m^3. While at Al-Faw station the density of zooplankton ranged between (4623 - 53211 ind./m^3) during December and May, respectively (Table 2) and the annual density reached 235661 ind./m^3 (Table 3).

The copepods were prevalent in the two study stations, and their density ranged between (7-10538 ind./m^3) during December and August respectively at Al-Siba station and comprised 72.33% of total zooplankton (Table 1). While at Al-Faw station the density of copepods ranged between (2710-48966 ind./m^3) during December and May respectively, and comprised 88.35% of total zooplankton (Table 2).

Cirripede larvae was the another important groups of zooplankton, with an annual density of 7916 ind./m^3, making up 13.68% of total zooplankton in the Al-Siba station, and the density ranged between (2 - 3018 ind./m^3) during December and June, respectively. Conversely, at Al-Faw station, the annual density was 14918 ind./m^3 at a rate of 6.33%, and the density ranged between (2 - 8235 ind./m^3) during July and March, respectively. Another important taxonomical groups was that of planktonic gastropods, as its highest density reached 5818 ind./m^3 in Al-Faw station, and 3712 ind./m^3 in Al-Siba station. Then Polychaetes larvae and adults, with an annual density of 745 ind./m3 recorded at Al-Siba station and 999 ind./m^3 in Al-Faw station, while the annual density of Cladocera was 1780 ind./m^3 at Al-Siba station and 832 ind./m^3 at Al-Faw station (Table 3).

The total zooplankton density in the Al-Siba station ranged between (21 - 13883 ind./m^3) during December and June, respectively, the relationship between the salinity and the density of zooplankton was positive (0.83), while at Al-Faw station the total of zooplankton was ranged between (4623 - 53211 ind./m^3) during December and May, respectively, the relationship between the salinity and the density of zooplankton was negative (-0.259). The results of the statistical analysis showed that there were significant differences (P <0.05) in the number of zooplankton between the study stations.

Ecological indices

Richness index (D)

Figure (7) shows the monthly changes in the values of the richness index for Copepoda in the two study stations during the sample collection period, as the highest value (3.14)% was recorded during July at the Al-Faw station, while the lowest value at the same station was (0.69)% in December 2011 as for Al-Siba station, its highest value was (2.40)% in July and September and the lowest value (0)% in December 2011.

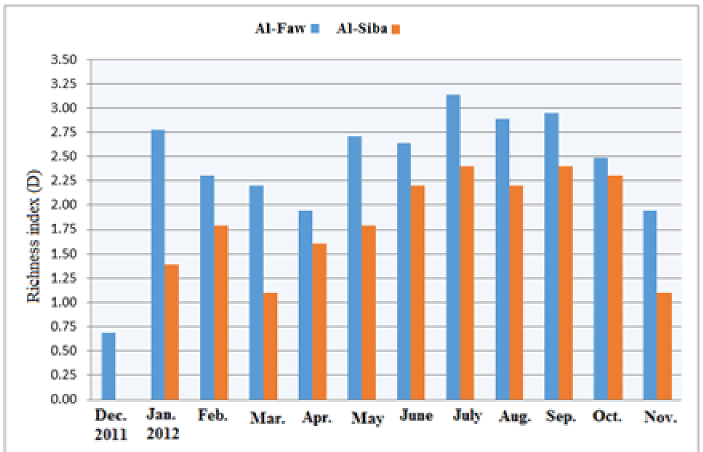

Figure 7. The monthly changes in the values of the richness index (D) for Copepoda in the Shatt Al-Arab stations during the study period.

Evenness index (J) Figure (8) shows the monthly differences in the Evenness index values for the studied species of Copepoda, as the highest value in the Al-Faw station reached (0.83)% during December 2011, while the lowest value in it (0.62)% in November, while in the Al-Siba station was Its highest value (0.95)% in March and the lowest value (0)% in December 2011.

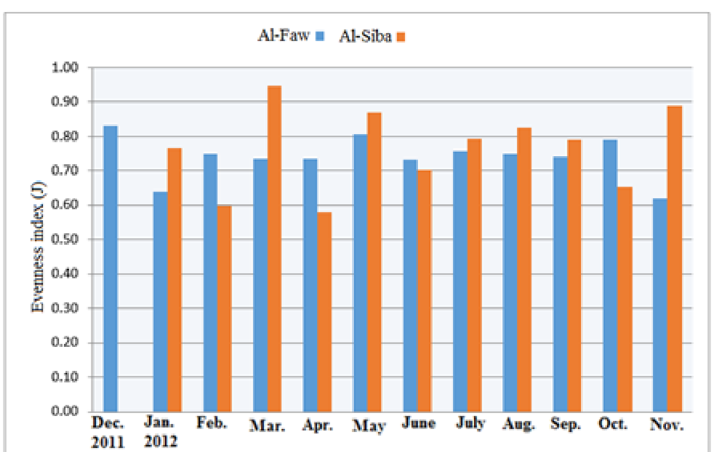

Figure 8. The monthly differences in the values of the Evenness index (J) for Copepoda in the two study stations.

Table 1. Monthly density of zooplankton (ind./m3) at St. 1 (Al-Siba).

ZOOPLANKTON	Dec. 2011	Jan. 2012	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
COPEPODA												
CALANOIDA												
Subeucalanus flemingeri	0	0	0	0	0	0	0	140	0	0	0	0
S. subcrassus	0	0	0	0	0	0	0	94	0	0	0	0
Paracalanus aculeatus	0	0	0	0	0	0	1012	1454	938	44	270	0
Parvocalanus crassirostris	0	0	0	0	0	0	1006	506	563	88	216	0
Bestiolina arabica	0	0	0	0	0	0	50	140	563	176	162	0
Clausocalanus minor	0	0	0	0	0	0	0	0	0	308	0	0
Pseudodiptomus ardjuna	0	3	50	0	38	0	1256	375	2908	308	972	0
Acartia ohtsukai	0	0	0	0	0	0	1207	844	88	0	0	0
CYCLOPOIDA												
Oithona attenuata	0	0	0	0	0	0	47	0	0	0	9	0
Eucyclops serrulatus	0	0	0	0	115	0	0	0	0	0	0	0
Acanthocyclops vernalis	0	0	0	79	38	0	0	0	0	0	0	0
Microcyclops varicans	0	0	50	39	0	0	0	0	0	0	0	0
Cyclops sp.	0	13	1012	197	0	294	0	94	0	44	0	187
HARPICTICOIDA												
Clytemnestra scutellata	0	0	0	0	0	94	0	0	0	132	162	0
Harpacticiod sp.	0	0	0	0	0	234	0	0	225	88	0	0
Microsetalla sp.	0	0	0	0	2	0	0	140	0	0	108	0
Ectinosom sp.	0	1	50	0	1	187	0	0	0	266	0	47
Copepodite stages	0	0	152	314	38	24	251	1360	469	748	594	0
Copepod nauplii	7	5	102	158	0	469	5030	2389	2814	1276	3347	140
Eggs of copepod	0	0	50	0	0	0	201	0	1970	0	216	0

ZOOPLANKTON	Dec. 2011	Jan. 2012	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
OTHER ZOOPLANKTON												
Rotifera	0	0	0	0	0	0	0	0	0	528	0	0
Cirriped larvae	2	9	101	0	220	1407	3018	32	281	1496	1350	0
Planktonic Gastropoda	0	0	0	0	0	0	805	750	375	0	1782	0
Polychetes larvae	12	152	0	0	0	0	0	94	281	88	0	0
Polycheta adult	0	0	0	118	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	1	281	0	47	0	44	378	0
Cladocera	0	0	0	0	0	1640	0	0	0	0	0	140
Crab larvae	0	0	0	0	0	234	0	47	187	0	108	0
Isopoda	0	0	0	0	1	0	0	0	0	0	0	0
Total of Copepod	7	22	1466	787	232	1302	10060 7536	10538	3478	6056	374	
Total of Other Zooplankton	14	161	101	118	222	3562	3823	970	1124	2156	3618	140
Final Total	21	183	1567	905	454	4864	13883	8506	11662	5634	9674	514

Table 2. Monthly density of zooplankton (ind./m3) at St. 2 (Al-Faw).

ZOOPLANKTON	Dec. 2011	Jan. 2012	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
COPEPODA												
CALANOIDA												
Canthocalanus pauper	0	0	0	0	0	0	0	46	0	92	0	0
Subeucalanus flemingeri	0	0	0	0	0	0	27	12	10	36	96	0
S. subcrassus	0	0	0	0	0	0	0	235	66	23	240	0
Acrocalanus gibber	0	74	0	0	0	4333	0	70	110	230	0	0
Paracalanus sp.	0	0	0	0	0	0	1815	0	330	1196	0	0
P. aculeatus	0	111	0	745	0	9750	1885	938	322	0	1710	0
Parvocalanus crassirostris	0	37	0	0	0	2700	812	589	264	860	1710	0
Bestiolina arabica	0	37	0	0	0	4038	5958	259	660	851	1221	0
Clausocalanus minor	0	0	0	0	0	3575	0	0	66	240	0	0
Pseudodiptomus ardjuna	0	1517	7294	5098	4845	9750	0	0	0	0	0	9388
Temora turbinata	0	0	0	0	0	0	0	187	0	0	0	0
Calanopia minor	0	0	0	0	0	0	0	23	0	0	0	0
Labidocera sp.	0	0	0	0	0	0	0	23	0	0	0	0
L. minuta	0	0	0	0	0	0	0	1	22	46	0	0
Pontella danae cylonica	0	0	0	0	0	0	0	0	0	1	0	0
Acartia ohtsukai	0	74	8235	392	441	2166	622	352	660	690	480	0
A. (Acartiella) faoensis	0	0	74	235	0	0	0	0	0	0	0	0
Tortanus forcipatus	0	0	0	0	0	0	0	23	0	0	0	0
CYCLOPOIDA												
Oithona sp.	709	0	78	0	0	0	150	70	110	46	0	0
O. attenuata	0	37	0	372	0	325	541	1466	330	115	144	0
O. brevicornis	0	0	156	0	0	0	0	117	0	0	0	0
Eucyclop serralatus	0	0	0	0	0	108	0	0	0	0	0	0
Cyclops sp.	0	148	3137	8335	9933	1124	489	187	440	391	0	281

ZOOPLANKTON	Dec. 2011	Jan. 2012	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
HARPICTICOIDA												
Macrosetella gracilis	0	37	0	0	0	0	0	1	0	0	0	0
Euterpina acutifrons	0	0	0	0	0	0	325	212	132	0	0	0
Clytemnestra scutellata	0	0	0	0	0	108	27	47	1	0	48	23
Harpicticoid sp.	0	74	0	0	0	0	0	0	0	23	48	0
Microsetella sp.	0	37	235	0	88	108	0	23	0	23	48	23
Ectinosom sp.	0	37	0	0	0	0	27	23	1	0	0	0
POECILOSTOMATOIDA												
Corycaeus dahli	0	0	0	0	0	0	0	2	0	0	0	0
C. andrewsi	0	0	0	0	0	0	0	0	0	23	0	0
C. lubbocki	0	74	0	0	0	0	0	0	0	0	0	0
Copepodite stages	0	1154	4705	2745	2649	8450	1435	1150	2310	2310	1955	2946
Copepod nauplii	2001	2049	9254	8235	6137	2106	541	531	440	1127	977	7276
Eggs of copepod	0	260	1254	470	353	325	0	0	0	0	0	821
OTHER ZOOPLANKTON												
Cirripede larvae	1063	629	2385	8235	927	1300	27	2	0	92	0	258
Planktonic gastropoda	0	670	0	941	220	2925	731	3	88	0	240	0
Polychetes larvae	0	74	156	372	0	0	81	2	44	184	0	0
Polycheta adult	0	37	0	0	0	0	0	1	0	0	48	0
Ostracoda	425	37	784	235	0	0	0	0	0	0	0	0
Cladocera	425	407	0	0	0	0	0	0	0	0	0	0

ZOOPLANKTON	Dec. 2011	Jan. 2012	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
Tintinnida	0	0	0	2352	441	0	0	0	0	0	0	0
Crab larvae	0	0	0	0	220	0	81	2	44	23	130	0
Sagitta sp.	0	0	0	0	0	0	3	14	15	4	20	0
Acetes japonicus	0	0	0	0	0	0	0	3	0	1	0	0
Lucifer sp.	0	0	0	0	0	0	0	4	0	0	0	0
Sergisted	0	0	0	0	0	5	4	0	2	0	0	0
Shrimp larvae	0	0	0	0	0	0	0	0	1	2	3	4
Mysis larvae	0	0	0	1	0	0	0	0	0	1	0	0
Fish larvae	0	0	0	0	0	0	0	0	6	0	0	0
Jelly fish	0	0	0	0	0	15	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	1	0	0	1
Total of Copepod	2710	5757	34422	26627	24446	48966	14654	6596	6274	8323	8677	20758
Total of Other Zooplankton	1913	1854	3325	12136	1808	4245	927	31	201	307	441	263
Final Total	4623	7611	37747	38763	26254	53211	15581	6627	6475	8630	9118	21021

Table 3. Annual density (ind./m3) and annual percentage (%) of zooplankton at study area

Zooplankton	St. 1 (Al-Siba)		St. 2 (Al-Faw)	
	Annual density (ind./ m^3)	annual percentage %	Annual density (ind./ m^3)	**Annual percentage %**
COPEPODA				
Canthocalanus pauper	0	0.00	138	**0.06**
Subeucalanus flemingeri	140	0.24	181	**0.08**
S. subcrassus	94	0.16	564	**0.24**
Acrocalanus gibber	0	0.00	4817	**2.04**
Paracalanus sp	0	0.00	3341	**1.42**
P. aculeatus	3718	6.42	15461	**6.56**
Parvocalanus crassirostris	2379	4.11	6972	**2.96**
Bestiolina arabica	1091	1.89	13024	**5.53**
Clausocalanus minor	308	0.53	3881	**1.65**
Pseudodiptomus ardjuna	5910	10.21	37892	**16.08**
Temora turbinate	0	0.00	187	**0.08**
Calanopia minor	0	0.00	23	**0.01**
Labidocera sp	0	0.00	23	**0.01**
L. minuta	0	0.00	69	**0.03**
Pontella danae cylonica	0	0.00	1	**0.0004**
Acartia(Acartiella)faoensis	0	0.00	309	**0.13**
*A. (Odontacartia) ohtsukai **	2139	3.70	14112	**5.99**
Tortanus forcipatus	0	0.00	23	**0.01**
Oithona sp	0	0.00	1163	**0.49**
O. attenuata	56	0.10	3330	**1.41**
O. brevicornis	0	0.00	273	**0.12**
Eucyclop serralatus	115	0.20	108	**0.05**
Acanthocyclops vernalis	117	0.20	0	**0.00**
Microcyclops varicans	89	0.15	0	**0.00**
Cyclops sp	1841	3.18	24465	**10.38**
Macrosetella gracilis	0	0.00	38	**0.02**
Euterpina acutifrons	0	0.00	669	**0.28**
Clytemnestra scutellata	388	0.67	254	**0.11**
Harpicticoid sp	547	0.95	145	**0.06**
Microsetella sp	250	0.43	585	**0.25**
Ectinosom sp.(Halectinosoma)	552	0.95	88	**0.04**
Corycaeus (Dithrichocorycaeus)dehli	0	0.00	2	**0.001**
C. (Dithrichocorycaeus) andrewsi	0	0.00	23	**0.01**
C. (Dithrichocorycaeus) lubbocki	0	0.00	74	**0.03**
Copepodite stages	3950	6.83	31809	**13.50**
Copepod nauplii	15737	27.20	40683	**17.26**
Eggs of copepod	2437	4.21	3483	**1.48**

Other Zooplankton				
Rotifera	528	0.91	0	**0.00**
Cirriped larvae	7916	13.68	14918	**6.33**
Planktonic gastropoda	3712	6.41	5818	**2.47**
Polychetes larvae	627	1.08	913	**0.39**
Polycheta adults	118	0.20	86	**0.04**
Ostracoda	751	1.30	1481	**0.63**
Cladocera	1780	3.08	832	**0.35**
Tintinnida	0	0.00	2793	**1.19**
Crab larvae	576	1.00	500	**0.21**
Sagitta sp	0	0.00	56	**0.02**
Acetes japonicus	0	0.00	4	**0.002**
Lucifer sp	0	0.00	4	**0.002**
Sergisted	0	0.00	11	**0.003**
Shrimp larvae	0	0.00	10	**0.003**
Mysis larvae	0	0.00	2	**0.001**
Nematoda	0	0.00	0	**0.00**
Fish larvae	0	0.00	6	**0.002**
Jelly fish	0	0.00	15	**0.01**
Isopoda	1	0.002	2	**0.001**
Total of Copepod	**41858**	**72.33**	**208210**	**88.35**
Total of Other Zooplankton	**16009**	**27.67**	**27451**	**11.65**
Final Total	**57867**	**100**	**235661**	**100**

Diversity index (H)

Figure (9) shows the monthly variation in the values of the Diversity index of Copepoda in the study stations, as the highest value was recorded in the Al-Faw station (2.37)% in July, while the lowest value in this station was (0.57)% in December 2011, while in the Al-Siba station Its highest value was (1.90)% in July and September, and the lowest value (0)% in December 2011.

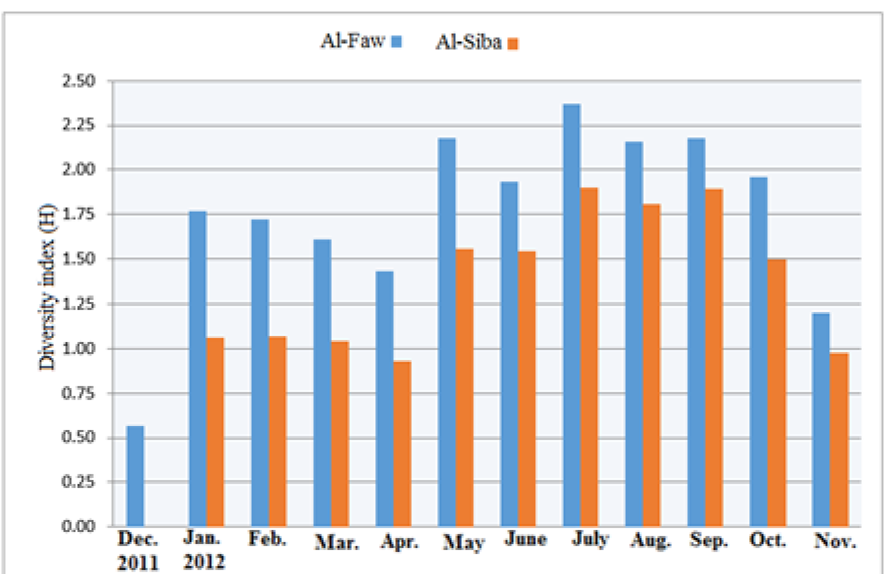

Figure 9. Monthly variation in the values of the Shannon Diversity Index (H) for the Copepoda of the study stations.

Relationships of Copepoda with the environmental conditions

Analysis of the correlation coefficients between some species of Copepoda and the environmental parameters using (CCA) canonical correlation analyses (CANOCO). CCA – ordination showed that the numbers of the dominant species of Copepoda were related to the salinity, pH, temperature and chlorophyll-a Figure (10).

Positive significant relationships were obtained between water temperature and chlorophyll-a, and water temperature and pH. Whereas negative significant relationships between water temperature and salinity and water temperature and dissolved oxygen.

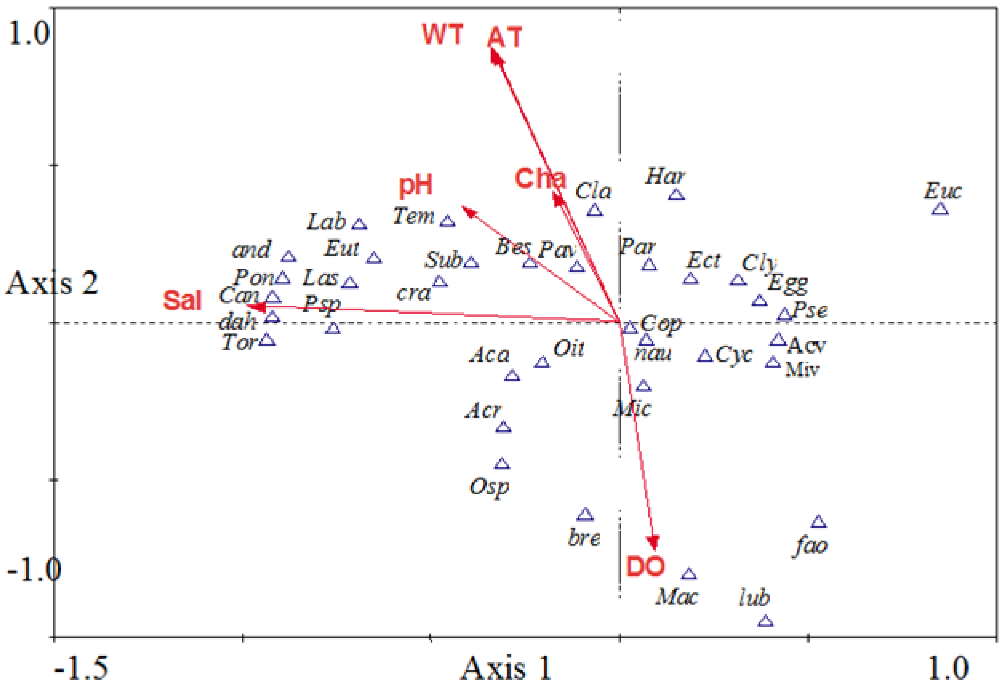

Figure 10. CCA analysis of the correlation coefficients between some species of Copepoda and the environmental factors during 12 months in the study region. **Abbreviation**: Can- *Canthocalanus pauper*; Acr- *Acrocalanus gibber*; Par- *Paracalanus aculeatus*; Psp- *Paracalanus* sp; Pav- *Parvocalanus*; Sub- *Subeucalanus*; cra- Subeucalanus; Bes- Bestiolina Arabica; Cla- *Clasocalanus minor*; Pse- *Pseudodiptoms*; Tem- *Temora turbinate*; Lab- *Labidocera minuta*; Las- *Labidocera* sp; Aca- Acartia(Odontacartia)ohtsukai; fao- *Acartia (Acartiella) faoensis*; *Pon- Pontella* danae cylonica; Tor- *Tortanus forcipatus*; *OitOithona attenuate*; bre- *Oithona brevicornis*; Acv- *Acanthocyclops vernalis*; Miv- *Microcyclops varicans*; Osp- *Oithona* sp; Cyc- *Cyclops* sp; Euc- *Eucyclops serrulatus*; Mac- Macrosetella gracilis; Eut- Euterpina acutifrons; Cly- *Clytemnestra scutellata*; Har- *Herpicticoid* sp; Mic- *Microsetella* sp; Ect- *Ectinosom* sp.(Halectinosoma); and- *Corycaeus (Dithrichocorycaeus)*; dah- *Corycaeus(Dithrichocorycaeus)*; lub- *Corycaeus(*Dithrichocorycaeus); Cop- Copepodite stages; nau- Copepoda nauplii; Egg- Egges of copepod; Eut- Euterpina acutifrons.

4 Discussion

Water temperature is one of the environmental factors that affect aquatic organisms. The change in temperature leads to circulation of water masses, which have a major impact on aquatic organisms through its impact on the main biological processes (Al-Saadi et al., 1986). The results noted that physical factors (salinity and temperature) have an effect on the change in zooplankton density, and that changes in water temperature between the two stations in the same month may be due to differences in the time of sample collection during one day.

The relationship between water temperature and the density of zooplankton (Pearson's r) in the two study stations was (0.794 and 0.770), respectively. However, the strength of this relationship varies from species to species (Vijverberg 1980).

The difference in the distribution of the density of zooplankton from one region to another and from time to time in the same station is due to the difference in environmental conditions (Ajeel et al., 2001). The rise in water temperature plays an important role in regulating productivity (Mehra, 1986; Al-Handhal et al., 1992).

The pH is one of the environmental factors affecting the aquatic environment and the basic characteristic prevails in Iraqi waters due to the abundance of bicarbonate and carbonate ions (Al-Saadi et al., 1993; Al-Rubaei, 1997 Hassan, 1997). The pH value is affected by many components such as bottom soil, water content of gases, negative and positive ions, and the presence of aquatic plants (Evans and Ryan, 2010; Sereflisan et al., 2009; Halse et al., 1998). The low pH has dangerous implications for the aquatic environment, as it reflects the state of the transformation of the water from a neutral, light base in the non-polluted natural waters to a light acidic environment and this has a major impact on the aquatic environment and the biology in it as well as the chemical reactions of water (Al-Jizany, 2005). The relationship (Pearson's r) between the pH and the density of zooplankton was (0.695) at station Al-Siba and (0.867) at station Al-Faw. This may be due to that the species at the Al-Faw station, which is of a brackish water, differs from the species at the Al-Siba station, which is of a freshwater.

Salinity is extremely important in determining the distribution of species, as species that are more tolerant to large ranges of salinity are wider distribution (Van Donick et al., 2003; Grzesiuk and Mikulski, 2006). The effect of high salinity is observed first at the molecular level, at the individual level, then communities, and finally ecosystems. The effect of salinity on freshwater crustaceans is observed through mutation in form, behavior, life history, growth rate, age and size of the first reproduction and the size of births, as the birth rate rises when salinity concentrations rise, and the sensitivity to variation of salinity concentrations varies between species and between individuals of the same species (Grzesiuk and Mikulski, 2006). Salinity is an abiotic factor that determines the ideal environment for freshwater crustaceans, as the optimum concentration of freshwater crustacean salinity ranges from (0.5 - 2 psu). When comparing freshwater living with salinity tolerance and survival, Copepoda, Ostracoda, Parasiticidia are more tolerant of salinity than Cladocera, Palaemonidae. (Jeppesen et al., 1994; Grzesiuk and Mikulski, 2006). The higher and lower tolerated salinity concentration plays a major role in stressing the factors that cause a change in the physiology, behavior, phenotype, and life history of aquatic organisms (Horrigan et al., 2005). The growth of organisms slows in high concentrations of salinity as it needs an ideal volume to reach the time of reproduction and thus the salinity affects the size and time of the first reproduction (Teschner, 1995; Ehlinger and Tankersley, 2004; Grzesiuk and Mikulski, 2006). In addition, the salinity was considered a major factor in controlling the abundance of zooplankton (Madhupratap, 1979) and the Copepoda are more abundant during the period of salinity increase (Madhupratap et al., 1975; 1977). There was a positive correlation between salinity and density of zooplankton (Pearson's r =0.693) at station Al-Siba and, (0.822) at station Al-Faw.

The results of the current study showed that the zooplankton densities peaked in June at St. 1 and in May at St. 2 because of the constant temperature and dissolved oxygen. The dissolved oxygen was the lowest at 6 mg/L at Al-Siba station during the summer and the highest rate was 12 mg/L at Al-Faw station during the winter, the reason is that the concentration of dissolved oxygen in the water is inversely proportional to the temperature, the zooplankton densities fluctuated as dissolved oxygen and temperature changed. Chlorophyll-a is an estimate of the biomass of phytoplankton (Wasmund et al., 2006; Shivaprasad et al., 2013), and to study the productivity of the aquatic environment (Hussain et al., 1991), its concentrations vary according to the species of phytoplankton (Yoder and Kennelly, 2003) and they support the zooplankton community and other life forms in the food chain (Camacho et al., 2007).The results of the current study showed that there are two peaks of chlorophyll-a concentration, the first peak during the spring and the second during the autumn and this is consistent with previous studies on the Shatt Al-Arab, such as (Antione, 1983, Abbas, 2010 and Hammadi, 2010). The relationship between the Chlorophyll-a and the density of zooplankton was (0.561) at station Al-Siba and (0.642) at station Al-Faw.

The current study showed that there are differences in the density of zooplankton in the two study stations, and this difference was evident in the Copepoda group as it was the dominant group in the study stations and was less dense in the station Al-Siba, as the group of Rotifera dominated in some months of the year despite the fact that most species of Rotifers live in fresh water some species may be found in brackish water (estuaries) and marine environments (Fradkin, 2001).

Table 4. Comparison of density of zooplankton (ind./m^3) in different areas in Basrah with previous studies

Locality study area	Mish – size (mm)	Zooplankton density	References
Garmat Ali	0.250	9 - 1050	Ajeel et al. (2004)
Shatt Al-Arab	0.090	110 - 2047	Ajeel (1998)
Shatt Al-Arab	0.090	70 - 27670	AL-Zubaidi (1998)
Shatt Al-Arab	0.120	76 - 12297	Ajeel (2004)
Shatt Al-Basrah	0.120	53 - 3483	Ajeel (2004)
Shatt Al-Basrah	0.120	5811 - 95514	Ajeel 2012
Khour AL-Zubair	0.090	1026 - 42454	Ajeel (1990)
Khour AL-Zubair	0.120	12 - 13625	Ajeel (2004)
Khour AL-Zubair	0.120	3549 - 20328	Ajeel 2012
Khour Abdullah	0.090	2565 - 24940	Ajeel (1990)
Khour Abdullah	0.200	214 - 6546	Salman et al. (1990)
Khour Abdullah	0.120	1223 - 7029	Ajeel (2017)
Shatt Al-Arab estuary	0.120	185 - 32856	Ajeel (2017)
Shatt Al-Arab (Al-Siba)	0.85	21-13883	Current study
Shatt Al-Arab (Al-Faw)	0.85	4623-53211	Current study

Also the chlorophyll-a has a prominent role in increasing the density of zooplankton, as between statistical analysis there is a positive correlation between chlorophyll-a and zooplankton numbers as the latter feeds on them and this is consistent with the Al-Lami, (1998), Ahmed and Ghazi (2009) and Abbas (2010), whose results indicated increased zooplankton during the summer because of the abundance of phytoplankton in this season of the year. In general, marine zooplankton species are more sensitive than fresh water zooplankton species due to the low pH, as it varies with different species, for each species has a range of tolerance, so the limits of zooplankton tolerance to pH in fresh water ranges between (3.5 - 4.5) and in marine species tolerate between (5.0 - 6.7) (Vangenechten et al., 1989; Wamada and Ikeda, 1999). It was noticed that the abundance of zooplankton increases if we turn towards the Arabian Gulf and this is consistent with (Al-Zubaidi, 1998) in the Shatt Al-Arab estuary, as we note that the highest abundance of zooplankton was in the Al-Faw station near the Arabian Gulf, this study agreed with the study of Abdel-Sahib et al., (2003) on the barnacles larvae in some areas of the Shatt Al-Arab, Al-Jizany (2005) on zooplankton in some areas of Shatt Al-Arab and its branches, Abbas (2010) on the abundance of Cladocera and some zooplankton in the northern part of the Shatt Al-Arab and Hammadi (2010) on a Rotifers Shatt Al-Arab as data confirmed that the zooplankton density increases during the summer and less in winter.

The density of some zooplankton such as crab larvae, shrimp larvae, fish larvae and Cladocera showed a small number, and this result agreed with a previous study (Abbas, 2010). Noting that the process of comparing different zooplankton groups in terms of species composition is somewhat unacceptable because the net yield of zooplankton varies according to the size of the mesh openings, in addition, using one type of nets may collect specific species of zooplankton and not collect other species due to their ability to escape from the net (Raymont, 1983). A comparison of the results of the present study with those of previous studies in different regions may be meaningful because of the different mesh sizes of nets used in the collection of samples (Table 4). Biological factors control abundance, major groups and the size of the zooplankton community (Vutukuru et al., 2012). Whenever the environment is healthy and its natural biological diversity, and when its disturbance and its physical and chemical properties change, the sensitive species of this change will disappear and will be limited to the species that bear the change in the environment.

5 Conclusion

1. The current study showed that the zooplankton are important environmental indicators, which we can assess the quality and viability of the aquatic environment through it, as it is highly vulnerable to environmental conditions.
2. Shatt Al-Arab water was brackish to salty water, and the salinity was most extreme and influencing factor in the composition of species.
3. The current study showed that the Copepoda is the dominant group in study area and reached its highest value in the Al-Faw station. Pseudodiptomus ardjuna, Acartia (odontacartia) ohtsukai and Cyclops sp. were dominance in the study area.
4. The alkaline characteristic prevailed in the waters of the Shatt Al-Arab.

Conflict of interests

The authors declare that they have no conflict of interest.

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