Distribution and Abundance of Copepoda in Shatt Al-Basrah Channel, Southern Iraq

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Received 27/12/2024 Accepted 02/03/2025 Published 25/06/2025

Abstract

The ecology and structure of Copepoda community have been studied in two stations (S1, S2) at Shatt Al-Basrah channel: S1 was upstream the dam and S2 was down of the dam. Zooplankton samples were collected monthly for one year during the period from December 2011 until November 2012 by using Plankton net with 85 µm mesh size and 30 cm mouth aperture, by the vertical collection method. Eighteen species of copepods belonging to 15 genera were identified in the study area. In S1, there were 13 species belonging to 13 genera. However, 15 species belonging to 13 genera were recorded in S2. It was observed that the Order Calanoida was dominant in the two study areas, including 11 species, belonging to nine genera, followed by the Order Harpacticoida, which includes four species belonging to four genera, then the Order Cyclopoida, which is represented by three species belonging to two genera. The highest density of Copepoda reached 20283 ind./m3 in S2 during May 2012, whereas they disappeared in December, January, and March in S1.

Keywords: Zooplankton, Shatt Al-Basrah, Copepoda, Distribution, Abundance, Ecology .

Introduction

The productivity of aquatic environments depends on the plankton (phytoplankton and zooplankton) (Reddy *et al*., 2012). Zooplankton is an indicator of water quality and nutritional status of the aquatic environment (Shayesthfar *et al*., 2010; Kulkarni and Surwase, 2013). Also, it is a major component of heterotrophic organisms that have a great importance in the food chain, as they are the primary consumers of phytoplankton, and a major food source for other aquatic organisms such as fish and shrimps, which are called secondary producers. Thus, energy is transferred to higher trophic levels, providing organism's protein, carbohydrates, fats, and minerals (Guy, 1992).

There are about 2000 species of copepods in the world (Al-Yamani and Prusova, 2003), and they represent a widespread group of zooplankton in all seas and oceans,

P-ISSN: 1812-237X, E-ISSN: 2788-5720, https://ijaqua.uobasrah.edu.iq/index.pip/iaqua

making up 70% of marine zooplankton (Raymont, 1983) and 82% of the zooplankton in the northwest Arabian Gulf (Khalaf and Ajeel, 1994). The first study of zooplankton in Iraq was that of Gurney (1921), where he recorded 77 species belonging to Rotifera, Cladocera, and Copepoda collected from the Amara City to Shatt Al-Arab estuary. In Garmat Ali Marshes, AL-Sabonchi *et al.* (1986) studied seasonal changes in abundance and quality of zooplankton and identified 21 genera belonging to Rotifera, Cladocera, and Copepoda.

Khalaf (1988) recorded 10 species of copepods in Khour Abdullah and Khour Al Zubair, and he recorded two species *Clausocalanus minor* and *Centropages tenuiremis* for the first time in the Arabian Gulf. Salman *et al.* (1990) mentioned that the highest abundance of zooplankton in Khour Abdullah occurred in July and December 1983 due to the presence of copepods. Ajeel (1990) studied the ecology and biology of some important marine Copepoda species in the Northwest Arabian Gulf, and he recorded 23 species of copepods belonging to 18 genera. In 1998, Al-Zubaidi studied the distribution and abundance of zooplankton in the Shatt Al-Arab estuary, northwest of the Arabian Gulf, and recorded six species of Copepoda in the Arabian Gulf and 10 species in the Iraqi waters for the first time. Khalaf (2007) described the larval stages of *Acartia* (*Acartiella*) *faoensis* in Khour Al-Zubair southern Iraq. Khalaf (2008a) described a new species, *Phyllodiaptomus irakinsis*, from Shatt Al-Arab River. In addition, Khalaf (2008b) recorded a Calanoid species, *Bestiolina arabica*, from Khour Al-Zubair and the Shatt Al-Arab River. While in Shatt Al-Basrah channel, 21 species of Copepoda were recorded; Copepoda constituted about 44.7% of the total zooplankton at Shatt Al-Basrah and Khour Al-Zubair (Ajeel, 2012).

Copepods are the most abundant and dominant zooplankton in the coastal and estuarine environments, constituting about 80–90% of total organisms (Kleppel *et al.,* 1991; Irigoien *et al.,* 2002). Khalaf (1988) found that they constitute 85–90% of the total zooplankton in Khour Abdullah, while they reached 70% in the Kuwaiti waters (Al-Yamani and Prusova, 2003). In the Arabian Gulf, the first study of Copepoda was conducted along the eastern coast in 1912 by the German scientist Pesta. He recorded 31 species, including one new species, *Acartia pietschmani*. Michel *et al.* (1986) studied the abundance and diversity of zooplankton in the Kuwaiti marine waters. The results showed that copepods were the most abundant and widespread, both in terms of quality and quantity, constituting about 83% of the total zooplankton.

Al-Khabbaz and Fahmi (1998) studied the distribution of copepods in the Arabian Gulf through the ROPME program. Off the coasts of the Emirates, Qatar, Bahrain, and Saudi Arabia, they identified 24 genera and concluded that copepods constituted 66.6% of the total zooplankton. The dominant genera were *Oithona* and *Paracalanus*. Al-Yamani *et al.* (1998) studied the distribution of zooplankton in the Arabian Gulf within the ROPME Convention and confirmed that Copepoda formed about 64% of the total zooplankton, the dominant orders were Cyclopoida and Calanoida. The aims of this study were to assess Copepoda at Shatt Al-Basrah channel. As Copepoda are a major food source for fish, their fertility in the water environment is an indicator of the fertility of the area for fishing. The study also aims to show the variation of zooplankton spatially and temporally and their relationship to environmental conditions, in order to provide detailed information about the actual environmental situation of Shatt Al-Basrah.

Materials and Methods

Study area

The length of Shatt Al-Basra Channel is approximately 38 km and its average width is around 59 m. During periods of low water levels, the depth of the water in the channel reaches about 3.5 m. The Khour Al-Zubair Channel is connected with Shatt Al-Basrah at 6 km from its beginning. There is a regulator dam established at a distance of 22 Km from the beginning of the Canal. The dam is closed during the high tide to prevent seawater from entering the canal, and opened during low tide to allow water to flow through. (Abdul Amir and Sadkhan, 2011). The first station was chosen upstream the dam, located at a longitude of 47° 45' 59.52" E and a latitude of 30° 25' 47.00"N. The second station was located just down of the dam at a longitude of 47° 46' 58.53" E and a latitude of 30° 23' 42.76"N. This station is characterized by a higher concentration of salinity than the first station because its water is affected by the salinity of Khour Al-Zubair (Figure 1).

Sample collection

Zooplankton samples were collected monthly from the two stations during the period from December 2011 to November 2012 (Figure 1). Collection was made vertically from near the bottom to the surface layer of the water column during the daytime, with respect to tide, using a plankton net of 85 µm mesh-size, and 30 cm in diameter of mouth aperture, by using a wooden medium-sized boat. The samples were immediately preserved in 4% buffered formaldehyde. Water temperature, salinity, pH and dissolved oxygen (DO) were measured in the field using a digital multi meter instrument, YSI incorporated 556 MPS. Chlorophyll-a was measured in the laboratory. Identification of some species was made with the aid of the following guides, keys and references: Wickstead (1965); Khalaf (1988, 1991, 1992, 2008 a, b); Zheng Zhong (1989); Al-Yamani and Prusova (2003); Al-Yamani *et al.* (2011).

Water volume, which was filtered through the plankton net, towed vertically represented by the volume of a cylinder which was calculated by the formula:

$$V = r^2 \pi h$$

Where:

V= the volume of the cylinder (water volume filtered through the net).
r= diameter of the mouth aperture of plankton net.
h= the height of cylinder which represented the depth from which the net was towed to the surface of the water.

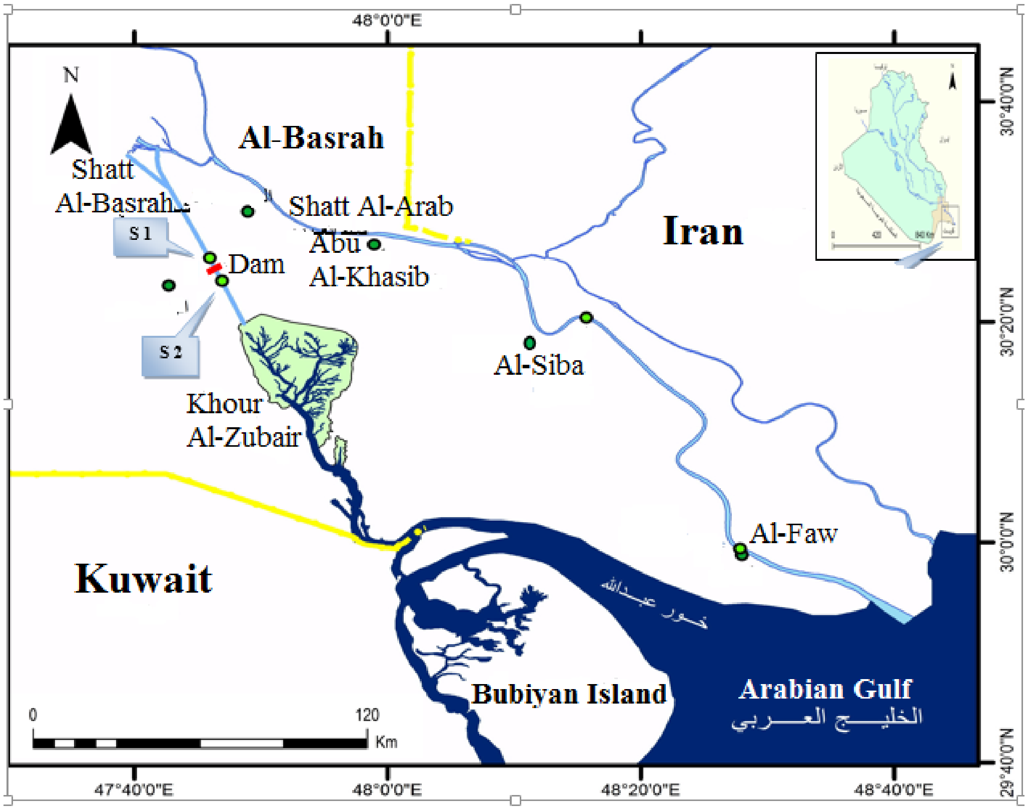

Figure 1. Map of lower Mesopotamia showing the sampling station.

Ecological indices

Richness index (D)

The Richness index was calculated from the equation of Margalef (1968) as:

$D = S - 1 / \ln N$

Where: S = Number of species,

N = Total number of individuals in the sample

Evenness index (J)

The Evenness index was calculated by the equation of Pielou (1977) as follows:

$J = H / \ln S$

Where: H = Diversity index,

S = Number of species

Diversity index (H)

The Diversity index was calculated from the equation of Shanon and Weaver, (1949) as follows:

$H = - \sum Pi \ln Pi$

Where: Pi = Ratio of the number of individuals of each species to the total number.

Statistical analysis

The statistical analysis of the results was carried out using Completely Randomized Design (CRD) and finding the significant differences between the stations using the Revised Least Significant Differences Test (RLSD) (Al-Rawi and Khalaf Allah, 1980). The correlation coefficient (r) between the studied parameters was calculated for each of the stations using the statistical program SPSS (version 26, 2023).

Canonical correspondence analysis (CCA) was applied to assess the relationships between different environmental factors and species of Copepoda, using the statistical program Canoco (ter Break and Smilaur, 2002), which is one of the most widely used program in water sciences (Ter Braak, 1986).

Results

Hydrographic parameters

The maximum value of water temperature was 29°C recorded in July 2012, while the minimum temperature was 14 °C in December 2011 on stations 1 and 2 (Figure 2). Statistical analysis showed the absence of significant differences ($P \leq 0.05$) in water temperature between the studied stations. The monthly variations in salinity values were truly extreme as the lowest value of salinity reported in May 2012, which was 17‰ at St. 1 (before the dam), while the highest value was 48‰ recorded in August at St. 2 (after the dam) (Figure 3). The results of statistical analysis showed the presence of significant differences ($P \leq 0.05$), between the studied stations.

There are monthly variations in the pH values observed during the period of the study ranging between 6 in December 2011 at St. 1, to 8.9 at St. 2 in August 2012 (Figure 4). Statistical analysis showed significant differences ($P \leq 0.05$) in the pH between the two stations. The highest values of DO were 11 mg/L on station 2, while the lowest value was 5 mg/L on station 1 in December 2012 (Figure 5). A significant difference ($P \leq 0.05$) was found between the two stations. The monthly variation in the values of chlorophyll-a was ranging between the highest 19.9 mg/m^3 in October 2012 on S2 and the lowest values of 1.1 mg/m^3 on S1 in December 2011 (Figure 6). No significant differences ($P \leq 0.05$) between the studied stations were detected.

Species composition

In the current study, 18 species of copepods were identified. It was found that the Order Calanoida was dominant in the two study stations, including 11 species, belonging to 9 genera, (*Subeucalanus, Acrocalanus, Paracalanus, Parvocalanus, Bestiolina, Clausocalanus, Pseudodiptomus, Temora, Acartia*), followed by Order Harpacticoida, four species belonging to four genera, then Cyclopoida, three species belonging to two genera. In the S1, 13 species belonging to 13 genera were recorded (Table 1). While, 15 species belonging to 13 genera were recorded at the second station (Table 2).

Quantitative study

The Copepoda is present for most months of the year, where it reached its highest density (11105 ind./m3) on S1, whereas it disappeared in December 2011, January and March 2012 (Table 1). While on S2 the density of Copepoda ranged between 3865-20283 ind./m3 during January and May, respectively (Table 2). The annual density of Copepods reached 30033 ind./m3 at S1, while it reached 101999 ind./m3 at S2 (Table 3).

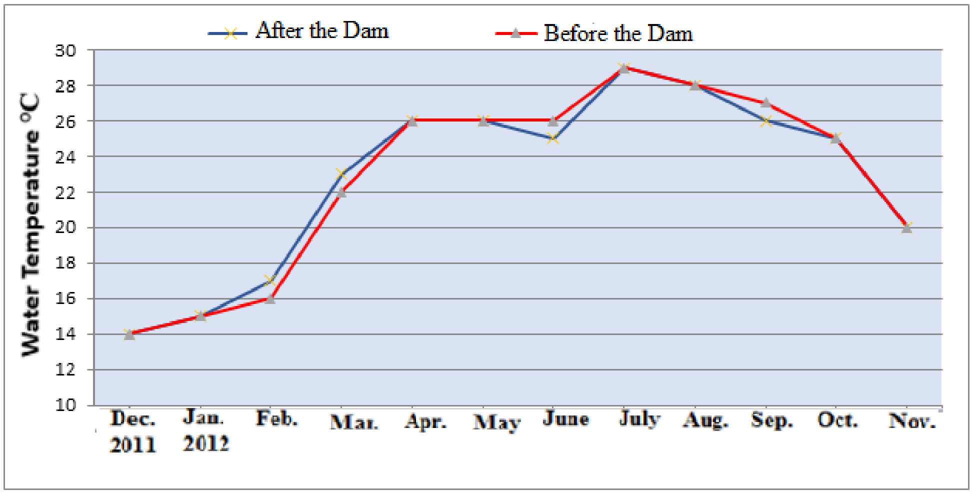

Figure 2. Water temperature °C in the study area during Dec. 2011 to Nov. 2012.

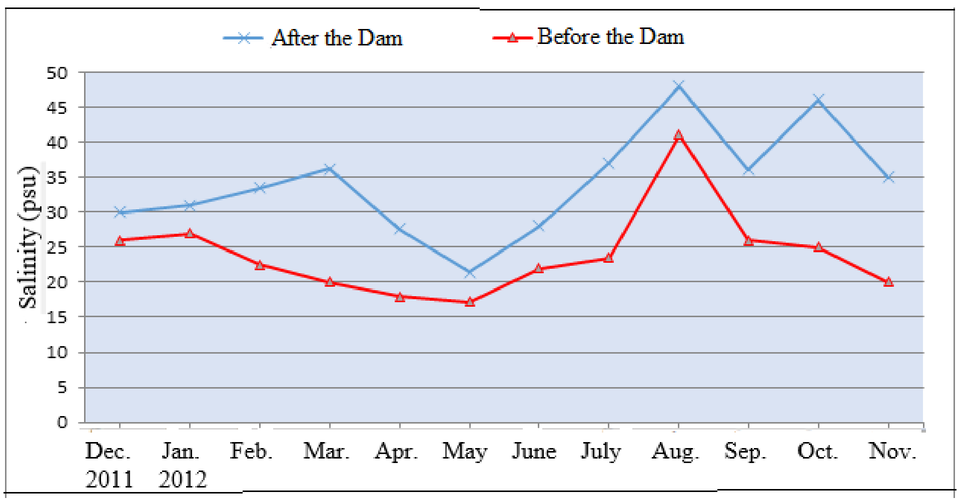

Figure 3. Salinity concentration (‰) in the study area during Dec. 2011 to Nov. 2012.

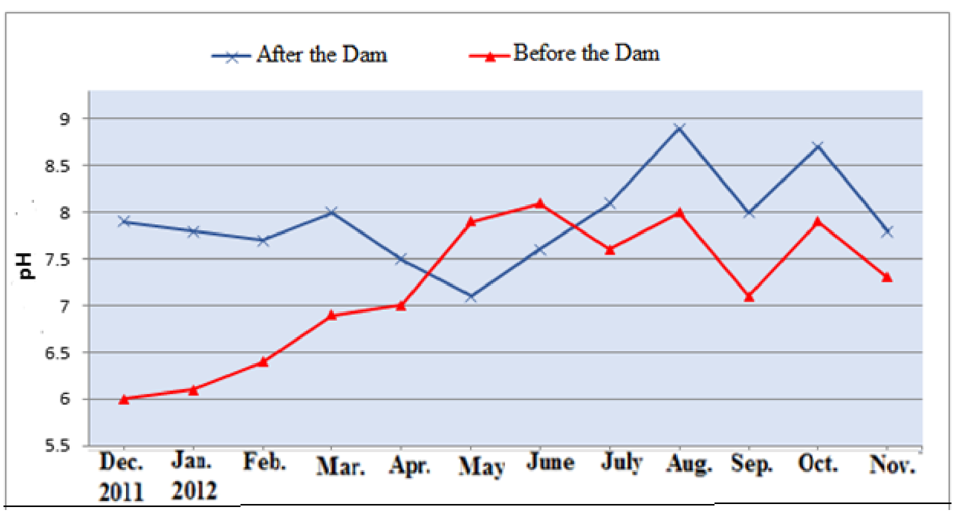

Figure 4. Hydrogen ion concentration (pH) in the study area.

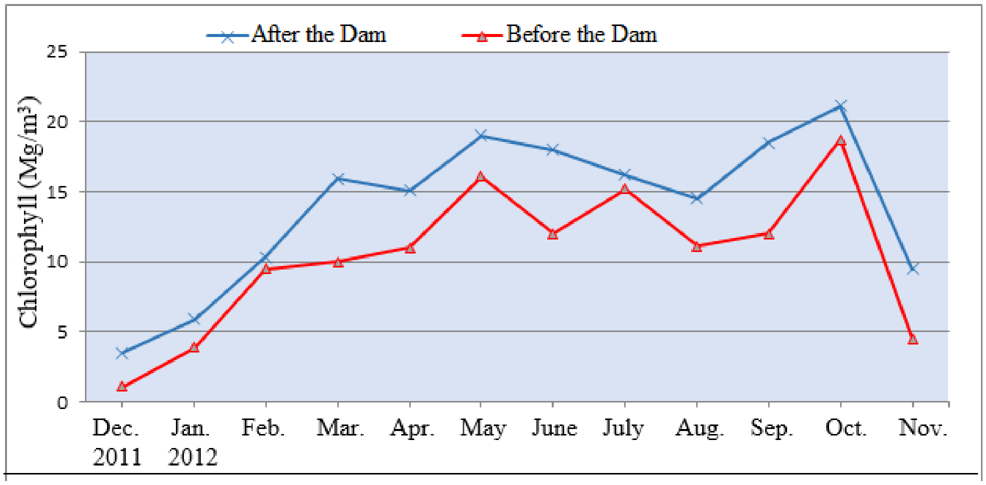

Figure 6. Chlorophyll-*a* concentration (mg/m3) in the study area.

Table 1. Monthly density of Copepoda (ind./m3) at S1 (Shatt Al-Basrah upstream the dam)

COPEPODA	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
CALANOIDA												
Acartia (Odontacartia) ohtsukai	0	0	354	0	0	0	0	0	313	469	220	100
Acrocalanus gibber	0	0	0	0	0	0	0	0	0	0	44	51
Bestiolina arabica	0	0	0	0	0	0	201	0	65	140	132	201
Clausocalanus minor	0	0	0	0	0	0	301	0	0	0	0	0
Paracalanus aculeatus	0	0	0	0	0	0	603	0	251	469	88	302
Parvocalanus crassirostris	0	0	0	0	0	0	302	0	0	281	0	956
Pseudodiptomus ardjuna	0	0	71	0	3024	1911	2012	176	0	0	0	0
Temora turbinata	0	0	0	0	0	0	0	176	0	0	0	0
CYCLOPOIDA												
Cyclops sp.	0	0	71	0	0	302	0	408	0	375	132	0
Oithona attenuate	0	0	0	0	0	0	0	0	104	0	0	0
HARPACTICOIDA												
Ectinosom sp. (*Halectinosoma*)	0	0	0	0	0	0	0	0	0	94	0	0
Microsetella sp.	0	0	0	0	0	0	0	0	104	0	0	0
Other Harpacticoida	0	0	0	0	0	0	151	118	156	0	0	0
Copepodite stages	0	0	212	0	756	603	2515	176	52	656	44	352
Copepod nauplii	0	0	71	0	2079	553	5030	352	452	238	264	400
Total	0	0	779	0	5859	3369	11105	1406	1497	2722	924	2362

The Calanoida was the dominant group in the study stations, as it constituted 43.99 % of the total Copepoda at the first station, while Cyclopoida and Harpacticoida constituted 4.63% and 2.07% respectively. The Copepodite stages and Nauplii constituted 49.3% of the total Copepoda. At the S2, the Calanoida constituted 53.97% of the total Copepoda, while the Cyclopoida and Harpacticoida constituted 1.26% and 0.41% respectively. The Copepodite stages and Nauplii constituted 44.48% of the total Copepoda (Table 3).

Table 2. Monthly density of Copepoda (ind./m3) at S2 (Shatt Al-Basrah after the dam).

COPEPODA	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
CALANOIDA												
Acartia (*Acartiella*) *faoensis*	0	0	0	0	0	176	0	0	0	0	0	0
Acartia (*Odontacartia*) *ohtsukai*	1182	1106	2541	1769	2560	6332	1280	4892	4161	2394	4303	836
Acrocalanus gibber	0	221	0	0	0	0	1344	0	0	0	234	88
Bestiolina arabica	0	132	0	0	0	880	408	32	320	35	782	0
Subeucalanus flemingeri	0	0	0	0	0	88	0	0	0	0	0	0
Clausocalanus minor	0	0	0	0	0	0	288	0	0	105	0	0
Paracalanus aculeatus	0	0	0	0	0	0	544	0	192	45	704	88
Paracalanus sp.	177	0	0	0	0	0	0	640	0	0	0	0
Parvocalanus crassirostris	236	0	0	0	0	176	320	96	128	0	0	370
Pseudodiptomus ardjuna	295	88	0	885	5890	4401	1120	32	0	140	0	0
CYCLOPOIDA												
Cyclops sp.	177	0	0	0	0	440	0	96	0	70	234	0
Oithona sp.	118	0	14	0	0	0	0	0	0	0	0	0
HARPICTICOIDA												
Clytemnestra scutellata	0	1	2	0	0	0	0	0	0	0	0	0
Ectinosom sp. (*Halectinosoma*)	0	0	0	0	64	0	0	0	128	0	0	0
Microsetella sp.	59	0	0	0	0	88	0	0	0	0	78	0
Copepodite stages	886	769	177	1106	768	2861	800	3201	704	704	1956	132
Copepod Nauplii	1477	1548	2600	6637	3201	4841	1024	1540	4161	2816	1017	448
Total	4607	3865	5334	10397	12483	20283	7128	10529	9794	6309	9308	1962

Acartia (Odontacartia) ohtsukai was the most abundant species and this was for the first time to occur in the Iraqi waters, reaching 33356 ind./m^3, (32.01%) and Copepod Nauplii were 9439 ind./m^3, (30.24%) of the total Copepoda on second and first station, respectively (Table 3). It was noted that *A.* (*O.*) *otsukai* was predominant species and present in all months of the year in Shatt Al-Basrah after the dam, while it was present at 5 times in the Shatt Al-Basrah before the dam. Also it was found that the Copepodite stages and nauplii were predominant at the two stations while, *Clausocalanus minor,* *Temora turbinata, Oithona attenuata, Microsetella* sp., *Ectinosom* sp. (*Halectinosoma*) were rare species at S1. Whereas *Subeucalanus flemingeri* and *Acartia* (*Acartiella*) *faoensis* was absent at S1 and rare at S2 (Table 4). In the first station it was observed that the dominance species were *Pseudodiptomus ardjuna* 23%, *Paracalauns aculeatus* 6%, *Parvocalanus crassirostris* and *A.* (*O.*) *ohtsukai* 5% of the total Copepoda (Figure 7). While, in the second station *A. (O.) ohtsukai* formed 32% and *P. ardjuna* 13% of the total Copepoda (Figure 8). Figure (9) showed the highest density of Copepodite stages (3201 ind./m3) during July at S2 and 2515 ind./m3 during June at S1. While the highest density of the Naupliar stages of Copepoda was 6637 (ind./m3) during March at S2 and 5030 (ind./m3) during June at S1 (Figure 10).

Table 3. Annual density (ind./m3) and percentages of Copepoda at the study area

Copepoda species	**S1: Upstream the Dam**		**S2: Down the Dam**	
	Annual Density ind./m3	**percentage %**	**Annual Density ind./m3**	**percentage %**
Acartia (*Acartiella*) *faoensis*	0	0	176	0.17
Acartia (*Odontacartia*) *ohtsukai*	1456	4.84	33356	32.7
Acrocalanus gibber	95	0.32	1887	1.85
Bestiolina Arabica	739	2.46	2589	2.54
Clausocalanus minor	301	1	393	0.38
Paracalanus aculeatus	1713	5.7	1573	1.54
Paracalanus sp.	0	0	817	0.8
Parvocalanus crassirostris	1539	5.12	1326	1.3
Pseudodiptomus ardjuna	7194	23.95	12851	12.6
Subeucalanus flemingeri	0	0	88	0.08
Temora turbinate	176	0.58	0	0
Total of CALANOIDA	**13213**	**43.99**	**55056**	**53.97**
Cyclops sp.	1288	4.29	1017	1
Oithona attenuate	104	0.34	0	0
Oithona sp.	0	0	132	0.13
Total of CYCLOPOIDA	**1392**	**4.63**	**1149**	**1.26**
Clytemnestra scutellata	0	0	3	0.002
Ectinosom sp.	94	0.31	192	0.18
Microsetella sp.	104	0.34	225	0.22
Other Harpacticoid sp.	425	1.41	0	0
Total of HARPACTICOIDA	**623**	**2.07**	**420**	**0.41**
Copepodite stages	5366	17.87	14064	13.79
Copepod nauplii	9439	31.43	31310	30.69
Total of Copepod	**30033**	**100**	**101999**	**100**

Table 4. Monthly presence of Copepods and their percentages in the two study stations

COPEPODA	S1: Upstream the Dam			S2: Down the Dam		
	The number of presence	Percentage of presence (%)	Presence	The number of presence	Percentage of presence (%)	Presence
Subeucalanus flemingeri	0	0	-	1	8	R
Acrocalanus gibber	2	17	F	4	33	F
Paracalanus aculeatus	5	42	A	5	42	A
Paracalanus sp.	0	0	-	2	17	F
Parvocalanus crassirostris	3	25	F	6	50	A
Bestiolina arabica	5	42	A	7	58	A
Clausocalanus minor	1	8	R	2	17	F
Pseudodiptomus ardjuna	5	42	A	8	67	A
Temora turbinata	1	8	R	0	0	-
Acartia (*Odontacartia*) *ohtsukai*	5	42	A	12	100	P
Acartia (*Acartiella*) *faoensis*	0	0	-	1	8	R
Oithona attenuata	1	8	R	0	0	-
Oithona sp.	0	0	-	2	17	F
Cyclops sp.	5	42	A	5	42	A
Clytemnestra scutellata	0	0	-	2	17	F
Other Harpacticoida	3	25	F	0	0	-
Microsetella sp.	1	8	R	3	25	F
Ectinosom sp.	1	8	R	2	17	F
Copepodite stages	9	75	P	12	100	P
Copepod nauplii	9	75	P	12	100	P

R = Rare species (less than 10%), F = Few species (10-40%), A = Abundant species (40-70%), P = Predominant species (>70%), - = 0.

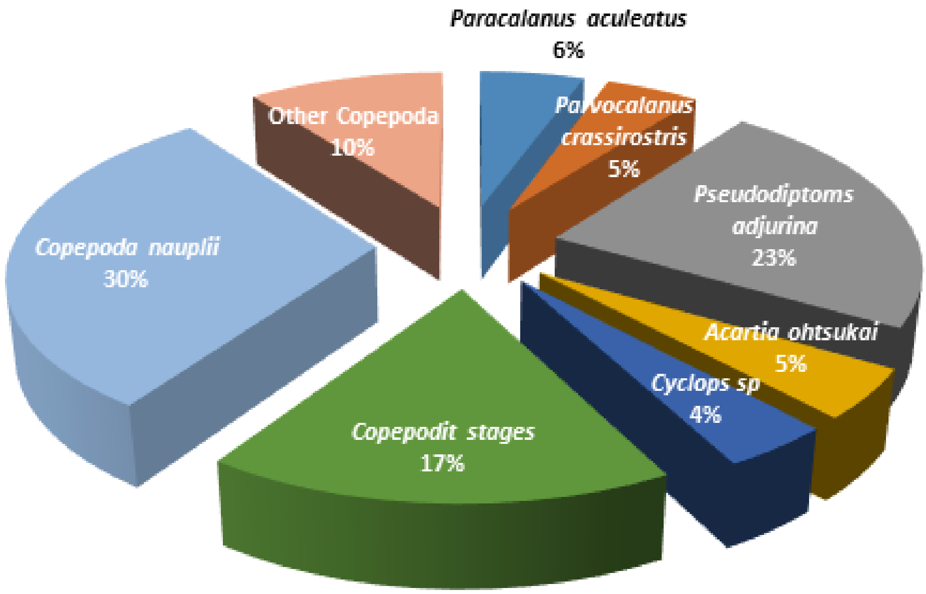

Figure 7. The percentages of the dominant species of Copepoda at S1 (Shatt Al-Basrah before the Dam)

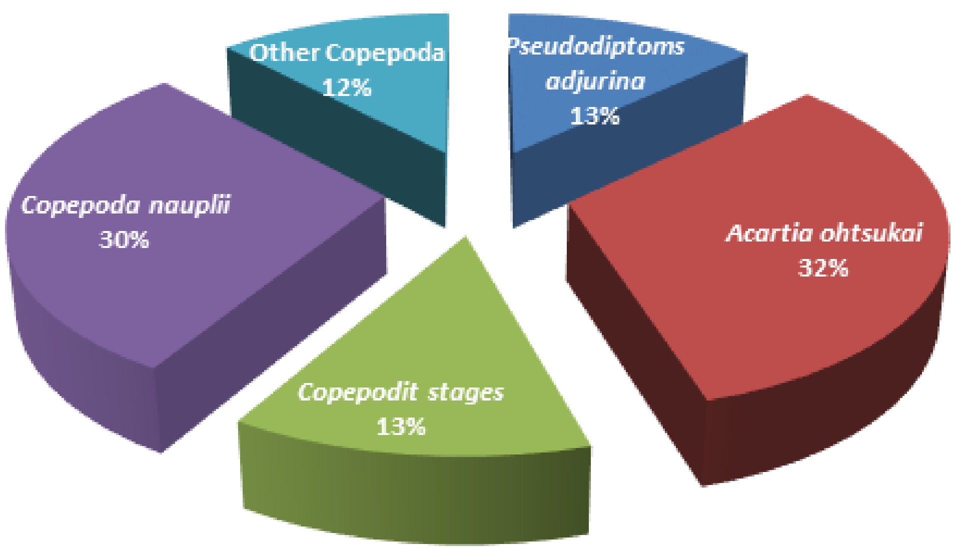

Figure 8. The percentages of the dominant species of Copepoda at S2 (Shatt Al-Basrah after the Dam)

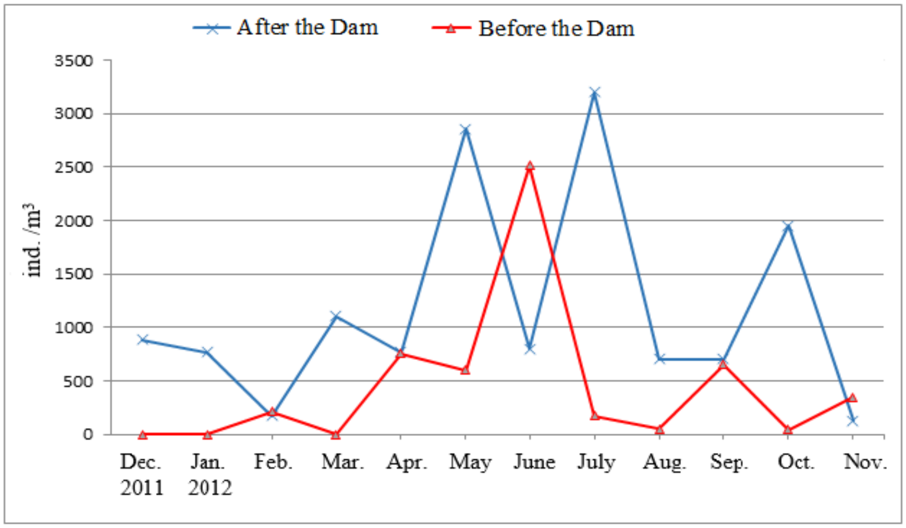

Figure 9. Monthly variation of Copepodite stages (ind./m3) in the study area.

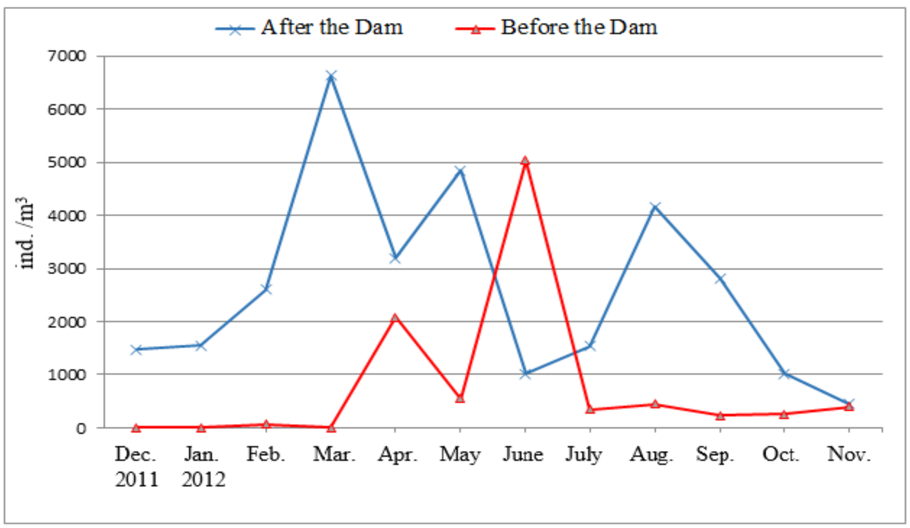

Figure 10. Monthly variation of Naupliar stages (ind./m3) in the study area.

Check List of Copepoda in the study area

Phylum: Arthropoda

Subphylum: Crustacea

Class: Maxillipoda

Subclass: Copepoda (Milne – Edwards, 1840)

Order: Calanoida (Sars, 1903)

Family: Eucalanidae (Giessbrecht, 1892)

Subeucalanus flemingeri (Prusova, Al-Yamani and Al-Mutariry, 2001)

Family: Clausocalanidae (Giessbrecht, 1892)

Clausocalanus minor (Sewell, 1929)

Family: Pseudodiaptomidae (Sars, 1902).

Pseudodiaptomus ardjuna (Brehm, 1953)

Family: Timoridae (Giessbrecht, 1892)
Temora turbinata (Dana, 1849)
Family: Acartiidae (Sars, 1903)
Acartia (*Odontacartia*) *ohtsukai* (Ohtsukai, 2006)
Acartia (*Acartiella*) *faoensis* (Khalaf, 1991)
Order: Cyclopoida (Burmeister, 1843)
Family: Oithonidae (Dand, 1853)
Oithona attenuata (Farran, 1913)
Oithona sp.
Family: Cyclopidae (Dana, 1853)
Cyclops sp.
Order: Harpacticoida (Sars, 1903)
Family: Ectinosomatidae (Sars, 1903)
Ectinosoma sp. (Halectinosoma)
Microsetella sp.
Family: Clytemnestridae (A.Scott, 1909)
Clytemnestra scutellata (Dana, 1848)
Family: Paracalanidae (Giessbrecht, 1892)
Acrocalanus gibber (Giessbrecht, 1888)
Paracalanus aculeatus (Giessbrecht, 1888)
Pracalanus sp. (Boeck, 1864)
Parvocalanus crassirostris (Dahl, 1894)
Bestiolina arabica (Ali *et al*., 2007)

Effect of Ecological Factors

Figure (11), shows that the salinity, water temperature and dissolved oxygen have the greatest impact on copepod species.

Clytemnestra scutellata	Cly	*Pseudodiptomas adjurina*	Pse	*Acrocalanus gibber*	Acr
Other Herpacticoid	Har	*Temora turbinata*	Tem	*Paracalanus aculeatus*	Par
Microsetella sp.	Mic	*Acartia ohtsukai*	Aca	*Paracalanus* sp.	Psp
Ectinosoma sp.	Ect	*Acartia faoensis*	fao	*Parvocalanus crassirostris*	Pav
Copepodite stages	Cop	*Oithona attenuata*	Oit	*Subeucalanus flemingeri*	Sub
Copepoda nauplii	nau	*Oithona* sp.	Osp	*Bestiolina arabica*	Bes
		Cyclops sp.	Cyc	*Clausocalanus minor*	Cla

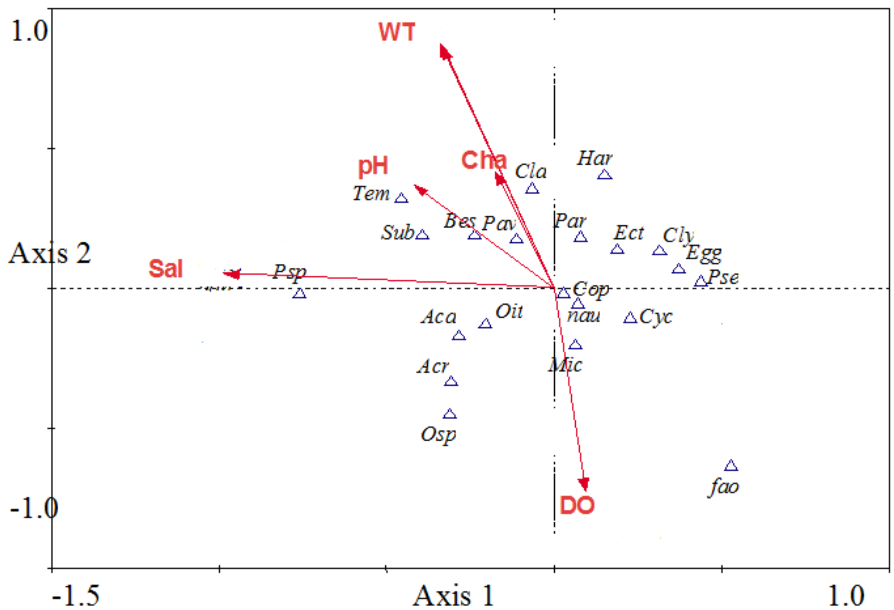

Figure 11. The correlation between Copepoda species and physical and chemical factors in the two study stations during the study period.

Ecological indices

Richness index (D)

The highest value of 2.4% was recorded during May at the second station, while the lowest value at the same station was 1.61% in March 2012. As for the first station, its highest value was 2.2% in June and the lowest value was 0% in December 2011, January and March 2012 (Figure 12).

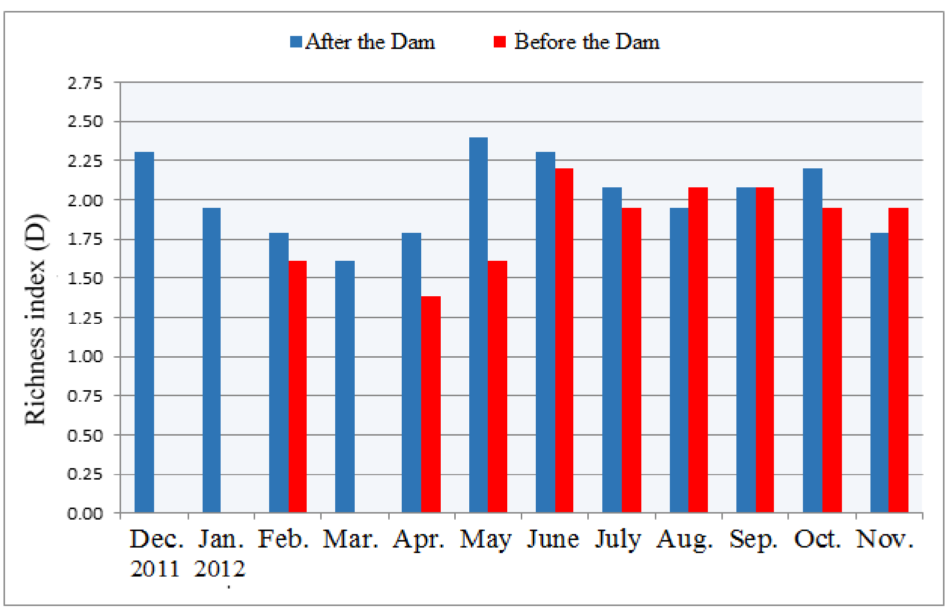

Figure 12. Monthly variation of the values of richness index (D) of the Copepoda in the two study stations.

Evenness index (J)

The highest value in the first station reached 0.93% during September 2012, while the lowest value was 0% in December 2011, January and March 2012. In the second station, the highest value was 0.94% in June, and the lowest value was 0.47% in February 2012 (Figure 13).

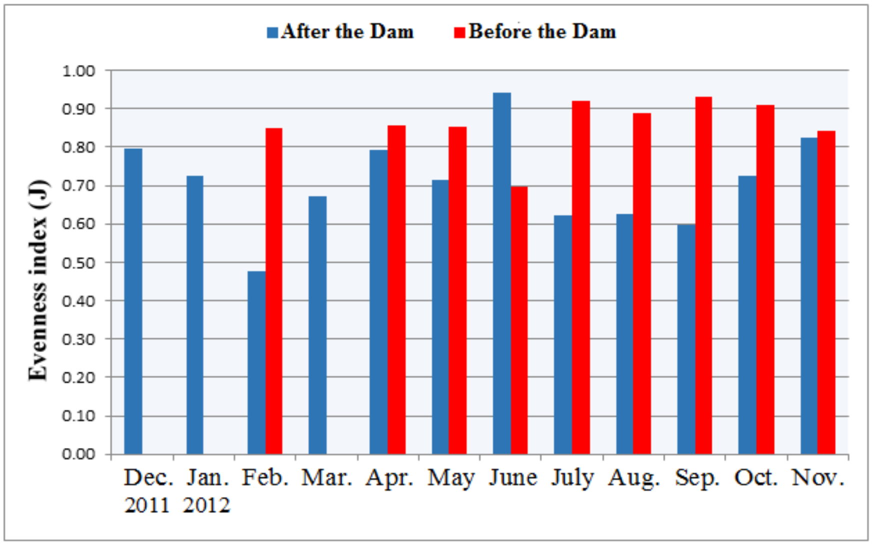

Figure 13. Monthly differences of the values of Evenness index (J) for the Copepoda in the two study stations.

Diversity index (H)

The highest value 1.94% was recorded during September, and 0% during December 2011, January and March 2012. In the second station the highest value 2.17% was during June, while the lowest value was 0.85% during February 2011 (Figure 14).

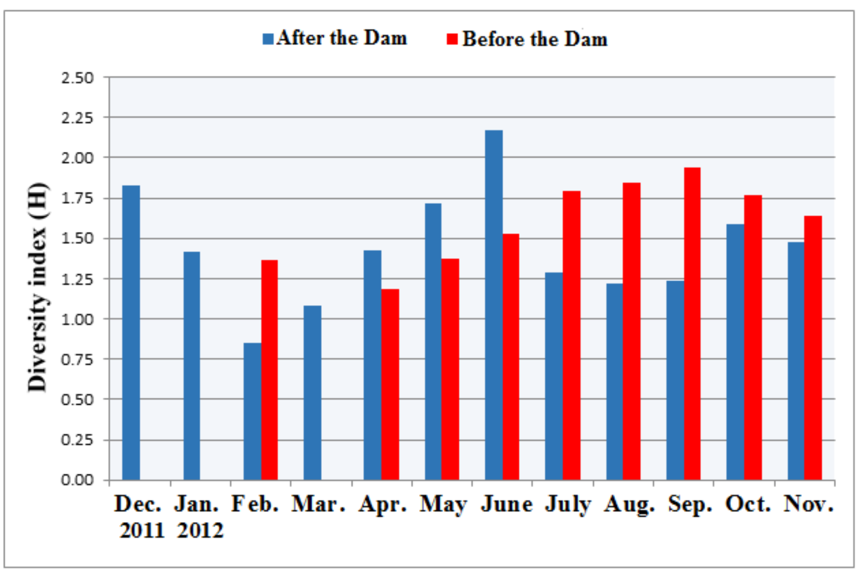

Figure 14. The monthly variation of the values Shannon's Diversity Index (H) for the Copepoda in the two study stations.

Discussion

The zooplankton are used as indicators for pollutants in the environment, and they respond quickly to changes in the environment. They are also indicators for the state of water bodies, the biological factors that control abundance, major groups, and the size of the zooplankton community including predation (Vutukuru *et al.*, 2012). This is indicated by the evenness index. Whenever the environment is healthy and characterized by the diversity of its biology, and when its disturbance and its physical and chemical properties change, the sensitive species will disappear and the community will be limited to the species that can tolerate the change in the environment (Vutukuru *et al.,* 2012).

In the current study, an increase in water temperature was observed (29°C). The rise in water temperature plays an important role in regulating productivity (Mehra, 1986; Al-Handhal *et al.*, 1992). Water temperature is one of the specific environmental factors that affect aquatic organisms. The change in temperature leads to a rotation of water bodies, which have a major impact on aquatic organisms through its impact on the main biological processes (Al Saadi *et al.*, 1986). The differences of distribution and density of zooplankton from one region to another and from time to time in the same station may be due to the differences in the environmental conditions (Ajeel *et al.*, 2001).

The study area is considered an extreme area in terms of salinity, as it reached 41 and 48 ppt during August 2012 in the first and second stations, respectively. Therefore, the species recorded in the region are tolerant of high salinity. Salinity is an extremely important factor in determining the geographical distribution of species, as species that are more tolerant to a wide range of salinity are more prevalent (Van Donick *et al.*, 2003; Grzesiuk and Mikulski, 2006). The effect of salinity on freshwater crustaceans is observed through changes in form, behavior, life history, growth rate, age and size at first reproduction, and size of offspring, as the birth rate rises when salinity concentrations increase, and the sensitivity to variations in salinity concentrations varies between species and 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 salinity for freshwater ranges from 0.5 to 2‰. When comparing salinity tolerance and survival in freshwater, Copepods, Ostracods, and Parasiticidia are the most tolerant of salinity than Cladocera and Palaemonidae (Jeppesen *et al.*, 1994; Grzesiuk and Mikulski, 2006). The growth of organisms slows in high salinity concentrations as it requires an ideal size 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). Moreover, the pH is one of the environmental factors and the alkaline characteristic prevails in Iraqi waters due to the abundance of bicarbonate and carbonate ions (Al-Saadi *et al.*, 1993; Al-Rubaie, 1997; Hassan, 1997). In the current study, the pH was recorded in an alkaline direction, especially in the second station (after the dam), while it was recorded in the first station (before the dam) in an acidic direction during the first four months. This is likely. The pH 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). A low pH has dangerous implications for the aquatic environment, as it reflects the transformation of the water from a neutral, slightly alkaline state in non-polluted natural waters to a slightly acidic environment. This shift in pH has a major impact on the aquatic environment and the biology within it (Al-Jizani, 2005). In general, marine zooplankton species are more sensitive than freshwater zooplankton species due to the low pH levels of water, as it varies with different species. Each species has a range of tolerance, so the limits of zooplankton tolerance to pH in freshwater ranges from 3.5 to 4.5, while marine species tolerate from 5.0 to 6.7 (Vangenechten *et al*., 1989; Wamada and Ikeda, 1999).

The source of dissolved oxygen in the aquatic environment is the photosynthesis process by aquatic plants and phytoplankton, as well as atmospheric air (Clark, 1996). The depletion dissolved oxygen affects the size, abundance, and diversity of population groups, which is evidence of water pollution (Abowi, 2010). The results showed that the depletion dissolved oxygen in Shatt Al-Basrah upstream the dam may be due to pollution with organic materials from sewage and the decomposition of organic materials, as well as the lack of water movement caused by the closure of the dam, leading to a decrease in the concentration of dissolved oxygen.

Chlorophyll-*a* is a key indicator of the biomass of phytoplankton (Yoder & Kennelly, 2003; Wasmund *et al*., 2006; Camacho *et al*., 2007; Shivaprasad *et al*., 2013). The results of the current study showed that there were two distinct peaks in chlorophyll-*a* concentrations: the first peak during spring and the second peak during autumn. This finding is consistent with the findings of previous studies, such as Antione (1983), Abbas (2010), and Hammadi (2010).

The current study showed that there were significant differences in zooplankton density between the two study stations, and this difference was particularly evident in the Copepoda group. Copepoda density was in the first station located upstream the dam compared to the second station, down the dam, due to the pollution with organic materials from sewage. The highest density of Copepoda was recorded during the summer months at both stations. This is consistent with Al-Lami (1998), Ahmed and Ghazi (2009), and Abbas (2010), who indicated increased zooplankton abundance during the summer months due to the seasonal abundance of phytoplankton, which serve as a primary food source for zooplankton.

The diversity of Copepoda or the richness of the species in the sample is a simple measure of the number of species in the sample, which is used as a guide for the water masses coming from different places. In the current study, the largest number of species of Copepoda was recorded at the second station, 15 species. This is likely due to the fact that this station is the closest to the Arabian Gulf as most of the recorded species were marine species, which confirms that they are coming from the saline water represented by the Arabian Gulf, as the highest salinity values were also recorded at this station.

It was noticed that the abundance of Copepoda increases if we turn towards the Arabian Gulf and this is consistent with the results of Al-Zubaidi (1998) in the Shatt Al-Arab estuary, Al-Jizani (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 Shatt Al-Arab, and Hammadi (2010) on rotifers in Shatt Al-Arab. These studies confirmed that the zooplankton density increases during summer and decreases in winter. The evenness value is related to the amount of diversity in the sample. The highest evenness value is 1 or close to it if there is no dominance by one species or a few species, i.e. when all species exist in the sample with almost the same abundance. Evenness is the opposite of dominance and its value ranges from 0 to 1; it is 0 when there is only one species and a value of 1 when all species are spread evenly (Dahms *et al.*, 2012; Stiling, 1999). Table (5) shows a comparison between the density of Copepoda in the current study and those of previous studies even though the comparison process is relatively due to the differences in the mesh size of the nets used.

Table 5. Comparison of Copepoda density in the current study with previous studies.

Study area	Density of Copepoda (ind./m^3)	References
Coast of Kuwait	186 - 1064	Yamazi (1974)
Coast of Kuwait	16440 -53603	Michel *et al.* (1986)
Arabian Gulf	5475 -31173	Al–Yamani *et al.* (1998)
Arabian Gulf	568 -12192	Al–Khabbaz and Fahmi (1998)
Khour Abdulla	163 -6074	Salman *et al.* (1986)
Khour Abdulla	1902 -23587	Ajeel (1990)
Khour Abdulla	416 - 5774	Ajeel (2017)
Khour Al-Zubair	253 -33989	Ajeel (1990)
Shatt Al-Arab	61 - 20067	Al–Zubaidi (1998)
Khour Al-Zubair	2400 -228500	Al-Shawi (2010)
Khour Al-Zubair	3479 -29778	Morad (2011)
Khour Al-Zubair	2441 - 18149	Ajeel (2012)
NW Arabian Gulf	10818 -14805	Morad (2011)
Shatt Al-Basrah	3766 -135611	Morad (2011)
Shatt Al-Basrah	3017 - 46801	Ajeel (2012)
Garmat Ali	4 - 1042	Ajeel *et al* (2004)
Shatt Al-Arab estuary	51 - 30368	Ajeel (2017)
Shatt Al-Basrah before the dam	0 - 11215	Present study
Shatt Al-Basrah after the dam	1962 - 20591	Present study

Conclusions

1. The current study showed that Copepoda are important environmental guides because they are very sensitive to environmental conditions through which we can

assess the quality and suitability of the aquatic environment, as they are highly susceptible to environmental conditions.

2. The Shatt Al-Basra Canal was characterized as polluted water due to the dumping of sewage and agricultural drainage water.
3. *Acartia (Odontacartia) ohtsukai* and *Pseudodiptomus ardjuna* predominate in the two study stations.
4. The alkaline characteristics prevailed in the waters of the Shatt Al-Basra Channel.
5. There is a close relationship between chlorophyll-*a* and the density of Copepoda, as it depends on it for nutrition. The greater number of phytoplankton, the greater number of Copepoda.

Acknowledgements

We would like to thank Prof. Dr. Salman D. Salman, (pensioned off)/ Marine Sciences Center, Department of Marine Biology, for reading the manuscript and for his critical advice.

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توزيع ووفرة مجذافيات الأقدام في قناة شط البصرة جنوب العراق

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تاريخ الاستلام: 2024/12/27 تاريخ القبول: 2025/03/02 تاريخ النشر : 2025/06/25

المستخلص

تم دراسة بيئة وبنية مجتمع مجذافيات الأقدام في محطتين في قناة شط البصرة، المحطة 1 قبل السد، والمحطة 2 بعد السد. جمعت عينات العوالق الحيوانية شهريا لمدة سنة خلال الفترة من كانون الاول 2011 حتى تشرين الثاني 2012 باستخدام شبكة العوالق حجم فتحاتها 85 ميكرون وفتحة الفم 30 سم، بطريقة الجمع العمودي. تم التعرف على ثمانية عشر نوعا من مجذافيات الأقدام تنتمي إلى 15 جنسا في منطقة الدراسة. في المحطة الأولى كان هناك 13 نوعا تنتمي إلى 13 جنسا. بينما تم تسجيل 15 نوعا تنتمي إلى 13 جنسا في المحطة الثانية. ولوحظ أن رتبة Calanoida هي السائدة في محطتي الدراسة، وتضم 11 نوعا تنتمي إلى 9 أجناس، تليها رتبة Harpacticoida تضم 4 أنواع تنتمي إلى 4 أجناس، ثم رتبة Cyclopoida تم تسجيل 3 أنواع تنتمي إلى جنسين. اعلى كثافة لمجذافيات الاقدام بلغت 20283 فرد/م3 في المحطة 2 خلال شهر ايار 2012 بينما اختفت في كانون الاول وكانون الثاني ومارس في محطة 1.

الكلمات المفتاحية: العوالق الحيوانية، شط البصرة، مجذافيات الأقدام، التوزيع، الوفرة، البيئة