GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

Check for updates

Diversity of Macrobenthic invertebrates at three stations from the middle part of Shatt Al-Arab River

Raghad Zaidan Khalaf *

Department of Ecology, College of Science, University of Basrah, Iraq.

GSC Advanced Research and Reviews, 2023, 15(03), 008–021

Publication history: Received on 16 April 2023; revised on 27 May 2023; accepted on 30 May 2023

Article DOI: https://doi.org/10.30574/gscarr.2023.15.3.0161

Abstract

The present study aimed at the community of macrobenthic invertebrates in three stations of the Shatt Al-Arab River, including Al-Muftia, Sendibad, and Al-Mohammadiat, and samples were collected for a period of six months, from July 2018 to December 2018, during which some environmental factors were measured. The macrobenthic invertebrate samples collected in three monthly replicates for each station were isolated and identified, and the densities, relative abundance, and ecological indices such as diversity, richness, and evenness were calculated. The results showed that the ranges of environmental factors measured for the water of the study stations, in general, were as follows: air temperature (26-39 °C), water temperature (20-32 °C), pH (7.1-8.1), electrical conductivity (5.1-10.7 mS/cm), dissolved oxygen (6.6-9.8 mg/L), and calcium between (80.2-160.3 mg/L). During the study, 12 species of invertebrates were recorded, two of which belonged to the phylum Annelida, five to the phylum Arthropods, and five to the phylum Mollusca. The highest density of registered species was recorded (944 ind/m^2) during December at the Mohammadiat station for the species *Melanoides tuberculata* of Mollusca, and the highest relative abundance of registered groups was for the Mollusca group and amounted to 95%.As for the diversity indices, the highest value of diversity was 1.42 in Mohammadiat station during September, the highest value of richness was 1.61 in Sendibad station during November, and the highest value of evenness was 0.82 in Mohammadiat station during October.

Keywords: Macroinvertebrates; Species identification; Ecological indices; Iraq

1. Introduction

Rivers, streams, wetlands, and lakes are habitats for many small organisms known as macroinvertebrates. These organisms include insects, crustaceans, Annelida, mollusks, and spiders, which are commonly used to describe animals that lack spines and can be observed with the naked eye [1].

Macroinvertebrates are mostly slow-moving animals that form relatively stable communities in sediments that do not change over long periods of time and are affected by sediment properties and the upper layer of water [2]. They can also be collected and counted [3].

Macroinvertebrates play an important and essential role in the ecosystem of which they are a part, as they represent food for fish, amphibians, and waterfowl they contain high amounts of elements and proteins and are easily digestible, thus forming the main source of fish food [4].They break down organic matter and nutrients when aquatic plants die or are eaten by herbivores, resulting in non-living organic matter (litter), which becomes available to atrophic microorganisms as a source of energy, and break down or decompose these organic materials to release the remaining energy, materials, and elements, which are later used by aquatic plants and algae. That is, it accelerates the process of breaking down organic matter into simple inorganic substances such as nitrates and phosphates [5], and thus is the link

* Corresponding author: Raghad Zaidan Khalaf

between primary producers and secondary consumers [6]. Many also live in water for over a year; some have long stays [7], and some have a short larval stage and are used as guides for acute and chronic stimulants [8].

Some studies have been conducted on macrobenthic invertebrates in the Shatt al-Arab River, including the study by [9] on the potential of some snails as bioindicators of trace metal levels in the East Hammar marsh near the Shatt Al-Arab River [10], which showed the possibility of using functional analysis of the composition of the macroinvertebrate community as an alternative to the characteristics of the ecosystem. [11] studied the seasonal variation of aquatic Annelida and some macrobenthic invertebrates from northern Basrah City, and [12] studied the community of macrobenthic invertebrates in three different aquatic habitats in southern Iraq, one of which was Shatt al-Arab. There are local studies that dealt with macroinvertebrate groups individually, including the study of [13] on the diversity of Mollusca in the southern part of the Euphrates River, and [14] recorded a type of Mollusca for the first time in the Shatt Al-Arab River. The current study aimed to investigate the community of macrobenthic invertebrates at three stations in the Shatt Al-Arab region and to apply ecological indices to them.

2. Material and methods

2.1. Description of study area

Three study stations were chosen, all located in Shatt Al-Arab (Fig.1). The Al-Muftia station (the first) was characterized as being close to the Iraqi ports and the presence of wrecks of some ships and many fishing boats, as well as the presence of some plants represented by *Bacopa monnieri and* reeds *Phragmites australis*.

The AL-Sendibad Station (the second) was 2.5 km from the first station. It is characterized by the speed of its water flow and plant types represented by papyrus *Typha domingensis*, *P. australis*, *Ceratophyllum demersum*, and *Vallisneria spiralis.* Al-Mohammadiat station (the third) was also characterized by the speed of the water currents and the presence of aquatic plants represented by *T. domingensis*, *P.australis*, *C. demersum*, and *V. spiralis.*it was5.75 km away from the first station. Station locations were determined using a Geographical Positioning System (Table 1). The aquatic plants were classified according to [15] and [16].

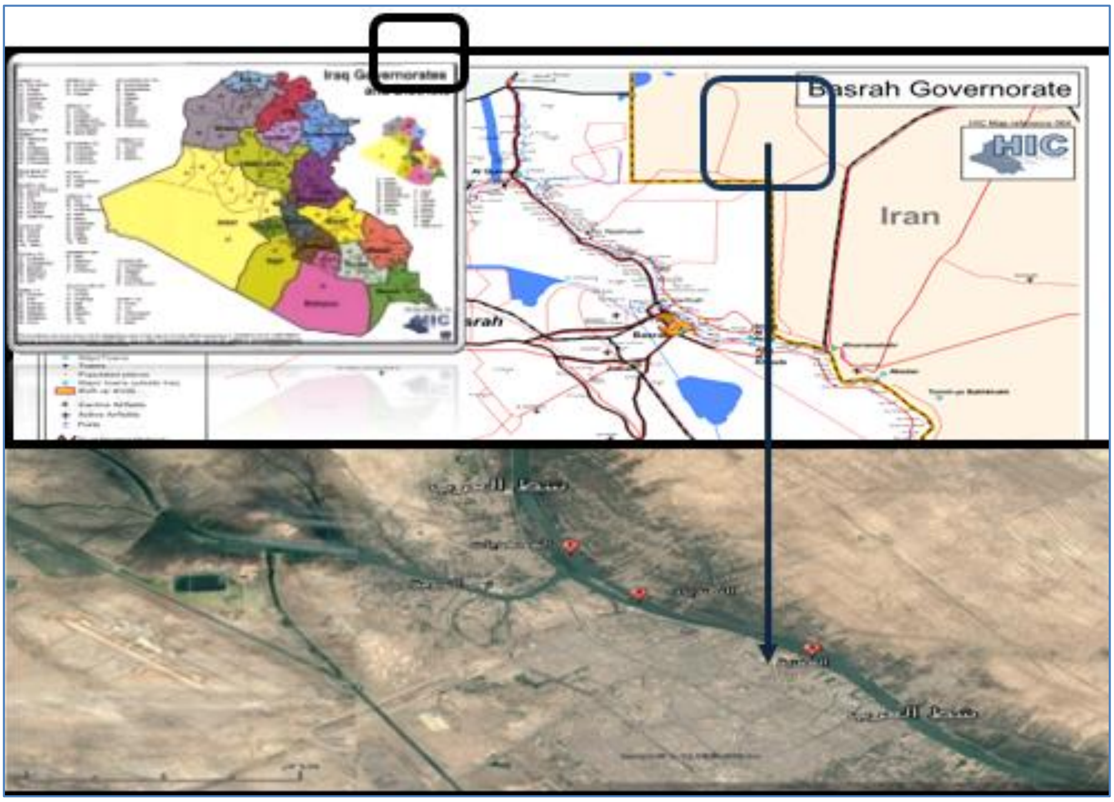

Figure 1 Map of study stations

Table 1 Coordinates of Study Stations

Station	Coordinates
Al-Muftia (St.1)	"No:30 34 993 E:47 46 443"
Al-Sendibad (St.2)	"No: 30 33 881 E:47 47 496"
Al-Mohammadiat (St.3)	"No: 30 32 522 E:47 49 593"

2.2. Physical and Chemical Factors

During the study period, physical and chemical factors, including air and water temperature, electrical conductivity, potential hydrogen (pH), and dissolved oxygen, were measured using the Winkler method and calcium.

2.3. Sample collection

The monthly samples were collected using the quadrate method, as a metal square with a side length of 30 cm was used, and the samples were collected for a period of six months and by three replicates from each station during daylight hours for the period from July 2018 to December 2018, during the lower tide period, and the three replicates were distributed over the intertidal zone As the first replicate was chosen from the upper area from which the tidal water recedes first, the second replicate from the middle region, and the third replicate was taken from the lower area at the lowest flow, The samples were then fixed in the field using 4% formalin and transferred to the laboratory for isolation and identification

2.4. Identification

Several different taxonomic keys were used to identify macrobenthic invertebrates for the group of annelids used [17], arthropods by [18], [19], and [20], and mollusks by [21] and [22].

2.5. The structure of the community

2.5.1. Qualitative structure

The qualitative structure of macrobenthic invertebrates was clarified according to the taxonomic keys mentioned earlier, as the macrobenthic invertebrates whose presence was recorded at the study stations were identified as the lowest classification taxa.

2.5.2. Quantitative structure

- Density

The density (ind/m^2) of the classification taxa recorded during the study was done according to the method of [23] using quadrat as the equation:

Benthos No/m^2 = **-------**x 1000 A.S
Whereas:
N = Number of organisms collected per sample,
A = Area of collecting tool (30*30 cm)
S = Replicates were performed.

- Relative abundance (Ra)

Relative abundance is calculated according to the equation given in [24]:

Ra(%) =(N/Ns)* 100

Whereas:
Ra (%) = relative abundance
N = number of individuals of one species in the sample and Ns = total number of individuals.

- Ecological indices

Ecological indices (diversity, richness, and evenness) were calculated using this program.

PAST, Version 1.34 (Paleontological Statistics)

- Diversity index (H)

The diversity index value, according to [25] and [26] was calculated using the following equation:

$$H = - \sum Pi \ln Pi$$

Whereas:
H = Diversity Index
Pi = Ratio of the number of members of each species to the total number.

- Richness index (D)

The evidence of richness was deduced from the equation developed by [27] as follows:

$$D = S\text{-}1 / \ln N$$

S = number of species and N = total number of individuals in the sample.

- Index (J) Evenness

The equitability index [28] is obtained using the following equation:

$$J = H/\ln S \text{ as}$$

J = Index of Equivalence,
H = Index of Diversity,
S= the number of species.

3. Results

3.1. Physical and Chemical Factors

3.1.1. Air temperature

The highest air temperature was 39 °C and was recorded at the second and third stations in July; the lowest was 26 °C and was recorded at the third station in December (Fig. 2).

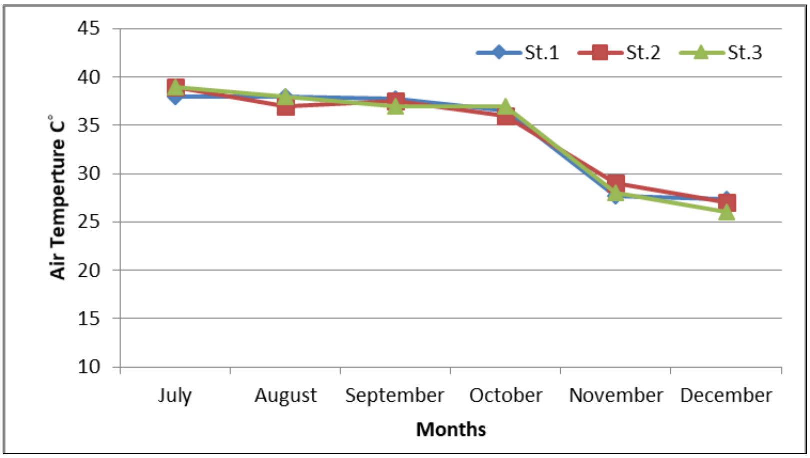

Figure 2 Monthly changes in air temperature (°C) recorded at the study stations during the sample collection period

3.1.2. Water temperature

The highest water temperature was 32 °C, recorded at the second station in July, the lowest at 20 °C, and the third station in December (Fig. 3).

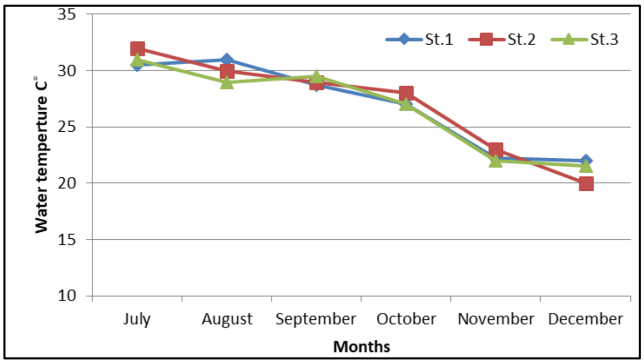

Figure 3 Monthly changes in water temperature (C̊) recorded at the study stations during the sample collection period

3.1.3. pH

The highest pH value 8.1 was recorded at the third station in August, and the lowest 7.1 was recorded at the second station in October (Fig. 4).

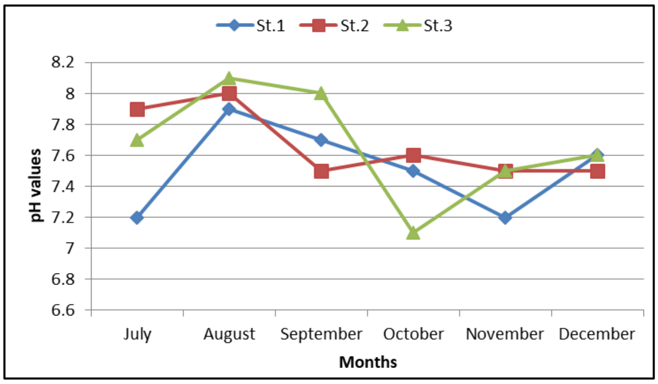

Figure 4 Monthly changes in pH recorded at the study stations during the sample collection period

3.1.4. Electrical conductivity

The highest electrical conductivity was 9.2 mS/cm, recorded at the third station in December and the lowest 5.1 mS / cm at the first station in July (Fig. 5).

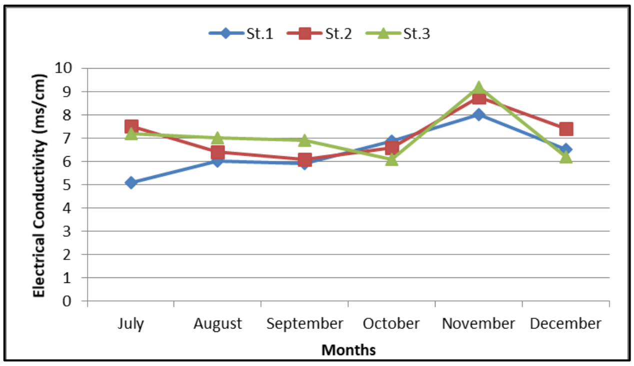

Figure 5 Monthly changes in electrical conductivity recorded at study stations during the sample collection period

3.1.5. Dissolved oxygen

The highest dissolved oxygen value recorded in December at the third station was 9.8 mg/l, while the lowest was 6.6 mg/l during July at the first station (Fig. 6).

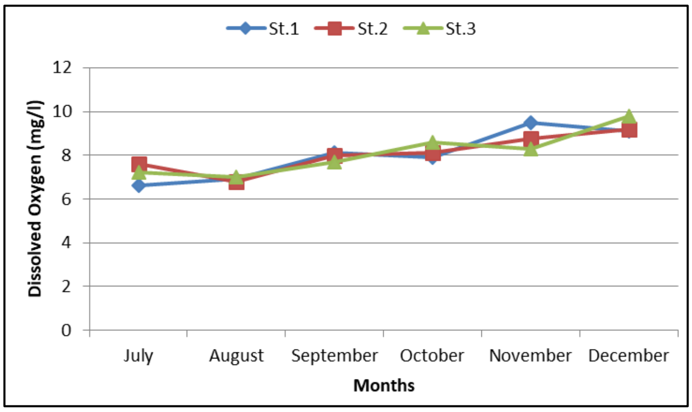

Figure 6 Monthly changes in dissolved oxygen values recorded at study stations during the sample collection period

3.1.6. Calcium

The highest value of calcium ion was recorded in the second station during September and October amounted to 160.3 mg/l, while the lowest value was recorded during July at the first and third stations and amounted to 80.2 mg/l. (Fig. 7).

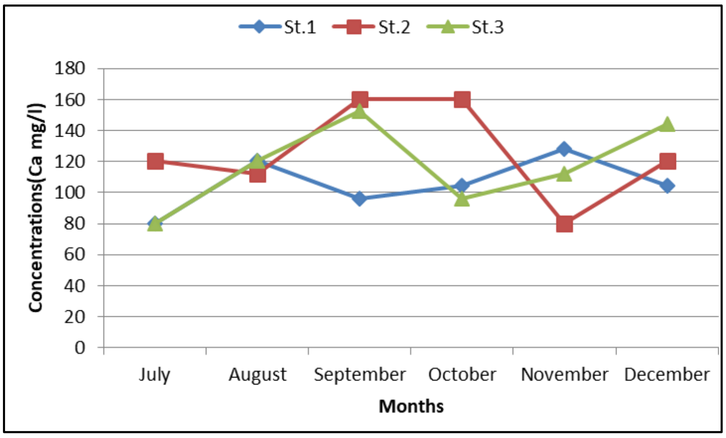

Figure 7 Monthly changes in calcium levels recorded at study stations during the sample collection period

3.2. Community structure

3.2.1. Qualitative structure

The macrobenthic invertebrates recorded during the current study belonged to three phyla: annelida, arthropods, and mollusks. The total number of species recorded during the study period was 12. Two belonged to the phylum Annelida, five species of arthropods, and the other five molluscs. Seven species were recorded at Al-Muftia station (St.1),11 at Sendibad station (St.2), and nine species were recorded at Al-Mohammadiat station (St.3) (Table 2).

Table 2 Composition of macrobenthic invertebrate communities recorded at the study stations.

Taxa	Stations		
Phylum1: Annelida	St.1	St.2	St.3
Dendronereides heteropoda	+	+	+
*Limnodrilus hoffmeister*i	+	+	-
Phylum2: Arthropoda			
Parhyale basrensis	-	+	+
Sphaeroma a annandalei	+	+	+
Metapeneaus affinis	+	+	+
Seasarma boulengeri	-	+	+
Amphibalanus amphitrite	-	+	+
Phylum3: Mollusca			
Melanoides tuberculata	+	+	+
Melanopsis nodosa	+	+	+
Melanopsis costata	-	-	+
Neritina violacea	-	+	-
Corbicula fluminalis	+	+	-

+ exists and - does not exist.

3.2.2. Quantitative structure

Monthly density of species

Table 3 Monthly changes in density (ind/m^2) of macrobenthic invertebrates recorded at the First station during the study period.

Taxa	Density (ind/m2)					
Phylum1: Annelida	July	August	September	October	November	December
Dendronereides heteropoda	4	0	7	7	4	0
*Limnodrilus hoffmeister*i	0	7	7	19	0	0
Phylum2:Arthropoda						
Sphaeroma a annandalei	4	7	15	0	19	44
Metapeneaus affinis	0	4	4	0	37	0
Phylum3: Mollusca						
Melanoides tuberculata	148	56	96	59	296	274
Melanopsis nodosa	0	0	4	0	22	0
Corbicula fluminalis	0	4	0	0	0	11

The highest density of *D. heteropoda* of annelida was recorded in October and November in the third station, amounting to 11 individual /m^2 and for *L.hoffmeisteri* in the first and second stations, it reached (74 and 19) individual/ m^2 during December and October, respectively. *S. annandalei* reached (163 and 333) individuals/m2, respectively, and *M. affinis* in the third station and reached 44 individuals / m^2 during December. Still, within the mollusk group, it reached the highest density (944, 888, and 296) individual / m^2 for the species *M. tuberculata* during December in the second and third stations, respectively. During November at the first station, the lowest density was 0 individual/m^2. It was recorded during the months of the study for some species belonging to groups of annelida, arthropods, and mollusk at the study stations (Tables 3,4 and5).

Table 4 Monthly changes in density (ind/m2) of macrobenthic invertebrates recorded at the second station during the study period

Taxa	Density (ind/m2)					
Phylum1: Annelida	July	August	September	October	November	December
Dendronereides heteropoda	0	0	7	11	26	7
*Limnodrilus hoffmeister*i	37	44	56	67	30	74
Phylum2: Arthropoda						
Parhyale basrensis	0	11	15	7	44	0
Sphaeroma a annandalei	7	7	26	0	333	41
Metapeneaus affinis	0	0	0	0	11	41
Seasarma boulengeri	4	0	7	0	4	7
Amphibalanus amphitrite	7	4	11	15	7	15
Phylum3: Mollusca						
Melanoides tuberculata	366	374	426	207	518	888
Melanopsis nodosa	0	0	11	15	4	11
Neritina violacea	0	4	4	11	4	7
Corbicula fluminalis	0	0	0	0	0	7

Table 5 Monthly changes in density (ind/m^2) of macrobenthic invertebrates recorded at the third station during the study period.

Taxa	Density (ind/m2)					
Phylum1: Annelida	July	August	September	October	November	December
Dendronereides heteropoda	0	4	7	11	11	0
Phylum2: Arthropoda						
Parhyale basrensis	15	56	48	0	41	19
Sphaeroma a annandalei	0	0	52	0	163	56
Metapeneaus affinis	0	0	0	0	7	44
Seasarma boulengeri	0	0	4	0	0	4
Amphibalanus amphitrite	7	0	4	4	7	4
Phylum3: Mollusca						
Melanoides tuberculata	274	185	152	22	352	944
Melanopsis nodosa	4	7	11	0	0	7
Melanopsis costata	7	0	15	0	0	7

Monthly Relative Abundance of Species for Study Stations

The relative abundance of each species within the main group and at each study station was studied*. M. tuberculata*had the highest monthly relative abundance in all study stations (95, 86.9 and 89) %, respectively, in the three study stations during July. The lowest relative abundance was 0 %, recorded for some species during the study months and at all stations (Fig. 8,9 and 10).

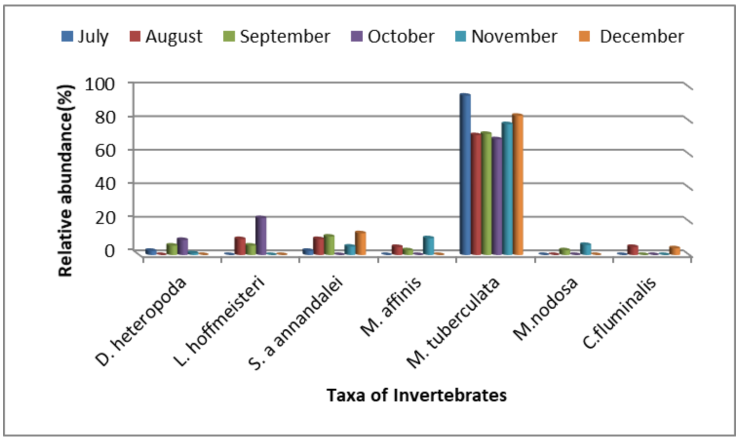

Figure 8 Monthly changes in the relative abundance (%) of marine invertebrate species at the First Station

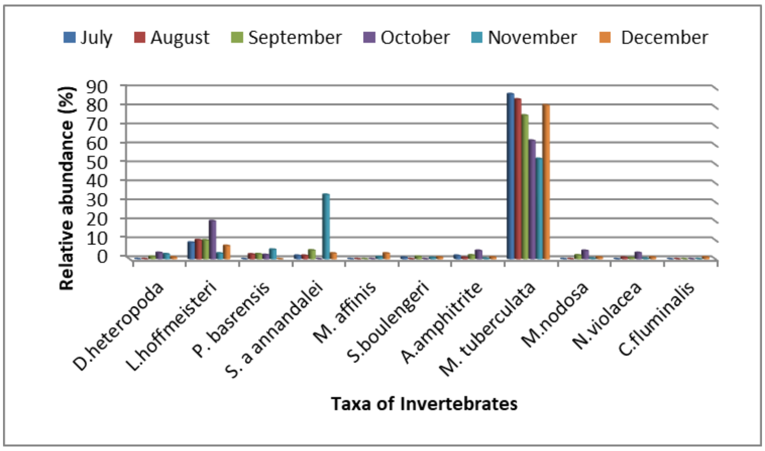

Figure 9 Monthly changes in relative abundance (%) of macrobenthic invertebrate species at the second station

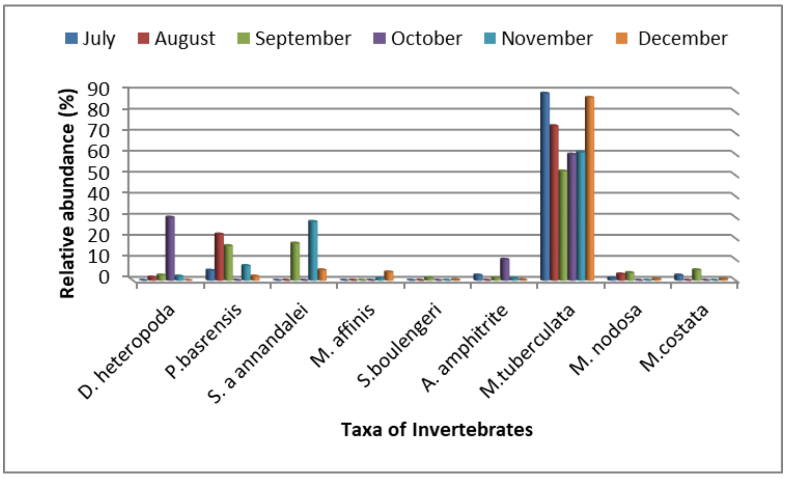

Figure 10 Monthly changes in relative abundance (%) of macrobenthic invertebrate species at the Third Station

Monthly relative abundance of main groups for each station during the study

The monthly relative abundance of the main groups of macrobenthic invertebrates was calculated at all study stations, and the Mollusca group occupied the highest relative abundance of all stations, amounting to (95,87 and 93) % during July at the three study stations, respectively (Table.6).

Table 6 Monthly changes in the relative abundance of the main groups of macrobenthic invertebrates recorded during the study period.

Taxa		**Relative abundance (%)**					
Phylum	Stations	July	August	September	October	November	December
Annelida	St. 1	2.5	10	11	30	1	0
Arthropods	St. 1	2.5	14	14	0	15	13.5
Mollusca	St. 1	95	76	75	70	84	86.5
Annelida	St. 2	9	10	11	23	6	7
Arthropods	St. 2	4	5	11	7	41	14
Mollusca	St. 2	87	85	78	70	53	79
Annelida	St. 3	0	2	3	30	2	0
Arthropods	St. 3	7	22	37	10	38	12
Mollusca	St. 3	93	76	60	60	60	88

3.3. Ecological indices

3.3.1. Al –Muftia(St.1)

Diversity index values for macrobenthic invertebrates ranged from 0.22-0.99, with the lowest in July and the highest in September. Regarding the richness index, the lowest value was 0.45 in December, with the highest being 1. 39 were recorded in September. The evenness index values ranged from 0.21-0. 73, with the lowest recorded in July and the highest in October (Fig.11).

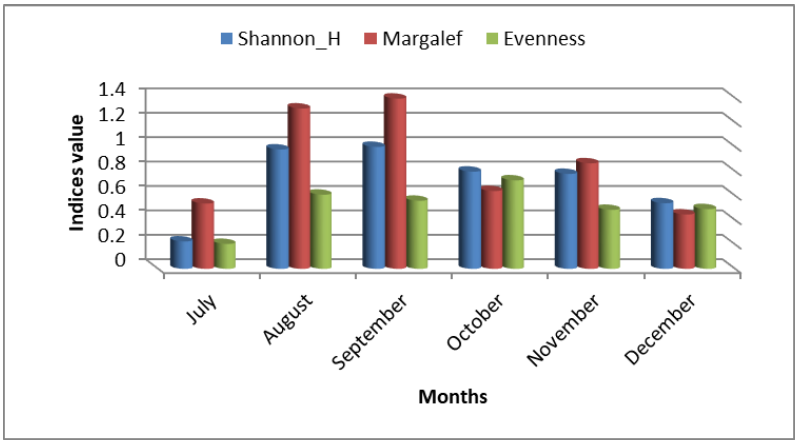

Figure 11 Monthly changes in ecological indices values for benthic invertebrates at the first station

3.3.2. Al-Sendibad(St.2)

The lowest value of the diversity index for macrobenthic invertebrates was recorded in July (0.52), with the highest value of 1. 21, and was recorded in October. The richness index values ranged from 0.85.1. The 61 lowest was recorded in July and the highest in November. The evenness index values ranged from 0.32-0. The 62 lowest was recorded in July and the highest in October (Fig.12).

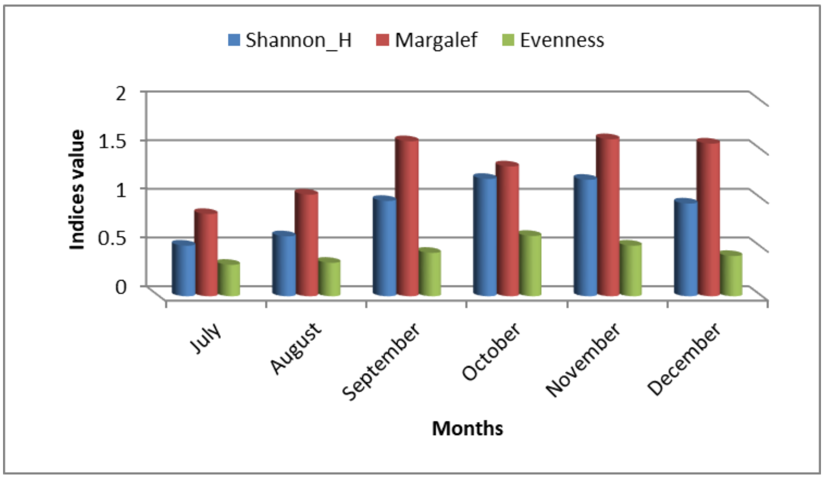

Figure 12 Monthly changes in ecological indices values for benthic invertebrates at the second station

3.3.3. AL-Mohammadiat(St.3)

Diversity index values for macrobenthic invertebrates ranged from 0.48- 1.42, with the lowest recorded during July and the highest during September. Richness index values ranged from 0.71-1.61. The lowest was recorded in August and the highest in September. Evenness index values ranged from 0.28-0. The 82 lowest recorded during December and the highest recorded during October (Fig.13).

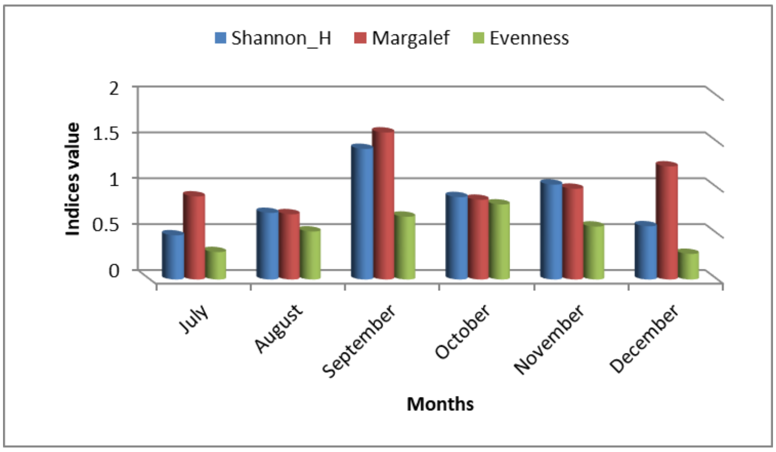

Figure 13 Monthly changes in ecological indices values for benthic invertebrates at the Third Station.

4. Discussion

The current study showed that the density and abundance of macrobenthic invertebrate aggregates are not heterogeneous between study stations, and such data can be used to analyze the seasonal variations in benthic invertebrates and their diversity, as well as the seasonal variations in water quality variables.

One of the most important reasons for these groups of macroinvertebrates in Shatt al-Arab is the presence of vegetation. One of the characteristics and advantages of the water body is the presence of vegetation, as aquatic plants prepare a surface for macrobenthos to live in, as they balance water flow, light, and heat transmittance.

Salinity is an important environmental factor, and macroinvertebrate communities have different tolerances to salinity; in general, crustaceans are more able to withstand increased salinity than insects.

The diversity of large invertebrates at different freshwater sites varies depending on the season, life cycle, runoff, water quality, and habitat. The Mollusca group recorded a high abundance for the rest of the groups and came in second place group arthropods, perhaps due to the success factors characterized by the phylum of arthropods [29] found that the arthropods could adapt to diverse environmental habitats; owing to the multiplicity of feeding patterns and physiological behavior. The high abundance of the Mollusca group is due to the species *M.Tuberculata* as this species, is characterized by its abundance and dominance in most freshwater and brackish water environments, and this is identical to the study of [30], as it recorded the highest abundance in the Euphrates River.

The group Annelida has occupied the least abundance for the rest of the groups due to environmental instability. [31] explained that the presence of worms in the tidal zone is strongly associated with the change of seasons and the bottom quality.

This fluctuation in benthic density and abundance is due to multiple factors, including longevity, migration, the growth rate of the organism, and decimation, as well as a direct correlation between the velocity of currents and the density of macrobenthic invertebrates [32]. This fluctuation in the density and abundance of the main benthic invertebrates during the different seasons was considered normal [33]. Species abundance and diversity are influenced by changes in a habitat's physical, chemical, and biological characteristics [34].

The Mollusca group recorded the highest density and abundance in the current study, which may be because gastropods prefer running water saturated with oxygen more than water with little ventilation [35].This group is also characterized by a high ability to reproduce and spread; therefore, it builds an integrated population wherever appropriate conditions are available [36].The responses of different classes vary according to environmental factors [37].

In terms of diversity, the highest diversity was recorded at Sendibad station during October, as well as a value close to that at Al-Mohammadiat station during September, reflecting macroinvertebrates' preference for environmental conditions during these months [38]. The regions characterized by clear thermal seasonal changes become highly diverse and abundant, and the study of [39] showed a preference for macrobenthic invertebrates to low and temperate water temperatures, which was recorded in the current study.

As for the evenness index, which is used as an environmental indicator of the presence of disturbance or imbalance in the habitats of the environment [40], the lowest value was recorded in December at Muhammadiat station because of the dominance of one species of Mollusca over the rest of the species, while the highest value was recorded during October for the same station because of the spread of species in an almost integrated manner.

5. Conclusion

The community of macrobenthic invertebrates was observed and documented at three stations in the middle section of the Shatt al-Arab River. The presence of certain aquatic plants characterizes these stations. Macrobenthic invertebrates included species from the annelida, arthropod, mollusk gastropod, and bivalve communities. Throughout the study period, the mollusk community exhibited the highest relative abundance. The station at Mohammadiat had the greatest diversity of benthic invertebrate communities, whereas the station at Sendibad had the highest species richness. Additionally, Mohammadiat demonstrated the highest evenness among the recorded communities.

Compliance with ethical standards

Acknowledgments

We would like to thank the Department of Ecology, University of Basrah, for their invaluable support throughout our research. Their assistance was instrumental in the successful completion of the study.

Statement of ethical approval

The current research was conducted with the ethical approval of the University of Basrah, which granted permission to collect water samples and animals from the Shatt Al-Arab River.

References

[1] Water and Rivers Commission. Water Facts: Water Quality and Macroinvertebrates. 2001.

[2] El-Shabrawy GM, Khalil MT. Macrobenthos of Lake Bardawil and Zaranik Lagoon. A report presented to the nature conservation sector, EEAA. Medwetcoast project, conservation of wetland and coastal ecosystems in the Mediterranean region, ecological survey of Zaranik nature protectorate, GEF; 2003. 30 p.

[3] Adakole J, Anunne P. Benthic macroinvertebrates as indicators of environmental quality of an urban stream, Zarie, Northern, Nigeria. J Aquat Sci. 2003;18(2):85-92.

[4] Yildiz S, Rusen M, Balik S. The Oligochaeta (Annelida) Fauna of Yuvarlak Stream (Koycegiz, Turkey). Turkish Journal of Fisheries and Sciences. 2006; 7:01-06.

[5] George A, Abowei J, Daka E. Benthic Macro Invertebrate Fauna and Physico-Chemical Parameters in Okpoka Creek Sediments, Niger Delta. Nigeria International Journal of Animal and Veterinary Advances. 2009; 1(2):59-65.

[6] Ishaq F, Khan A. Diversity Pattern of Macrozoobenthos and their Relationship with Qualitative Characteristics of River Yamuna in Doon Valley Uttarakhand. American-Eurasian Journal of Toxicological Sciences. 2013; 5(1):20-29.

[7] Kazanci N, Dugel M. Ordination and classification of macroinvertebrates and environmental data of stream in Turkey. Water Science and Technology. 2000; 47:7-8.

[8] Adamus PR, Brandt K. Impacts on Quality of Inland Wetlands of the United States: A Survey of Indicators, Techniques, and Applications of Community Level Biomonitoring Data. USEPA Environmental Research Lab, Corvallis, Oregon; 1990. 406 pp.

[9] Aziz NM, Marina BA, Qzar EA. The Potential of some snails as bioindicators of trace metals level in East Hammar marsh, south of Iraq. Basrah journal of science. 2010; 28(2B):228-242.

[10] Al-Khafaji KK. Functional analysis of the structure of the macroinvertebrate community in the Shatt al-Arab - Basra - Iraq [dissertation]. Basra: University of Basrah; 2105. 129 p.

[11] Al-Abbad MY, Al-Mayah SH, Abdul Redha NW. Seasonal variation of annelids and some benthic macroinvertebrates with a new record of the species Nais raviensis Stephenson, 1941 (Oligochaeta: Naidinae) from northern Basrah city. Basra Research Journal (Science). 2015; 41(1):64–85.

[12] Khalaf RZ. Synecology of macrobenthic invertebrate of three different aquatic habitats at southern Iraq [dissertation]. Basra: University of Basrah; 2016. 243 p.

[13] Chasib HH, Khalaf RZ. Diversity of Mollusca in the Southern part of the Euphrates River. Marsh Bulletin. 2022;17(1):52-65.

[14] Okash AN, Al-Abbad MY, Hammadi NS. First record of the blue mussel Mytilus edulis (Linnaeus, 1758) in the Shatt Al-Arab River, Basrah, Iraq. AACL Bioflux. 2022; 15(4):1675-1679.

[15] Al-Saadi HA, Al-Mayah AA. Aquatic plants in Iraq. Publications of the Center for Arabian Gulf Studies. University of Basrah; 1983. 192 p.

[16] Al-Mayah AA, Al-Hameem FH. Aquatic plants and algae. Basra: Dar Al-Hikma Press, University of Basrah; 1991. 735 p.

[17] Timm T. A Guide to the Freshwater Oligochaeta and Polychaeta of Northern and Central Europe. Lauterborina. 2009; 66:1-235.

[18] Edmondson WT. Freshwater Biology. United States of America; 1976. 1248 p.

[19] Rasheed KA. Study of some Biological Aspects of Freshwater Shrimp Ataephyradesmarestiorientalis Bouvier, 1913 in Shatt Al-Arab, Iraq. MSc Thesis. College of Science, Basrah University; 1985. 86pp.

[20] Al-Maliki TH. Guide and characteristics of shrimp species in South Waters Iraq [dissertation]. Basra: University of Basrah, Marine Science Center; 2013. 192 p.

[21] Ahmed MM. Systematic study on the Mollusca from Arabian Gulf and Shatt Al-Arab. Basrah: Center for Arab Gulf Studies, Basrah University; 1975. 87 p.

[22] Frandson F. A field guide to freshwater snails in countries of the WHO eastern Mediterranean region. Danish Bilharziasis Laboratory; 1983. 45 p.

[23] Mohan VC, Sharma KK, Sharma A, Watts P. Biodiversity and Abundance of Benthic Macro-invertebrates Community of River Tawi Vicinity of Udhampur City (J and K) India. Int Res J Environ Sci. 2013;2(5):17-24.

[24] Odum WA. Insidious Alteration of the Estuarine Environment. Trans Am Fish Soc. 1979; 99:836-847.

[25] Shannon CE, Wiener W. The Mathematical Theory of Communication. University of Illinois Press, Chicago, USA; 1949. 117pp.

[26] Romos S, Cowen RK, Re P, Bordalo AA. Temporal and Spatial Distribution of Larval Fish Assemblages in the Lima Estuary (Portugal). Estuar Coast Shelf Sci. 2006; 66:303-314.

[27] Margalef R. Perspectives in Ecology Theory. University of Chicago Press, Chicago; 1968. Cited by Fausch KD, Lyons J, Karr R, Angermeier PL. 1990.

[28] Pielou EC. Mathematical Ecology. John Wiley, New York; 1977. 385pp.

[29] Sharma S, Dubey S, Chaurasia R, Dave V. Macroinvertebrate Community Diversity in Relation to Water Quality Status of Kunda River (M.P.), India. J Discovery. 2013;3(9):40-46.

[30] Al-Yacoub GA, NajimShA, Al-Khazali AM. Diversity and Density of Mollusca (Gastropoda and Bivalvia) population in the Euphrates River at Al-Nasiriyah, southern Iraq. Ecology, Zoo diversity. 2022;56(6):473-484.

[31] Collado R, Schmelz R. Oligochaete distribution patterns in two German hardwater lakes of different trophic state. Limnologia. 2001; 31:317-328.

[32] Habdija I, Primc H, Matonickin R, Kucinic M, Radavovic I, Milisa M, Mihaljevic Z. Current velocity and food supply as factors affecting the composition of macroinvertebrates in bryophyte habitats in Karst running water. Biologia Bratislava. 2004;59(5):577-593.

[33] Amri N, Jamili S, Abdolbaghian S. Diversity of Macrobenthos Communities and their Relationships with Environmental Factors in Jajroud River, Iran. Resources and Environment. 2014;4(2):95-103.

[34] Pimenta M, De Marco P. Leaf Beetle (Chrysomelidae: Coleoptera) Assemblages in a Mosaic of Natural and Altered Areas in the Brazilian Cerrado. NeotropEntomol. 2015; 44:242-255.

[35] Malek BA. Snail-Transmitted Parasitic Diseases. ICRC Press. Florida; 1980.

[36] Aho J. Regional variation in the diversity of freshwater Gastropoda in Southern and Western Finland. Publ Univ Joensuu Ser BII. 1978; 8:10.

[37] Menta C, Remelli S. Soil Health and Arthropods: From Complex Systems to Worthwhile Investigation. Insects. 2020; 11:54. doi:10.3309/insects/1010054.

[38] Geraci GJ, Zhou X, Al-Saffer MA. Barcoding Iraq: aquatic insects of the Tigris/Euphrates river basin useful for biosurveillance. In: 4th International Barcoding Life Conference. Adelaide, Australia; 2011.

[39] IMET (Italian Ministry of Environment and Territory), M. Environment, M. Water resources, M. Municipalities, and Iraq Foundation. Overview of present conditions and current use of the water in the marshlands area. Vol. 1, book 4 (marshlands). 2006. 256 p.

[40] Park YS, Verdonschot PF, Chon TS, Gevrey M, Lek S. Macroinvertebrate Community Assemblages. EU project. 1999:198-205.