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Monitoring Environmental Changes in the Shatt al-Arab River Using the Organic Pollution Index (OPI) and Two Species of Benthic Invertebrates *Melanoides tuberculata* and *Neritina violacea*

Nada M. Al-Baghdadi[1], Mohammed F. Abbas[1], Ghassan A. Al-Najare[2], Kadhim H. Younis[2], Rafid M. Karim[1, *]
[1]Marine Biology Department, Marine Science Center, University of Basrah, Basrah, Iraq
[2]Marine Vertebrates Department, Marine Science Center, University of Basrah, Basrah, Iraq
[*]Corresponding Author: rafid.karim@uobasrah.edu.iq

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ABSTRACT

The current study seeked to monitor five selected stations in the Shatt al-Arab River using the organic pollution index (OPI) and the presence and abundance of two species of snails, *Melanoides tuberculata* and *Neritina violacea*. The temperature values ranged from 12.2- 27.5°C, and the salinity ranged from 0.7- 6.79ppt. Whereas, the pH values fluctuated between 6.5 and 8.4. For the biological oxygen demand (BOD5)**,** values were recorded, with the highest values being 6mg.l-1 at the fifth station. Nitrate values ranged from 0.012 to 4.95µg/ l, and phosphate values ranged from 0.11 to 0.589µg/ l.. The average organic pollution index values were registered, with the highest rate at the fourth station (4.19) and the lowest at the first station (1.65). The monthly values of the density of *M. tuberculata* per square meter ranged between 192 and 16 individuals/ m². The annual average density of *M. tuberculata* (Individual/ m2) ranged from 120 for the first station to the lowest density of 36 for the third station. While, for the second species, *N. violacea*, the highest values at the stations reached 96, 120, 96, 50, 48 individuals/ m^2, respectively, during November. In addition, no individuals were recorded during July at all stations; the average annual density of *N. violacea* was between 47.33 individuals/ m^2 at Garmat Ali and 13 individuals/ m^2 at Hamadan station. It was found that individuals of the *M. tuberculata* species are denser than the *N. violacea* species for all stations; the former species is also affected by temperatures more than the second species, therefore the highest density was noticed in the autumn and spring seasons. The non-populated stations recorded less organic pollution than the rest, as an inverse relationship was found between the annual rates; for OPI water, the annual average density of *M. tuberculata* was greater than that of the second species.

INTRODUCTION

Water is a crucial, vital resource for living organisms and the environment in general, and environmental factors in water play a significant role in determining the health of aquatic ecosystems and their impact on wildlife and humans. Aquatic ecosystems are among the most critical biological ecosystems, providing the appropriate environment for aquatic organisms and performing functions, which include securing water, supporting agriculture and fishing, and maintaining ecological balance **(Xu *et al.*, 2019)**. The growth and development of human societies, the advancement of agriculture and industry, the increase in well-being, and the elimination of epidemics and diseases have contributed to the prolongation of human life. These factors have led to explosive increases in population numbers and the accompanying growth of cities and civilization, which began to produce forms of waste and pollutants previously unknown to water. Consequently, this has led to the deterioration of water quality and the disappearance or extinction of some species present in it **(Mouloud *et al.*, 1991)**. Organic pollution is considered one of the most dangerous types of pollution, and it poses a significant threat to the natural aquatic environment and human health **(Bastami *et al.*, 2015)**. This pollution causes an increase in the concentration of pollutants in the aquatic environment, leading to the bioaccumulation of pollutants in aquatic organisms such as freshwater molluscs **(Yu, *et, al.*, 2008)** in addition to water pollution and harmful effects on natural ecosystems **(Islam *et al.*, 2015)**. Freshwater snails belong to the most widespread invertebrate animals; they are often the most important living organisms, feeding on algae and dead organic materials and serving as food for other organisms; molluscs contribute to maintaining the appropriate biological balance **(Kwong *et al.*, 2010)**. These species form large populations and tolerate wide ranges of temperature, salinity, pH, and other parameters **(Cicero & Carlos, 2019)**. Water temperature plays a vital role in determining the quality of the aquatic environment, and temperature affects the speed of growth of aquatic organisms and their vital activities. For example, certain water temperatures can be favorable for certain types of fish and marine organisms, and the pH affects the ability of organisms to endure and adapt to the aquatic environment; for example, the appropriate pH can be crucial for aquatic and marine shell organisms. Salinity expresses the dissolved salts in the water, which differs between salt and fresh water. A change in salinity affects the distribution of aquatic organisms and metabolic processes. Much research confirmed that the gastropod invertebrate *M. tuberculata* has invaded aquatic ecosystems on a large scale in many warm regions since it can adapt, migrate, and establish itself in diverse environments **(Supian & Ikhwanuddin, 2002)**. The current study aimed to monitor environmental changes in the tidal zone of the Shatt al-Arab River using the organic pollution index (OPI) and two species of invertebrates, *Melanoides tuberculata* and *Neritina violacea.*

MATERIALS AND METHODS

1. Description of the study area

Samples were collected monthly from five stations selected in the Shatt al- Arab River covering the period from December 2022 till November 2023 during the low tide period. The first station (Al-Diyr) is located at coordinates 47˚34ˈ56.01" E 30˚48ˈ05.79" N. It is characterized by a slope of the beach and a coastal gradient of about two meters. The area is surrounded by agricultural lands planted with palm trees and secondary irrigation canals. The tidal movement affects the water level, and small boats pass through this area; wastewater is poured into the area as it is populated and affected by agricultural waste. Numerous different aquatic and semi-aquatic plants grow. The monastery water station is approximately 100 meters away from it, which is responsible for distributing water. Station ٢ (Garmat Ali) is situated within the coordinates 30˚34˙11.62" N 47˚45˙08.84" E. A slope of the beach characterizes this station with a distance of about five meters and a coastline containing the remains of rocks and stones. Moreover, there are few plants, the water level is affected by the movement of tides, and small and large boats pass through this area for fishing. Station 3 (Sandbad Island) is found within the coordinates 30˚34˙30.78" N47˚46˙35.69" E. A slight slope of the beach characterizes it, and the water level is affected by the movement of tides. The bottom is muddy, with rocks, stones, and plants such as *Phragmites australis* and *Typha. domingensis* on the sides. The area is affected by water coming from the Najibiya power generation station from the west. Population centers and orchards are also located on the eastern side of the Shatt al-Arab River. The area is affected by sewage water and agricultural waste directly from the secondary branches, and there is much movement in this area of small boats used for fishing. Station 4 (Al-Salhiya Island) is at coordinates 30˚30˙42.11"N 47˚51˙18.60"E opposite to the teaching hospital on the north-eastern side of the river, the beach slopes by three meters. The area is affected by pollution due to the presence of some houses. Small and large boats pass through its waters for fishing or recreational trips, transportation operations for people or petroleum derivatives, grazing operations for animals that occur in the area, and plants near the water, especially *P. australis*; the presence of some remains of ancient ships also characterizes the region. Station 5 (Hamadan): This station is located within the coordinates 30˚27˙51.62" N 47˚54˙12.58" E; the area is characterized by water currents that are not high, and the coastal gradient is slight, i.e., the low tide area contains stones and few plants. The area is exposed to sewage due to its proximity. Of the houses, small boats pass within the waters of the station, as it is located on a subsidiary river of the Shatt al-Arab. Fishing is practiced extensively in the area by the residents. The area is also characterized by palm groves, and many types of crops are cultivated.

2. Environmental characteristics

Some environmental characteristics were measured in the field during low tide simultaneously with the collection operations, including water temperature, salinity concentrations, and pH in the field at the selected study stations at the times of monthly sample collection using a device type (665MPS—YSI—Model 57, manufactured by Kalbuneh Company, USA). Salinity results were expressed in ppt.

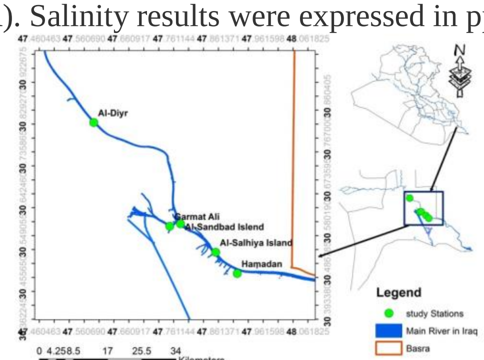

Fig. 1. Map of the study area showing sampling stations

2.1. Dissolved oxygen

The smart sensor dissolved oxygen meter AR8210 was used to directly measure the level of dissolved oxygen in the water of the study stations by placing the device's electrode in the water for two minutes.

2.2. Biological oxygen demand (BOD_5)

The biological oxygen demand (BOD_5) was calculated by measuring the amount of dissolved oxygen. The samples were then left in the dark at 20°C for five days in an incubator, after which the dissolved oxygen was measured again, according to the method described by the American Public Health Association **(APHA, 2005)**.

2.3. Effective nitrate (NO3) (mg nitrogen-nitrate.l^{-1})

After stabilizing the sample in the field, the method of **Parson *et al.* (1984)** was followed. The concentration was read using a spectrophotometer, type Pu8670 vis\NiR Philips, English-made, with a wavelength of 543nm. The result was expressed in micrograms of nitrogen atom/liter after taking the average for two readings for each sample.

2.4. Nitrite (NO_2) (mg nitrogen- nitrite.l^{-1})

The method of **Bendschneider and Robinson (1952**) has been followed and approved by **Parsons *et al.* (1984)**. The concentration was measured using the device above at a wavelength of 543nm. The result was expressed in micrograms of nitrogen atoms per liter (µg N/L) after taking the average TIN reading for each sample.

2.5. Effective phosphate (PO_4) (mg phosphorous-phosphate.l^{-1})

The method of **Murphy and Riley (1962)** was adopted and approved by **Parsons *et al.* (1984)** by using the device above at a wavelength of 850nm, and the result was expressed in micrograms of phosphorus atom/liter after taking an average of two readings for each sample.

3. Collecting and preserving living samples

Samples were collected from each station during daylight hours; the specified area of clay was taken to collect samples of the two species of snails. They were collected from the same wooden square, which contains aquatic and semi-aquatic plants, most of which were filamentous algae, containing most of the snails between their threads. These samples were placed in separate containers according to type, with a quantity of river water, clay, and algae, and transported to the laboratory.

4. Isolation of laboratory organisms

The samples were washed in the laboratory with water and carefully cleaned of clay and other materials in two stages. For this purpose, sieves with different opening diameters were used. In the first stage, a sieve with an opening diameter of 2000 micrometers was used to isolate samples more prominent than 2mm in size. In the second stage, the filtered water from the first sieve was passed through another sieve with an opening diameter of 500 micrometers to isolate the smaller samples. The snails were sorted by species and placed in separate bottles. They were all preserved in bottles containing 4% formalin. The numbers of the two species in all stations were counted.

5. Total density and identifying of species

The density (individuals/ m2) of the horizontal distribution of the two species was calculated by calculating the number of individuals for the studied species by using the Quadrate method (the number of individual per square meter). The classification of the study species was conducted by comparing them to literature references and identifying them according to **Najim (1959)**, **Ahmed (1975)** and **Frandsen (1983)**. This process was carried out using a dissecting microscope.

6. Organic pollution index (OPI)

The organic pollution index (OPI) was applied based on **Boluda *et al.* (2002)** and according to the following equation:

$$\text{OPI} = \left(\sum_{i=1}^{n} \frac{Ci}{Cmi}\right)/n$$

Where, Ci: the empirical value for each variable analyzed; Cmi: the maximum allowed; and n: the number of variables used.

There are limits to the permissible concentrations of some environmental indicators, as presented in Table (1).

Table 1. Permissible limits for some environmental factors locally and globally

Indicator	Permissible limit		Measuring unit
	Iraqi Standards and Metrology Organization (1967	**EPA (2001)**	
BOD_5	<5	-	$mg.l^{-1}$
NO_3	15	0.076	$mg.l^{-1}$
PO4	0.04	0.13	$mg.l^{-1}$

The current study used the standards contained in the System for Preserving Rivers from Pollution No. 25 of 1967 and the American standards of the Environmental Protection Agency **(EPA, 2001)**.

According to **Boluda *et al.* (2002)**, if the index value is more than one, this indicates the presence of organic pollution; if it is less than one, it means that this pollution does not exist.

RESULTS

Fig. (2) shows the water temperatures for the stations under study during the study period; the highest temperature value was 27.5°C for the third station during August, while the lowest value was 12.2°C in December, and the values for the remaining stations varied during the study period. The results of the statistical analysis showed that there were significant differences (*P*< 0.05) between the months of the study. The analysis results showed a significant difference between December, January, February, March, and the rest of the study months.

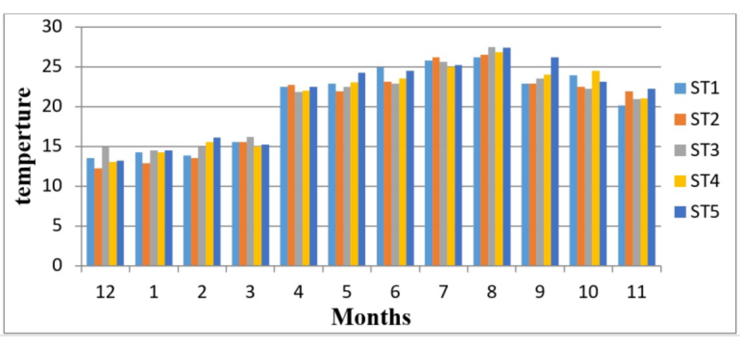

Fig. 2. Water temperatures at the stations during the study period

Fig. (3) shows the salinity values at the stations during the study period. The results showed differences in the salinity values between the months and between the stations studied, as the highest salinity values reached 6.79‰ during September at Hamadan station. The lowest value was recorded during December (0.7‰) at Al-Diyr station, while the values fluctuated in the rest of the stations during the months of the study. The statistical analysis results showed no significant differences ($P< 0.05$) between the months of the study and at the same level of probability, as the analysis results showed a significant difference between the Hamadan station and the first station. The monastery is on one side, and the rest of the stations are on the other side. The pH values fluctuated between the lowest and highest concentrations (6.5, 8.4) at Sindbad and Hamadan stations, respectively, during February and July throughout the study period, as they tended toward acidic at Sindbad station and toward essential at Hamadan station. The statistical analysis results showed significant differences ($P< 0.05$) between the months of the study and the presence of a significant difference at the same level of probability between the stations (Fig. 4).

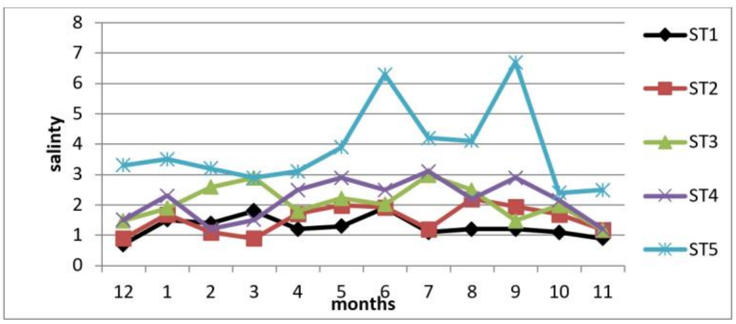

Fig. 3. Salinity values at the stations during the study period

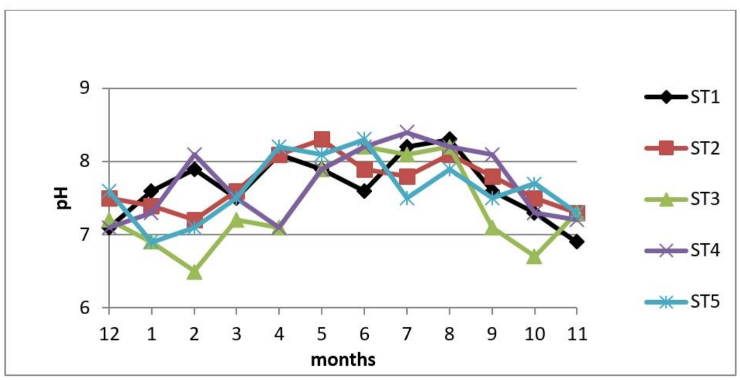

Fig. 4. pH values at the stations during the study period

The dissolved oxygen values at the stations during the study period are noted in Fig. (5). A significant fluctuation was detected between the stations depending on the months of the study, as the highest values recorded were 9.80, 9.44, 8.81, 8.40, 7.64mg.l^{-1}, respectively, in March at the stations 4, 1, 3, 2, 5, respectively, while the lowest values recorded were 6.24, 6.21, 6.12, 5.54, 5.50mg.l^{-1} in St 1, St 3, St 2, St 5, St 4, respectively, during June, and at St 1, St 3 and St 4 in July, as well as in St 1 and St 5 in August. The results of the statistical analysis showed that there were significant differences between the months. The study stations are at a probability level of $P> 0.05$. The values of biological oxygen demand (BOD^5) at the study stations during the sample collection period showed slight differences between the study stations, while they were clearer between the months, as the lowest values in most stations and most months reached $1mg.l^{-1}$, while the highest value was 6mg l^{-1} for the fourth station at Al-Salhiya. Moreover, the statistical analysis results showed no significant differences between the months and stations of the study at a probability level (P> 0.05) (Fig. 6).

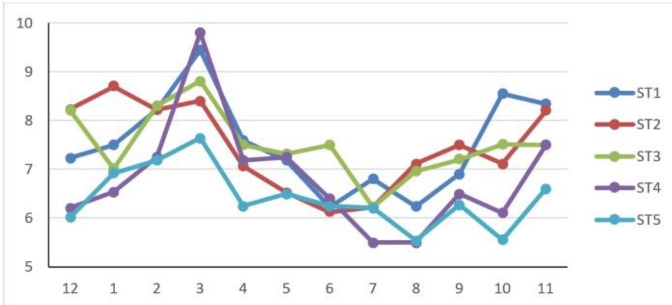

Fig. 5. Dissolved oxygen values at the 5 stations during the study period

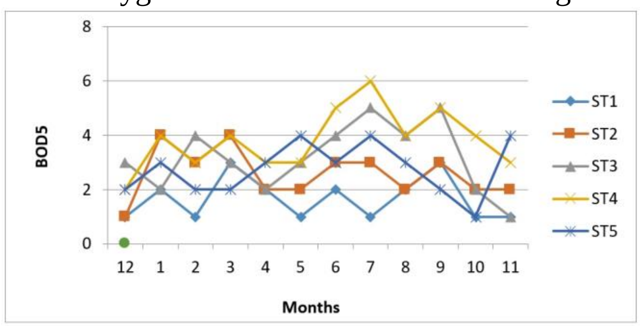

Fig. 6. Values of biological oxygen demand (BOD5) at the 5 stations during the study period

The highest nitrite values reached $4.95mg.l^{-1}$ in July at the fourth station, while the lowest concentration reached ($0.08mg.l^{-1}$) in August at the second station. The results of the statistical analysis showed that there were significant differences (P> 0.05) between the second station on one side and the rest of the stations on the other side and at the same level of probability between April and November on the one hand and the rest of the months on the other hand (Fig. 7). Fig. (8) shows the monthly changes in nitrate values, as the highest values were recorded in March and amounted to $7.22mg.l^{-1}$ for St 4 at Al-Salhiya station, while the lowest values were recorded in station 1 at Al-Diyr in July at $1.071mg.l^{-1}$. It was noted that there were significant differences between months and study stations (P< 0.05).

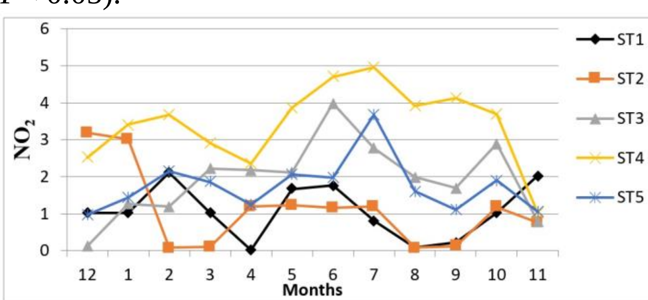

Fig. 7. Nitrite values at the stations during the study period

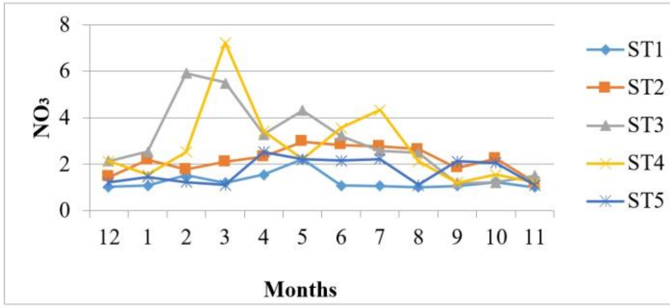

Fig. 8. Nitrate values at stations during the study period

Fig. (9) displays the monthly changes in phosphate values for the study stations. The lowest values were recorded in December and March for the second and first stations at 0.11mg/ l, and the highest values were during October and amounted to 0.589mg/ l for the fourth station. The results of the statistical analysis showed that there were differences (P< 0.05) between the first, second, and fifth stations on the one hand and the rest of the stations on the other hand, and at the same level of probability between September and October on the one hand and the rest of the months on the other hand.

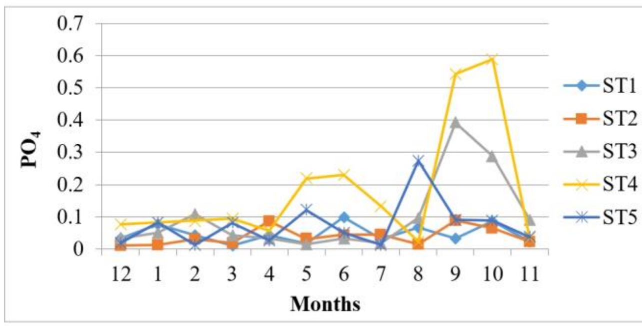

Fig. 9. Phosphate values at stations during the study period

1. Organic pollution index (OPI)

Fig. (10) exhibits the stations' monthly organic pollution index values; the highest value at the fourth station in November reached 7.49, while the lowest value at the first station in December reached 1.12. Fig. (11) reveals the average values of the overall index, as it reached the highest rate at the fourth station and the lowest rate at the first station (4.19, 1.65, respectively).

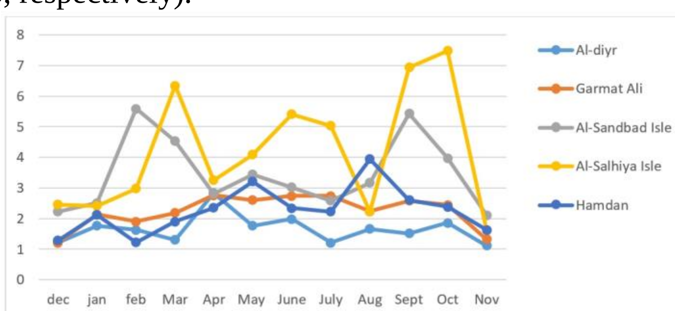

Fig. 10. Monthly organic pollution index values for stations

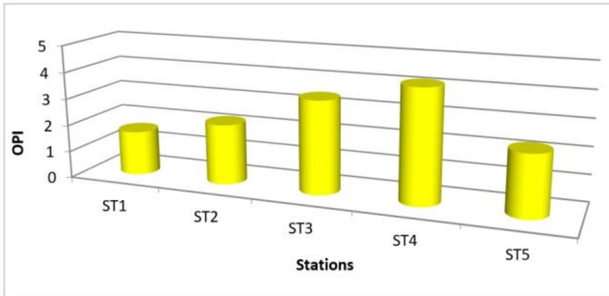

Fig. 11. Average annual organic pollution index values

2. *Melanoides tuberculata*

Taxonomy:

Kingdom: Animalia/
Phylum: Mollusca /
Class: Gastropoda
Family: Thiaridae/
Genus: *Melanoides* Olivier, 1804/
Species: *M. tuberculata* (O.F.Müller, 1774).

Plate 1. Image for *Melanoides tuberculata*

The shell length was more than twice the width. The number of shell whorl about 8- 11, featured by axial lines of rust- coloring patches. The aperture was oval shaped and approximately 1/3 the length of the shell. The inner lip was slightly thickened and the outer one was thin **(Silva *et al*., 2019)**. Because of the base color of the shell, this species is commonly known as the "red rimmed melania" **(Duggan, 2002)** (Plate 1). Fig. (12) shows the monthly values of the density of the species *M. tuberculata* per square meter. The highest values were recorded in the first station (Al-Diyr) at 192 individuals/ m^2 during the May and October months, while the lowest values were recorded at the third and fourth stations (Al-Sandbad and Al-Salhiya). It reached 16 individuals/ m^2 during the winter and summer months. The results of the statistical analysis showed that there was a significant difference between the stations at the level of probability ($P< 0.05$) between the first station and the rest of the stations and at the same level of probability between December, April, June, November and the rest of the months. Fig. (13) shows the annual average density of *M. tuberculata* per one square meter (individuals /m^2). The highest density was at Al-Diyr station, with 120 individuals/ m^2, and the lowest was at Sindbad station, with 36 individuals/ m^2.

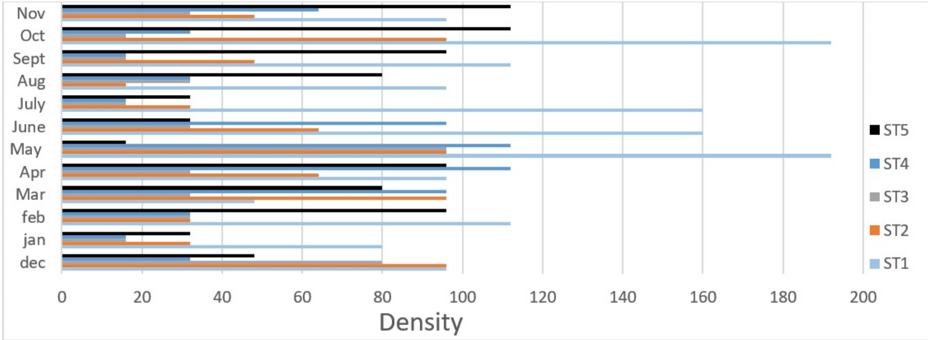

Fig. 12. Monthly values of the *Melanoides tuberculata* species density per square meter

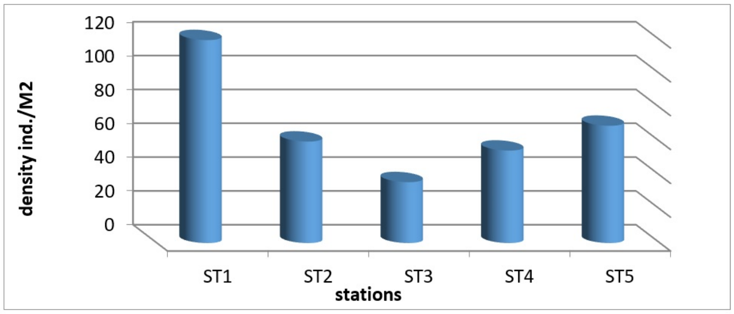

Fig. 13. Values of the annual average density of *Melanoides tuberculata* per square meter

3. *Neritina violacea*

Family: Neritidae/ Species: *Neritina Violacea* (Gmelin, 1791)
common Name: *Violet Nerite/* Habitat: near Mangrove
Origin: Malaysia

About 2 cm. The shell is thick, heavy, and oval with a sunken spire. When alive, the shell is covered with a 'skin' (periostracum) and usually covered with silt and algae. The shell pattern is actually pale with fine purplish bands and 'tent' markings. The flat underside may range from whitish with an orange tinge to bright brick red, often with a narrow dark rim. The straight edge at the shell opening may have no 'teeth' or some tiny ones in the central part. The operculum is thick, smooth, and similar in color to the underside with dark patches and blotches. The body is said to be orange with black patches, but those seen were pale with dark spots and a black foot (Plate 2).

Plate 2. Image for *Neritina violacea*

The highest values for the density of this species were 96, 120, 96, 50, 48 individuals/ m^2 in the five stations, respectively, during November, while the values fluctuated in the rest of the months, and no individuals were recorded during July in all stations. The results showed a significant difference between the stations at the level of probability ($P< 0.05$) between the second station and the first and third stations on the one hand and between the fourth and fifth stations on the other hand. Additionally, significant differences were observed between November and July, and at the same probability level between the rest of the months (Fig. 14). Fig. (15) shows the values of the annual average density of the species *N. violacea* per square meter. The highest number of individuals was at Garmat Ali, with 47.33 individuals /m^2, and the lowest value was at Hamadan station, with 13 individuals/ m^2. The results of the statistical analysis showed a significant difference between the stations, at a probability level of $P< 0.05$ between the first and third stations on the one hand and between the fourth and fifth stations on the other hand, and at the same level of probability between the stations and the second station on the other hand.

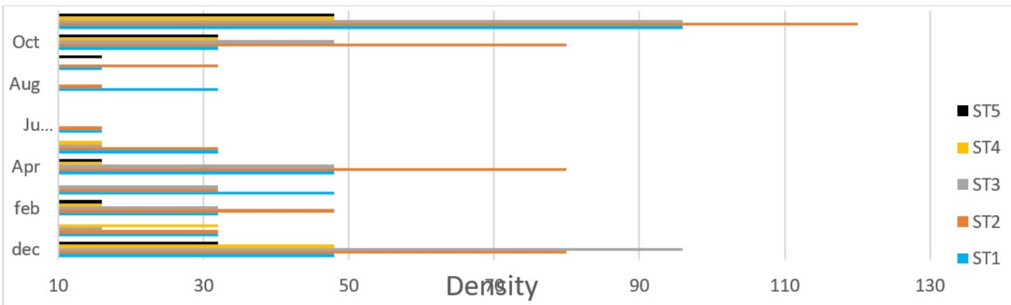

Fig. 14. Monthly values of the *Neritina violacea* species density per square meter

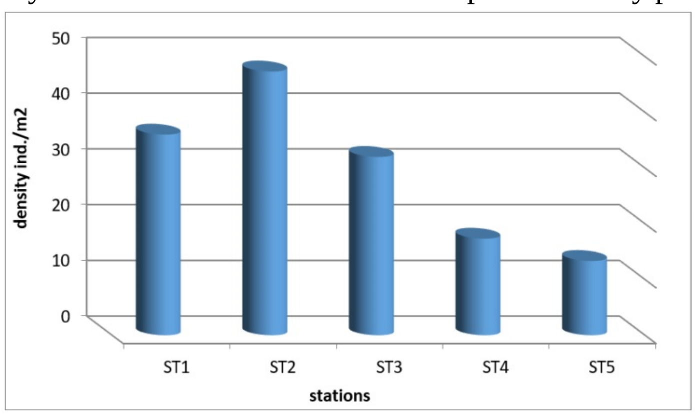

Fig. 15. Values of the annual average density of *Neritina violacea* per square meter

4. Multivariate Canonical analysis

Fig. (16) shows the relationship between environmental factors, the organic pollution index (OPI), and the density of the two species *M. tuberculata* (sp.1) and *N. violacea* (sp.2) for the first station using multivariate analysis (PCA). The organic pollution index (OPI) positively correlates with water temperature, salinity, and dissolved oxygen and is inversely correlated with the nitrate group and BOD_5. The results show that water temperature, pH, salinity, and the index affected the distribution and density of the second species inversely and directly on the nitrate group and BOD_5. In the second station, all environmental factorswere directly correlated with the value of the organic pollution index. In contrast, the index's value was inversely correlated with the values of DO, NO_2, and the density of the first and second species (Fig. 17).

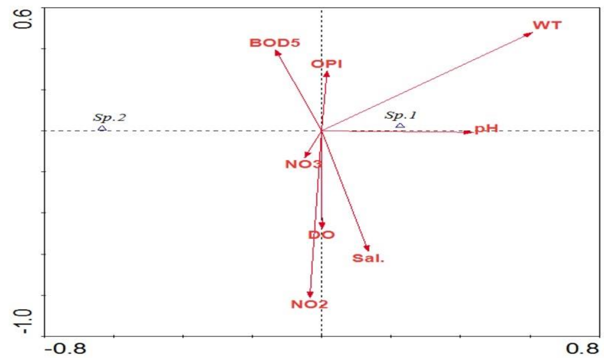

Fig. 16. Multivariate PCA analysis of environmental factors for the first station

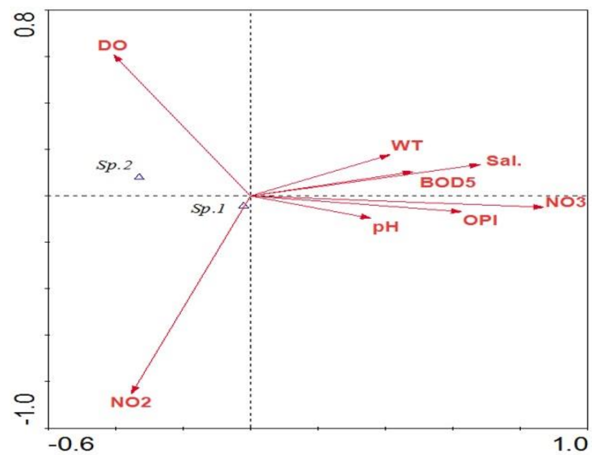

Fig. 17. Multivariate PCA analysis of environmental factors for the second station

Fig. (18) shows that the values of the environmental factors and the index at station three were directly correlated with the densities and distribution of the first species, except for dissolved oxygen; in contrast, the same environmental factors and OPI were inversely correlated with the densities and distribution of the second species and directly correlated with dissolved oxygen in station four (Fig. 19). The influence of the factors was stronger on the first species than on the second species. While the index values were inversely related to dissolved oxygen, NO_3, and pH, and directly related to the rest of the factors.

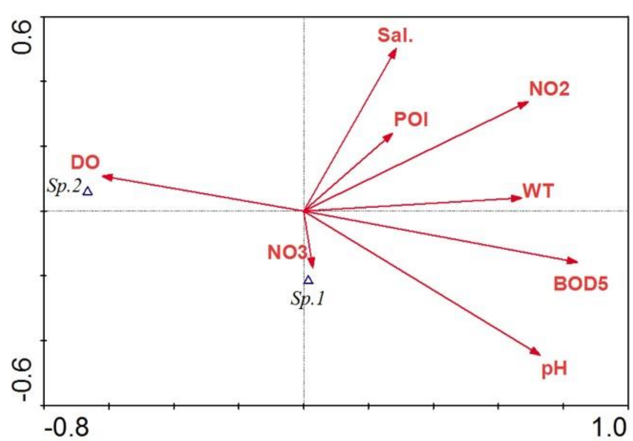

Fig.18. Multivariate PCA analysis of environmental factors for the third station

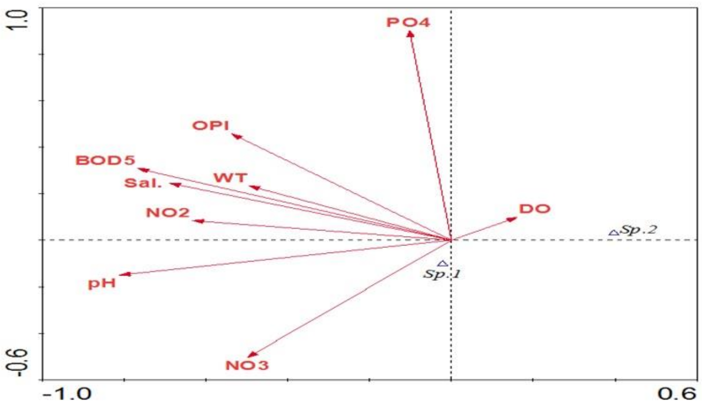

Fig. 19. Multivariate PCA analysis of environmental factors for the fourth station

Fig. (20) shows that the environmental factors and index values at the fifth station were inversely related to the densities and distribution of the first and second species and that the strength of the factor had the highest influence on the distribution and density of the first species. The index values were directly correlated with all environmental factors. Additionally, No_2, PH, and water temperature values had the most influence on the index.

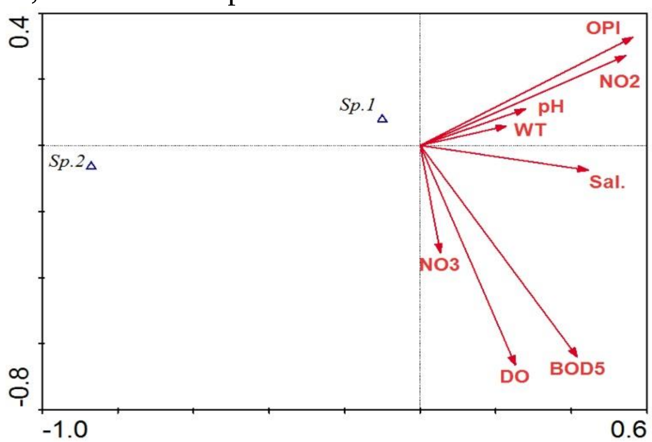

Fig. 20. Multivariate PCA analysis of environmental factors for the fifth station

DISCUSSION

Climate change plays an essential role in the variation of environmental factors, which include drought and their constant change, either in a positive or negative direction **(Al-Najare, 2020)**. Since the qualities of water in different bodies of water are affected by many environmental factors that may be physical or chemical, in addition to the vegetation present in the water body **(Wetzel, 2001)**. Temperature and salinity are among the influencing physical factors, and the chemical factors consist of pH, dissolved oxygen, biological requirement, nitrate and nitrite, and phosphate, which depend on seasonal and locational changes. Water temperature is one of the most critical environmental factors in the density and distribution of aquatic organisms **(Power, *et al.*, 2000)**. Temperatures show a direct and indirect relationship in changing water's physical and chemical properties. Therefore, they can be considered when determining metabolic rates, toxicity of compounds, dissolved oxygen and other dissolved gases, and water density **(Fondriest, 2015)**. The results of the current study showed that water temperature has monthly variations. The reason for this is the change in the region's climate, the difference in the length of the day and the dates for collecting samples, and the water movement during the tides. The highest values were recorded during summer, especially in July and August, while the lowest in winter. This may be due to the nature of Iraq's climate in general. It was observed that there are significant differences between stations; locational differences in water temperature may be due to differences in the sampling time, and this is consistent with studies that dealt with the environmental characteristics of the waters of southern Iraq **(Radi, 2014, Ahmed, 2017, Yaseen *et al,* 2017, Al-Najare 2020, Al-Najare, 2023)**. Salinity values in the current study of the stations showed differences. Furthermore, there were changes within each station over different periods and between stations. The salinity values for the stations were similar from the beginning of the study in December to November and began to gradually increase, reaching their peak in September due to rising temperatures during the summer and the gradual advance of seawater to the fifth station. The tidal phenomenon that characterizes the Shatt al-Arab River has an important role in the environmental changes of the river at present, as salts move through it into the water body due to the weak discharge capacity of fresh water in the opposite direction and are concentrated in the last station. **Al-Taei *et al*. (2014)** stated that this disturbance in the ecosystem of this surface is unstable in a certain direction. The lower the discharges and levels of the waters of the Shatt al-Arab, the worse the situation becomes, and this is what the study of **AI-Tememi *et al*. (2015)** suggested, and its connection to the significant increase in salinity, thereby affecting the ecosystems of the Shatt al-Arab and its biodiversity, as well as the lack of benefit from its waters. This finding is not consistent with the results of the current study. The reason may be due to the time of collection of the samples, which was during the low tide period, or to the increase in the amounts of water discharge, while the results showed similar salinity values at all stations during the period. This study is consistent with most regional studies (Table 2). Most aquatic species have adapted to specific salinity levels; any concentration of salinity outside the tolerance range of these organisms, including invertebrates, can lead to their death due to the change in the osmotic regulation resulting from the increase or decrease of ions present in the water. This fundamentally and negatively affects the metabolic capabilities of living organisms. In particular, the ratio of potassium ions to sodium and oxygen solubility in salt water is 21‰ less than in fresh water at the same temperature **(Al-Najare, 2020)**.

Iraqi waters are characterized by their alkalinity throughout the year and the entry of large quantities of seawater, which are often alkaline, contributes to this characteristic **(Al-Baghdadi *et al.,* 2019)**. The results of the current study showed that the acid indicator values were within the normal range and in the alkaline direction, which is consistent with many studies that dealt with pH values in the region **(Al-Hejuje, 2014; Al-Saad *et al*. 2015; Mohamed *et al*., 2015; Al-Dubakel, 2016; Abood, 2018; Baghdadi *et al*., 2023)**. The decrease in the pH values also results from pollution or the decomposition of aquatic organisms, which contributes to the release of carbon dioxide and the consumption of dissolved oxygen, which are typical characteristics of pollution of water bodies **(Jia *et al*., 2022)**.

Table 2. Salinity concentrations of Shatt al-Arab River during different periods

Reference	Region	Period	Salinity ‰
Yaseen (2018)	Abu Al-Khaseeb	2014- 2015	1.8– 12.5
Abood (2018)	Abu Al-Khaseeb	2015- 2016	1.6– 4.6
Younis *et al.* (2010)	Garmat Ali River	2003- 2004	1.54- 2.35
Lazem (2009)	Garmat Ali River	2007- 2008	1.2- 3.3
Yaseen *et al.* (2016)	Garmat Ali River	2014- 2015	1.8- 9.2
Hameed (2017)	Garmat Ali River	2015- 2016	1.5- 6.0
Present study	Shatt Al-Arab River	2022- 2023	6.7- 0.7

Dissolved oxygen values varied between high and low during the study months; high dissolved oxygen values were recorded during the winter and spring at the study stations. The reason may be attributed to the low temperatures during these cold months and the activity of phytoplankton and aquatic plants during the spring, which led to its increase while it was recorded. The lowest values are during August and September. The reason is due to the high temperatures with the decrease in the dissolution of gases, as well as the high rates of decomposition of dead aquatic organisms due to bacterial activity and the continuous mixing processes of the bottom due to the tides, which leads to the consumption of dissolved oxygen by these organisms and thus an increase in the value of the biological oxygen demand **(UNEP, 2008; Sari *et al*., 2020)**, the greater a load of organic matter present in the water, the more oxygen is required, as the aquatic system that is indicated by a high value of the biological requirement tends to have a lower concentration of dissolved oxygen, as well as a pattern of a positive relationship between salinity and the biological requirement. Oxygen results from the physiological effort exerted in respiration and the osmotic regulation of the existing aquatic organisms. The greater the load of organic materials in the water, the more oxygen is required **(Hussein, 2014)**. BOD_5 values increase, especially in the summer, when temperatures rise, evaporation processes increase and water levels entering the Shatt al-Arab from the north and south decrease, while lower values are recorded during the cold months. A correspondence between BOD_5 values with effective nitrates and phosphates coincides with the observations of **Makki *et al*. (2023)** on some marshes north of Basrah. The highest concentrations of these factors were recorded at Al-Salhiya station, followed by Sinbad station. In contrast, the lowest concentrations of the previously mentioned factors were recorded at Al-Salhiya station Al-Diyr, and this result is identical to the monthly organic pollution index values, which reflect the factors that most influence the organic pollution index. The BOD_5 values reflect the organic pollution values. The more organic materials in the water, the more oxygen is required, hence the BOD_5 levels increase **(Sari *et al*., 2020)**. This result shows the effect of the index values on vegetation cover, and the influential nitrite factor had the same role on organic pollution despite not being included in the pollution index calculation. In general, the pollution index values at stations characterized by the presence of submerged plants were lower than those in which they were not present due to the role of plants in absorbing nutrients, nitrates, phosphates, and other elements during their growth process, thus removing nutrients from the water, and this ability increases the microbial activity to reproduce microorganisms on the plant **(Xun, 2020; Rengi *et al*., 2021)**. The character of the vegetation cover of the intertidal area and fluctuations in the environmental conditions of these stations played an essential role in evaluating the aquatic environment's water quality, and the pollution levels are determined based on the OPI index during the study period at all stations. Recording high values of BOD_5 with active nitrates and phosphates at the Salhiya and Sindbad stations is linked to the self-purification of water and the transfer of pollutants. The rivers that pass through densely populated residential areas are exposed to pollution with waste and sewage. The results of the current study showed that the highest annual rate of organic pollution index occurred during the summer and autumn months at the Salhiya station. This concurs with what **Al-Baghdadi *et al.* (2019)** found in their study, and they also recorded the highest values at the Salihiya station. The importance of *M. tuberculata* is highlighted. It is considered a link between the aquatic and land environments and reflects the intertidal zone's environment. The highest density of this species coincided with the lowest value of the organic pollution index, which reflects an inverse relationship between them. This can be considered an indicator of low-pollution environments. The low salinity values at the Al-Diyr station, as well as the presence of aquatic plants that cover most of the tidal areas in the spring and autumn seasons, provided a suitable environment for the above species to live. This finding agrees with that of **Al-Baghdadi *et al*. (2023)** who obsereved that there is an inverse relationship between species density and salinity and a direct relationship with dissolved oxygen. The highest density of the species, as mentioned above, is during the spring and autumn months. The lowest values of species density were recorded for all stations with low temperatures since this factor has a vital role in the distribution and behavior of the existing aquatic organisms and is not rivaled by any other factor **(Al-Baghdadi *et al.*, 2020)**. Freshwater snails can be used as a bio-monitor of environmental pollution for freshwater ecosystems because of this strong positive association between the intertidal zone organic pollution and the snail species. However, human activities may play a significant role in the snail diversity and increased pollutant concentrations in sediments **Dutta *et al.* (2018)**. The species above recorded a higher density than the second species, *N. violacea*, since the first species is tolerant and widespread in most environments of the intertidal zone of the Shatt al-Arab, and this result agrees with previous studies on the Shatt al-Arab River **(Khalaf, 2011; Al-Baghdadi *et al.*, 2023)**. For the second species, *N. violacea*, the highest monthly values of species density coincided with the lowest values of the OPI index, especially in November, the diversity of macroinvertebrates and their differences in their degree of tolerance to pollution and environmental disturbance of all kinds make them a good indicator of pollution **(Tachet *et al.*, 2010)**, hence this species has been used in biological assessment programs in all ecosystems, especially in assessing water quality **(Mamert *et al.*, 2016)**. The absence of species during the hot months in this study shows the inverse correlation between these species and temperature, and these results match those of **Al-Baghdadi *et al.* (2021)**, who studied one of the species of polychaete worms in the Shatt al-Arab River, where its presence was not recorded in the hot months at the Duwaib and Sharsh stations. The absence of these species, in conjunction with high temperatures and low oxygen, indicates that these snails are considered a vital evidence of organic pollution. It has been confirmed that large invertebrates can be used in environmental monitoring because of their strong response to all types of pollution **(Kazanci & Dugal, 2000; Sharma & Rawat, 2009))**.

CONCLUSION

1-The organic pollution index (OPI) values were higher, indicating the presence of organic pollution at all the selected stations of the Shatt al-Arab River. The highest values were observed at the fourth station in November, while the lowest values were at the first station in December.
2- The *M. tuberculata* individuals were denser than *N. violacea* at all stations, and the presence of the first species was affected by temperatures more than the second species.
3- It was found that the density of the *M. tuberculata* species has an inverse relationship with the annual average water of the organic pollution index (OPI) to a greater extent than the second species for all stations.
We recommend using this study as an indicator to identify organic pollution in the Shatt al-Arab River. The availability of suitable environments, characterized by low pollution, water salinity, abundance of food, and other environmental factors, contributes to creat an environment suitable for the survival and abundance of these two species of snails.

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