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The Ecology of Two Aquatic Isopods *Annina mesopotamica* (Ahmed, 1971) and *Sphaeroma annandale annandale* (Stebbing, 1911) in the Intertidal Zone of the Garmat Ali River, Basrah, Iraq

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ABSTRACT
During the period from January to December 2022, two species of Isopods *Annina mesopotamica* (Ahmed, 1971) and *Sphaeroma annandalei annandalei* (Stebbing, 1911) were studied in the intertidal zone of the Garmat Ali River. The current study aimed to assess the density, occurrence and distribution of the two species and their relationship to the surrounding environmental factors. Monthly samples from three fixed stations were collected, using a quadrate with an area of $0.0625m^2$ at each station. The monthly rates of various environmental factors, including temperature, pH, salinity, current speed, light transmittance and DO, as well as the presence of these two species, were evaluated. The population density of *S. annandalei* reached 192 individuals/m^2 during May at station 3. The lowest value was 16 individuals/m^2 recorded during June and October at first two stations and in July at the third station. On the other hand, the highest values for *A. mesopotamica* reached 144 individuals/m^2 during May at station 3, no individuals were recorded during Sept. at station 2 and in Aug. and Sept. at station 3. The findings revealed no notable distinction between the linear regression equations for male and female animals, which allowed for their consolidation into a single linear equation for each species. At the three stations an inverse significant correlation was found between salinity, temperature and light transmittance with the numerical density of the two species. Additionally, the pH, DO and current speed had a significant positive correlation with the numerical density.

INTRODUCTION

The intertidal zone is a harsh environment and only a very few species can survive these extreme conditions. In this zone, species of terrestrial origin may be found near the high tide mark together with aquatic species. The sphaeromatid isopod, *Sphaeroma annandalei* is one of few aquatic species which adapted to cope with this habitat. It lives in burrows made by the isopod on the river banks and sometimes it burrows into wood. It is found in the marshes and further down in Shatt Al-Arab river where salinity increases considerably. The water where the sampling was done is an Oligohaline brackish water with a salinity of 1.3-2.7ppt **(Abdul-Latif, 2020; Al-Baghdadi *et al.*, 2020)**.

The isopod *S. annanalei* belongs to the family Sphaeromatidae. The sopods are an essential component of the invertebrate fauna that live associated with species of attached organisms (such as algae, sponges, mussels, oysters, and barnacles). They also attach to the roots supporting reeds and other plants **(Saoud, 1997; Al-Baghdadi *et al*., 2020)**. As in other habitats, the isopods play an essential role in this ecosystem. They are known to feed on detritus and leftover organic matter and are prey for many species of invertebrates and fish. **Ahmed (1971)** classified the species belonging to the genus *Sphaeroma,* considered it as a new species, and called it *Sphaeroma irakiensis*. **Harrison and Holdich (1984)** indicated that this name is synonymous with the species *S. annandale* **(Stebbing, 1911)**.

However, **Ahmed (1971)** identified *Annina meopotamica* as *Excirolkana mesopotamica* and **Bruce (1986)** included it under the genus *Annina*.

Species belonging to the isopod group are widely used in environmental measurement and monitoring programs for coastal areas worldwide. The diversity at large invertebrates and the ability of species to withstand pollution and environmental risks make them vital environmental indicators for monitoring the aquatic environment. Abiotic factors have a crucial role in structuring aquatic ecosystems and significantly impact the functioning of soil organisms **(Sfenthourakis & Hornung, 2018)**.

The study aimed to find the relationship between some environmental factors with the numerical abundance of the two species, *A. mesopotamica* and *S. aannandalei*, during the months of the study, and to study the growth through the relationship between length and weight.

MATERIALS AND METHODS

Three locations were chosen within Garmat Ali River, which are about 5-7km north the city center of Basrah **(Al-Assadi *et al.*, 2015)**, and a distance between the sites is close and approximately equal (Plate No. 1). The Garmat Ali River branches off into some side branches, the most important of which are the Khartrad and Al-Asafiya canals. These canals are used to water the orchards spread on both sides of the river. Aquatic plants grew on both sides of the river, and their species vary from place to place. The density of their populations varies according to the season during the year, and the distribution of their species depend on the level and depth of the river like *Typha domingensis, Phragmites australis, Vallisneria spiralis,* and *Ceratophylum demersum.* The area is a home to many waterbirds, especially seasonally migratory ones. Due to large floods witnessed in Iranian and Iraqi territories, the Shatt al-Arab River was recharged 6.7 to 12.1 km3/year **(Ministry of Water Resources, 2022)**. Three selected locations were chosen on the Garmat Ali River, and the distances between the sites are close and approximately one kilometer; the first station (30˚34ˈ24.70" N, 47˚44ˈ44.65" E), the second (30˚34ˈ10.83" N, 47˚45ˈ18.63" E) and the third (30˚34ˈ29.26" N, 47˚45ˈ49.59" E).

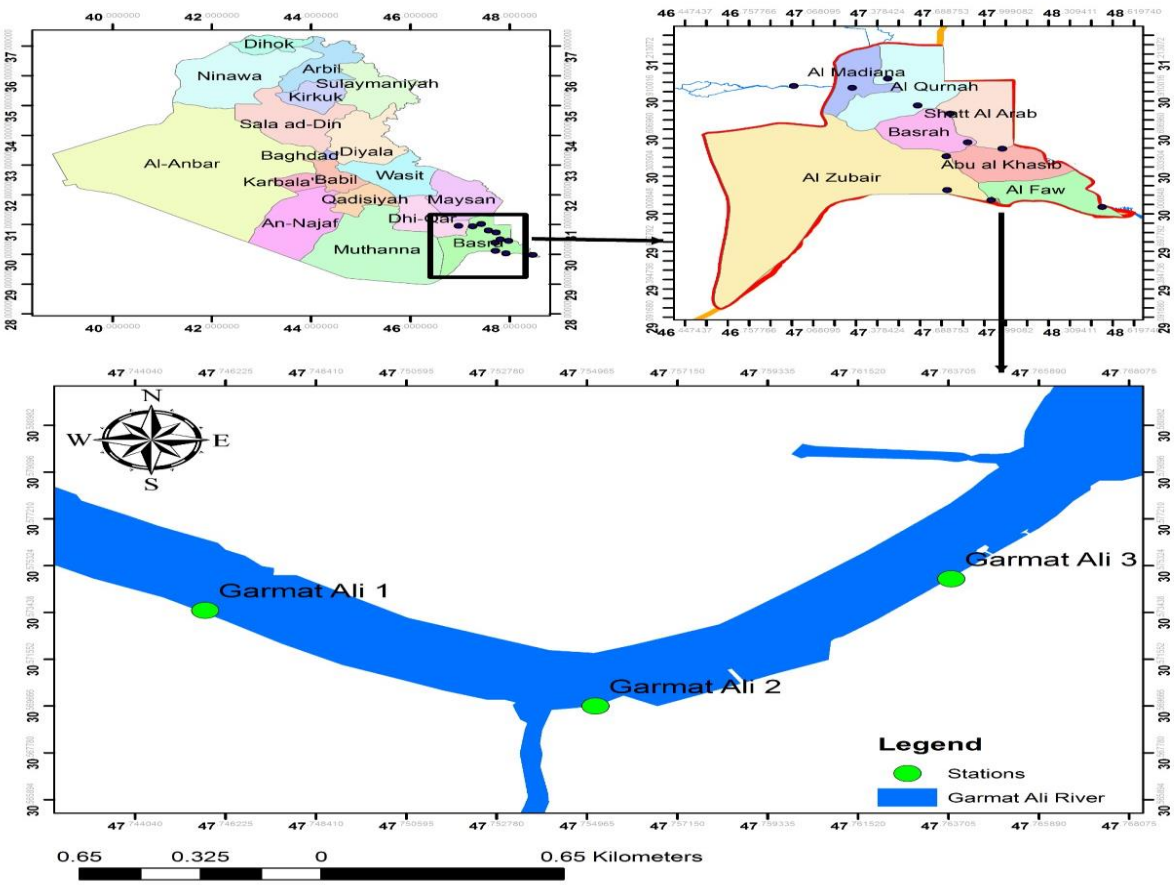


Plate 1. Map of the study area

Environmental factors were measured at the selected study stations at monthly intervals using a 665MPS - YSI - Model 57, manufactured by Kalbuneh Company, USA, and the salinity was expressed in ppt. This is done by placing the electrode of the device below the water surface level for 4-5 minutes and recording the readings from the device. A SMART SENSOR DO Meter AR8210 was used directly at the study stations by placing it as an electrode in the water for two minutes to measure DO. The current speed of the stream was measured using a Current Meter Model (CM2) and was measured in m/s **(APHA, 2005)**. Moreover, light trancparency was measured using secchi disc. Light transmittance was calculated using the following equation: light transparency = (first depth + second depth) / 2.

The organisms were collected from the intertidal zone, and fifteen replicates were taken to cover the upper and lower intertidal zone, transversely, and for each station, which represents the population density of each of the three studied stations. Samples were taken using a wooden quadrate with a side length of 25cm. This area is taken from the clay to a depth of 10cm until the holes in which the fauna are located disappeared. Samples of *S. annandalei* and *A. mesopotamica* were placed in plastic containers containing 70-80% ethyl alcohol for preservation. The abundance per square meter was measured, and the length for each animals was measured by taking the distance from the middle of the front edge of the head to the end of the back edge of the tail using a vernier caliper. After being dried at 60°C for 24 hours, the samples were weighed with a sensitive balance. The same samples were taken to the incinerator to burn at a temperature of 450-600°C and for four hours after that, the weight of the ash was recorded. Another group of samples of the same two species were isolated during the study period at all stations and preserved by freezing without adding any preservative to measure the weights and lengths to the animals. The linear regression equation was used to calculate the average weight as a function of the dry weight in the presence of the average length for the species studied, as follows:

$(Y = a + b\,x)$

Where, Y = wet weight, X = animal length.

RESULTS

1- Temperature

The temperatures varied at the three stations. The highest temperature was recorded (36.5°C) during August at station 2 and the lowest temperature was recorded (8.1°C) during January at station 3. In the current study significant differences were recorded at the level $P < 0.05$ between months of the study at the period from April to September on the one hand, and the winter months on the other hand. At the same probability level, the stations did not show any significant differences between them (Fig. 1).

2-Hydrogen Ion concentration (pH)

The acid function values for all stations were in the basic direction during the study period, as the highest value reached 7.9 during November at the first station and June and December at the second station. As for the lowest value (6.4), it was recorded during February at the first station. Moreover, significant differences were recorded at the level $P < 0.05$ between months of the current study, however there were no significant differences between the three stations (Fig. 2).

3-Salinity

The highest salinity value was 2.5‰ during September in the first and third stations, 2.3‰ during the same month in the second station, and the lowest was 0.98‰ during January in the first station. Significances differences were recorded between January and the rest of the study months at the level $P < 0.05$. At the same probability level, the stations had no significant differences between them (Fig. 3).

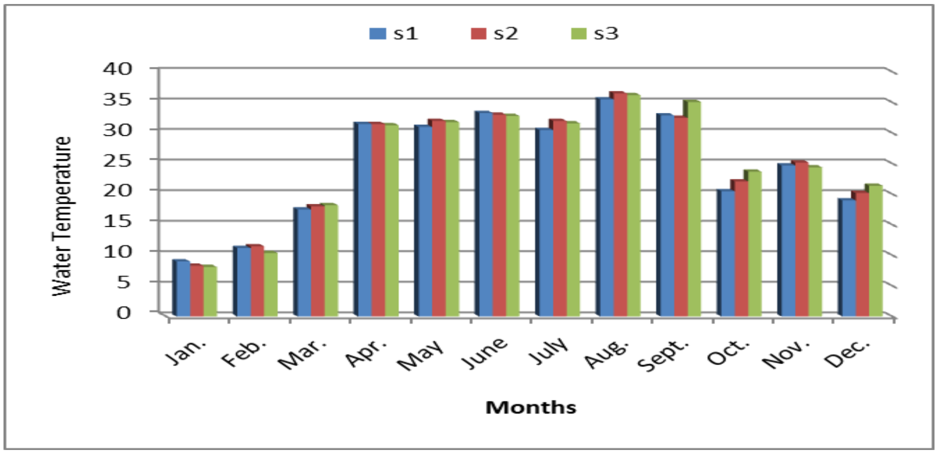


Fig. 1. Temperatures at the three stations in Garmat Ali River during the study months

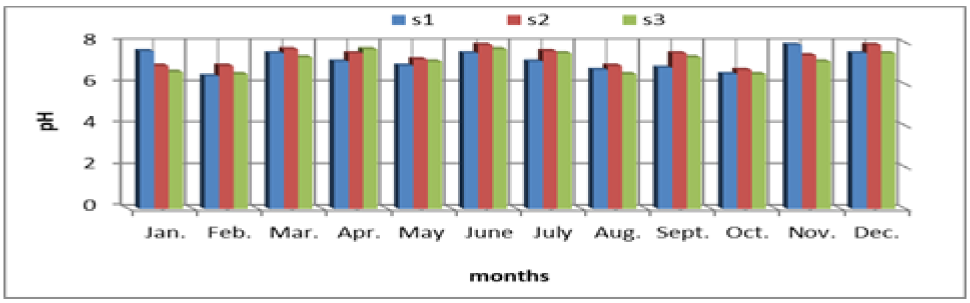


Fig. 2. The pH changes at the three stations in Garmat Ali River during the study months

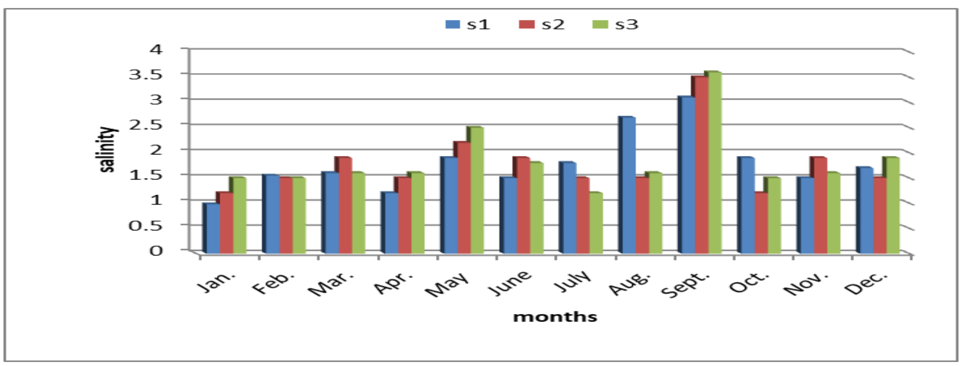


Fig. 3. Salinity changes at the three stations in Garmat Ali River during the study months

4- Current Speed

The water current speed values varied between 0.18 and 99.0m/ s, with the lowest values (0.18 and 0.19m/ s) recorded during August at station 2 and station 1, respectively, and 0.19m/ s during September at station 3, but the highest values (0.99 and 0.87 and 0.91m/ s) were recorded during January at three stations, respectively. Positive differences were recorded between the study months at the level of $P<0.05$ (Fig. 4).

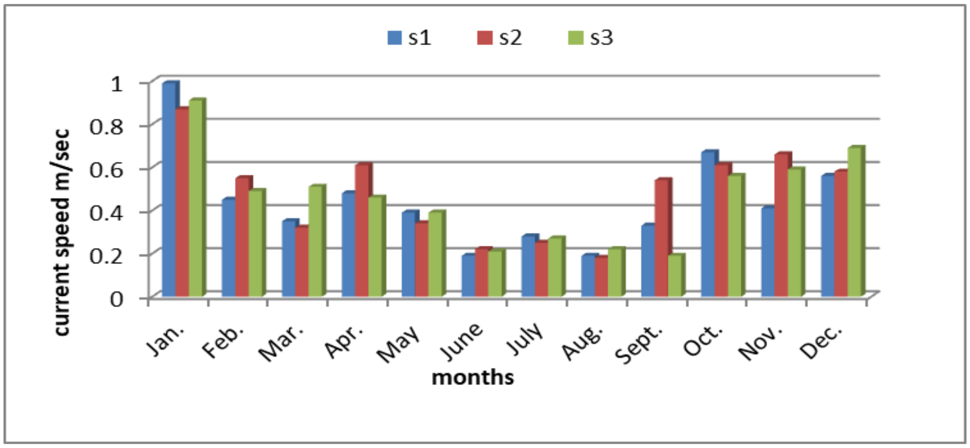


Fig. 4. Changes the current velocity values change (m/s) at the three stations in Garmat Ali River during the study months

5 - Light transmittance

It was observed that there were monthly changes in the measurements of light transmittance in the water column at the three study stations, as the ranges were between 45-69, 41-65 and 44-69cm at station 1, 2 and 3, respectively. The highest value was 69cm recorded during December and January for the stations 1, 2 and 3, respectively, and the lowest measurement was 41cm during September at station 2. Positive differences were recorded between the study months at the level of $P<0.05$ at the three stations (Fig. 5).

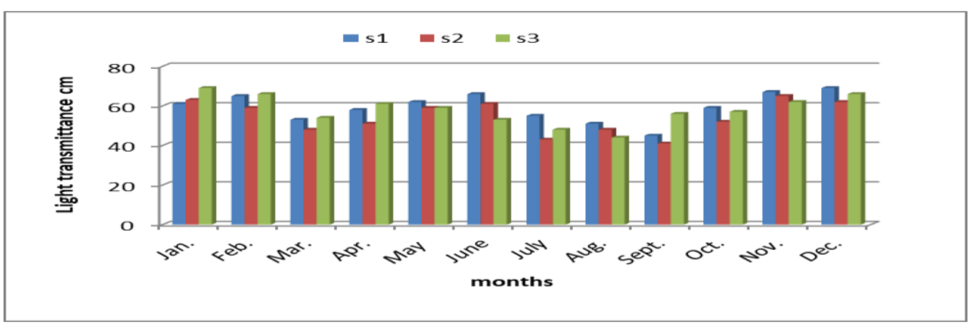


Fig. 5. Monthly changes in water light transmittance values (cm) at the three stations in Garmat Ali River during the study months

6. Dissolved oxygen (DO)

The highest DO values of 10.2 and 9.1mg/ L were observed during December at stations 1 and 3, respectively, and 9.2mg/ L during January at station 2. The lowest values of 6.5, 6.8 and 6.5mg/ L were observed during August at stations 1, 2 and 3, respectively. Positive differences were recorded during the study months at three stations, between August and the rest of the months of the year. At the same probability level, the stations had no significant differences (Fig. 6).

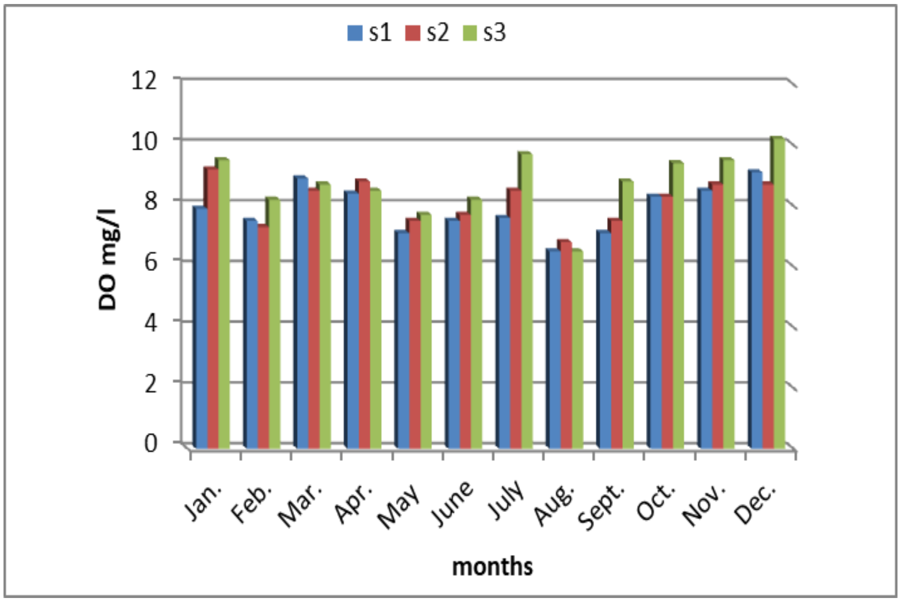


Fig. 6. Monthly changes in DO values (mg/l) at the three stations in Garmat Ali River during the study months

Population density

S. annandalei

According to Fig. (7), there were site differences in the population density of *S. annandalei* at station 1, 2 and 3, with the highest values (192 individuals/m^2) recorded during May at station 3, while the lowest values (16 individuals/m^2) were recored during June and October at station 1 and July at station 3. The highest total number of individuals of this species during the year was recorded at the first station (672 individuals/m^2), while the total number of individuals for the station 1 and 3 reached (944 individuals/m^2). The results of the statistical analysis showed significance differences at the level $P<0.05$ between November and the rest of the year and between May, July, September, October and the rest the year, and between May, August, September, November and the rest of the year. At the same probability level, positive differences were found between station 1 and the rest of the stations.

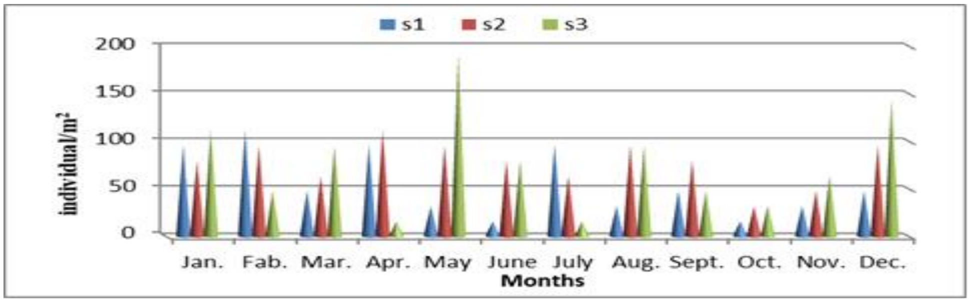


Fig. 7. Density of *S. annandalei* at the three stations in Garmat Ali River during the study months

A. mesopotamica

The highest values (144 individuals/m^2) of *A. mesopotamica* was during May at station 3, no presence of this species was recorded during September at station 2 and August and September at station 3. The results also showed that this species' lowest total number of individuals was recorded at station 2 (416 individuals/m^2). In comparison, the highest total number (1226 individuals/m^2) was recorded at station 3. The results showed that there were positive differences at the level $P < 0.05$ between August and September and the rest of the year, and between February, May, July, and November and the rest of the year, and between December, January, March, April, June, and November and between remaining months of the year. At the same probability level, significant differences were found between station 2 and the rest of the stations (Fig. 8).

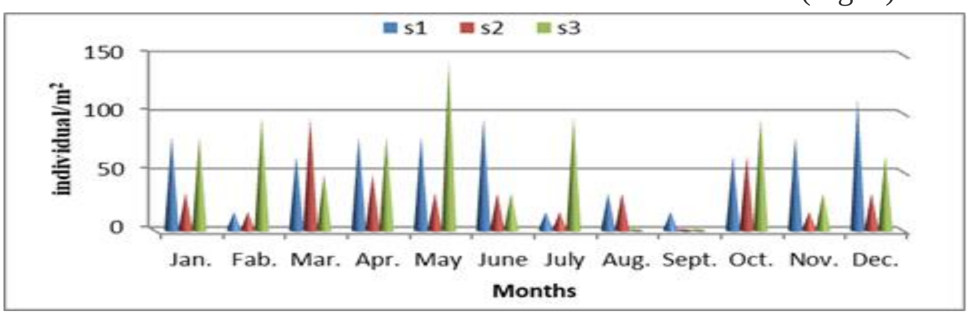
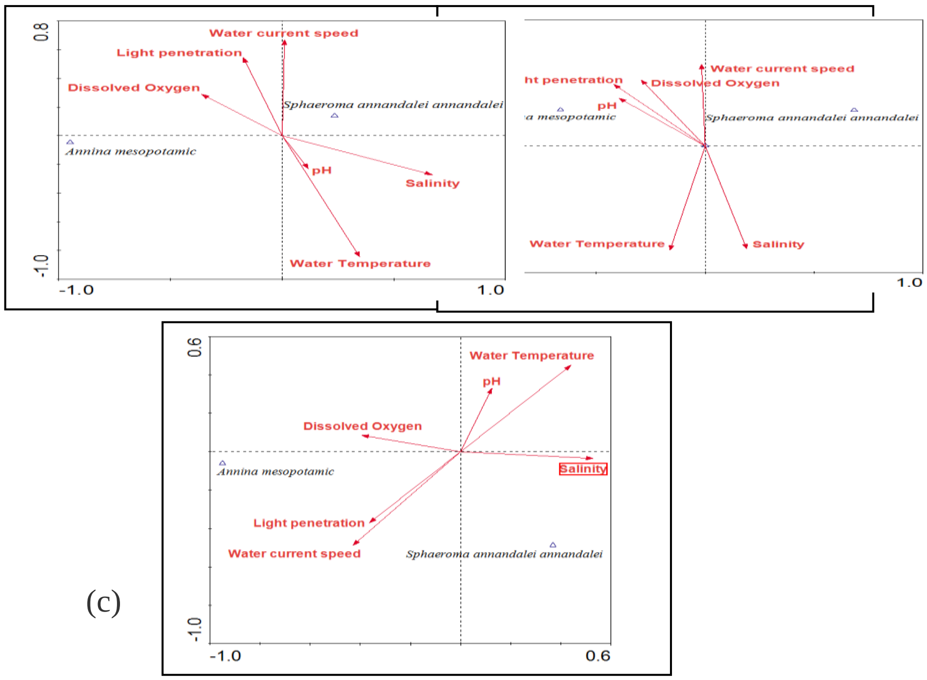


Fig. 8. Density of *S. mesopotamica* at three stations in Garmat Ali River during the study months

Multiple statistical analysis of the two species with environmental factors

S. annandalei had an inverse significant correlation with temperature. The highest density of the species in the first site coincided with the lowest value of the acid function, and the lowest values of the density of the first species coincided with the high values of the acid function in the second site. A direct relationship appeared between the density of the first species and salinity in the first site. There was also a direct relationship between the density of the first species with the speed of the current, and a direct relationship with the dissolved oxygen. As for *A. mesopotamica,* the lowest densities of it were associated with higher temperatures at all sites. The lowest densities also coincided with the lowest values of acidity function of the first site. An inverse relationship was found between the density of the second species with salinity at all sites. A positive relationship was found for the second species with light transmittance, and it was clearer in the first site than in the rest of the sites. The decrease in current speed also coincided with the absence of individuals of the second species, especially in the third site, and with the least presence of the second species in the first site (Figs. 9, 10, 11)

(a) (b)



(c)

Fig. 9. CCA analysis of the relationship between environmental factors and the two species isopods at **(a)** station 1, **(b)** station 2, and **(c)** station 3 .

Morphological measurements

A linear regression analysis equation was used to calculate the average weight as a function of weight (dry, ash) in the presence of the average length of the species, each within its length categories, for thirty-seven specimens of *S. a. annandalei* at each station:

Station 1(a): had the lowest dry weight of 0.118mg with a length of 1.006mm and the highest dry weight of 16.7 mg with a length of 8.9mm according to equation(1)

$y = 2.0339x - 1.087$ ------------1

$R^2 = 0.8858$

The lowest ash weight was 0.096 mg, with a length of 1.006 mm, and the highest ash weight was 10.5 mg, with a length of 8.9mm Fig. (10a).

$y = 1.3673x - 0.9974$ -----------2

$R^2 = 0.8742$

Station 2 (b) had the lowest dry weight, 0.024 mg, with a length of 0.622 mm, and the highest dry weight, 18.7 mg, with a length of 9.9 mm,(equation 3)

$y = 2.027x - 0.9916$------------3

$R^2 = 0.9476$

The lowest ash weight was 0.019 mg, with a length of 0.622 mm, and the highest ash weight was 12.5 mg, with a length of 9.9 mm (equation 4) Fig. (10b).

$y = 1.3786x - 0.9908$-----------4

$R^2 = 0.9073$

Station 3(c)**:** had lowest dry weight of 0.015 mg with a length of 0.82 mm and the highest dry weight of 16.9 mg with a length of 9.9 mm according equation (5)

$y = 1.7764x + 0.8894$----------5

$R^2 = 0.9286$

According to equation (6) (Fig. 10c), the lowest ash weight was 0.019 mg, with a length of 0.82 mm, and the highest ash weight was 11.5 mg, with a length of 9.9 mm.

$y = 1.4609x + 0.1856$----------6

$R^2 = 0.9338$

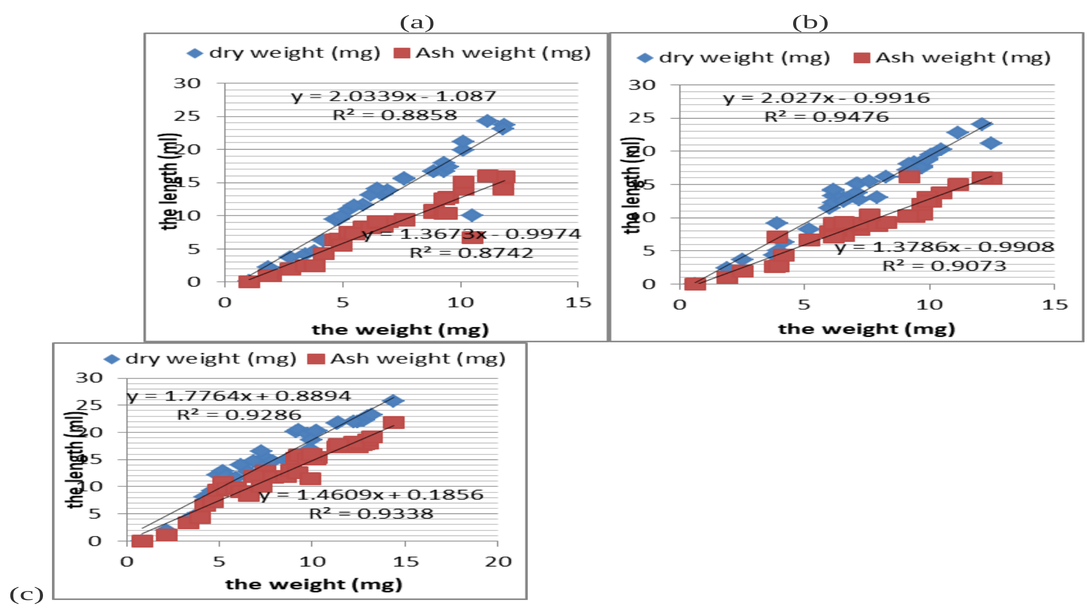


Fig. 10. The relationship between the length (mm) and dry weight and ash weight (mg) of the isopods *S. annandalei* at **(a)** station 1, **(b)** station 2, and **(c)** station 3

As for *A. mesopotamica*

Station1 (a): had the lowest dry weight of 3.276 mg with a length of 4.3 mm and the highest dry weight of 7.981 mg with a length of 8.8 mm according to equation (7)

$y = 1.1879x - 2.2474$--------------7

$R^2 = 0.952$

The lowest ash weight was 3.165 mg with a length of 4.3 mm, and the highest ash weight was 6.212 mg with a length of 8.8 mm, according to equation (8) Fig. (11a).

$y = 0.7586x - 0.1816$ -------------8

$R^2 = 0.9146$

According to equation (9), station 2 had the lowest dry weight of 3.279 mg with a length of 4.5 mm and the highest dry weight of 7.977 mg with a length of 8.5 mm.

$y = 1.1322x - 1.8628$ ------------9

$R^2 = 0.9322$

According to equation(10) the lowest ash weight was 3.177 mg, with a length of 4.5 mm, and the highest ash weight was 6,211 mg, with a length of 8.5 mm. Fig. (11b).

$y = 0.7364x - 0.0477$-------------10

$R^2 = 0.8954$

Station 3 (c)**:** had the lowest dry weight of 2.102 mg with a length of 4.9 mm and the highest dry weight of 7.987 mg with a length of 8.7 mm according to equation(11)

$y = 1.2207x - 2.498$ -------------11

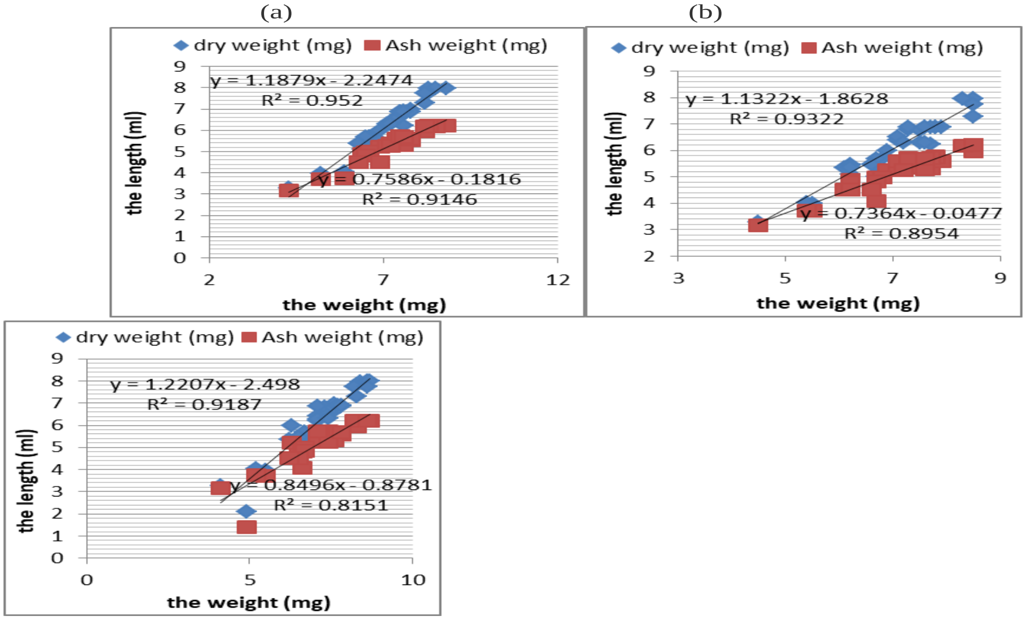
$R^2 = 0.9187$

According to equation(12) Fig. 11 (c), the lowest ash weight was 1.391 mg, with a length of 4.9 mm, and the highest ash weight was 6.217 mg, with a length of 8.6 mm.

$y=0.8496x - 0.8781$------------12

$R^2=0.8151$

(a) (b)



(c)

Fig. 11. The relationship between the length (mm) and dry weight and ash weight (mg) of the isopods *A. mesopotamica* at **(a)** station 1, **(b)** station 2, and **(c)** station 3

DISCUSSION

Physical and chemical properties

The results of the current study revealed that there were differences in water temperature between the various months, as the highest water temperature was recorded during August at all the stations. It is generally observed that the rise in water temperature of the ecosystem is closely related to the ambient air temperature **(Ishaq & Khan, 2013)**, and the shallowness of the river and its rapid heating during daylight hours during the summer months make it vulnerable to air temperatures **(Corbett, 2004)**. The differences in temperature during the months of the year affected the occurrence, abundance and distribution of the studied species, as an increase in the densities of two species were observed during the months of May and November at the three stations. This is due to the high and direct effect of moderate temperature on the activity of aquatic organisms on the one hand and the speed of growth of phytoplankton and the availability of nutrients for these organisms on the other hand **(Al-Aboudi, 2009)**.

The results of the current study regarding temperature agree with the previous local studies **(Ahmed, 2015; Abdul Rasoul, 2019; Abdul-Latif, 2020)**.

The pH is an important and very influential factor in the aquatic environment, as it directly effects on the density and occurrence of organisms in any aquatic environment **(Peterson *et al.*, 1987)**. In the current study it was found that a slight differences in the pH measurements with non-significant differences between the three stations, and this reason may be the regulating ability of the water resulting from its carbonate and bicarbonate contents **(Stirling, 1985)**. The values were within the basic trend and this is a distinctive characteristic of the Iraqi inland waters, it is also considered suitable for aquatic life **(Adeniji, 1989)**.

The highest pH values were recorded in the summer, specifically in July due to the low river discharge, causing an increase in the concentration of dissolved salts as a result of the intrusion of the sea front towards the northern part of the river. This is consistent with what was found by **Al-Maliky (2012)** and **Al-Hejuje (2014)**.

Salinity determines the occurrence, density and distribution of aquatic organsims. It is a variable factor with large and rapid fluctuations that affects the densities, distribution and occurrence of aquatic organisms and determines the size and diversity of the communities **(UNEP, 2008; Abowei, 2010)**.

The kind of species and the abundance in the water vary with salinity **(Nielsen *et al.*, 2003)**. In the present study the salinity concentration was high at the three stations, and the lowest salinity recorded was at the first station, which was higher than what was recorded in the previous studies **(Moyel, 2010; Mohammad *et al*., 2014; Moyel, 2014)**.

The increase in salt concentration in the waters of the Shatt al-Arab is a result of the rise in water temperature as a result of evaporation and the lack of water revenues coming from the Tigris and Euphrates rivers due to the construction of dams on reservoirs in Turkey, Syria, and Iran **(Hussain & Grabe, 2009)**. There are many studies that showed an increase in salinity values during the summer, which were consistent with the results of the current study **(Al-Hejuje, 2014; Ahmed, 2015; Al-Kanani, 2017; Abdul Rasoul, 2018)**.

Light transmittance

The current study indicated a decrease in light transparency values during the summer months as a result of lower water levels and a higher concentration of suspended materials due to high productivity that reduces light transmittance **(Al-Rudaini, 2010)**. **Gilbert *et al*. (2002)** suggested that the reasons for this are due the difference in the photoperiod, the higher of organic matter, and the water level. Light transmittance values increased in the cold months due to the decrease in the abundance of plankton as a result of lower temperatures. This is consistent with some previous studies such as **Rady (2014)**. Light transmittance values also decreased as a result of the agitation of the bottom, erosion of the sides of the river, and decomposition of organic materials due to the rise in water temperature, while light transmittance values increased at the Sharish station, perhaps due to the width of the river cross-section and the low speed of the current.

Significant differences were also found between the months, as several factors affected the light transparency, including the clarity of the atmosphere, the angle of incidence of the sun's rays, and the flows entering the river from the areas surrounding it. which help in the growth of phytoplankton and reduce the values of transparency **(Hussein & Fahad, 2008)**. The movement of boats, mixing processes, and tides also have an impact on light transparency. When comparing this study with the previous ones, it showed similar results, but with lower values **(Ahmed, 2017; Al-Kanani, 2017)**. The reason may be due to measuring permeability in the area of the river edges near the coast, where the amount of mixing with the river edges is high.

Dissolved oxygen

Flow velocity has a positive effect on dissolved oxygen **(Null *et al.*, 2009)**. A sharp decrease in the amount of dissolved oxygen in water occurs as a result of respiration processes carried out by aquatic organisms, decomposition processes of organic matter, high temperature, and oxidation processes of inorganic matter **(Sahu *et al.*, 2000)**. Dissolved oxygen in natural or polluted waters depends on the physical, chemical, biological activities and activities of water bodies. Studies have shown that dissolved oxygen is an important factor determining water quality and the level of organic pollution in water bodies **(Wetzel & Likens, 2006)**. The high concentration of dissolved oxygen in water is also due to several factors, including flow and continuous mixing in the water and the presence of aquatic plants and algae. **(Schillorn-Van Veen, 1980)**.

The oxgyen values recoded at the three stations in the current study were within the permissible limit, which is a result consistant in its upper limit to what was recorded by many researchers **(Al-Hejuje, 2014; Ahmed, 2015; Al-Kanani, 2017; Abdul Rasoul, 2019)**.

The current study showed that individuals of the two species are more adapted to living in the spring months. This is evident in the second and third stations, more than at station 1, which confirms that the appropriate temperature and food availability have a positive effect on increasing the density of these two species of crustaceans.

Salinity at the three stations of the current study was almost similar in the three stations. **Daoud (1976)** mentioned that individuals of the species *S. annandalei* can resist salinity up to 15ppt. It was shown through the study that individuals of both species live in the upper regions at the intertidal area, and are present in higher densities in the sections far from the water's edge than closer to the water's edge. It was found that individuals of both species prefer to live and dig in strong clay soils, while the density is reduced or nonexistent in clay soils saturated with water or sand. **Harvey *et al.* (1973)** noted that the species *S. rugicauda* prefers to dig and live in clay soils and does not dig in sandy soils.

The density rates at the three stations showed clear seasonal changes. The total density was high in November and December 2021 and decreased during January 2021. Density rates during the period from January to February showed a clear convergence, which indicates that there were no high deaths during these months. As for in March, the density increased despite the absence of a new generation, and the reason for this may be due to an error in the collection of species samples due to emigrants from closer sites, the density continued to increase during April as a result of the descent of small individuals into the population, then it decreased during the months of May and June 2021. This decrease can be analyzed by the large deaths in small individuals in addition to the expected effect of predation by other organisms. Then the density showed a significant increase during the months of July, August, September and October 2021 and reached the highest rate as a result of the entry of small individuals of the new generation. Through this we can conclude that density rates are high during the summer months, while density decreases during the winter months. This is consistent with the conclusion of **Daoud (1976)** in his study on *S. annandalei* in the region. **Bamber (1985)** also noted in his study of *Cyathura carinata* that there is a rapid increase in the population in the summer.

CONCLUSION

The current study attempted to find the relationship between the variable values of the influencing environmental factors and their direct effects on the numerical abundance of the two species of isopods.

The two species belonging to the isopod group are widely used in environmental measurement and monitoring programs for coastal areas worldwide. The diversity at large invertebrates and the ability of species to withstand pollution and environmental risks make them vital environmental indicators for monitoring the aquatic environment. Abiotic factors have a crucial role in structuring aquatic ecosystems and significantly impact the abundance species in their environments.

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