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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 2021, 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 aim of the current study was to investigate the density, occurrence, and distribution of these two species, as well as their relationship to surrounding environmental factors. Monthly samples were collected from three fixed stations using a quadrat with an area of 0.0625 m² at each station. The study evaluated monthly rates of various environmental factors, including temperature, pH, salinity, current speed, light transmittance, and dissolved oxygen (DO), in relation to the presence of these two species. The population density of *S. a. annandalei* reached 192 individuals/m² in May at station 3, while the lowest density (16 individuals/m²) was recorded in June and October at the first two stations, and in July at the third station. In contrast, the highest population density for *A. mesopotamica* was 144 individuals/m² in May at station 3, with no individuals recorded in September at station 2, nor in August and September at station 3. The findings revealed no significant difference between the linear regression equations for male and female individuals, allowing them to be combined into a single equation for each species. At all three stations, significant inverse correlations were found between the numerical density of the two species and factors such as salinity, temperature, and light transmittance. In addition, pH, DO, and current speed showed significant positive correlations with the numerical density of the species.

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 a. annandalei* is one of few aquatic species which is adapted to cope with this habitat. It lives in burrows made by the isopod on the river banks, and sometimes it burrows into wood. Moreover, it is found in the marshes and further down in Shatt al-Arab River where salinity increases considerably. The water in which the sampling was conducted is oligohaline brackish water, with a salinity ranging from 1.3 to 2.7ppt **(Abdul-Latif, 2020; Al-Baghdadi *et al*., 2020)**.

The isopod *Sphaeroma a. annandalei* belongs to the family Sphaeromatidae. Isopods are an essential component of the invertebrate fauna, living in association with species of attached organisms such as algae, sponges, mussels, oysters, and barnacles. They are also found on the roots of reeds and other plants **(Saoud, 1997; Al-Baghdadi *et al.*, 2020)**. As in other habitats, isopods play an important role in the ecosystem, feeding on detritus and leftover organic matter, and serving as prey for many species of invertebrates and fish. **Ahmed (1971)** classified a species within the genus *Sphaeroma*, considering it a new species, which he named *Sphaeroma irakiensis*. However, **Harrison and Holdich (1984)** later indicated that this name is synonymous with *S. a. annandalei* **(Stebbing, 1911)**.

In contrast, **Ahmed (1971)** identified *Annina mesopotamica* as *Excirolana mesopotamica*, and **Bruce (1986)** reclassified it under the genus *Annina*.

Species of isopods are widely used in environmental monitoring programs for coastal areas worldwide. Their diversity, as well as their ability to withstand pollution and environmental stress, makes them valuable environmental indicators for monitoring aquatic ecosystems. Abiotic factors play a crucial role in structuring aquatic ecosystems and significantly impact the functioning of soil organisms **(Sfenthourakis & Hornung, 2018)**.

This study aimed to explore the relationship between certain environmental factors and the numerical abundance of *A. mesopotamica* and *S. a. annandalei* during the study period. It also seeked to examine the growth of these species through the relationship between length and weight.

MATERIALS AND METHODS

Three locations were selected along the Garmat Ali River, located approximately 5-7 km north of the city center of Basrah **(Al-Assadi *et al.*, 2015)**. The distance between the sites is close, approximately one kilometer (Plate No. 1). The Garmat Ali River branches into several side canals, with the most significant being the Khartrad and Al-Asafiya canals. These canals are used for irrigating the orchards located on both sides of the river. Aquatic plants, which vary in species from place to place, grow along the riverbanks. The density of these plants fluctuates with the seasons, and the distribution of species depends on the water level and depth of the river. Notable species include *Typha domingensis*, *Phragmites australis*, *Vallisneria spiralis*, and *Ceratophyllum demersum*. The area also supports many waterbirds, particularly migratory species that visit seasonally. Due to significant floods in both Iranian and Iraqi territories, the Shatt al-Arab River was recharged with 6.7 to 12.1km³ of water per year **(Ministry of Water Resources, 2022)**.

The three selected sites on the Garmat Ali River are situated approximately one kilometer apart. The coordinates for each station are as follows: the first station (30˚34ˈ24.70" N, 47˚44ˈ44.65" E), the second station (30˚34ˈ10.83" N, 47˚45ˈ18.63" E), and the third station (30˚34ˈ29.26" N, 47˚45ˈ49.59" E).

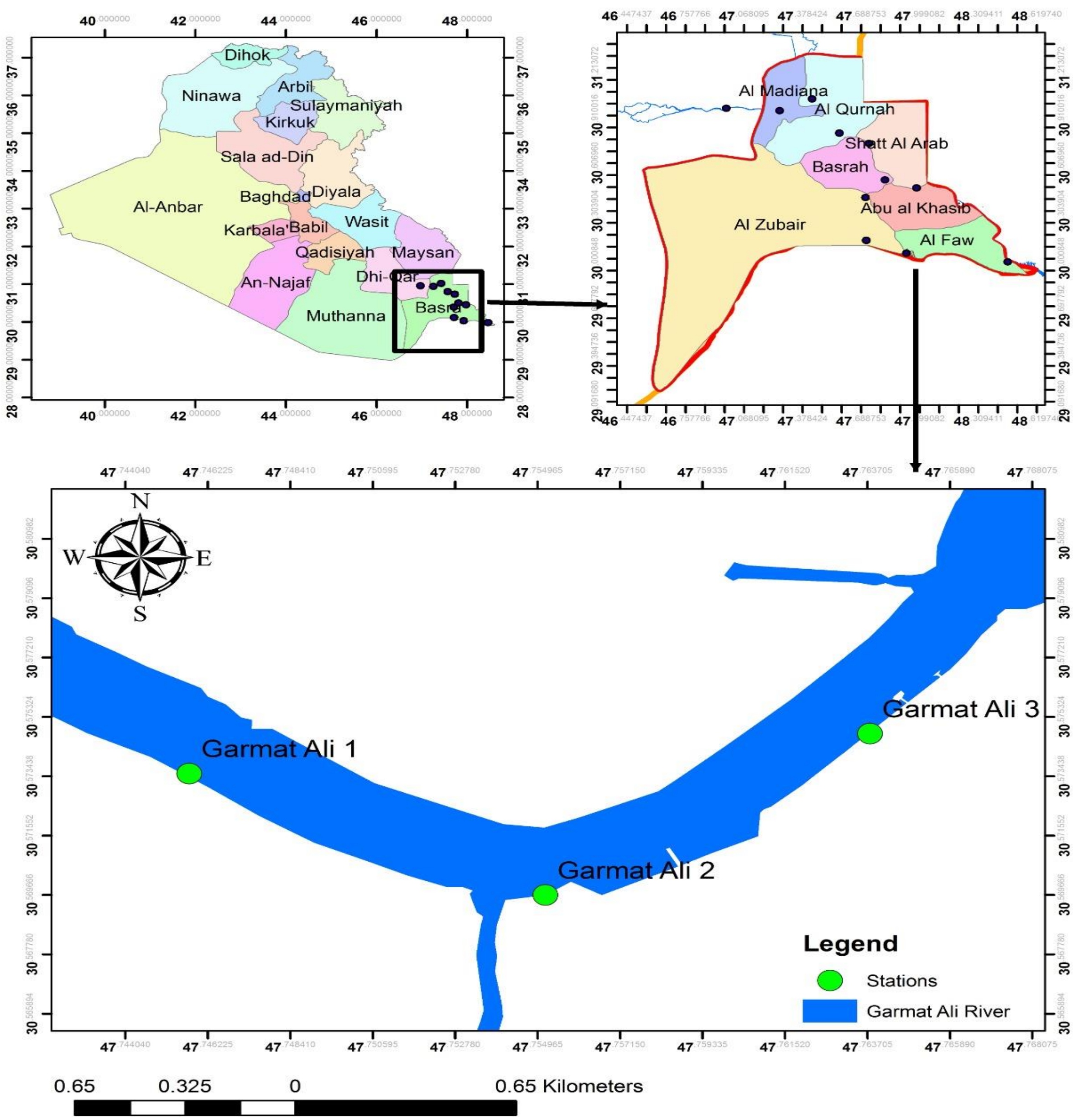


Plate 1. Map of the study area

Environmental factors were measured at the selected study stations on a monthly basis using the 665MPS YSI Model 57, manufactured by Kalbuneh Company, USA. Salinity was expressed in parts per thousand (ppt). The device's electrode was placed just below the water surface for 4-5 minutes to record the readings. Dissolved oxygen (DO) was measured at the study stations using the SMART SENSOR DO Meter AR8210. The electrode was placed in the water for two minutes to measure DO. Current speed was measured using the CM2 Current Meter, with readings expressed in m/s **(APHA, 2005)**, while light transparency was measured using a Secchi disk. Light transmittance was calculated using the following equation:
Light transparency = (first depth + second depth) / 2.

Organisms were collected from the intertidal zone, with fifteen replicates taken to cover both the upper and lower intertidal zones at each station. These replicates represented the population density at each of the three study stations. Samples were taken using a wooden quadrat with a side length of 25cm, which was inserted into the clay to a depth of 10cm, until the fauna were no longer found. Samples of *S. a. annandalei* and *A. mesopotamica* were placed in plastic containers containing 70-80% ethyl alcohol for preservation.

Abundance per square meter was calculated, and the length of each animal 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. Samples were then weighed based on their dry weight using a sensitive balance after drying at 60°C for 24 hours. The same samples were later incinerated at a temperature of 450-600°C for four hours, and the weight of the ash was recorded.

Another set of samples from both species were collected throughout the study period at all stations and were preserved by freezing without any preservatives. These were used to measure the weights and lengths of the animals. The linear regression equation was used to calculate the average wet weight as a function of the dry weight in relation to the average length of the species studied. The equation used was:

$$Y=a+bX$$

Where, **Y** is the wet weight and **X** is the animal length.

RESULTS

1. Temperature

The temperatures varied across the three stations. The highest temperature, 36.5°C, was recorded in August at station 2, while the lowest temperature, 8.1°C, was observed in January at station 3. In the current study, significant differences were found between the months of April to September and the winter months ($P< 0.05$). However, no significant differences were observed between the stations at the same probability level (Fig. 1).

2. Hydrogen ion concentration (pH)

The pH values at all stations were generally in the basic range during the study period. The highest value, 7.9, was recorded in November at the first station, as well as in June and December at the second station. The lowest value, 6.4, was recorded in February at the first station. Significant differences were observed between months (*P*< 0.05), but no significant differences were found between the three stations (Fig. 2).

3. Salinity

The highest salinity value was 2.5‰ during September at the first and third stations, 2.3‰ during the same month at the second station, and the lowest was 0.98‰ during January at the first station. Significant 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).

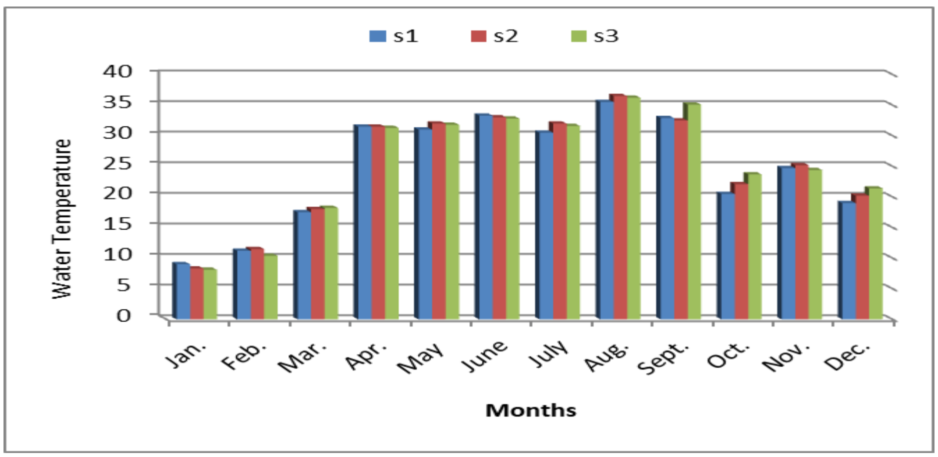


Fig. 1. Temperatures at the three stations in Garmat Ali River during the study months

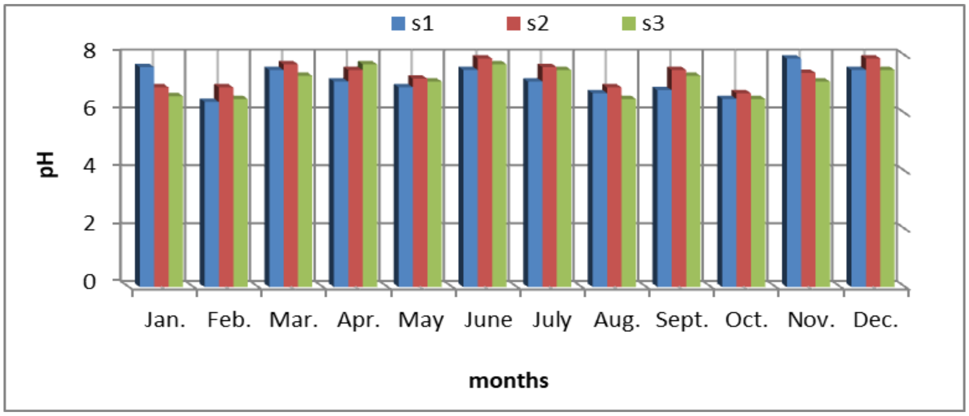


Fig. 2. The pH changes at the three stations in Garmat Ali River during the study months

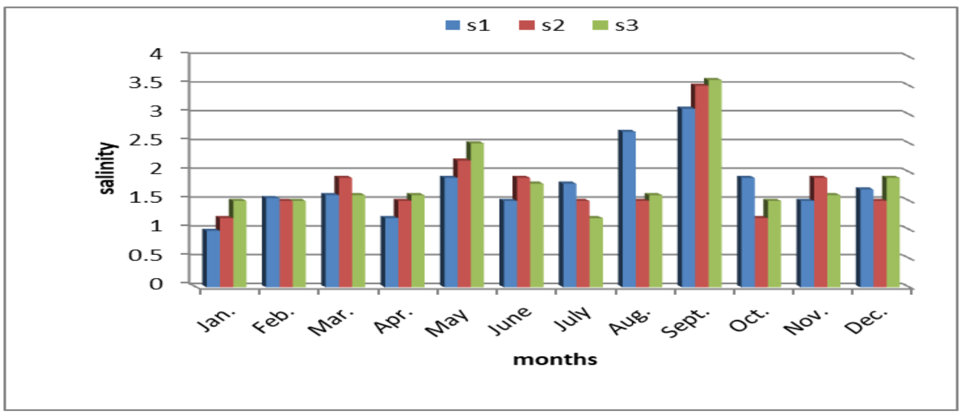


Fig. 3. Salinity changes at the three stations in Garmat Ali River during the study months

4. Current speed

The water current speed values varied between 0.18 and 99.0m/ s, with the lowest values (0.18 and 0.19 m/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).

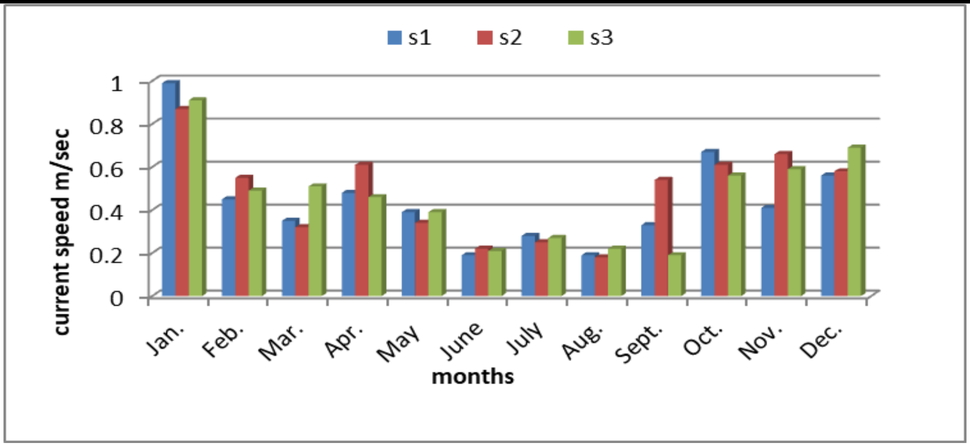


Fig. 4. Changes the current velocity values change (m/s) at the three stations in Garmat Ali River during the study months

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 measurements were 69cm, recorded in December and January at stations 1, 2, and 3, respectively. The lowest measurement, 41cm, was recorded in September at station 2. Positive differences were observed between the study months, with a significance level of $P< 0.05$ at all three stations (Fig. 5).

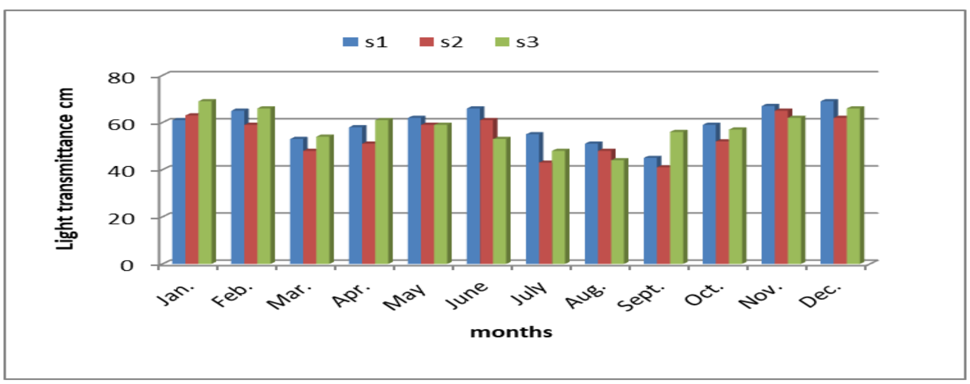


Fig. 5. Monthly changes in water light transmittance values (cm) at the three stations in Garmat Ali River during the study months

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 remaining months of the year. At the same probability level, the stations had no significant differences (Fig. 6).

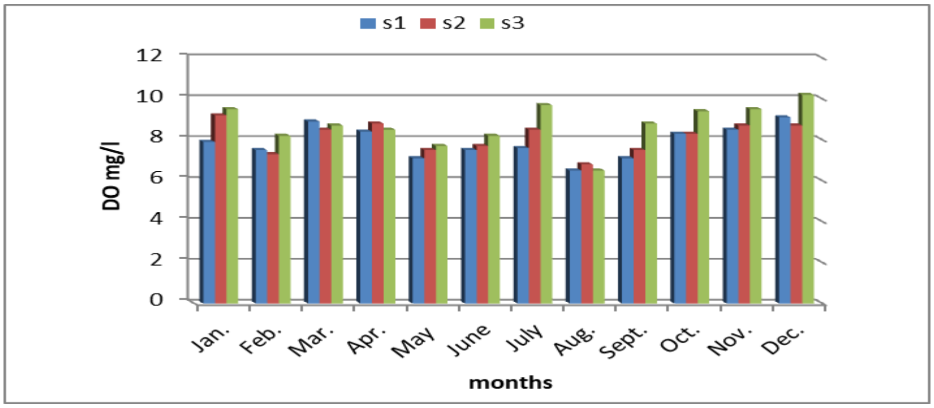


Fig. 6. Monthly changes in DO values (mg/l) at the three stations in Garmat Ali River during the study months

Population density

S.a. annandalei

According to Fig. (7), there were differences in the population density of *S. a. annandalei* across stations 1, 2, and 3. The highest density, 192 individuals/m², was recorded in May at station 3, while the lowest density, 16 individuals/m², was recorded in June and October at station 1, and in July at station 3. The highest total number of individuals for this species throughout the year was recorded at station 1 (672 individuals/m²), while stations 1 and 3 each had a total of 944 individuals/m². Statistical analysis revealed significant differences at the $P < 0.05$ level between November and the rest of the year, as well as between May, July, September, October, and the rest of the year. Positive differences were also found between station 1 and the other stations at the same probability level.

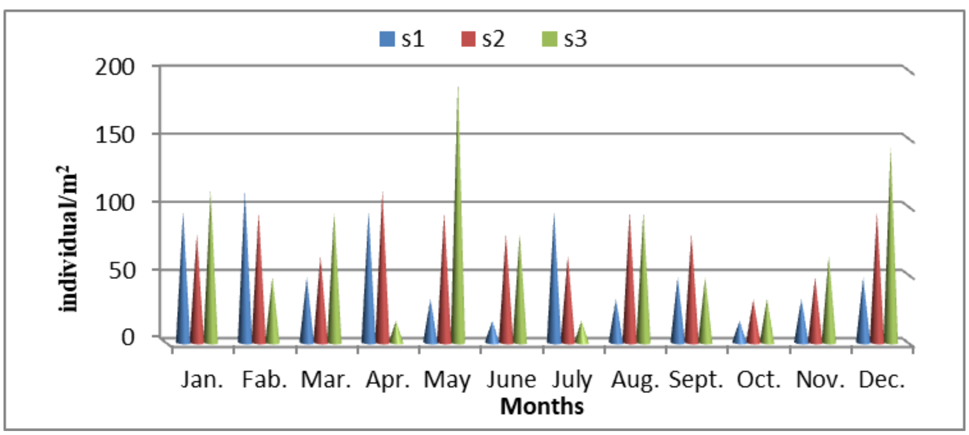


Fig. 7. Density of *S.annandalei annandalei* at the three stations in Garmat Ali River during the study months

A. mesopotamica

The highest population density of *A. mesopotamica* (144 individuals/m²) was recorded in May at station 3. No presence of this species was recorded in September at station 2, nor was in August and September at station 3. The results also showed that the lowest total number of individuals for this species was recorded at station 2 (416 individuals/m²), while the highest total number (1226 individuals/m²) was recorded at station 3. Statistical analysis revealed significant differences at the $P< 0.05$ level between August and September and the rest of the year, as well as between February, May, July, and November and the rest of the year. Additionally, significant differences were observed between December, January, March, April, June, November, and the remaining months of the year. At the same probability level, significant differences were also found between station 2 and the other stations (Fig. 8).

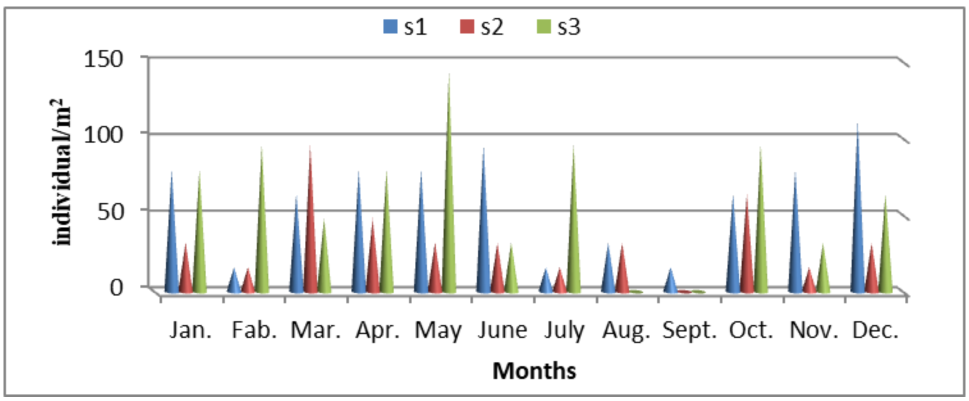


Fig. 8. Density of *S.A. mesopotamica* at three stations in Garmat Ali River during the study months

Multiple statistical analysis of the two species with environmental factors

S. a. annandalei showed a significant inverse correlation with temperature. The highest density of this species at the first site coincided with the lowest pH values, while the lowest densities at the first site corroborated with the highest pH values at the second site. A direct relationship was observed between the density of *S. a. annandalei* and salinity at the first site. Additionally, a direct relationship was found between the species' density and current speed, as well as with dissolved oxygen levels.

For *A. mesopotamica*, the lowest densities were associated with higher temperatures at all sites. The lowest densities also coincided with the lowest pH values at the first site. An inverse relationship was observed between the density of *A. mesopotamica* and salinity across all sites. A positive relationship was found between *A. mesopotamica* density and light transmittance, with the relationship being more pronounced at the first site compared to the other sites. The decrease in current speed also concurred with the absence of *A. mesopotamica*, especially at the third site, and with the lowest presence of this species at the first site (Figs. 9, 10, 11).

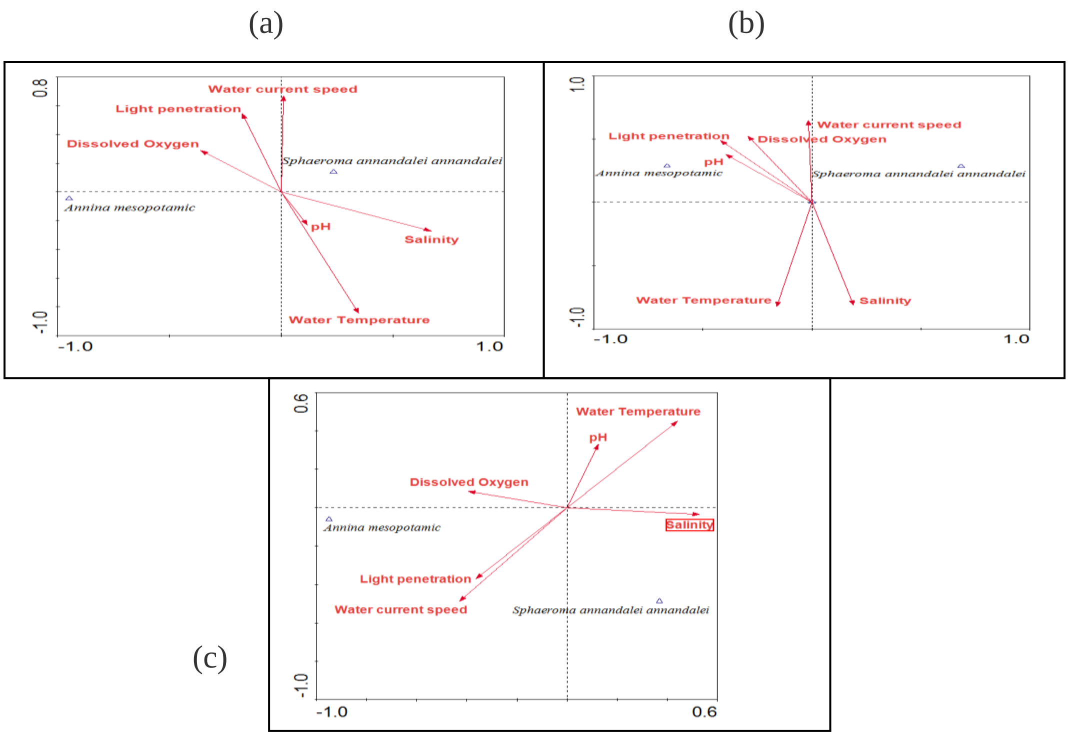


Fig. 9. CCA analysis of the relationship between environmental factors and the two species isopods at station 1 (a), station 2 (b), and (c) station 3

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 as follows:

Station 1(a): had the lowest dry weight of 0.118mg with a length of 1.006mm and the highest dry weight of 16.7mg 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 0.096mg, with a length of 1.006mm, and the highest ash weight was 10.5mg, 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, 0.024mg, with a length of 0.622mm, and the highest dry weight, 18.7mg, with a length of 9.9mm (equation 3)

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

$R^2 = 0.9476$

The lowest ash weight was 0.019mg, with a length of 0.622mm, and the highest ash weight was 12.5mg, 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 0.015mg with a length of 0.82mm and the highest dry weight of 16.9mg with a length of 9.9mm according equation(5)

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

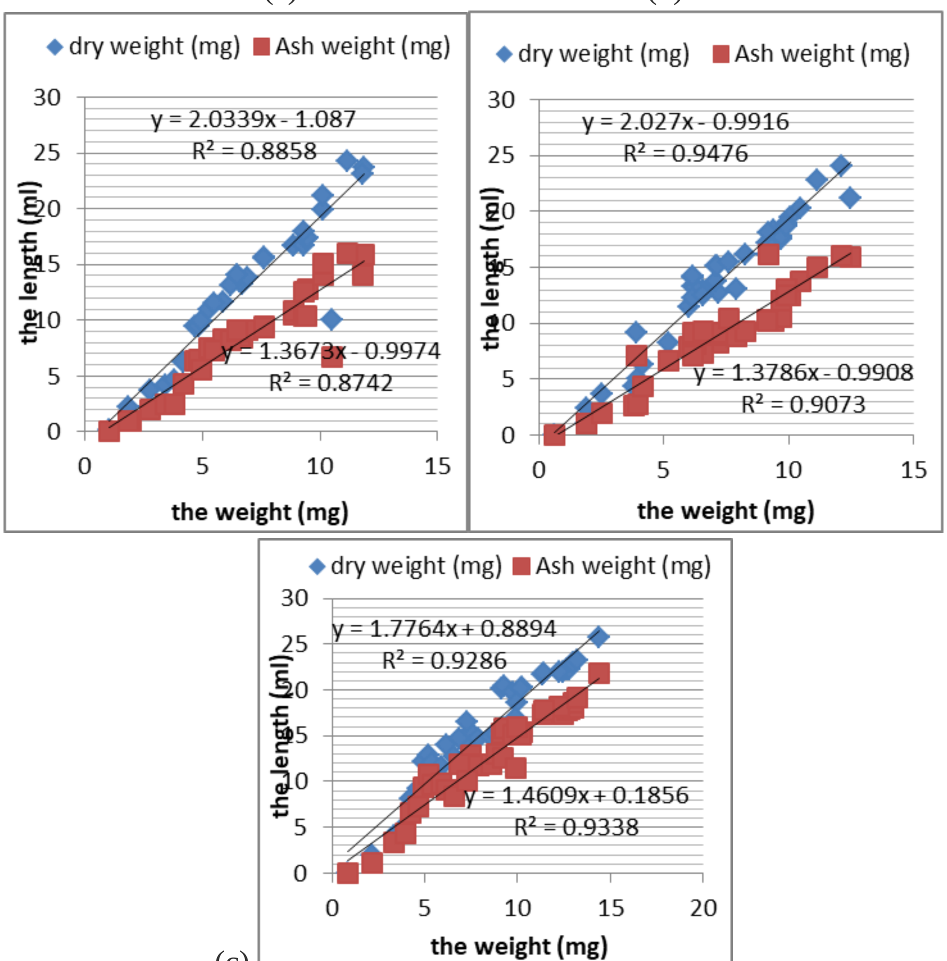
$R^2 = 0.9286$

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

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

$R^2 = 0.9338$

(a) (b)



(c)

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

A. mesopotamica

Station 1(a): had the lowest dry weight of 3.276mg with a length of 4.3mm and the highest dry weight of 7.981mg with a length of 8.8mm according to equation (7)

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

R^2 = 0.952

The lowest ash weight was 3.165mg with a length of 4.3mm, and the highest ash weight was 6.212mg with a length of 8.8mm, 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 3.279mg with a length of 4.5mm and the highest dry weight of 7.977mg with a length of 8.5mm.

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

R^2 = 0.9322

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

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

R^2 = 0.8954

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

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

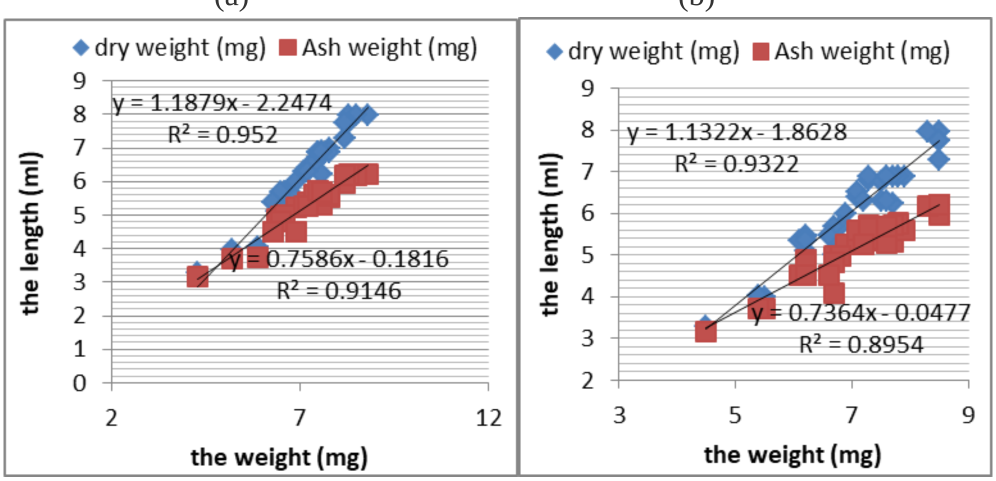
R^2 = 0.9187

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

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

R^2=0.8151

(a) (b)



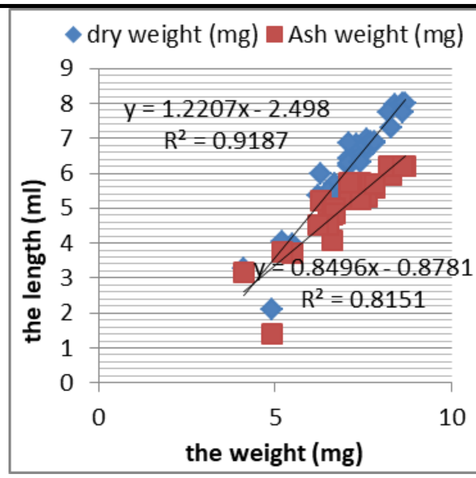
(c) 

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

DISCUSSION

Physical and chemical properties

The results of the current study reveal that there are 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)**. Moreover, 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 was observed during May and November at the three stations. That's from the high and direct effective 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)**.

pH is an important and influential factor in aquatic environments since it directly affects the density and occurrence of organisms **(Peterson *et al.*, 1987)**. In the current study, only slight differences in pH measurements were observed, with no significant differences between the three stations. This may be due to the water's buffering capacity, which is influenced by its carbonate and bicarbonate contents **(Stirling, 1985)**. The pH values remained within the basic range, which is a characteristic feature of Iraqi inland waters and is 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 toward 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)**. Numerous studies determined the increase in salinity values during the summer season, and their finding is 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 variations in factors such as photoperiod, organic matter, and water level contribute to differences in light transmittance. In this study, light transmittance values increased during the colder months, likely due to the decrease in plankton abundance as temperatures dropped, consistent with previous studies **(Rady, 2014)**. However, light transmittance decreased when the bottom was disturbed, the riverbanks eroded, or organic materials decomposed due to rising water temperatures. Interestingly, light transmittance increased at the Sharish station, possibly because of the river's wider cross-section and lower current speed.

Significant differences in light transparency were found across months. Several factors influenced light transparency, including atmospheric clarity, the angle of sun rays, and the inflow from surrounding areas, which promote phytoplankton growth and reduce transparency **(Hussein & Fahad, 2008)**. The movement of boats, mixing processes, and tidal effects also impacted light transparency. Upon comparing the current study with previous research, the results are apparently similar but with generally lower values **(Ahmed, 2017; Al-Kanani, 2017)**. This could be due to the measurements being taken near the river edges, where higher mixing occurs.

Dissolved oxygen

Flow velocity positively affects dissolved oxygen levels **(Null *et al.*, 2009)**. Dissolved oxygen decreases sharply due to respiration by aquatic organisms, organic matter decomposition, high temperatures, and the oxidation of inorganic materials **(Sahu *et al.*, 2000)**. The level of dissolved oxygen in both natural and polluted waters depends on physical, chemical, and biological factors. Studies have shown that dissolved oxygen is a key indicator of water quality and organic pollution levels **(Wetzel & Likens, 2006)**. In addition, higher dissolved oxygen concentrations are linked to factors such as water flow, continuous mixing, and the presence of aquatic plants and algae **(Schillorn-Van Veen, 1980)**.

The oxygen values recorded at the three stations in this study were within permissible limits, consistent with findings from several other researchers **(Al-Hejuje, 2014; Ahmed, 2015; Al-Kanani, 2017; Abdul Rasoul, 2019)**.

The study indicated that the two species were more adapted to the spring months, particularly at stations 2 and 3, compared to station 1. This suggests that optimal temperature and food availability positively affect the density of these two species of crustaceans.

Salinity

Salinity values were similar across all three stations in this study. **Daoud (1976)** found that *S. annandalei* can tolerate salinities up to 15ppt. The study showed that individuals of both species are found in higher densities in the upper intertidal zone, particularly farther from the water's edge. They prefer to burrow in strong clay soils, and densities are lower or absent in clay soils saturated with water or in sandy soils. **Harvey *et al.* (1973)** noted that *S. rugicauda* also prefers to burrow in clay soils and to avoid sandy areas.

Density variations

The density of both species showed clear seasonal changes. Total density was high in November and December 2021, then decreased in January. From January to February, the density rates converged, indicating no significant mortality during this period. In March, density increased despite the absence of a new generation, possibly due to sampling errors or the movement of individuals from nearby sites. Density continued to rise in April as small individuals entered the population, but decreased in May and June, likely due to high mortality among small individuals and predation by other species. Density peaked in July, August, September, and October 2021, as new individuals entered the population. Overall, density was at its highest value during the summer months and at its lowest during the winter months, a trend that aligns with **Daoud's (1976)** findings on *S. a. annandalei* in the region. In this context, **Bamber (1985)** noted a rapid population increase in summer for *Cyathura carinata*.

CONCLUSION

The current study aimed to explore the relationship between the varying values of environmental factors and their direct effects on the numerical abundance of the two isopod species. These species are widely used in environmental monitoring programs for coastal areas around the world. The diversity of large invertebrates and their ability to withstand pollution and environmental risks make them important environmental indicators for monitoring aquatic ecosystems. Abiotic factors play a crucial role in structuring aquatic ecosystems and significantly influence the abundance of species within these environments.

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