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Environmental Factors Impact on Zooplankton Density in Kiteiban Canal on Shatt Al-Arab, Iraq

Mhmood A. Chaloob and Naeem S. Hammadi*
Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Basra, Iraq

***Corresponding Author:** naeem.hammadi@uobasrah.edu.iq

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ABSTRACT

This study aimed to investigate the impact of environmental factors on the density and distribution of zooplankton in the Kiteiban Canal, a branch of the Shatt al-Arab River in Basra Governorate, Iraq. Seasonal samples were collected from three stations between autumn 2024 and summer 2025, with key physicochemical parameters such as temperature, salinity, dissolved oxygen, nitrate, and phosphate analyzed. The results showed that the highest zooplankton density was recorded in spring, particularly at Station 3, due to optimal environmental conditions. A positive correlation was observed between nitrate concentration and zooplankton density, while phosphate showed no direct effect. These findings highlight the importance of monitoring seasonal changes to ensure the sustainability of the aquatic ecosystem in the region.

INTRODUCTION

Zooplankton, as crucial components of aquatic food webs, exhibit population dynamics highly sensitive to physicochemical variables within their habitat **(Maytham *et al*., 2019; Hammadi *et al*., 2024a)**. These microscopic organisms play a pivotal role in energy transfer from primary producers to higher trophic levels, making their abundance and community structure key indicators of aquatic ecosystem health **(Abbas *et al*., 2014)**. In particular, the density of zooplankton is directly influenced by environmental factors such as nutrient availability, temperature, pH, and the presence of aquatic macrophytes **(Hammadi, 2019)**. For instance, nutrient enrichment, specifically the availability of nitrates, phosphates, and silicates, significantly enhances phytoplankton growth, which in turn supports a higher density of zooplankton, serving as their primary food source **(Ravera, 1980)**.

Conversely, extreme fluctuations in temperature and pH can induce physiological stress, leading to reduced reproductive rates and increased mortality among zooplankton populations. Furthermore, alterations in water temperature not only affect zooplankton directly at physiological and behavioral levels but also indirectly influence their communities by modulating the availability and quality of food resources and the intensity of predation from higher trophic levels **(Hammadi, 2019)**. For example, elevated water temperatures can stimulate the proliferation of cyanobacteria, which can be detrimental to zooplankton due to toxin production and reduced water quality, thereby impacting the survival of economically important fish species that rely on zooplankton as a food source during their early life stages **(Rose *et al*., 2016)**.

The Shatt al-Arab River has been the focus of numerous ecological studies addressing the seasonal and spatial variations in zooplankton density, which serves as an important indicator of water quality and ecological balance **(Maytham *et al*., 2019)**.

According to **Ajeel and Abbas (2016)**, the total zooplankton density at three stations along the Shatt al-Arab (Al-Ashar, Abu Al-Khasib, and Al-Faw) ranged from 253 ind./m³ (recorded in Abu Al-Khasib during summer) to a maximum of 69,223 ind./m³ (in Al-Faw during winter). The dominant groups were Copepoda, followed by Cirripede larvae and Cladocera.

In a more comprehensive study, **Abbas *et al*. (2022)** documented variations in density and diversity across four stations in the northern part of the Shatt al-Arab from 2008 to 2009. Total densities ranged from 79 to 65,170 ind./m³, with Cirripede larvae being the most abundant group at most stations.

In the central region of the river, **Maytham *et al*. (2019)** reported seasonal densities of zooplankton between July and November. Copepoda densities ranged from 0.12 to 88.23 ind./L, while Rotifera densities ranged from 0.52 to 20.44 ind./L. Cladocera showed the lowest densities, ranging from 0.06 to 1.45 ind./L.

A specialized study on Rotifera conducted between February 2007 and March 2008 showed densities ranging from 1.09 to 650.99 ind./L, and revealed a positive correlation between Rotifera abundance and environmental factors such as temperature, suspended solids, and chlorophyll-*a* **(Hammadi, 2019)**.

For regional comparison, a study in the Al-Hammar Marshes reported total zooplankton densities ranging from 725 to 151,413 ind./m³, with an average of 39,336 ind./m³. Crustaceans constituted the majority (approximately 96.3%), with Copepoda accounting for the highest proportion (80.3%), followed by Cirripede larvae, Rotifera, and Cladocera in decreasing order **(Abbas & Ajeel, 2022)**.

Maytham *et al*. (2019) utilized zooplankton communities and the Canadian water quality index (CWQI) to assess the water quality of the central section of the Shatt al-Arab River. They reported a significant deterioration in the water quality of the Shatt al-Arab River, attributed to fluctuations in freshwater inflow and elevated levels of pollution; these conditions have led to a noticeable decline in biological productivity and an increased stress on microbial communities, particularly zooplankton, especially in areas impacted by industrial and municipal discharges.

In the nearby Al-Hammar Marshes, a related study showed that total zooplankton densities ranged from 725 to 151,413 ind./m³, with an average of 39,336 ind./m³. Crustaceans dominated the zooplankton community, accounting for more than 96% of the total density **(Abbas & Ajeel, 2022)**.

This study aimed to assess the impact of environmental factors (such as salinity, temperature, pH, and nutrients) on the density and distribution of zooplankton in the Kiteiban Canal, one of the branches of the Shatt al-Arab in Basra Governorate, Iraq. It also seeked to identify the dominant species and the factors influencing their seasonal variations.

MATERIALS AND METHODS

The current study was conducted in the Kiteiban Canal, one of the irrigation canals of the Shatt al-Arab in Basra Governorate, Iraq, which the farmers of the region depend on for agriculture. Three stations were selected in it: the first at the Shatt al-Arab, the second in the middle of the canal, and the third at its end (Fig. 1).

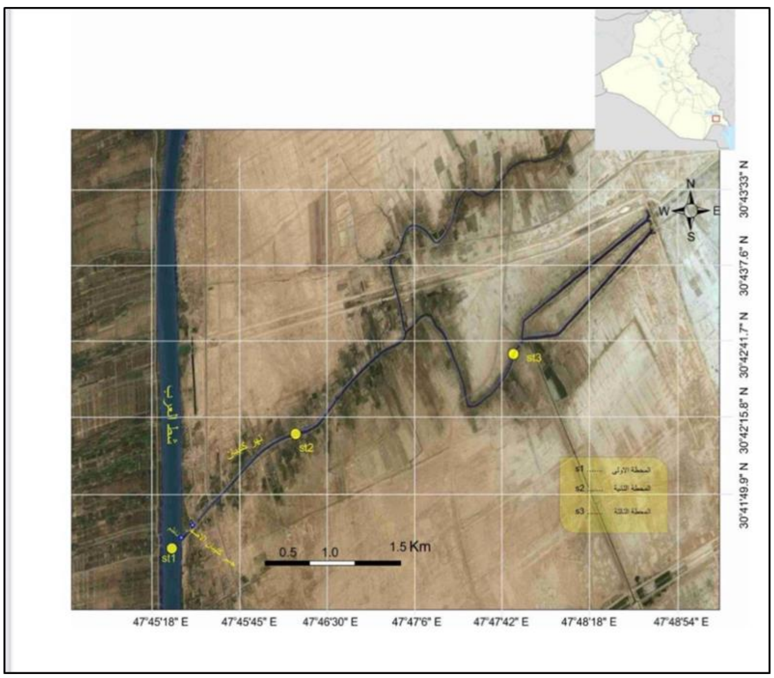

Fig. 1. Map of study area in the Kiteiban Canal

Seasonal samples were collected from fall 2024 to summer 2025 to assess environmental variations. Key physicochemical parameters, including water temperature and salinity were measured using calibrated instruments. Light penetration was determined using a Secchi disk to evaluate water transparency. Dissolved oxygen, nitrate, and phosphate concentrations were analyzed according to the standard methods of the American Public Health Association **(APHA, 2005)**. These measurements aimed to understand the ecological conditions influencing aquatic life dynamics. Zooplankton density was assessed by collecting samples using a plankton net with a mesh size of 50 micrometers and a mouth diameter of 40cm. The collected samples were concentrated and preserved in labeled bottles containing 4% formalin to ensure proper fixation. The final volume of each sample was adjusted to 100 milliliters for standardization. Enumeration of zooplankton individuals was performed using a Sedgwick-Rafter counting chamber. The results were expressed as individuals per cubic meter to estimate population density accurately.

RESULTS AND DISCUSSION

The highest water temperature was recorded at Station 3, reaching 32.5°C during the summer, while the lowest temperature was 13°C in the winter. Seasonal fluctuations in temperature were observed across all stations. However, statistical analysis revealed no significant differences in water temperature among the stations (Fig. 2). These results indicate a relatively uniform thermal regime across the study area despite seasonal variations.

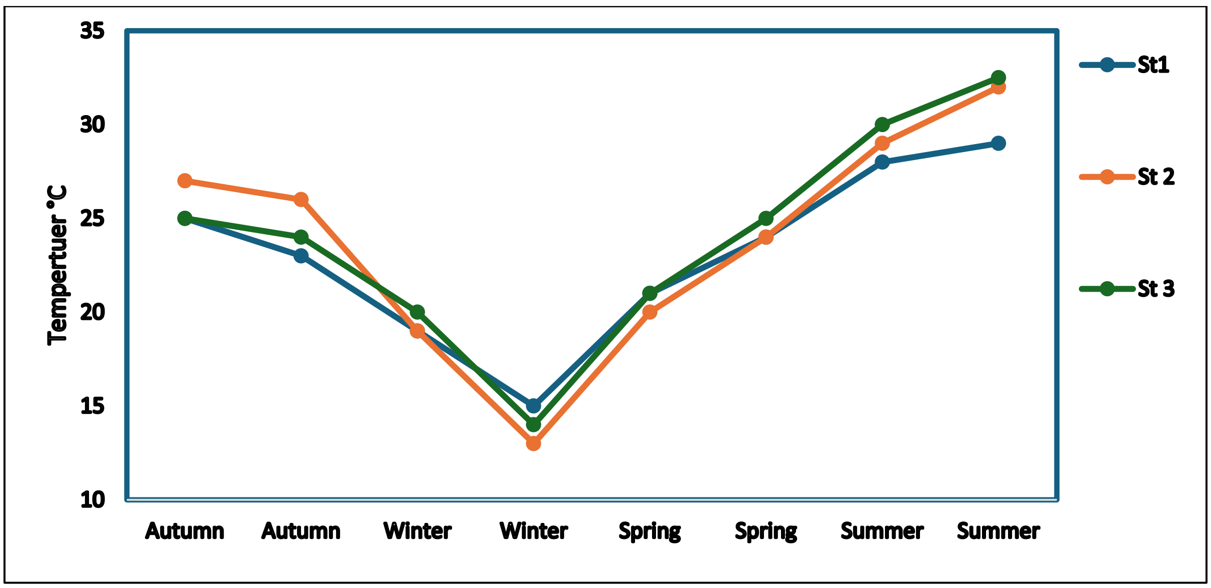

Fig. 2. Seasonal variations in the water temperature values for the study stations during 2024-2025

Regarding zooplankton density, significant seasonal variation was observed. The highest densities were recorded in spring, particularly at Station 3, where the density peaked at 1,644.01 individuals/liter. This increase is attributed to optimal environmental conditions during this season, such as moderate temperatures, increased light radiation, and abundant nutrients, which enhance primary production and thus positively impact zooplankton levels **(Wetzel, 2001; Reynolds, 2006)**. The increased zooplankton density during this period may also be linked to increased activity of microalgae (phytoplankton), which are the primary food source for zooplankton **(Lampert & Sommer, 2007)**. In contrast, zooplankton densities decreased during the summer despite higher temperatures, which may be attributed to the negative effects of excessive heat, low dissolved oxygen levels, increased activity of natural predators, or even a decline in primary production due to intense light or nutrient deficiency due to high consumption **(Gyllström *et al.*,**

2005). Increased evaporation rates may also lead to changes in water salinity, limiting the growth of some sensitive species **(Allan *et al*., 2007)**.

Light penetration measurements obtained using a Secchi disk demonstrated distinct seasonal and spatial variations among the three sampling stations during the study period. The highest transparency was observed in winter, with a maximum depth of 53cm recorded at Station 1, followed by 45cm at Station 3. In contrast, the lowest light penetration occurred during spring, with a minimum of 21cm recorded at Station 2. Statistical analysis revealed a significant difference in light penetration between Station 1 and both stations 2 and 3 ($P \leq 0.05$) (Fig. 3).

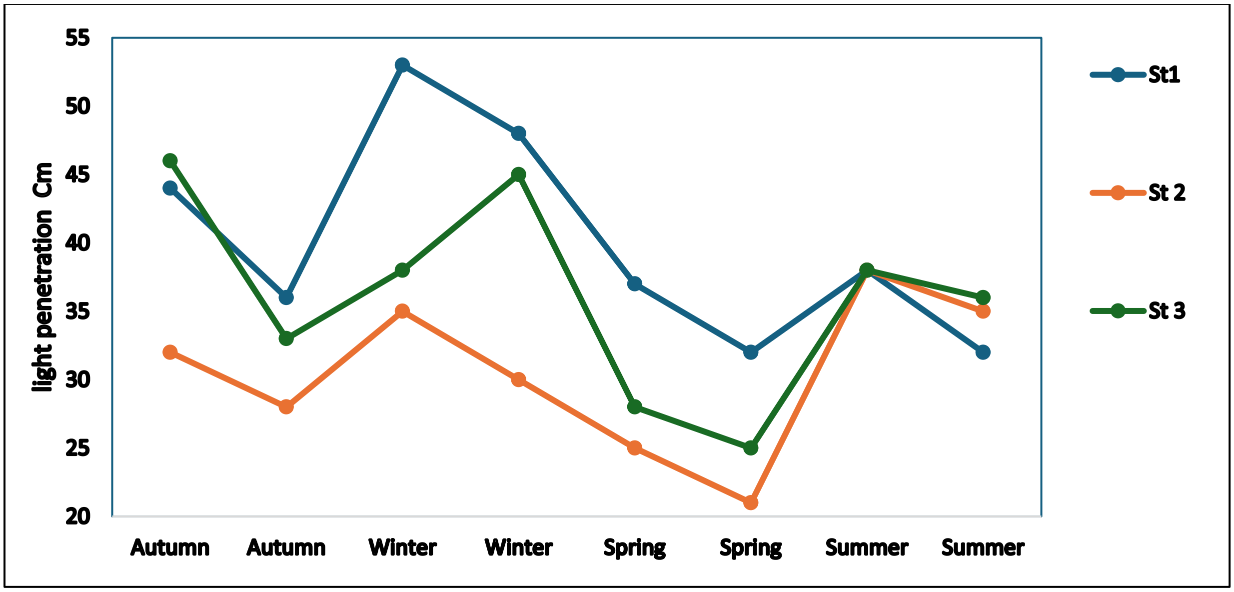

Fig. 3. Seasonal variations in the light penetration values for the study stations during 2024-2025

In spring, a significant decrease in light penetration was observed, especially at station 2 (21cm), while the highest zooplankton densities were recorded (up to 1644 individuals/L) at station 3. This corresponds to the onset of peak phytoplankton growth, as a result of moderate temperatures and increased solar radiation, which leads to increased turbidity due to the density of phytoplankton, the primary food source for zooplankton **(Hammadi *et al*., 2024b)**. This pattern is a common ecological behavior in aquatic systems, where the spring bloom of phytoplankton leads to reduced water transparency and increased density of early consumers **(Lampert & Sommer, 2007)**. In summer, light penetration readings were approximately equal across the three stations (32– 38cm), while moderate zooplankton densities were recorded. This balance may reflect a temporary stability in the ecosystem. However, on the other hand, high temperatures may limit the reproduction of some species, reduce oxygen concentrations, and increase nutrient consumption, which is reflected in the density of zooplankton **(Gyllström *et al*., 2005)**.

Salinity results showed significant seasonal and spatial variation among the three stations. The lowest value was recorded during autumn at Station 1 (1.1‰), while the highest value was 6.1‰ at Station 3 during the summer. In general, salinity was low in autumn and winter, began to increase in spring, and reached its highest levels in summer due to the increased evaporation and decreased freshwater flow. Statistical analyses also revealed significant differences ($P \leq 0.05$) between the stations, especially during spring and summer, with Station 3 having higher salinity concentrations than stations 1 and 2 (Fig. 4).

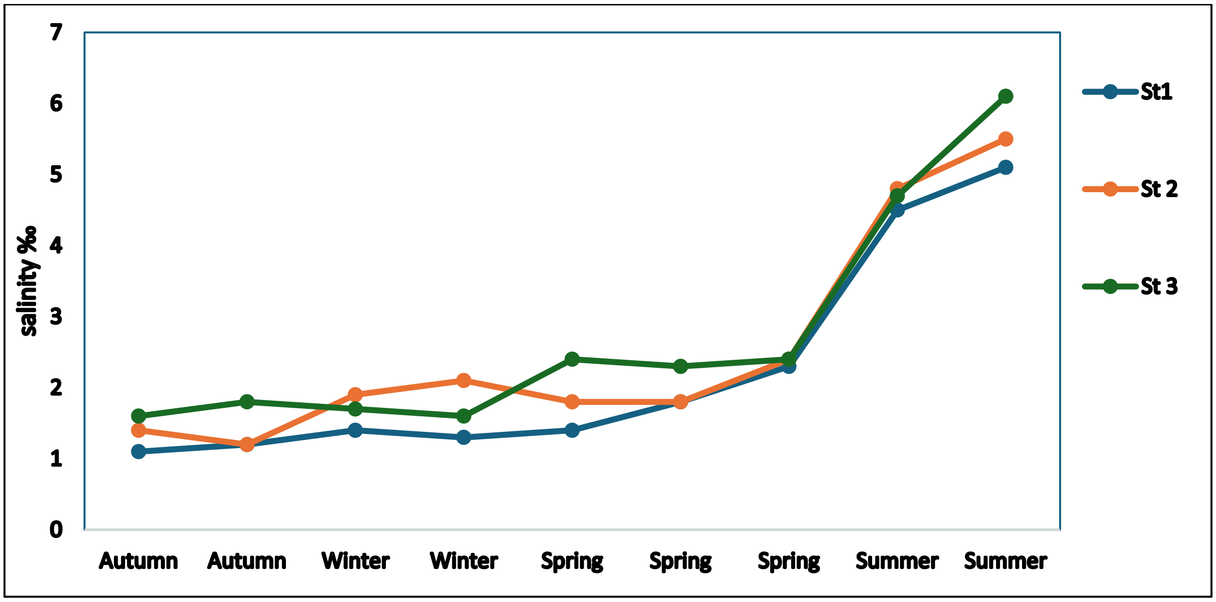

Fig. 4. Seasonal variations in the salinity values for the study stations during 2024-2025

Dissolved oxygen concentrations exhibited seasonal variations across the study period. The highest values were recorded during the winter at all stations, ranging from 8.0 to 9.5mg/ L, which can be attributed to lower water temperatures that enhance oxygen solubility. In contrast, oxygen levels gradually declined during the spring and reached their minimum during the summer, particularly at stations 2 and 3, where values ranged between 6.0 and 5.5mg/ L. This reduction is likely due to elevated temperatures and increased microbial decomposition of organic matter, both of which contribute to oxygen depletion in the water column. Statistical analysis revealed no significant differences in dissolved oxygen concentrations between the three stations ($P \leq 0.05$) (Fig. 5).

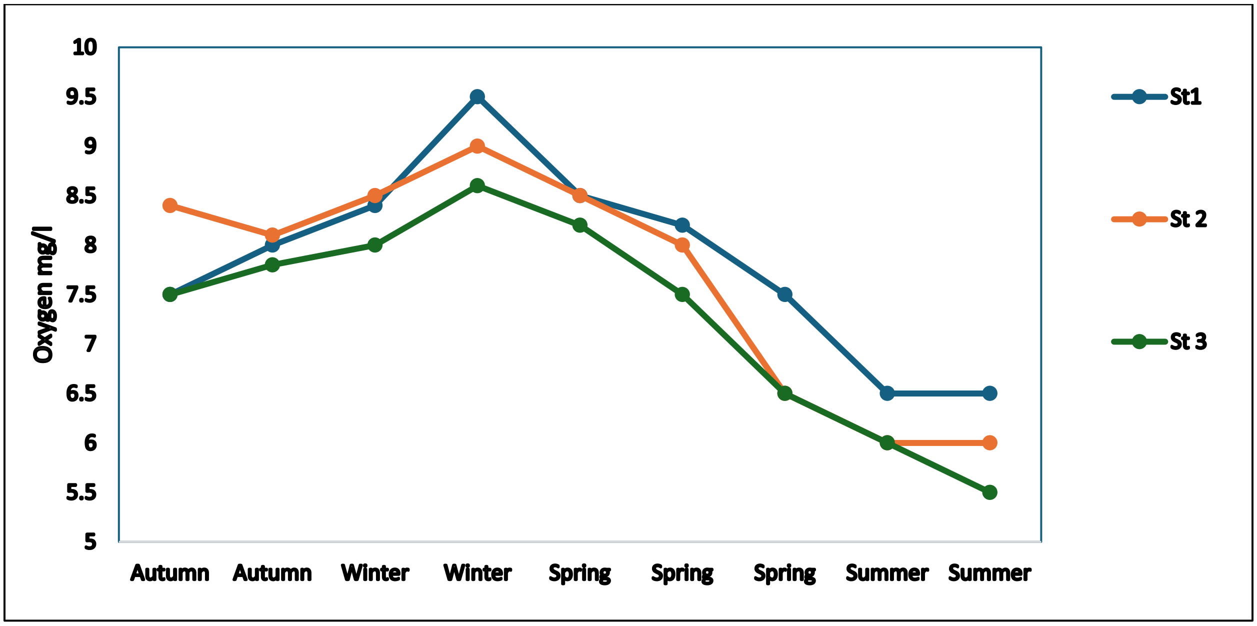

Fig. 5. Seasonal variations in the dissolved oxygen values for the study stations during 2024-2025

The analysis of nitrate concentrations revealed significant seasonal and spatial variations among the studied stations. The lowest concentrations were recorded during autumn, gradually increasing in winter and peaking in summer, with the highest value observed at Station 3 (4.67mg/L) (Fig. 6). In contrast, the lowest concentration was observed at Station 2 in autumn, reaching 0.651mg/ L. Statistical analysis showed significant differences in nitrate concentrations between seasons and stations ($P \leq 0.05$), reflecting the influence of seasonal environmental factors and anthropogenic activities **(Hammadi *et al.*, 2023)**.

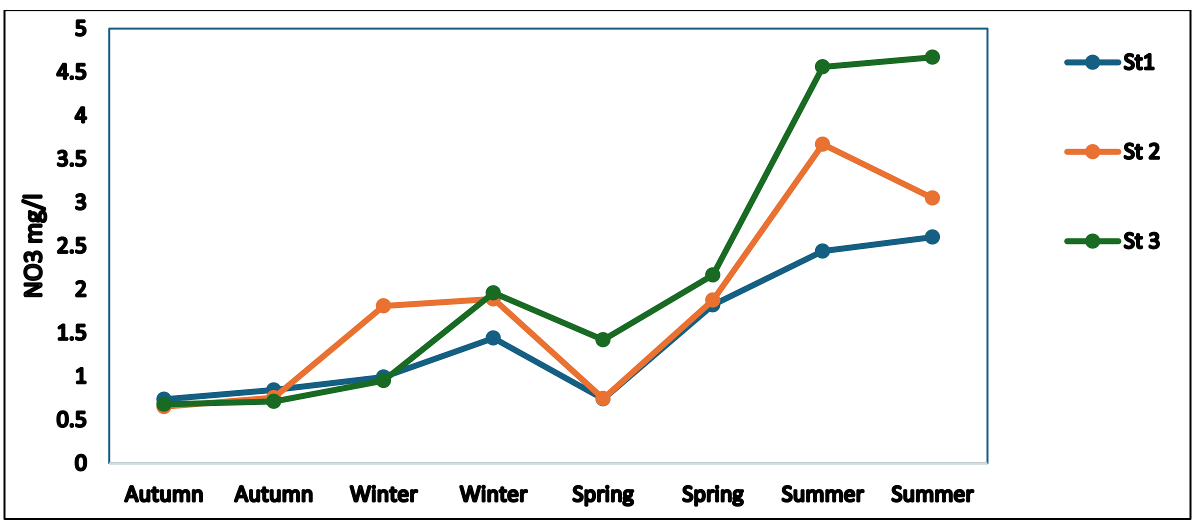

Fig. 6. Seasonal variations in the nitrate values for the study stations during 2024-2025

The data demonstrate a clear positive correlation between nitrate concentrations and zooplankton density across all stations and seasons. The highest zooplankton densities were observed during the spring season, coinciding with increased nitrate concentrations. Specifically, Station 3 recorded the peak density at 1644.01 individuals/m³, with a nitrate concentration of 2.166mg/ L. This pattern suggests that nitrate availability, as a vital nutrient, contributes to the stimulation of phytoplankton growth, which represents the fundamental food source for zooplankton.

Previous studies have shown that nitrate, being an essential macronutrient, significantly enhances primary productivity in aquatic systems **(Wetzel, 2001; Reynolds, 2006)**. Phytoplankton, the primary producers in these ecosystems, rely on nitrate and other nutrients for growth. When nitrate levels are elevated, phytoplankton biomass increases, thereby providing more food for zooplankton **(Smith *et al*., 1999)**. As a result, zooplankton populations flourish in response to this enhanced food availability, particularly under favorable environmental conditions such as those observed in spring.

Conversely, the lowest zooplankton densities were recorded during autumn, which also coincided with the lowest nitrate concentrations. This reduction is likely due to limited primary productivity caused by nutrient scarcity, resulting in decreased food availability for zooplankton **(Jeppesen *et al*., 2005)**.

Therefore, the observed seasonal variations in zooplankton density can be attributed to fluctuations in nitrate levels, which play a fundamental role in shaping the structure and productivity of aquatic food webs.

The analysis of phosphate (PO_4^{3-}) concentrations revealed a noticeable variation across seasons and stations. The highest concentrations were recorded during the winter season, peaking at Station 3 with a value of 16.191mg/ L, while the lowest concentration was observed in the spring at Station 1 (1.009mg/ L). Statistical analyses indicated that the differences in phosphate concentrations among seasons and stations were significant at $P \leq 0.05$ level (Fig. 7).

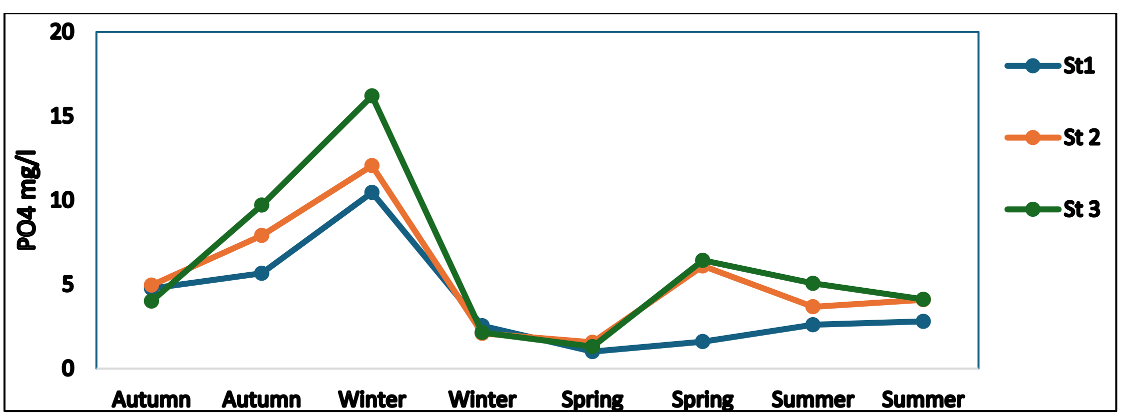

Fig. 7. Seasonal variations in the phosphate values for the study stations during 2024-2025

In comparison with zooplankton density, spring exhibited the highest abundance, particularly at Station 3 (1644.01 individuals/m³), despite the observed decline in phosphate concentrations during this season. Conversely, the elevated phosphate levels recorded in winter did not correspond with similarly high zooplankton densities. This indicates that the relationship between phosphate and zooplankton abundance is not linear and may be modulated by other environmental factors such as nitrate availability, temperature, and light intensity **(Hammadi, 2019)**. Phosphate (PO_4^{3-}) is a critical macronutrient for phytoplankton growth, serving as a key component in nucleic acids and energy transfer molecules like ATP **(Reynolds, 2006)**. However, the presence of phosphate alone may not be sufficient to drive primary productivity if other limiting factors—such as nitrogen availability—are not met **(Smith, 1998)**. The low zooplankton densities in winter, despite high phosphate concentrations, may be attributed to reduced temperatures and lower solar irradiance, both of which can limit phytoplankton photosynthetic activity and thus reduce the food available for zooplankton **(Sommer *et al*., 1986)**. Moreover, nutrient co-limitation is a common phenomenon in aquatic ecosystems, where the simultaneous availability of nitrogen and phosphorus is often required to support optimal algal growth **(Elser *et al*., 2007)**. Therefore, the peak zooplankton densities in spring could be the result of favorable nitrate levels combined with optimal temperature and light conditions that collectively enhanced phytoplankton productivity **(Maytham *et al*., 2019)**.

These findings underscore the complexity of nutrient-dynamics and food-web interactions in aquatic systems. While phosphate is essential for primary production, its effect on higher trophic levels such as zooplankton is mediated by a suite of environmental factors, highlighting the multifactorial nature of ecosystem functioning **(Hammadi, 2019)**.

The results revealed clear variations in zooplankton density across different seasons and sampling stations. Spring recorded the highest overall densities, with a peak at Station 3 reaching 1644.01 individuals/m³, followed by Station 2 with 1458.9 individuals/m³, and Station 1 with 1216.7 individuals/m³. This increase reflects favorable environmental conditions during spring—such as higher temperatures, increased light availability, and nutrient enrichment—that promote the growth of phytoplankton, the primary food source for zooplankton. In contrast, the lowest densities were recorded during autumn, particularly at Station 2 with 67.42 individuals/m³, indicating less favorable conditions for zooplankton growth and reproduction during this season. Statistical analyses confirmed the presence of significant differences in zooplankton density among seasons and stations ($P \leq 0.05$), highlighting the substantial influence of temporal and spatial factors on the distribution and abundance of zooplankton within the aquatic ecosystem **(Hammadi *et al*., 2024a)** (Fig. 8).

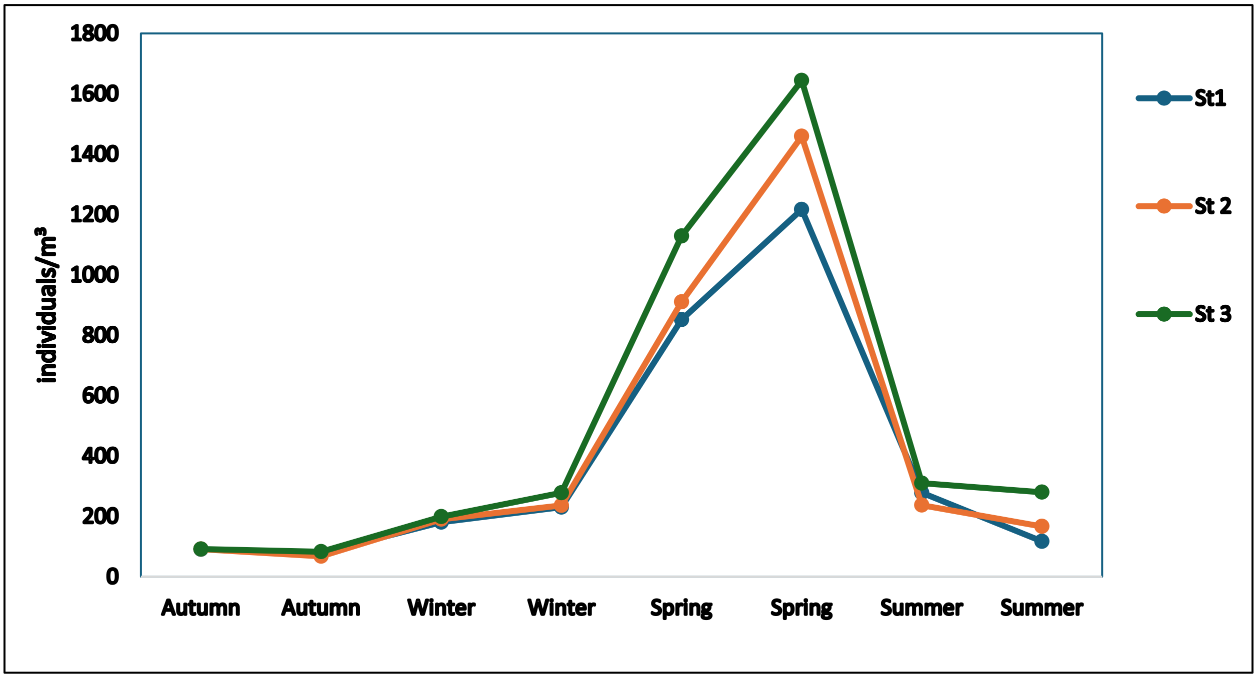

Fig. 8. Seasonal variations in the zooplankton density values for the study stations during 2024-2025

The zooplankton density data in the Shatt Al-Arab Canal shows a clear seasonal variation, with the highest densities recorded in spring, followed by winter and summer, and the lowest densities observed in autumn. When compared with global studies, it is evident that zooplankton densities in aquatic systems vary widely depending on the environment, biodiversity, and water conditions **(Dodson *et al.*, 2000; Wetzel, 2001)**. In freshwater bodies of moderate to high quality, zooplankton densities typically range between 100 and 2000 individuals per cubic meter (ind./m^3), placing the recorded values from the Shatt al-Arab within this range, especially during spring, which indicates a relatively productive aquatic environment **(Carpenter *et al.*, 1985)**.

These results align with local studies conducted in the Shatt al-Arab, such as the work of **Maytham *et al.* (2019)**, who documented seasonal variations in zooplankton communities in the middle part of the Shatt al-Arab River, noting fluctuations in species composition and abundance influenced by environmental factors like temperature and nutrient availability. These studies linked the increased zooplankton densities to enhanced phytoplankton productivity, the primary food source for zooplankton, reflecting the trophic relationships in the aquatic ecosystem **(Hammadi, 2019)**.

Environmental factors such as temperature, salinity, and nutrient availability play a crucial role in determining zooplankton density and distribution **(Bellinger & Sigee, 2010)**. Elevated temperatures in spring stimulate metabolic activity and reproduction in zooplankton, while increased salinity during certain seasons may reduce biodiversity and density **(Kefford *et al*., 2004)**.

Therefore, the recorded values in the Shatt al-Arab Canal are reasonable and consistent with global and environmental standards for similar aquatic systems. Continuous monitoring of seasonal changes and human activities impacting these communities is essential to ensure the sustainability of the ecosystem in the region.

CONCLUSION

Based on the current findings, it can be concluded that:

1. Seasonal environmental factors had a significant impact on zooplankton density. The highest densities were recorded in spring, particularly at Station 3, due to moderate temperatures, increased solar radiation, and nutrient enrichment that enhanced primary productivity.

2. A strong positive correlation was identified between nitrate concentrations and zooplankton density. Elevated nitrate levels promoted phytoplankton growth, the primary food source for zooplankton, resulting in higher zooplankton abundance.

3. Phosphate concentrations did not exhibit a direct relationship with zooplankton density. Despite high phosphate levels during winter, zooplankton density remained low, indicating that other environmental factors such as temperature and light intensity play a more critical role in regulating productivity.

4. Zooplankton density in the Kiteiban Canal was generally higher than at Station 1 across most seasons. Station 3, located at the Canal's entrance, recorded the highest density of 1,644.01 individuals/m³ in spring, compared to 1,216.7 individuals/m³ at Station 1, reflecting more favorable ecological conditions within the Canal.

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