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The Effect of Temperature on Primary Productivity of Phytoplankton Khor Al-Zubair Lagoon in Basra City, Iraq

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ABSTRACT

This study aimed to assess the effect of temperature on the primary productivity of phytoplankton in the waters of Khor Al-Zubair lagoon in Basra City, Iraq, through a seasonal analysis of two stations. Environmental factors such as water temperature, permeability, salinity, pH, nitrates, and phosphates were measured. In addition, chlorophyll *a* along with primary productivity were evaluated using light and dark bottles.The results indicated that temperature had a greater impact on primary productivity than other environmental factors, particularly nitrates and phosphates, which were abundantly available in the study area. The highest productivity values were observed during the moderate climate of spring and autumn seasons, with the spring season recording the peak productivity values of 309.37 and 437.5mg C/m³/h for the first and second stations, respectively. The first station was classified as nutrient-rich, while the second station was identified as nutrient-limited during the spring phytoplankton bloom, based on chlorophyll a concentrations.

INTRODUCTION

Phytoplankton, the most important primary producers in marine ecosystems, play a crucial role in carbon sequestration and oxygen production in the global ocean **(Tao *et al.*, 2020)**. The productivity of phytoplankton is highly sensitive to temperature, with both positive and negative effects reported in various studies **(Cabrerizo *et al.*, 2021)**. For instance, slight increases in temperature can enhance phytoplankton growth, as higher temperatures can accelerate cellular processes and enzyme activity **(Sigman *et al.*, 2012)**. However, beyond an optimal range, elevated temperatures may negatively impact primary productivity by reducing photosynthetic capability, increasing respiration rates, and causing cellular damage. Additionally, temperature interacts with nutrient limitations and light intensity to further influence phytoplankton productivity **(Zhang *et al.*, 2018)**.

Overall, the relationship between temperature and phytoplankton primary productivity is complex and depends on the specific species involved and their environmental conditions

(Shimada *et al*., 2023). Temperature effects can be both positive and negative **(Yvon *et al*., 2015)**. Primary productivity in marine phytoplankton is regulated by several key environmental factors, particularly light, temperature, nutrients, and salinity. Extremes in these factors significantly affect primary productivity and, consequently, the biology and chemistry of aquatic ecosystems **(Parsons & Takahashi, 1973)**. In open ocean areas, rising water temperatures due to global warming can alter the timing and intensity of blooms, impacting the survival and hatching of commercial species **(Koeller *et al*., 2009)**.

The Arabian Gulf, in particular, remains one of the least studied areas regarding primary production, partly due to logistical challenges and the fragmented stewardship of different countries over various regions. Understanding biological productivity in this zone is crucial not only for economic interests but also in light of global changes. Rising sea surface temperatures, salinity, and light availability, driven by increased human activity, pose potential risks to phytoplankton production, which could serve as indicators of broader ecological changes **(Qurban, 2019)**. Furthermore, the Arabian Gulf faces significant environmental challenges, including climate change, which leads to extreme sea-surface temperatures, marine acidification, and rising sea levels **(Naser, 2014)**.

The objective of the present study was to investigate the dynamics of phytoplankton blooms and their associated diversity in the Al-Zubair lagoon system, focusing on environmental factors, particularly temperature, during different seasons and the ranges of primary production in this region.

MATERIALS AND METHODS

Description of study area

Khor Al-Zubair, a sprawling lagoon situated along the southern coast of Iraq, has long been a focal point of interest for researchers and environmental enthusiasts alike. This unique ecosystem, nestled between the Arabian Gulf and the Mesopotamian marshlands, represents a remarkable confluence of terrestrial and aquatic systems, offering a glimpse into the intricate balance that sustains life in this arid region. At the heart of this lagoon lies a complex tapestry of physical, biological, and socioeconomic factors that have shaped its evolution over time, with profound implications for the local population and the broader ecological landscape **(Al-Handal & Al-Rekabi, 1994)**. .

Khor Al-Zubair is located in southern Iraq, west of the city of Basra, between the 50′ longitude. It is one of the important bodies of water that overlooks 29' and 23' and two latitudes 58'northwest of the Arabian Gulf, which constitutes a waterway for maritime navigation, and is a suitable environment for the presence of many living organisms. The lower approaches to the creek are situated near the Kuwaiti island of Warba, approximately 8km southeast of Umm Qasr City. The total length of the canal is 40km, with a width ranging from 1km. The navigation channel reaches a depth of about 20m during the highest tide. Khor Al-Zubair is influenced by a tidal current system, covering an area of approximately 60km² **(Al-Ramadan, 1986)**. The prevailing tides in the northwest Arabian Gulf have an average speed of 0.9 to 1.09m/s, resulting in a mixed tidal system dominated by semi-daily tides and characterized by strong flow, reaching speeds of up to 1.28m/s.

Two stations were selected for the study. The first station is located at the beginning of the lagoon (30°19'21" N, 47°49'7" E), which receives water from the Shatt al-Basra Canal, known for discharging agricultural drainage and sewage. The second station is about 12 kilometers from the first, opposite the port of Khor Al-Zubair (30°19'49" N, 47°88'93" E), where it is influenced by marine water. Samples were collected during the low tide periods in autumn and winter of 2023, and spring and summer of 2024.

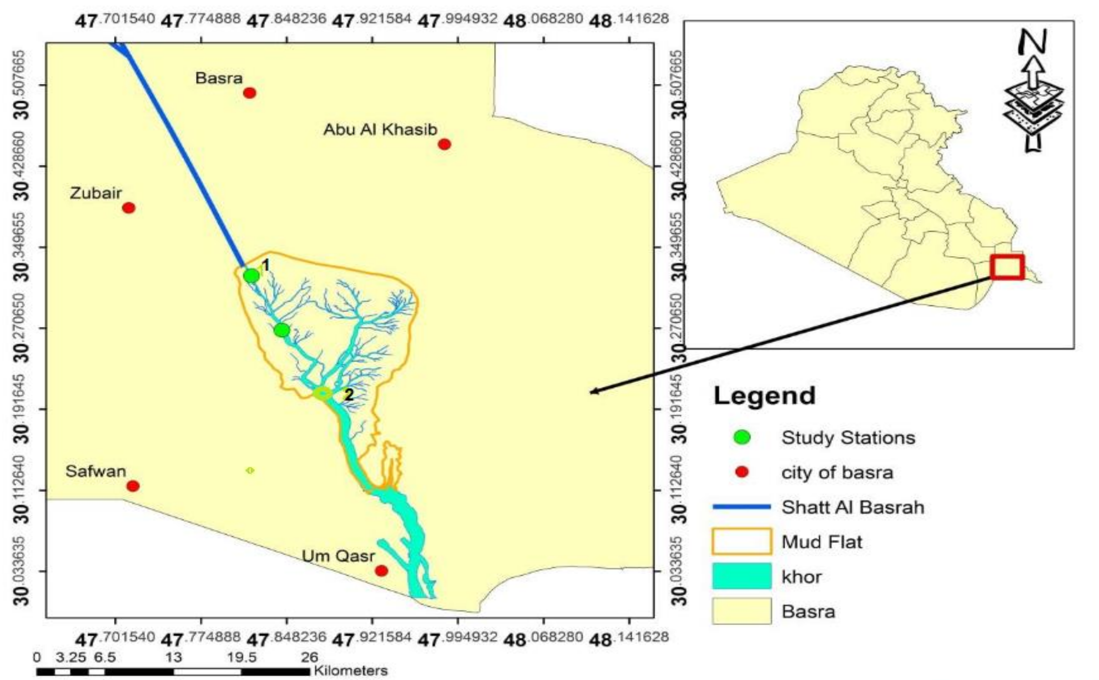

Fig. 1. Map of the study area showing the stations in Khor Al-Zubair lagoon

Ecological measurements

Some environmental factors were measured, including water temperature, transparency (m), salinity (ppt), pH, PO_4(mg/L), NO_3(mg/L), chlorophyll *a* (mg/m^3), moreover the light and dark bottles method was used to determine primary productivity **(APHA, 2005**). The equation below was used to determine primary productivity:

$$P.P \text{ mg C } m^{-3}. hr^{-1} = (L – D / T) X 0.375 X 1000$$

Where:

P.P = Primary Productivity

L = light bottle

D= dark bottle

T=time (hours)

0.375= from conversion oxygen to carbon 12/32

RESULTS

There is a clear seasonal variation in water temperatures in the study area, as the lowest in the winter was 15.1ºC at the second station, while the highest in the summer was 32.5ºC at the second station (Fig.2).

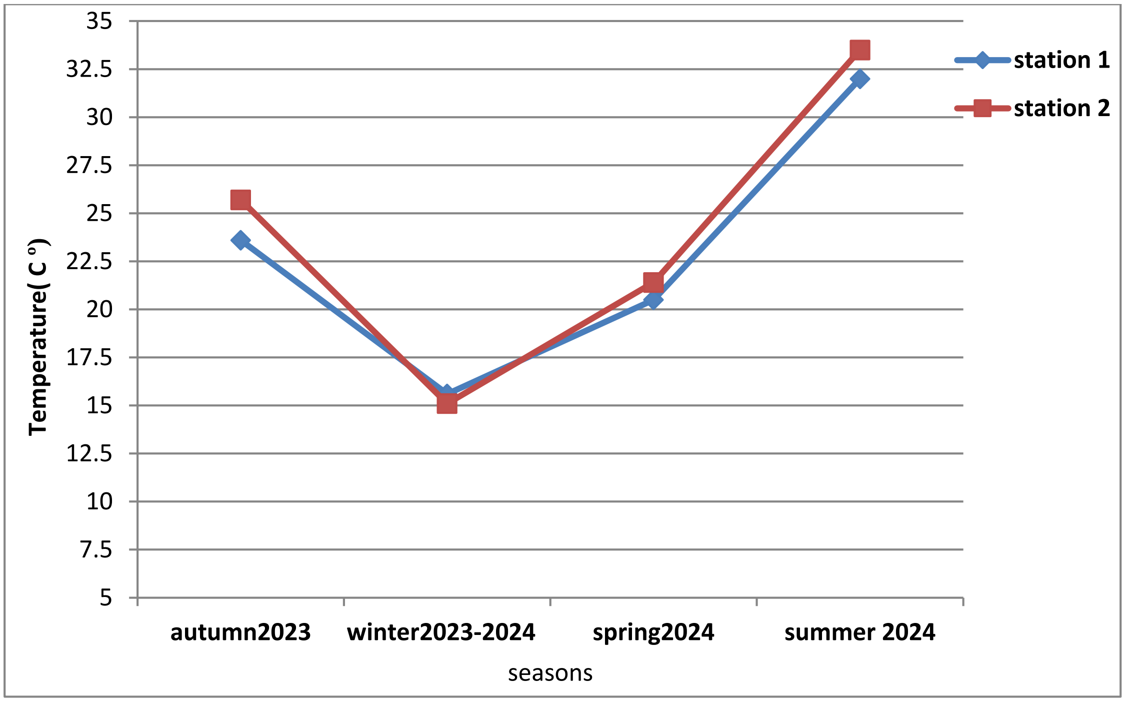

Fig. 2. Seasonal variations of water temperatures at the two stations under study

Fig. (3) illustrates the seasonal transparency limits for the two stations, ranging from 0.4 to 0.85 meters. The lowest transparency was recorded at the first station in spring, measuring 0.4 meters, while the highest transparency of 0.85 meters occurred in summer at the second station.

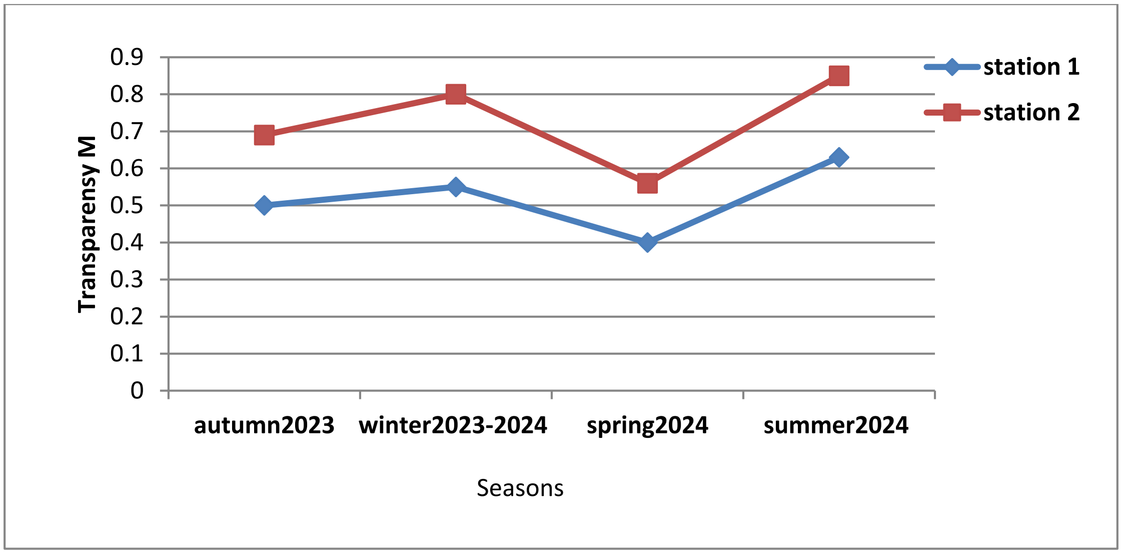

Fig. 3. Seasonal changes in light transmittance at the two study stations

Nutrient concentrations were variable between locations and sampling times (Figs. 4, 5). Nitrates recorded a range of 0.8-4.6mg/ L in the spring and summer, respectively, while the first station recorded higher concentrations of phosphate compared to the second station throughout all seasons, with a range of 2.2- 6.3mg/ L and 1.2-4.1mg/ L, respectively.

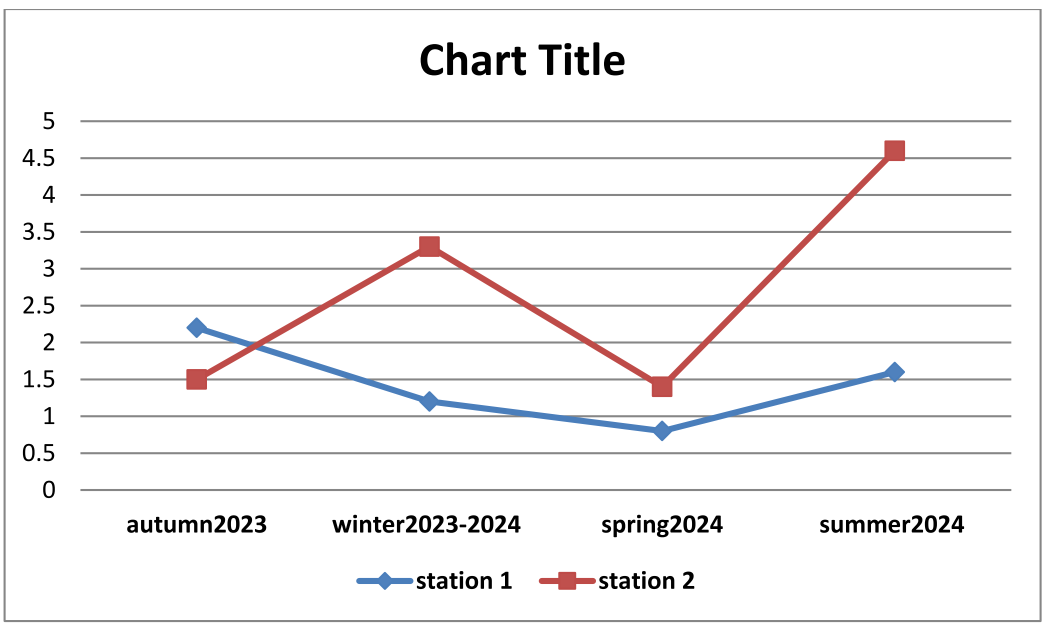

Fig.4. Seasonal variations of nitrate concentrations at the two study stations

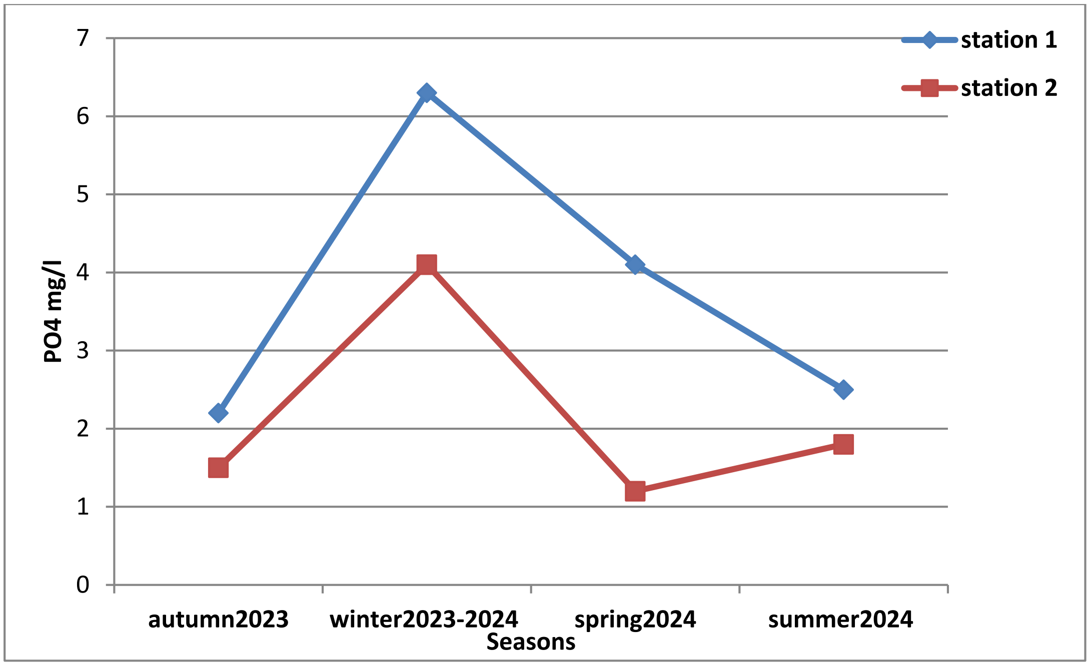

Fig. 5. Seasonal variations of phosphate concentrations at the two study stations

The readings of chlorophyll *a* concentrations agree with the primary productivity values in the stations, as the first station recorded the highest chlorophyll measurements with a range of 3.41 - 12.34mg/m^3 and productivity with a range of 250 - 609.37mg C/m^3/h in the summer and spring, respectively, compared to the second station, which recorded low values. In summer, chlorophyll concentrations ranged from 0.43 to 7.4mg/m^3, while productivity values varied from 62.5 to 250mg C/m^3/h during spring (Figs. 6 and 7).

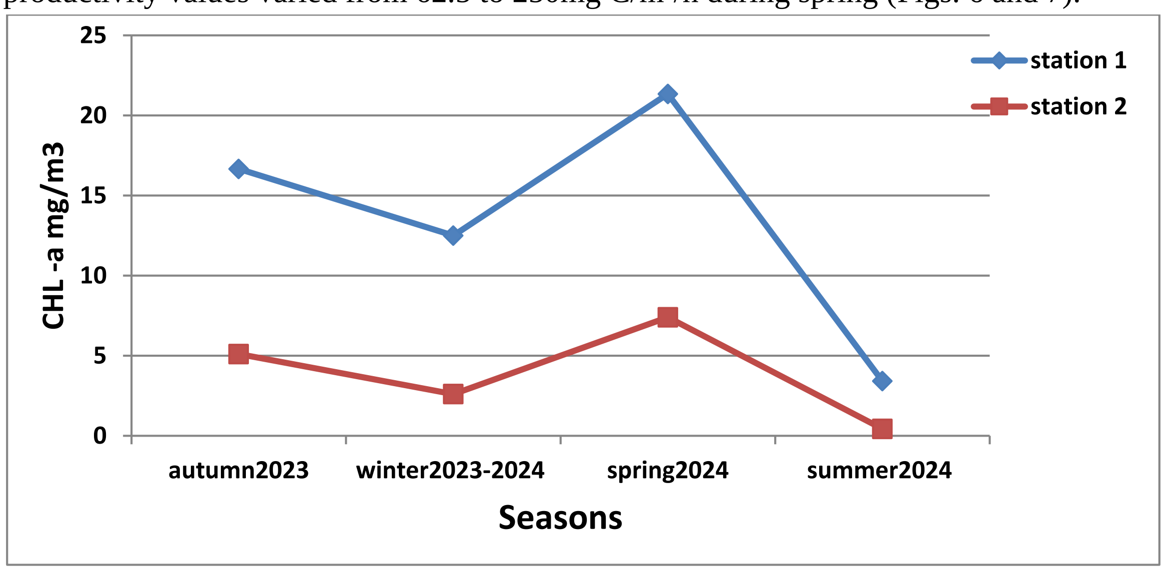

Fig. 6. Seasonal variations of chlorophyll *a* concentrations at the two study stations

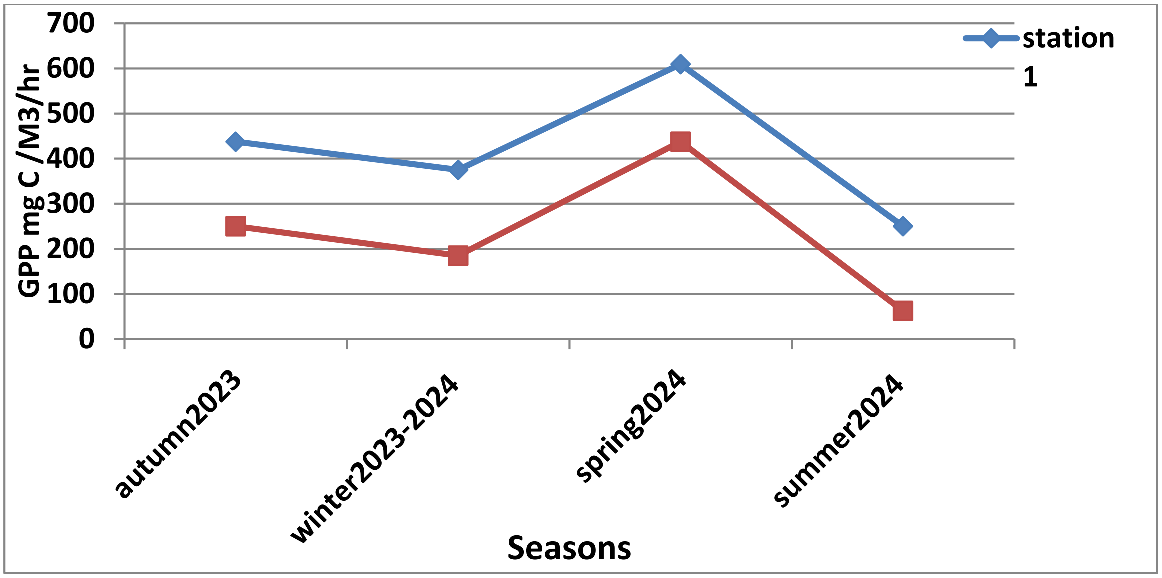

Fig. 7. Seasonal variations in primary productivity values of phytoplankton at the two study stations

Tables (1, 2) illustrate additional environmental factors such as salinity, pH, and oxygen levels. The second station exhibited the highest salinity concentration at 50ppt, whereas the first station recorded the highest pH value of 8.2. Additionally, the lowest oxygen concentration was found at the first station, measuring 4mg/L.

Table 1. Seasonal changes in salinity, pH and oxygen values at the first station

Season	**Salinity ppt**	**pH**	**Oxygen mg/L**
Autumn 2023	45	8.6	4.5
Winter 2023-2024	42	8.2	6
Spring 2024	41	8.4	6.5
Summer 2024	45	8.8	4

Table 2. Seasonal variations of salinity, pH and oxygen values at the second station

Season	**Salinity ppt**	**pH**	**Oxygen mg/L**
Autumn 2023	49	8.2	6.5
Winter 2023-2024	46	8.3	6.5
Spring 2024	45	8.3	7.5
Summer2024	50	8.4	6

DISCUSSION

Lagoons, like Khor Al-Zubair, experience significant environmental changes due to their connections to both seawater and freshwater sources. This lagoon connects to the Arabian Gulf with a discharge of 10,000m³/s while also receiving water from the Shatt al-Basra Canal and sewage drainage from Basra, contributing an additional 200m³/s **(Moran-Silva *et al.*, 2005)**.

Temperature plays a crucial role in these ecosystems, directly influencing the growth, distribution, and proliferation of aquatic organisms **(Mouillote *et al.*, 2005)**. In this study, water temperatures were higher than values recorded in previous research **(Al-Handal & Al-Rekabi, 1994; Hussein *et al.*, 2010; Al-Shaheen & Abdullah, 2022)**.

The findings indicated that temperature significantly affected phytoplankton primary productivity, with a peak productivity occurring during the moderate climates of spring and autumn, particularly in spring when blooms were evident at both stations. Conversely, the lowest productivity (437.5-250mg C/m³/h) was recorded during the high summer temperatures (32-32.5ºC). The results suggest that temperatures between 20-25ºC are ideal for phytoplankton growth in this area. Similar observations by **Fernández González and Marañón (2021)** indicated that optimal temperatures for phytoplankton growth ranged from 18-25ºC. At these optimal temperatures, metabolic rates, cellular processes, growth, and reproduction are enhanced, leading to an increased productivity **(Zohary *et al.*, 2021)**.

Nutrients such as nitrogen and phosphorus play a crucial role in regulating the growth, succession, and overall community structure of phytoplankton assemblages in various aquatic ecosystems, including coastal lagoons, lakes, and the open ocean **(Drake *et al.*, 2010)**. Nitrogen and phosphorus availability influence primary production rates, species distribution, and ecosystem structure, and are the major and important nutrients that limit primary production in some marine and estuarine environments **(Browning & Moore, 2023)**.The results showed that the concentrations of nitrate and phosphorus were high during the study seasons when compared to the study of **Al-Yamani (2006)** in the northern Arabian Gulf of the State of Kuwait and the study of **Al-Shawi (2010)** in the same area due to the impact of the discharge of the Shatt al-Basra drainage channel and the sewage water of Basra City, despite the optimum concentrations of these nutrients of 0.09 - 1.8mg/L for phosphorus and 0.9 - 3.5mg/L for nitrate **(Suryadi *et al.*, 2017)**. High productivity and prosperity of phytoplankton were not observed except in the moderate seasons as we explained, i.e. the effect of temperature was greater than the aforementioned nutrients despite their continuous availability throughout the study period. The study also showed a significant decrease in nutrient concentrations during the warm seasons, especially in the spring due to their absorption by phytoplankton, which leads to an increase in their primary productivity compared to the summer and winter seasons (**Effendi *et al.*, 2016)**. There is no clear relationship between primary productivity and nutrients, and the area affected by sewage effluents that have high concentrations of nutrients. Moreover, high salinity values were recorded at both study stations compared to previous studies **(Al-Yamani, 2006; Al-Shaheen & Abdullah, 2022)**.

CONCLUSION

The following important conclusions can be drawn from the effect of temperature on primary productivity in Khor Al Zubair waters:

1. Temperature's Impact: Temperature significantly affects phytoplankton primary productivity, even with adequate nutrient levels.
2. Seasonal Peaks: The highest primary productivity is observed during temperate seasons, particularly in spring and autumn.
3. Optimal Temperature Range: The optimal water temperature for phytoplankton growth is between 20 & 25ºC, which corresponds with peak productivity.
4. Nutrient Status Assessment: The first station is classified as highly nutrient-fed, while the second station is categorized as moderately nutrient-fed, based on chlorophyll *a* concentrations.
5. Comparative Temperature Trends: Current temperature readings are higher than those reported in previous studies in the same region and the broader Arabian Gulf area.

These findings underscore the importance of monitoring temperature and nutrient dynamics to understand and manage the ecological health of the Khor Al-Zubair lagoon.

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REFERENCES

Al-Handal, A.Y. and Al-Rekabi, K.M. (1994). Diatoms of turbid Lagoon in the North-West Arabian Gulf. Rivista di Idrobiologia, 33(1/2/3) 17-38.

Al-Ramadan, B. (1986). Introduction to marine physics in Khor Al-Zubair. Classification of Khor Al-Zubair. Proceedings of the first symposium on the marine nature of Khor Al-Zubair: (Publications of the Marine Science Center - University of Basrah, (7): 11-20.

Al-Shaheen, A. and Abdullah, S.(2022). Occurrence of Five Diatom Species in Khor Al-Zubair Lagoon, Southern Iraq with a new record of Cyclotella litoralis Lange & Syvertsen, 1989. Basrah J. Agric. Sci. 35(2).24-33,

Al-Shawi, I. (2010). An environmental and taxonomic study of plankton in Khor Al-Zubair with an estimation of petroleum hydrocarbon levels. PhD thesis,University of Basrah, 148pp.

Al-Yamani, F.; Subba Rao, D.V.; Mharzi, A.; Ismail, W. and Al-Rifaie, K.(2006). Primary Production of Kuwait, an Arid Zone Environment, Arabian Gulf . International Journal of Oceans and Oceanography, pp.27-49

APHA.(American public Health Association) (2005). "Standard methods for the examination of water and waste water" 21st edition. Washington, DC. 1400pp.

Browning, T.J. and Moore, C.M.(2023). Global analysis of ocean phytoplankton nutrient limitation reveals high prevalence of co-limitation. Nature Communications, 14(5014).

Cabrerizo M.J.; Marañón E.; Fernández-. and Aranguren-Gassis M. .(2021). Temperature Fluctuation Attenuates the Effects of Warming in Estuarine Microbial Plankton Communities. Mar. Sci. : 656282.

Cloern, J.E.; Foster, S.Q. and Kleckner, A.E.(2014). Phytoplankton primary production in the world's estuarine-coastal ecosystems. Biogeosciences, 11: 2477–2501.

Colijn, F. and Ludden, E. (1983). Primary production of phytoplankton in the Ems-Dollard Estuary. In Primary production in the Ems–dollard estuary, PhD Thesis University of Rijks/ Groningen pp. 99.

Drake, J.L.; Carpenter, Edward J.; Cousins, Mary and Nelson, K. L. (2010). Effects of light and nutrients on seasonal phytoplankton succession in a temperate eutrophic coastal lagoon. Hydrobiologia 654:177–192 DOI 10.1007/s10750-010-0380-y.

Effendi, H.;Kawaroe, M.;Fauzia, L.D. and Tri, P.M.(2016) Distribution of Phytoplankton Diversity and Abundance in Mahakam Delta, East Kalimantan. Environmental Sciences33: 496-504.

Fernández-González1, C.and Marañón, E.(2021) Effect of temperatureon the unimodal size scaling of phytoplankton growth. Scientific Reports.11:953

Hassan, F. M.; El-Sheekh, M. and Wahhab, T.A.(2023). Environmental factors drive phytoplankton primary productivity in a shallow Lake. Egyptian Journal of Aquatic Biology & Fisheries, 27(2): 1 – 12

Hussein, S.A.; Al-Shawi, I.J. and Abdullah, A.M. (2010). The impact of some environmental characteristics on the qualitative composition of phytoplankton and copepods community in the Khor Al-Zubair - North West Arabian Gulf. Basrah Journal of Science, 28(2): 155-177.

Koeller, P.; Fuentes-Yaco, C.; Platt, T.; Sathyendranath, S.; Richards, A.; Ouellet, P.and Orr, D. (2009). Basin-scale coherence in phenology of shrimps and phytoplankton in the North Atlantic Ocean. Science, 324: 791–793.

Moran-Silva, A.; Franco, L.; Chavez-Lopez, R.; Franco-Lopez, J.; Bedia, S. ;Espinosa, F.C.; Mendicta, F.G. ; Brown, P.N. and Peterson, M.S. (2005).Seasonal and spatial pattern in salinity, nutrients and chlorophyll a in the Alvarado lagoon system,Veracruz, Mexico. Gulf and Caribbean Research, 17: 133-143.

Mouillote, D.; Gaillard, S.; Aliaume, C.; Veriaque, M.; Belsher, T.; Troussellier, M. and Chi, T.D.(2005). The ability of taxonomic diversity indices to discriminate coastal Lagoon environments based on macrophytes communities. Ecological Indicators, 5(1): 1-17.

Naser, H.A.(2014). Marine Ecosystem Diversity in the Arabian Gulf: Threats and Conservation.Biodiversity - The Dynamic Balance of the Planet: https://www.researchgate.net/publication/262344502

Qurban, M.A. (2019).Primary production in the Saudi coastal waters of the Arabian Gulf. Marine Pollution Bulletin. 146: 417-426.

Parsons, T.R. and Takahashi, M.(1973) Environmental control of phytoplankton cell size. Limnol. Oceanogr.18: 511-515.

Sigman, D.M. and Hain, M.P. (2012) The Biological Productivity of the Ocean. Nature Education Knowledge 3(10):21.

Shimada, Y.; Sawai, Y; Matsumoto, D.; Tanigawa, K.;Kazumi, T.;Yuichi, N.M.; Shishikuraand, S.(2023). Marine inundation history during the last 3000 years at Lake Kogare-ike, a coastal lake on the Pacifc coast of central Japan. Progress in Earth and Planetary Science 10:49 https://doi.org/10.1186/s40645-023-00577-9.

Suryadi, R.; Ghulamahdi, M. and Kurniawati, A.(2017). Nitrogen and phosphorus fertilization to improve growth, seed production and thymoquinone content of black cumin. Buletin Penelitian Tanaman Rempah dan Obat / Bulletin of Research on Spice and Medicinal Crops.28(1);15-28.

Tao, W.; Niu, L.; Liu, F.; Cai, H.; Ou, S.; Zeng, D. and Lou, Q. (2020).Influence of river-tide dynamics on phytoplankton variability and their ecological implications in two Chinese tropical estuaries. Ecological Indicators**.115 :**106458https://www.sciencedirect.com/science/article/abs/pii/S1470160X20303952

Thomas, J. and Moore, C.(2023). Global analysis of ocean phytoplankton nutrient limitation reveals high prevalence of co-limitation. Nature Communications14:5014

Wetzel, R. G. (2001) Limnology Lake and River Ecosystems.Book.p1006.

Yvon-Durocher, G.; Allen, A.; Cellamare, M.; Dossena, M.; Gaston, K.J.; Leitao, M.; Montoya, J.M.; Reuman, D.C.; Woodward, G. and Trimmer, M. (2015). Five Years of Experimental Warming Increases the Biodiversity and Productivity of Phytoplankton.Plos Biology.p1-22.https://doi.org/10.1371/journal.pbio.1002324

Zhang, C.;Gao,H. ;Yao, X. ;Shi, Z. ;Shi, J. ;Yu, Y. ;Meng, L. and Guo, X.(2018). Phytoplankton growth response to Asian dust addition in the northwest Pacific Ocean versus the Yellow Sea. Biogeosciences, 15:749–765, https://doi.org/10.5194/bg-15-749-2018

Zohary, T.; Flaim, G. and Sommer, U. (2021). Temperature and the size of freshwaterphytoplankton. Hydrobiologia, 848:143–155. https://doi.org/10.1007/s10750-020-04246-6