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Evaluation of the Level of Phytoplankton Primary Productivity in the Karmat Ali River, Southern Iraq

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Abstract - The study of primary productivity in the Karmat Ali River in the southern Iraq, is the first study that addressed this topic, which aimed to evaluate the level of primary productivity in that area by identifying four sites along the river, namely (Al-Najibiya, Al-Mashhab , Al-Nagara and Al-Salal). Samples were collected seasonally starting from Winter until Autumn from year 2022, with reference to some environmental factors that may affect the values of primary productivity. The results of the study showed that the lowest level of primary productivity was in the Summer at site Al-Najibiya, as it reached 25.5 mg Carbon/m3 .hr., while its highest level appeared during the Spring at site (Al-Mashhab), as it reached 342.18 mg Carbon/m3.hr., while the temperature ranged between 11.8-33.4 C; salinity between 2.6-9.5 ppt , pH 7-8.6 , dissolved oxygen 1.6-15.5mg/l , turbidity 1.3-33.5NTU , reactive phosphate 0.01-0.21 mg/l, reactive nitrate 0.32-19.9mg/l , and as for the biomass represented by chlorophyll-a-, it ranged between 7.3-39.32mg/m3. The results also showed, through canonical correspondence analysis (CCA), that primary productivity values were closely related to chlorophyll a values, while turbidity was in the opposite direction.

تقييم مستوى الإنتاجية الأولية للهائمات النباتية في نهر كرمة علي - جنوب العراق

عقيل عبد الصاحب عبدا لحسين الوائلي

قسم الاحياء البحرية، مركز علوم البحار، جامعة البصرة، البصرة، العراق.

المستخلص - تعد دراسة الإنتاجية الأولية في نهر كرمة على جنوب العراق، الدراسة الأولى من نوعها التي تناولت هذا الموضوع، والتي هدفت إلى تقييم مستوى الإنتاجية الأولية في تلك المنطقة من خلال تحديد أربعة مواقع على طول النهر، وهي (النجيبية، والمسحب، والنكارة، والصلال)، حيث تم جمع العينات موسمياً ابتداءً من فصل الشتاء وحتى خريف عام 2022، مع الإشارة إلى بعض العوامل البيئية التي قد تؤثر على قيم الإنتاجية الأولية. وأظهرت نتائج الدراسة أن أدنى مستوى للإنتاجية الأولية ظهر في فصل الصيف في موقع النجيبية حيث بلغ 25.5 ملغم كربون/م^3 ساعة، في حين ظهر أعلى مستوى لها خلال فصل الربيع في موقع المسحب حيث بلغ 342.18 ملغم كربون/م^3 ساعة، في حين تراوحت درجة الحرارة بين 11.8 – 33.4 م°، والملوحة بين 2.6- 9.5 ملغم/لتر، والاس الهيدروجيني pH 7- 8.6 والأكسجين الذائب 1.6 – 15.5 ملغم/لتر، والعكارة 1.3 – 33.5 NTU، والفوسفات 0.01 - 0.21 ملغم/لتر والنترات 0.32 – 19.9 ملغم/لتر، أما الكتلة الحيوية المتمثلة بالكلوروفيل- أ- فقد تراوحت بين 7.3 – 39.32 ملغم/م^3 ، وأظهرت النتائج أيضًا، من خلال تحليل المراسلات الكنسي CCA أن قيم الإنتاجية الأولية كانت مرتبطة ارتباطًا وثيقًا بقيم الكلوروفيل أ، في حين كانت العكارة في الاتجاه المعاكس لها.

الكلمات المفتاحية: الإنتاجية الأولية، الهائمات النباتية، نهر كرمة علي، الكتلة الحية، جنوب العراق

Introduction

The Karmat Ali River is one of the main pillars of water resources in Basrah Governorate, as it constitutes the lower part of the ancient Euphrates River. It has great importance for the residents of the study area, as it is a stage where many different aspects of human activities have been based, especially since the area is located under dry and semi-dry climate conditions (Al-Jamali, 2018).

Primary productivity is one of the basic characteristics of aquatic plants and phytolpankton, through the formation of organic compounds from inorganic materials during the process of photosynthesis (Ervantes *et al*., 2021). Therefore, it is important to study the productivity of phytoplankton to determine the healthy and productivity of any aquatic environment, regardless of its type, because it represents the basic base of the food chains, as zooplankton and small larvae of some fish and invertebrates depend on it, in addition to the dependence of some fish of great economic value on phytoplankton (Kadeem *et al.,* 2021).

Primary production is highly variable and closely linked to the distribution of food materials. Studying primary productivity in the ecosystem is important because it provides information about understanding the energy available in the environment and the nature of its transfer within that system (Mattei *et al*., 2021). As we mentioned earlier, there is no previous study of primary productivity in the Karmat Ali River, the reason may be due to the scarcity of researchers in this field, so we will discuss some studies that determined the level of primary productivity in the Shatt al-Arab River, considering that they are linked to each other near Sinbad Island. Among the studies that showed the value of primary productivity in the Shatt Al-Arab River is the study of Antoine (1983), where he found that the primary productivity ranged between 5.1-37.6 mg C/m^3.hr., and this amount show that the primary productivity is low in the Shatt al-Arab.

Al-Zubaidi (1985) showed that the primary productivity at the sites of Al-Deir and Umm Al-Shuwaik ranged between 98.84-207 mg C/m^3 .hr. and 12.15-212.87 mg C/m^3.hr., respectively. As for Hadi *et al*., (1989), they found that the primary productivity ranged between 24.9-25.6 mg C/m^3.hr. in the Shatt Al-Arab River.

The study of Al-Moussawi (1992) showed that the primary productivity in the Al-Sindebad and Al-Ashar sites was 56.7 and 61.8 6 mg C/m^3.hr. respectively. Jassim (1999) noted that the primary productivity values in the study sites were consistent with the chlorophyll-a-concentration and the total numbers of phytoplankton, the highest value was recorded during the month of April at the Al-Hartha site, which reached 92. 6 mg C/m^3.hr., while the lowest value was recorded in the month of July, reaching 28.2 6 mg C/m^3 .hr. at the Al-Hartha site as well.

Al-Essa *et al*. (2007) explained the seasonal changes in the primary productivity of phytoplankton in the northern part of the Shatt Al-Arab River and the effect of some physical and chemical factors on it. This was done by selecting three study sites, namely Al-Deir, Al-Haritha and Sinbad, and they noted that the lowest rate of primary productivity was recorded during the summer and the highest rate during the spring. Hassan *et al*., (2011) noted in their study on the southern marshes that the primary productivity rate ranged between 9.38-249.79 mg C/m^3 .hr. Al-Waeli and Al-Athbi, (2020) noted that the lowest rate of primary productivity in the Shatt Al-Arab River was 12.49 mg C/m^3.hr. while the highest rate was 274 mg C/m^3.hr.

The study aims to evaluate the environmental reality of the Karmat Ali River waters through the primary productivity index of phytoplankton, with reference to some environmental factors affecting it.

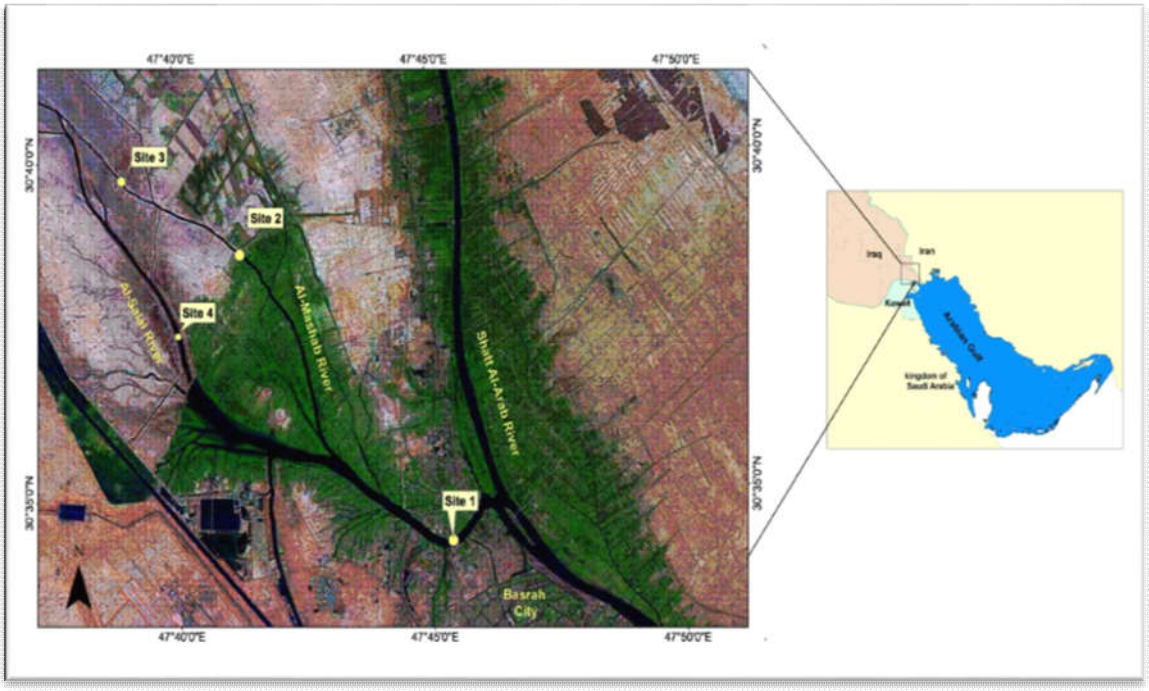
Materials and Methods

Description of the study area

The study area represents the Karmat Ali River, which is approximately 30 km long and is bounded by latitudes (30° 30' - 43' 30') north and longitudes (33° 44' – 46' 44') east. This river is considered a major source of irrigation for the surrounding agricultural lands. This river starts from Sindebad Island in the south and extends until it enters the Hammar Marsh north of Basra city. The average depth of the river is estimated at nine meters, while its width ranges between 250-300 meters (Aldoghachi and Abdullah 2021).

(Table 1) Coordinates of the study sites

Sites	North	East
Al-Najibiya (site 1)	N 30° 34' 15"	E 47° 45' 26"
Al-Mashhab (site2)	N 30° 38' 33"	E 47°41' 21"
Al-Nagara (site3)	N 30° 37' 24"	E 47°40' 02"
Al-Salal (site4)	N 30° 39' 41"	E 47°38' 59"



(Figure 1) Map showing sample collection site

Estimation Primary Productivity of Phytoplankton

The primary productivity rate of phytoplankton in an aquatic ecosystem can be calculated using the dissolved oxygen measurement technique in transparent and opaque bottles (Winkler bottles).

The dissolved oxygen rate in transparent bottles represents net production and respiration, while the dissolved oxygen rate in opaque bottles represents respiration only (Gokce and Altindag 2019).

The transparent and opaque bottles were incubated in the same location from which the bottles were filled and at the same depth by suspending the bottles in a suitable manner using floats prepared for this purpose, taking into account that the incubation site should be far from any source of misleading, the incubation period ranged between (3-4) hours for each site. After the incubation period, the samples were treated in the same way as the dissolved oxygen concentration was measured, the result was extracted according to the equation below after converting the oxygen reading to carbon, which was explained by (Vollenweider *et al*., 2011; Kromkamp *et al.,* 2017; Matthes *et al.,* 2020).

Primary Productivity mg C/ m^3. hr^{-1} = (L – D/ T) * 0.375
L - Amount of dissolved oxygen in light bottles
D - Amount of dissolved oxygen in dark bottles
T - Incubation period in hours
0.375- from conversion of oxygen to carbon 32/12

As for temperature, salinity and pH, were measured directly in the field using a multi-meter equipment, while dissolved oxygen was measured by the well-known method of azide conversion, which was explained by Lind (1979), turbidity was measured using a Hanna instruments and the result was expressed in Nephelometric Turbidity Unit (NTU), Phosphate and Nitrate were determined according to the method described by APHA (2012), the concentration of chlorophyll-a- was estimated based on the Lorenzen equation described by Vollenweider (2011).

Statistical analysis

The statistical program: Statistical Package for Social Science (SPSS) Ver.19 (Al-Rawi and Khalaf Allah, 1980) was used to conduct statistical analysis of the study results through the ANOVA test under the probability level ($P \leq 0.05$) to find the least significant difference (RLSD) between sites and Season. The Pearson Correlation Coefficient (r) was used to find positive and negative correlations between physical, chemical and biological environmental variables, in addition to using the statistical program; Canonical Correspondence Analysis (CCA), which shows the strength of the influence of environmental factors on the presence and spread of phytoplankton that appear or occur more frequently than other species

Results

The results indicated that the primary productivity rate of phytoplankton in all sites ranged between 25.5-342.18 mg C/m^3.hr, with the lowest rate at the Al-Najibiya site during the summer, the Al-Najibiya site also recorded another low value in the Autumn reaching 31.24 mg C/m^3.hr, and the Al- Salal site also recorded a low value in the Autumn reaching 62.5 mg C/m^3.hr, while the Al-Nagara site and Al-Salal site recorded equal average values during the Autumn and winter respectively reaching 150 mg C/m^3.hr. The highest rate of primary productivity of phytoplankton was recorded at Al-Mashhab site during the spring, reaching 342.18 mg C/m^3.hr. High rates were also recorded at Al-Najibiya site during spring reaching 331.49 mg C/m^3.hr. Al-Mashhab site recorded high values that were close to each other in all seasons, and Al-Nagara site recorded high values during the spring, Al-Sala site also recorded high values during the spring Figure 2.

The results of the statistical analysis showed significant differences below the probability level of $P < 0.05$ between some sites and between seasons for the same site.

The results of the statistical analysis of the Pearson correlation coefficient also showed that primary productivity was associated with a weak direct relationship with temperature and salinity

r = 0.353, 0.371 P ≤ 0.01 respectively. As for the correlation with pH, it was a very weak direct relationship r = 0.091 P ≤ 0.01, and the correlation with dissolved oxygen was a medium-strength direct relationship r= 0.488 P ≤ 0.01. As for the correlation between primary productivity and turbidity, phosphate and nitrate, it was an inverse correlation, r = - 0.261 P ≤ 0.01, - 0.461 P ≤ 0.01, - 0.497 P ≤ 0.01 respectively, the correlation between primary productivity and chlorophyll –a- was a strong direct relationship r= 0.736 P ≤ 0.01.

(Table 2) Pearson correlation coefficient (r) between variables at the Garmat-Ali river

Variables	C	Salin.	pH	DO	Tur.	PO_4	NO_3	Chl.a	Pri.Pro.
C	1								
Salin.	0.97	1							
pH	- 0.95	-0.98	1						
DO	- 0.91	-0.92	0.98	1					
Tur.	-0.54	-0.46	0.31	0.14	1				
PO4	0.51	0.69	- 0.7	- 0.65	0.06	1			
NO3	0.95	0.98	- 0.94	- 0.86	- 0.54	0.7	1		
Chla. A	- 0.25	-0.24	0.41	0.59	- 0.62	- 0.23	- 0.1	1	
Pri. Pro.	- 0.55	-0.59	0.73	0.84	- 0.39	- 0.59	- 0.48	0.9	1

As for the environmental factors, the temperature ranged between 11.8-33.4 C° . The lowest temperature appeared during the winter in the Al-Najibiya site, while the highest temperature was recorded during the summer in the same site, through statistical analysis significant differences appeared between the seasons for the same site and between the four seasons Figure 3.

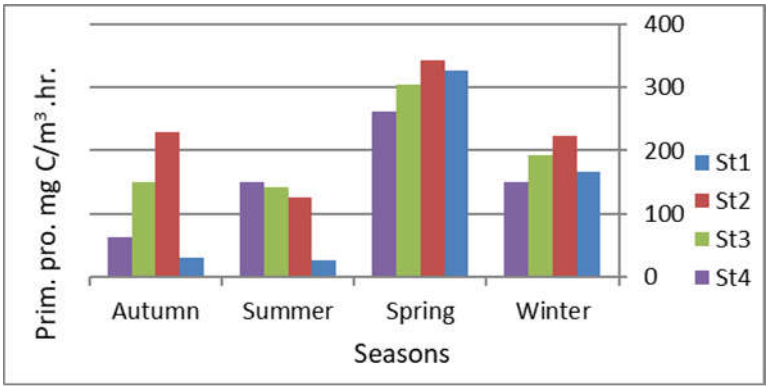
It was noted that the lowest salinity value appeared in the Al-Najibiya site, reaching 2.6 ppt during the spring, and the highest salinity rate appeared in the same site during the summer, reaching 9.5 ppt. The statistical analysis showed significant differences between the sites and seasons Figure 4. As for the pH, its rates were close in all sites and seasons, and no significant differences appeared between them, as they ranged between 7 and 8.6 Figure 5.

As for the dissolved oxygen, its rates ranged between 1.6 -15.5 mg/l. the lowest value appeared during the summer at the Al-Najibiya site, and the highest value appeared during the spring at the Al-Mashhab site, significant differences appeared between some sites and seasons Figure 6.

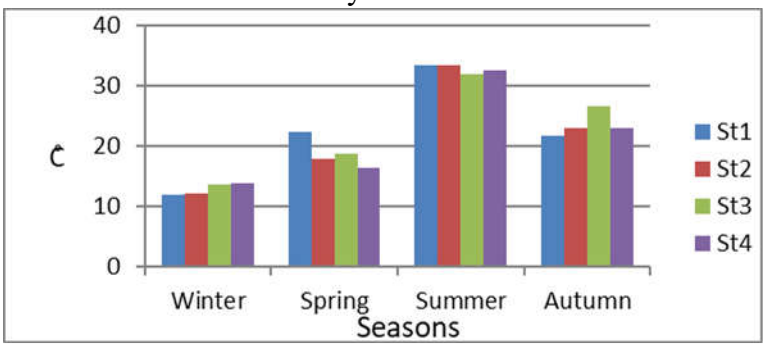
Turbidity rates ranged between 1.3 and 33.5 NTU, it was noted that the lowest rate was recorded during the spring at the Al-Salal site, and the highest rate was recorded at the Al-Nagara site during the winter, the statistical analysis showed significant differences between the seasons for the same site and between the sites Figure 7.

As for phosphate values, they ranged between 0.01-0.21 mg/l, with the lowest value recorded during the spring at Al-Mashhab site and the highest value recorded at Al-Najibiyah site during the summer No significant differences appeared between them Figure 8, while the lowest value for nitrate reached 0.32 mg/l during the spring at Al-Mashhab site and the highest value recorded during the summer at Al-Najibiyah site, reaching 19.9 mg/l, and significant differences appeared between some seasons and sites Figure 9.

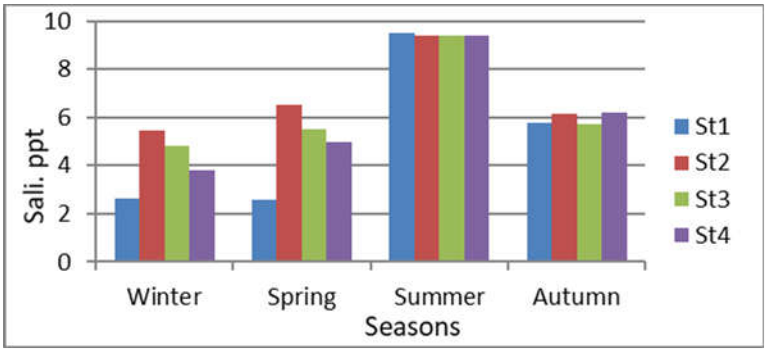
Chlorophyll-a- rates ranged between 7.3-39.32 mg/m^3, and the results showed that the lowest value was recorded during the Autumn at Al-Salal site, while the highest value was recorded during the spring at Al-Mashhab site. It was noted through statistical analysis that there were significant differences between seasons for the same site and between sites Figure 10.



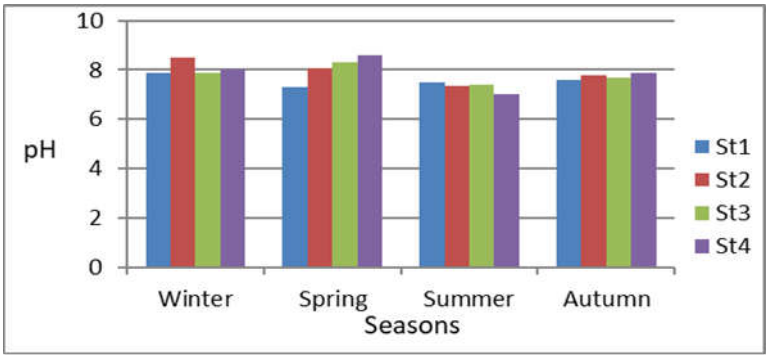
(Figure 2) Seasonally variations in the primary productivity in the Karmat Ali River for the year 2022



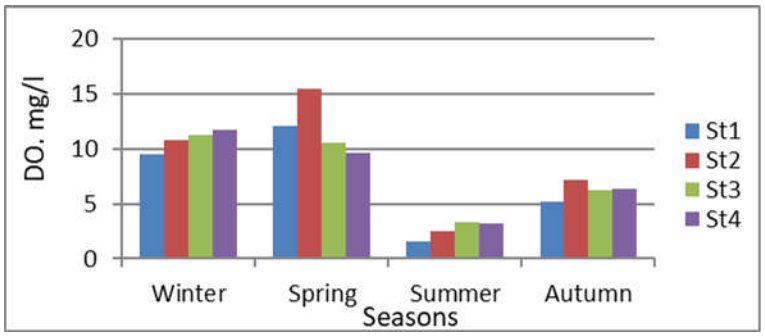
(Figure 3) Seasonally variations in the water temperature in the karmat Ali River for the year 2022



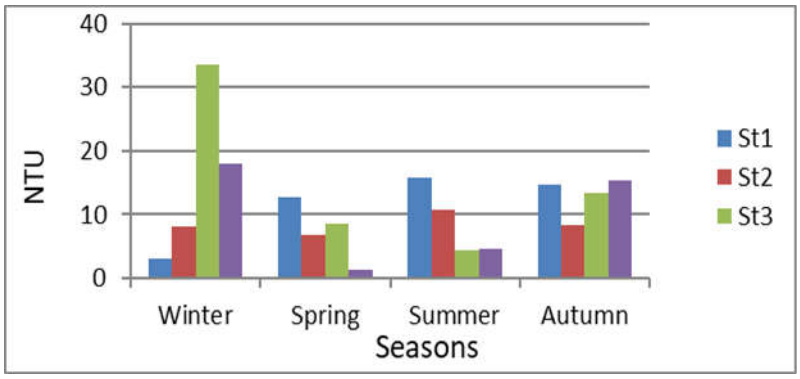
(Figure 4) Seasonal variations of salinity values in the Karmat Ali River for the year 2022



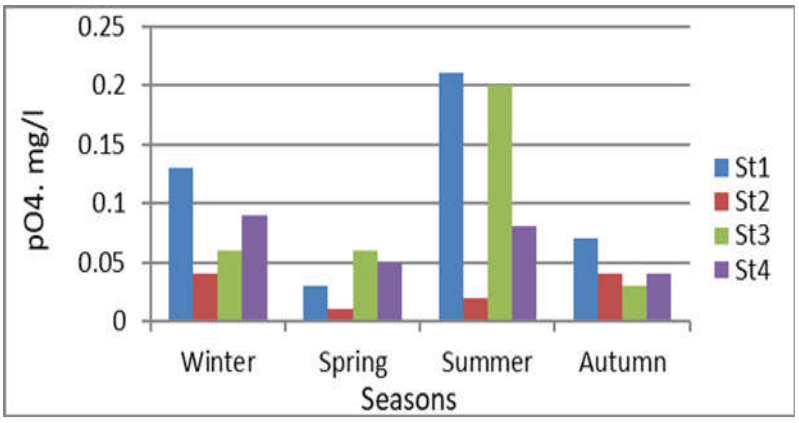
(Figure 5) Seasonally variations in the Hydrogen ion concentration (pH) values in the Karmat Ali River for the year 2022



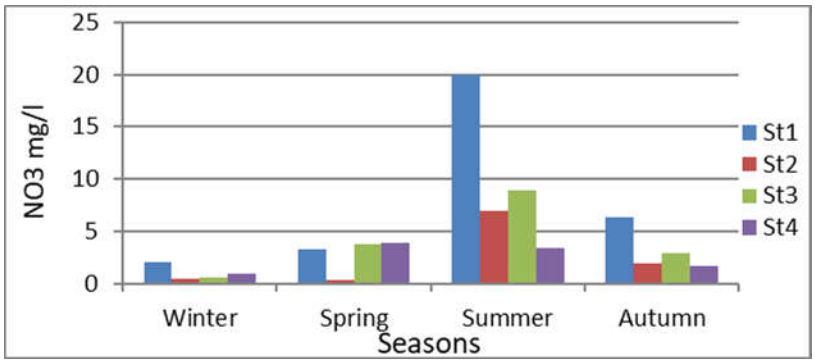
(Figure 6) Seasonally variations in the Dissolve Oxygen values in the Karmat Ali River for the year 2022



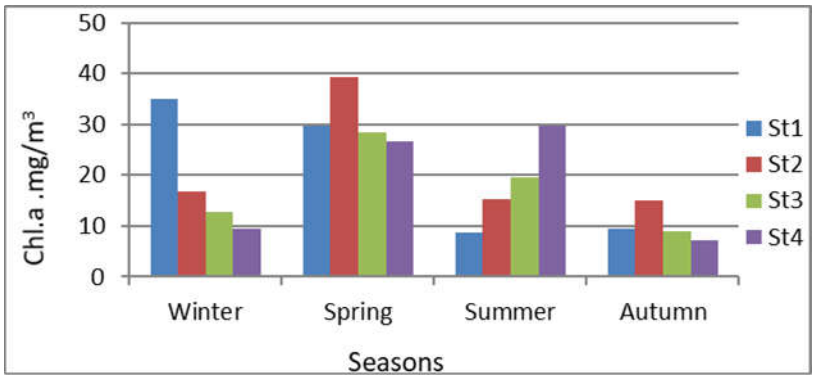
(Figure 7) Seasonally variations in the Turbidity values in the Karmat Ali River for the year 2022



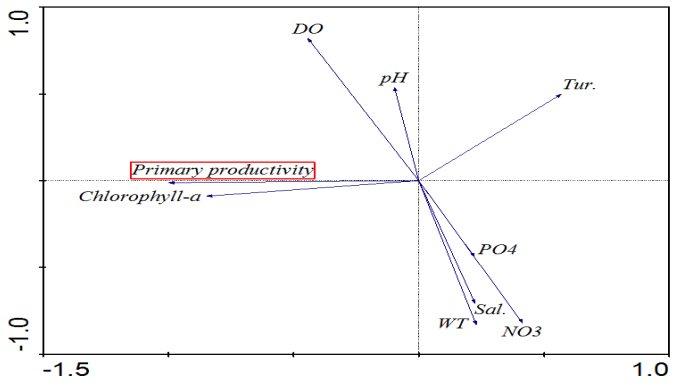
(Figure8) Seasonally variation in the phosphate values in the Karmat Ali River for the year 2022



(Figure 9) Seasonally variation in the nitrate values in the Karmat Ali River for the year 2022



(Figure 10) Seasonally variations in the Chlorophyll -a- values in the Karmat Ali River for the year 2022



(Figure 11) CCA analysis shows the strength of the influence of environmental factors measured during the seasonally study on primary productivity using Canoco statistical program.

Discussion

The primary productivity of phytoplankton in river and estuarine waters is regulated by two factors: nutrient availability and physical properties (Erye, 2000; Erye and Ferguson, 2006; Webster *et al*., 2005). itt was noted from the results shown in figure (2) that the values of primary

productivity were linked to the seasons and their timing in some site, while their rates rose and fell in other site according to the influence of physical and chemical factors that affected the fluctuation of values during the study period.

The results showed that the spring season recorded high values of primary productivity for all sites, indicating that moderate temperatures during the spring, season greatly help in increasing primary productivity values as a result of the flourishing of algae and aquatic plants during this season.

Many researchers have found that water temperature has a significant impact on the primary productivity of phytoplankton in fresh and salt water.

Some studies, such as (Esho and Besson, 1983; Khan and Siddiqui, 1971; Keithan and Lowe 1985), have indicated that primary productivity increases and decreases depending on the increase and decrease in temperature. Perhaps one of the reasons that makes the relationship strong between temperature and primary productivity is the increased ability of algae to reproduce with moderate temperatures as well as the acceleration of the release of nutrient salts from sediments as a result of stimulating bacterial activity, this is consistent with (Al-Zubaidi 1985; Abdullah 1989; Al-Moussawi 1992; Jassim 1999).

When looking at the time aspect, it becomes clear that the increase in primary productivity values in all sites was associated with the spring season, while the low values were associated with the summer and Autumn seasons in some sites, where the highest rates were recorded in the spring season, reaching 342.18 mg/C/m^3.hr, and the lowest rate was recorded in the summer season, reaching 25.5 mg/C/m^3.hr. figure 2. Through a study conducted by Al-Waeli (2021). It was found that the increase in primary productivity values in the spring season is accompanied by an increase in the rate of phytoplankton numbers during the same season, and then this increase was reflected in the increase in primary productivity values.

From Figure (2), it is clear that the Al-Nagara site was more productive in most seasons, and this may provide a biological indicator of the effect of elements and fertilizers flowing from agricultural lands near that site, which may increase the density of phytoplankton, and thus this increase may be reflected in the increase in primary productivity, (Guo, 2020).

The decrease in primary productivity in some site and in some seasons may not be due to high and low temperatures alone, but may be related to other factors such as increased water flow velocity, which in turn leads to destabilization of phytoplankton (Chmyr and Sysoyev, 2004).

As for turbidity, rivers that have long ebb and flow conditions and high turbulent kinetic energy have increased turbidity, so light is a limiting factor for primary productivity and thus the latter has affected the extent of light permeability, which negatively affected the productivity of phytoplankton (Eduardo, 1996; Muylaert *et al*., 2009). Therefore, statistical analysis of the Pearson correlation coefficient showed that the relationship between primary productivity and water turbidity is an inverse relationship.

Pearson's correlation coefficient values showed a strong positive correlation in some locations between primary productivity and chlorophyll-a, and that increasing chlorophyll values indicates an increase in the density of phytoplankton, as estimating chlorophyll is one of the important indicators used to estimate the biomass of phytoplankton in the aquatic environment, and this increase is positively reflected in the values of primary productivity (Omani and Biran, 2003). As for nutrients an inverse correlation was recorded with primary productivity, this is a natural occurrence in the aquatic environment because nutrients are consumed by phytoplankton

It is noted from Figure 11 (CCA) that the relationship between primary productivity and chlorophyll a is a strong relationship, and this is natural because the two variables express the

mass of phytoplankton in the aquatic environment. An increase in one of them is met by an increase in the other, which is a positive direct relationship.

As for the turbidity values, they have moved far away from primary productivity, and an inverse negative relationship appeared between them because the increase in water turbidity reduces the intensity of light penetrating through the water surface. Since light is a determining factor for primary productivity, turbidity plays a major role in the increase and decrease in primary productivity values.

Conclusions

The current study concluded that the primary productivity values were higher compared to the Shatt al-Arab River, which is the last branch of the Shatt al-Arab River. This may be due to the lower levels of pollutants released into the river as a result of its distance from the city center with its high population density, hospitals, hotels, and other factors that increase water pollution, as is the case with the Shatt al-Arab River, in addition to the presence of agricultural lands spread on both banks of the Karmat Ali River, which increases the flow of fertilizers into the river, which helps increase the density of phytoplankton in the study area.

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