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Original Article

Pelagic primary productivity in the Euphrates River, Samawa City, Iraq

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Abstract: This
This study quantified the seasonal primary productivity of the Euphrates River near Samawa City between January and December 2023 by assessing key biological characteristics at three selected sites. Annual productivity estimates ranged from 24925.18 to 58144.01 mg/m²/y. Water quality analysis revealed seasonal fluctuations in dissolved oxygen (4.8-13 mg/l), nitrate (1.84-9.83 µg/l), nitrite (0.08-3.05 µg/l), and phosphate (0.017-0.93 µg/l). Biological indices varied across sites and seasons. Principal Component Analysis (PCA) indicated a moderate positive correlation between phosphate levels and biomass, suggesting a potential influence of phosphate on the river's primary productivity.

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Introduction

The energy flow of the food chain in aquatic environments is supported by phytoplankton, whose net primary production may exceed 50% of the total biosphere (Behrenfeld et al., 2006). This process is known as primary productivity when living organisms use inorganic chemicals to produce basic organic compounds. Photosynthesis is the typical mechanism for this process. The removal of carbon dioxide from aquatic ecosystems is facilitated mainly by phytoplankton (Badger et al., 1998; Hamdan et al., 2018). Gross primary production of an ecosystem (or of a region) is the total biological productivity of that ecosystem (or region). There is a certain mass of organic matter that autotrophs can expend on themselves. Consumers, or heterotrophs, include herbivores and carnivores in every ecosystem. Oxygen and CO_2 uptake are primary productivity measures, and production rates are expressed as grams of organic carbon/m^2/h (Cloern et al., 2014).

The apparent phytoplankton production maximum could represent the potential of a well-acclimated ecosystem to tolerate new environmental conditions. The exponential growth of phytoplankton enables them to react quickly to immediate or indirect changes in their surroundings induced by humankind (Kromkamp et al., 2018). Numerous factors, including variations in hydrology, pollution, nutrient enrichment, and climate change, can influence phytoplankton productivity (Griffiths et al., 2020). Therefore, this signal may act as an early warning of direct food web pressure due to its sensitivity. The primary production is probably the most reliable measure of phytoplankton in an atrophic environment. It demonstrates that higher trophic levels may increase matter flow (Kromkamp et al., 2018). Besides participating in the nutrient cycle, phytoplankton help to keep the balance of biotic and abiotic organisms.

Primary producers form the energetic base for most global ecosystems. The carbon that plants fix during photosynthesis is the basic unit of most terrestrial and marine food webs. Most of a lentic system's leading producers are algae, which fix carbon and store

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essential nutrients like nitrogen and phosphorus for later use. Lake food webs and nutrient cycles rely heavily on algae (Vadeboncoeur and Steinman, 2002). The distribution and productivity of primary producers are affected by several factors, including those that affect primary production, distribution, and abundance of phytoplankton. This causes them to change with the seasons and the locations where they are measured. Carbon dioxide, sunlight, and nutrients are the primary factors that promote phytoplankton growth. However, other factors, including water depth, water temperature, wind, and grazers, also play a role. Since they form the aquatic food web base, algae play an essential role in freshwater (Zhang et al., 2016).

Studying primary production in an ecosystem can provide basic information about the environment's energy availability and transmission. Ecosystem food webs are, therefore, based on primary production. Optimal growth of aquatic food webs is predicted to occur as phytoplankton production rises (Alakm and Shaawat, 2010). Several studies, including Kromkamp et al. (2017), Nurfadillah et al. (2019), Herawati and Nurruhwati (2020), and Hamdan (2021), have researched primary productivity in various locations worldwide. Nevertheless, a few studies have only studied primary productivity in Iraqi aquatic habitats (AL-Hamdawe, 2009; Alakm and Shaawat, 2010; Al-Haidarey et al., 2018; Mahmoud et al., 2022). Therefore, this work aimed to measure the phytoplankton primary productivity and determine the environmental factors that drive it in the Euphrates River near Samawa City between January and December 2023.

Materials and Methods

Three sampling sites were chosen in the Euphrates River: the water sources, station 1, before entering the river's city center, station 2 in the city center, and station 3 located south of the second site (Fig. 1). One liter of triplicate subsurface water samples was taken monthly (January 2023 to December 2023). A 20 µm phytoplankton net was used for a quantitative and

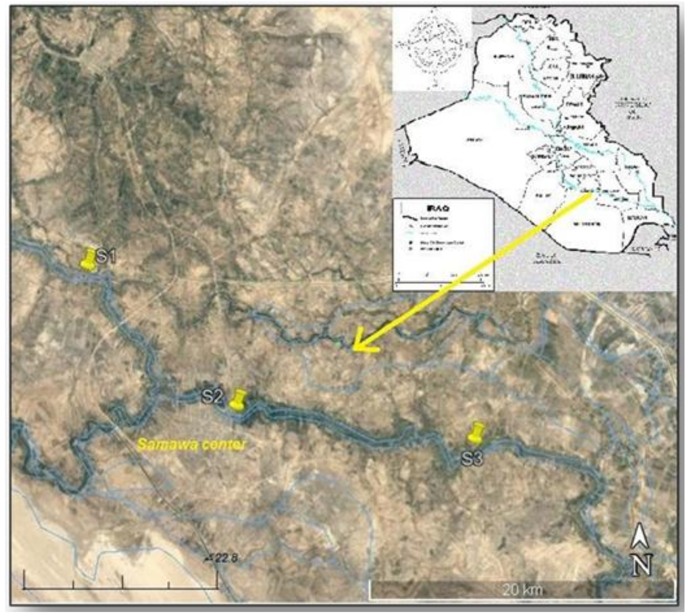

Figure 1. The studied sites in the Euphrates River.

qualitative study of microalgae. Samples were fixed with Lugol's solution. The algal biomass was estimated according to Eker-Develi and Kideys (2003), Hillebrand et al. (1999), Sun and Liu (2003), and Aktan (2005). Phosphorus, nitrate, nitrite, and dissolved oxygen (DO) were measured according to Al-Zurfi (2010).

Statistical analysis: The data were subjected to a one-way analysis of variance (one-way ANOVA) followed by a Duncan multiple range test using SPSS version 20.0 software. The Principal Component Analysis (PCA) was used to understand the relationships between primary productivity and physico-chemical parameters. A P-value < 0.05 was considered statistically significant.

Results and Discussions

The findings of the current study revealed a notable seasonal fluctuation in nitrate concentrations at the third sampling site, where the peak nitrate levels, reaching 9.83 $\mu g.l^{-1}$ during the winter months, contrasted sharply with the low point of 1.84 $\mu g.l^{-1}$ recorded during the summer period (Table 1). This seasonal variation can be attributed to the reduced abundance and density of algal populations in the summer, which consequently diminishes the

Table 1. Euphrates River physico-chemical parameters during the study period.

Study sites / Parameters	St 1 Range Mean±SD	St 2 Range Mean±SD	St 3 Range Mean±SD
Dissolved oxygen ($mg.l^{-1}$)	4.8-13 7.62±3.02	5-11 7.83±2.32	4.8-10 7.2±2.08
Nitrite (NO_2^-) ($\mu g.l^{-1}$)	0.47-2.67 2.57±0.76	0.08-3.05 2.45±0.87	0.12-3 2.51±0.83
Nitrate (NO_3^{-2}) ($\mu g.l^{-1}$)	2.63-9.00 7.51±2.09	1.84-9.89 6.17±2.29	2.38-9.83 6.35±2.28
Phosphate (PO_4^{-3}) ($\mu g.l^{-1}$)	0.03-0.93 0.69±0.28	0.017-0.80 0.813±0.27	0.04-0.82 0.811±0.25

biological uptake of nitrate in the photosynthetic process, along with the influence of enhanced water ventilation. This combination of factors triggers an increase in the concentration of DO, which, in turn, facilitates the oxidation of nitrite to nitrate (Amadi et al., 2010).

Within aquatic ecosystems, atmospheric oxygen readily dissolves into the water column until saturation is achieved. Furthermore, phytoplankton and submerged macrophytes significantly contribute to the oxygen budget through photosynthesis (Hoosier, 2000). An examination of the data presented in Table 1 reveals that the concentration of DO fluctuates between 4.8 and 13 mg/l throughout the study period. The notably elevated DO levels during the winter months at site 1 could be attributed to declining ambient temperatures, given the inherent capacity of colder water to retain a greater quantity of dissolved oxygen (Al-Asadi, 2015). This effect is also enhanced by photosynthetic activity of extensive aquatic vegetation such as macrophytes and microscopic algae, which contribute to further rise of dissolved oxygen levels, especially under high light conditions in winter.

High water temperature at site 3 in summer could be an influencing factor leading to low DO. This may be due to increased metabolic activity in microorganisms that prefer higher temperatures. These microbes are responsible for faster degradation of organic material within the ecosystem, leading to higher uptake of dissolved oxygen in the water body (Al-Haidarey et al., 2018).

The elevated concentrations of nutrients within the riverine ecosystem can be attributed, in part, to applying fertilizers on adjacent agricultural lands and the discharge of effluent from urban centers along the river's course (Al-Khafaji and Al-Taee, 2020). This finding aligns with the outcomes of the current work. The results revealed a significant positive correlation (r=0.77) between nitrate levels and DO, suggesting a potential interplay between these parameters. Seasonal changes indicated that the second site recorded the highest level of nitrite (3.05 $\mu g.l^{-1}$) in spring and the lowest (0.8 $\mu g.l^{-1}$) at that same site in summer (Table 1). This variation may be attributed to the increased nitrate oxidation to nitrite by nitrifying bacteria at lower temperatures and increased oxygen concentrations, or possibly due to increasing nitrite entry from agricultural land adjacent to the river (Zahidah et al., 2021).

The phosphate concentrations ranged from 0.017 to 0.93 $\mu g.l^{-1}$, with a higher mean value in the summer at site 1 (Table 1), and noticeable seasonal fluctuations were found. Several factors may have contributed to the particulate matter, including the decomposition of organic matter and aquatic plants, dust and fine soil particles containing phosphorus, an increase in the use of fertilizer rich in phosphate, a decline in water levels due to evaporation or phytoplankton uptake, and high phosphate concentrations (Al-Ghafily, 2018). Although it reaches its lowest level in the winter, this may be due to phosphate adsorption on organic and mineral particles at the bottom of the water or because aquatic plants absorb more phosphate (Al-Taee, 2017).

One way to learn about energy and how it moves

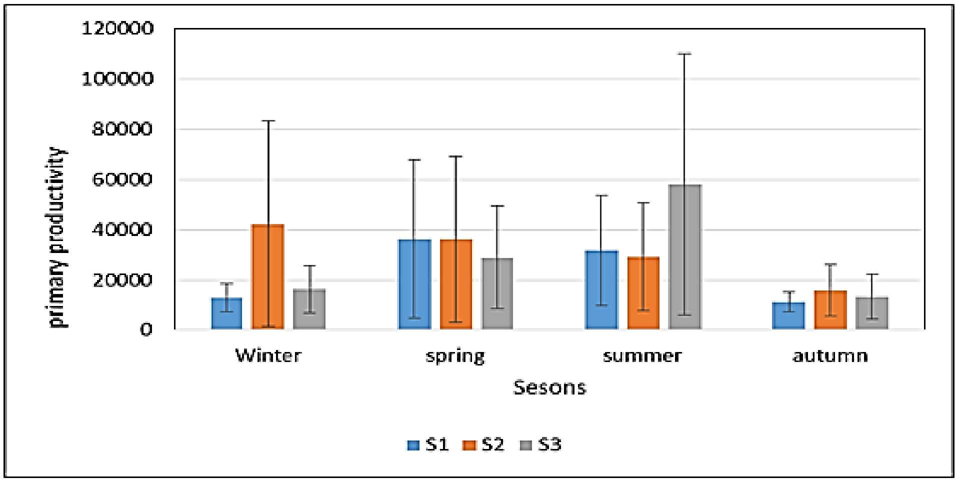

Figure 2. Seasonal variation for primary productivity in the studied sites.

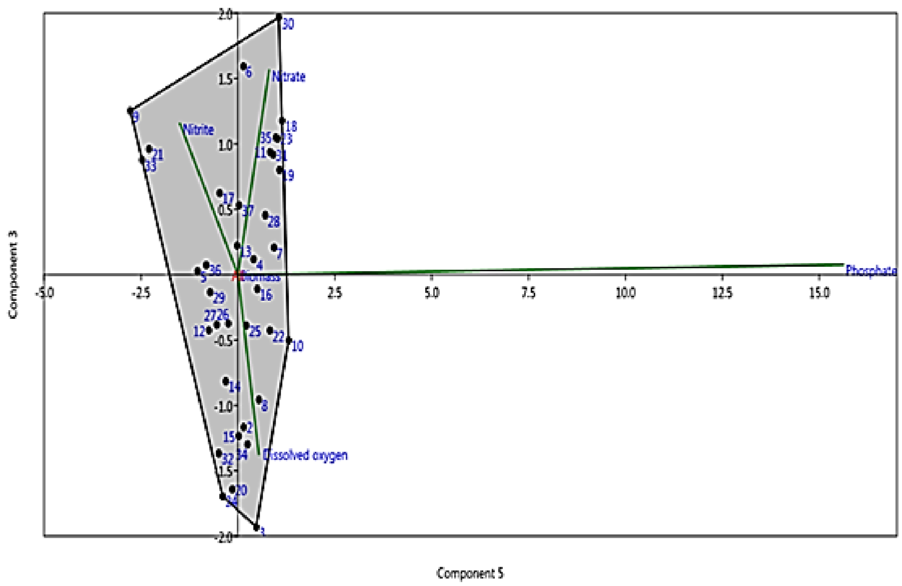

Figure 3. Principal component analysis results of the relationships between primary productivity and physico-chemical parameters.

through benthic and planktonic communities is to examine the primary productivity of aquatic ecosystems (Hamdan, 2021). Because phytoplankton can fix CO_2 during photosynthesis, phytoplankton provide the backbone of most aquatic ecosystems' primary production (Hashim and Al-Taee, 2015). Ecosystem primary productivity can be defined as the rate at which photosynthesis and chlorophyll synthesis transform light energy into organic compounds (Herawati and Nurruhwati, 2020).

The findings revealed that the mean P-NPP levels varied from 58144.01 to 24925.18 mg/m^2/y (Fig. 2), with notable variations ($P \leq 0.05$) across stations and seasons. During the summer at site 3, the P-NPP values were higher than those in the autumn at site 1. Primary production rises due to increased biomass from dominant phytoplankton species; nevertheless, changes in production values tend to follow phytoplankton density rather than chlorophyll-a concentrations. Even if the decrease in P-NPP may be due to the drop in water level (Gajanan and Satish, 2014), the decline in biomass of the dominant phytoplankton species might also be responsible. Individual biomass variations, rather than phytoplankton density in the river, were the primary drivers of variability in NPP from regrowth; the standing stock of carbon was also quite variable (Smale et al., 2020), as reported by Al Taee (2017).

PCA revealed the relationship between productivity and the studied parameters (Fig. 3). PCA results showed a moderate positive correlation between phosphate and biomass, suggesting that phosphate may have a greater impact on biomass than other factors. Therefore, phosphate may impact river productivity. The negative correlation between DO and nitrate with primary productivity agreed with the findings of Nurfadillah et al. (2019).

Conclusions

Primary productivity of phytoplankton, the main source of autochthonous organic matter in surface water systems, forms the basis for energy in all subsequent river production stages. The results showed that increased DO levels indicate water quality in water bodies lacking nutrients. Based on the results, both NO3 and DO play a role in determining the composition of the phytoplankton community in the river. The study also suggests that phytoplankton growth is likely to be more limited by phosphorus availability than by nitrogen. Therefore, slight increases in phosphorus may stimulate phytoplankton to produce a water bloom.

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