



Spatiotemporal Dynamics of Phytoplankton Community and Their Bioindication in the Upper Euphrates River, Iraq

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ABSTRACT

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The study examined the dynamics of phytoplankton communities in the upper Euphrates River, analyzing their relationship with environmental factors from November 2022 to October 2023. One hundred and fifty-five species, mainly diatoms, green algae, and cyanobacteria, were identified, with phytoplankton abundance increasing significantly upstream and downstream, with the highest densities in nutrient-rich and turbid waters. Upstream sites show balanced assemblages under oligotrophic to mesotrophic conditions, with higher turbidity, nitrate, and EC downstream and greater dissolved oxygen upstream, indicating nutrient enrichment and reduced flow velocity. Canonical correspondence analysis identified turbidity, nitrate, and pH as the key environmental variables shaping phytoplankton distribution, together accounting for 62.4% of the total variance in species–environment relationships. Turbidity and nitrate were positively correlated with the abundance of cyanobacteria (*Microcystis*, *Oscillatoria*) and chlorophytes (*Scenedesmus*, *Pediastrum*), while pH and dissolved oxygen were positively associated with diatom-dominated upstream communities (*Cyclotella*, *Fragilaria*, *Navicula*). Phytoplankton composition is sensitive to physicochemical gradients and nutrient loading, with tolerant species like *Nitzschia palea* and *Microcystis aeruginosa* indicating environmental pressure from nutrient enrichment and pollution. The present study validated the use of phytoplankton as bioindicators to monitor water quality variations in nutrient-affected river systems, demonstrating their accurate representation of the upper Euphrates River's trophic status.

1. INTRODUCTION

Rivers play an essential role in providing ecosystem services and serve as critical habitats for diverse planktonic communities. River ecosystems rely heavily on phytoplankton for their ecological stability and productivity [1]. Phytoplankton distribution and community structure vary with the dynamics of aquatic systems. They are characterized by basic structures, exponential growth, strong dispersal ability, and high sensitivity to ecological shifts [2]. As primary producers, they not only form the base of aquatic food webs but also act as reliable bioindicators of water quality and ecosystem health.

Phytoplankton diversity encompassing variation, functional structure, and species composition is highly dependent on climatic and geographical conditions [3, 4]. In river systems, particularly those in arid and semi-arid regions such as Iraq, hydrological fluctuations, pollution, and nutrient enrichment caused by agricultural runoff and domestic discharges impose unique ecological pressures on aquatic biota [5]. The Euphrates River, one of the principal water bodies in Iraq, is increasingly exposed to anthropogenic stressors, including reduced flow due to dam construction, urban effluents, and agricultural inputs, all of which influence phytoplankton dynamics. Although several studies have examined

phytoplankton diversity in the middle and lower reaches of the Euphrates River [6-8], few have focused on the upper section between Hit and Ramadi, where water quality is rapidly changing due to expanding human activities and climatic variability. This gap limits our understanding of spatial patterns of phytoplankton and their responses to physicochemical gradients in this ecologically sensitive region.

Therefore, this study aimed to investigate the spatiotemporal dynamics of phytoplankton communities in the upper Euphrates River, quantify the key environmental drivers shaping their composition and abundance, and assess the bioindicative potential of phytoplankton for evaluating eutrophication and environmental health in the river system.

2. MATERIALS AND METHODS

2.1 Study area

The research concentrated on a 60 km section of the Euphrates River in central Iraq. Water specimens were obtained from five different sites along the Euphrates River from November 2022 to October 2023. Sampling was conducted monthly to capture seasonal variations in

environmental conditions and phytoplankton dynamics. The study sites extended from the eastern borders of Hit city to the Ramadi district, covering both upstream and downstream sections (Figure 1 and Table 1).

At each site, three replicate samples were collected during

each sampling event to ensure statistical reliability. Replication also formed the basis for the least significant difference (LSD) test applied in data analysis, which was performed using temporal replicates (monthly observations) for each site.

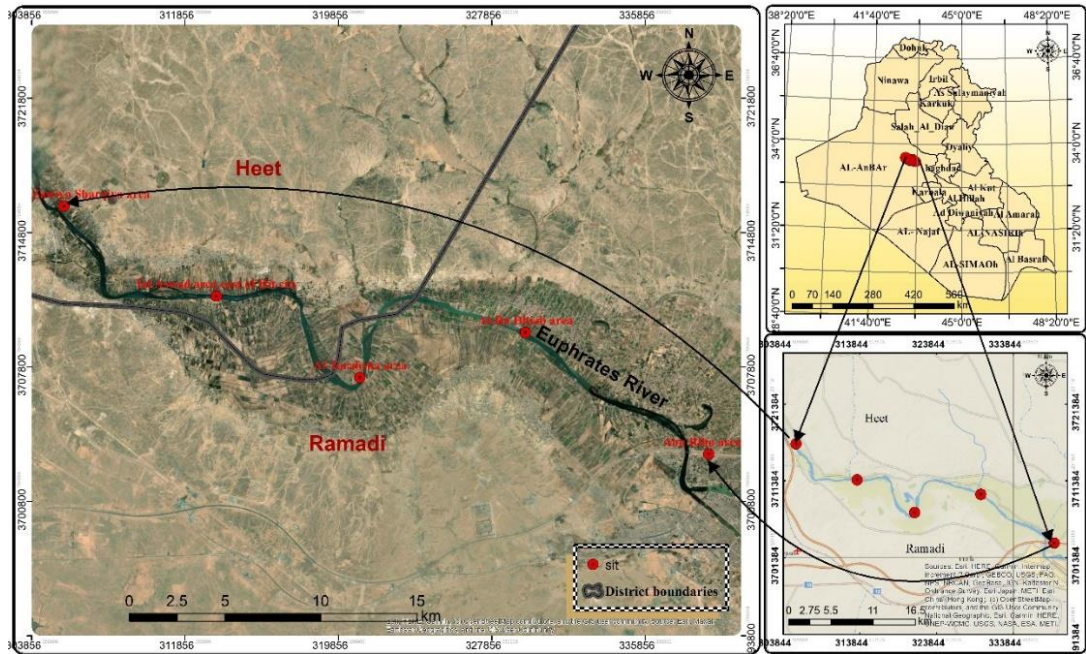


Figure 1. The study sites in the upper Euphrates River

Table 1. Coordinate values of the study sites

Sites	Symbol	Coordinates
Abu Risha area	St. 1	43°16'11" E, 33°27'24" N
Al-Bu Dhiab area	St. 2	43°09'56" E, 33°30'44" N
Al-Tarabsha area	St. 3	43°04'23" E, 33°29'23" N
Tal Aswad area, east of Hit city	St. 4	42°59'30" E, 33°31'36" N
Zawiya Sharqiya area	St. 5	42°54'18" E, 33°34'03" N

2.2 Determination of the physicochemical parameters

Samples were examined for physicochemical parameters of the water in the ecological laboratories, College of Science, Tikrit University. Environmental factors such as water temperature (°C), pH, electrical conductivity (EC, $\mu\text{S cm}^{-1}$), total dissolved solids (TDS, mg L^{-1}), total hardness (mg L^{-1}), chloride (mg L^{-1}), sulphate (mg L^{-1}), and nutrients (nitrate (NO_3^-), phosphate (PO_4^{3-}), and silica (SiO_3^{2-}) were determined based on standard methods described by the American Public Health Association [9].

2.3 Phytoplankton sampling and identification

Phytoplankton samples were collected using a 20 μm mesh plankton net in a horizontal tow at the water surface to ensure uniform coverage across the channel width. This procedure was conducted for both qualitative and quantitative assessments. For qualitative analysis, samples were immediately preserved with Lugol's iodine solution (final concentration 1%) for microscopic identification [5]. For quantitative estimation of phytoplankton abundance (cells $\times 10^3 \text{ L}^{-1}$), 1 L of river water was concentrated to 50 mL by sedimentation. Cell counts were performed using a Sedgwick–Rafter counting chamber under a compound light microscope

at 400 $\times$ magnification. A minimum of 400 cells was counted across 10–15 randomly selected fields of view to ensure accuracy, and the results were expressed as cells per litre following standard protocols. Identification of algal taxa was carried out using recognized taxonomic keys and monographs [10-13]. Phytoplankton species richness (D) was calculated according to Margalef's diversity index [14]:

$$D = (S - 1)/\ln(N)$$

where, S is the total number of species and N is the total number of individuals.

2.4 Statistical and multivariate analysis

Descriptive statistics (mean $\pm$ standard deviation) and one-way analysis of variance (ANOVA) followed by least significant difference (LSD) tests were used to determine spatial and temporal variations among sites using the Statistical Package for the Social Sciences (SPSS; IBM Corp., USA; version 20.0). Canonical correspondence analysis (CCA) was applied to examine the relationships between phytoplankton community composition and environmental variables. All measured physicochemical parameters were included in the ordination (temperature, turbidity, EC, TDS, pH, DO, BODs, total hardness, chloride, sulphate, nitrate, phosphate, and silica). Prior to analysis, environmental data were $\log_{10}(x+1)$ -transformed to normalize distribution and reduce skewness. CCA was performed using CANOCO version 5.0 software, and the significance of the axes was tested by Monte Carlo permutation tests (499 permutations, $p \leq 0.05$). Biplots were used to visualize species–environment correlations and the proportion of variance explained by the first two canonical axes.

3. RESULTS AND DISCUSSION

3.1 Phytoplankton composition, diversity, and spatial patterns

The present study recorded a total of 155 phytoplankton species belonging to 75 genera distributed across six major taxonomic divisions. The dominant division was Bacillariophyta (73 species; 47.10%), followed by Chlorophyta (54 species; 34.84%) and Cyanophyta (20 species; 12.90%), while Euglenophyta (3.23%), Chrysophyta (1.29%), and Dinoflagellata (0.65%) contributed fewer taxa, as shown in Figure 2(A).

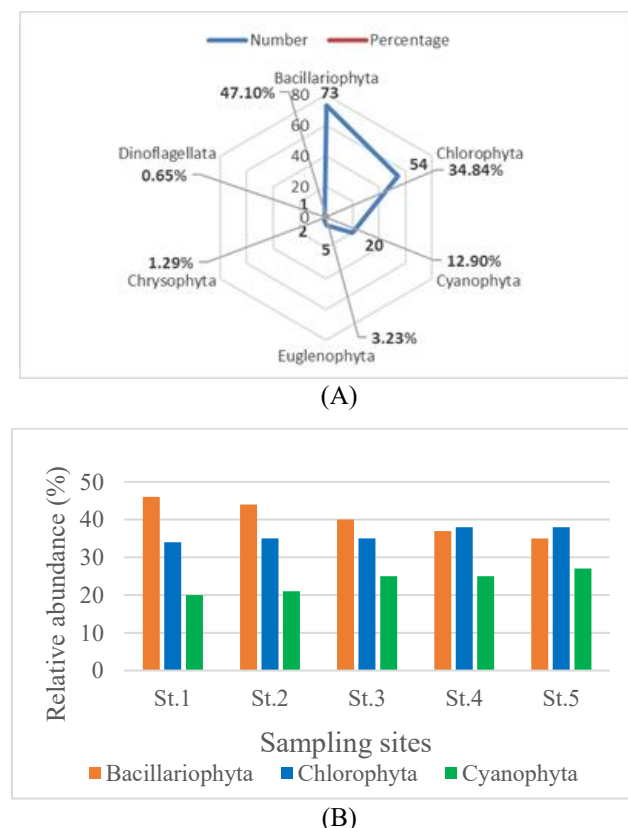


Figure 2. (A) Distribution of phytoplankton according to the number of species and their percentage presence in the study area; (B) Spatial variation in the relative abundance of major phytoplankton divisions across the upper Euphrates River, showing the dominance of Bacillariophyta upstream and the increasing prevalence of Cyanophyta downstream

This high diversity highlights the ecological richness of the upper Euphrates River and confirms the dominance of diatoms (Bacillariophyta) as the core component of its phytoplankton communities. Similar findings have been reported by studies [6–8], where diatoms dominate due to their adaptability to fluctuating flow and nutrient conditions [15]. The entire diversity pattern suggests that the upper Euphrates River supports a moderately productive ecosystem with a dynamic response to environmental gradients.

The spatial distribution analysis revealed that the relative abundance of Bacillariophyta decreased gradually from upstream (St. 1–St. 2) to downstream (St. 5), whereas Cyanophyta showed the opposite trend, increasing significantly at the lower reaches (Figure 2(B)). This pattern indicated a progressive transition from oligotrophic to

eutrophic conditions, driven by increasing nutrient loading and reduced flow velocity downstream.

The prevalence of genera such as *Cyclotella*, *Fragilaria*, *Nitzschia*, *Navicula*, and *Cymbella* indicates that phytoplankton composition is strongly influenced by nutrient dynamics and hydrological fluctuations. These genera are cosmopolitan and tolerant of wide ecological ranges [4, 16]. In contrast, Cyanophyceae, such as *Chroococcus*, *Pseudanabaena*, and *Microcystis*, and Chlorophyceae, such as *Scenedesmus*, *Pediastrum*, *Planctonema*, *Cosmarium*, and *Spirogyra*, were particularly abundant at nutrient-enriched downstream sites, where higher nitrate and phosphate concentrations promoted their proliferation. Their occurrence underscores their bioindicator value for assessing nutrient enrichment and eutrophication [14, 17].

Phytoplankton cell density ranged between 289×10^3 cells L^{-1} at St. 1 and 600×10^3 cells L^{-1} at St. 5, while richness values ranged from 17.29 to 18.22, reflecting moderately diverse but environmentally sensitive assemblages. Nevertheless, the dominance of certain species, such as *Nitzschia palea* and *Cyclotella meneghiniana*, in high abundances suggests localized environmental pressure. *Nitzschia palea*, in particular, is a tolerant taxon commonly associated with organic pollution and eutrophic conditions [16].

Higher phytoplankton densities and the prevalence of tolerant taxa at sites adjacent to urban settlements and agricultural zones (St. 4 and St. 5) indicate anthropogenic influences, particularly nutrient inputs from runoff and wastewater discharge. Such impacts have been shown to enhance algal growth and shift community structure in the Euphrates River system [6, 18]. Collectively, the composition, diversity, and spatial trends of phytoplankton in this study reflect an ecologically responsive community structure influenced by hydrological gradients, nutrient dynamics, and human-induced stressors, thus highlighting their importance as indicators of water quality and trophic status in the upper Euphrates River.

3.2 Physicochemical characteristics of water

The results in Table 2 showed that water temperature fluctuated between 12°C and 33°C in response to seasonal variations, within the optimal range for phytoplankton growth. Diatoms generally dominate in cooler conditions (winter–spring), whereas green algae and cyanobacteria often increase during warmer months due to their higher temperature tolerance [1, 2].

Turbidity values ranged from 1.8 to 21 NTU, with higher averages recorded at St. 1, St. 4, and St. 5. Essentially, turbidity plays a dual role in shaping phytoplankton communities. On one hand, increased suspended solids reduce light penetration, thereby limiting photosynthesis, particularly for smaller or less competitive green algae. On the other hand, moderate to high turbidity promotes the growth of turbulence-adapted diatoms such as *Aulacoseira granulata* and *Fragilaria ulna*, which were abundant at midstream and downstream sites [1, 17].

EC ranged between 810 and 1240 $\mu S\ cm^{-1}$, and TDS between 330 and 766 $mg\ L^{-1}$. Elevated values downstream suggest the influence of evaporation, agricultural return flows, and urban inputs. Many tolerant diatoms (*Nitzschia*, *Navicula*) are well adapted to such ion-rich environments [18, 19]. pH values (7.06–8.85) indicated a slightly alkaline environment

favorable for both diatoms and green algae, while cyanobacteria often proliferate when pH exceeds 8 due to enhanced carbon availability in the form of bicarbonates [6,

8]. This may partly explain the higher abundance of *Microcystis* at St. 5, where both nutrient peaks and alkaline conditions were observed.

Table 2. Physicochemical parameters of water samples

Physicochemical Factor	Site 1	Site 2	Site 3	Site 4	Site 5
Water Temp. (°C)	12-33 23.67 ± 0.60	13-30 23.66 ± 0.60	12-32 23.58 ± 0.58	12-31 23.54 ± 0.55	12-33 23.75 ± 0.50
Turbidity (NTU)	2.5-19.2 6.68 ± 1.44	1.9-9.5 5.52 ± 0.94	1.9-14 5.85 ± 1.06	1.8-16 6.65 ± 1.18	2.8-21 6.63 ± 1.49
E.C (µS cm ⁻¹)	810-1118 987.6 ± 30.65	850-1190 1087.2 ± 31.88	812-1190 1044.8 ± 31.61	975-1240 1099.5 ±	814-1190 1049.5 ± 24.0
TDS (mg L ⁻¹)	577-766 655.3 ± 18.12	593-700 639.8 ± 12.75	352-741 622.6 ± 29.12	520-745 604.7 ± 21.23	330-750 616.9 ± 30.5
pH	7.1-8.7 7.61 ± 0.18	7.06-8.85 7.67 ± 0.17	7.2-8.78 7.58 ± 0.12	7.13-8.1 7.60 ± 0.08	7.2-8.5 7.64 ± 0.13
Dissolved O ₂ (mg L ⁻¹)	4-9.8 6.70 ± 0.60	3.12-9 6.79 ± 0.60	3.5-9.5 6.55 ± 0.58	4.1-9.7 6.89 ± 0.55	4.4-8.88 6.71 ± 0.50
BOD (mg L ⁻¹)	1.3-3.7 2.3 ± 0.18	1-3.8 2.26 ± 0.23	1.2-3.7 2.51 ± 0.21	0.9-3.2 2.33 ± 0.20	1.2-4 2.53 ± 0.23
Total hardness (mg CaCO ₃ L ⁻¹)	219-745 484.5 ± 46.76	245-520 438.58 ± 29.06	320-612 440.92 ± 31.22	250-510 404.17 ± 27.74	235-588 432.67 ± 33.08
Chloride (mg L ⁻¹)	130-176 156.17 ± 3.49	140-173 158.83 ± 2.72	148-182 161.17 ± 2.64	150-190 160.5 ± 2.86	151-200 161.83 ± 3.67
Sulphate (mg L ⁻¹)	211-693 352.17 ± 44.65	185-442 341.75 ± 23.28	130-415 306.17 ± 25.36	177-570 339.75 ± 43.44	175-432 330.83 ± 24.43
Nitrate (µg L ⁻¹)	1.6-3.5 2.65 ± 0.18	1.8-3.8 2.94 ± 0.19	2-3.7 2.94 ± 0.16	2.1-3.5 2.88 ± 0.14	2.1-4.2 2.89 ± 0.18
Phosphate (µ L ⁻¹)	0.12-0.5 0.20 ± 0.03	0.12-0.5 0.20 ± 0.03	0.11-0.4 0.19 ± 0.02	0.12-0.5 0.20 ± 0.03	0.12-0.52 0.20 ± 0.03
Silica (mg L ⁻¹)	0.7-2.46 1.39 ± 0.15	0.72-2.25 1.32 ± 0.12	0.72-2.87 1.44 ± 0.18	0.8-2.3 1.40 ± 0.14	0.60-2.6 1.45 ± 0.16

Values are represented as mean ± standard deviation; n = 3.

Dissolved oxygen (DO) varied from 3.12 to 9.5 mg L⁻¹, with lower values in downstream sites, reflecting localized organic inputs from human activities. DO influences the distribution of aquatic creatures and is crucial for a river's ecological status and health [19]. This oxygen stress favours tolerant taxa such as *Euglena* and *Trachelomonas*, which were recorded in downstream sites [15].

Total hardness (219–745 mg L⁻¹) reflected the influence of calcareous geology in the catchment, consistent with earlier Iraqi river studies [8, 19, 20]. While hardness itself has limited direct effects on phytoplankton, it indicates carbonate-rich waters that buffer pH, indirectly favouring diatoms. Chloride and sulphate concentrations, which peaked downstream, can reflect both natural mineral dissolution and anthropogenic inputs. Elevated chloride has been associated with altered phytoplankton composition and decreased sensitive taxa, while sulphate enrichment may support cyanobacterial growth under certain conditions [21]. Nitrate and phosphate concentrations were relatively elevated in St. 4 and St. 5, likely due to agricultural runoff and rainfall-driven leaching, which enhanced primary productivity and increased the abundance of green algae, such as *Scenedesmus*, *Spirogyra*, *Planctonema*, and *Pediastrum* [15, 22].

3.3 Phytoplankton distribution in relation to environmental factors

The present study recorded distinct spatial variations in phytoplankton composition and abundance along the upper Euphrates River. The total phytoplankton density ranged from 289 × 10³ cells L⁻¹ at St. 1 to 600 × 10³ cells L⁻¹ at St. 5, while diversity indices (17.29–18.22) indicated moderately rich but environmentally responsive assemblages. However, the

prevalence of tolerant and opportunistic taxa at the downstream sites points to environmental stress and nutrient enrichment, consistent with earlier reports that phytoplankton communities respond sensitively to physicochemical fluctuations and nutrient loading in river systems [1, 2].

Diatoms (Bacillariophyta) were the most diverse and abundant group, particularly *Aulacoseira granulata*, *Fragilaria ulna*, *Cyclotella meneghiniana*, *Navicula* spp., and *Nitzschia palea*. *Aulacoseira* thrives under high turbulence and elevated silica concentrations. This explains its dominance at midstream sites (St. 3-St. 4) where turbidity and mixing were more pronounced. *Fragilaria ulna* and *Cyclotella* are indicators of moderate nutrient enrichment and hydrodynamic variability, showing close association with fluctuations in pH and nutrient levels [16, 23]. In contrast, *Nitzschia palea* and *Navicula veneta* were abundant downstream (St. 5), reflecting their tolerance to higher conductivity, organic matter, and nutrient enrichment. This distribution trend supports previous findings that *Nitzschia* and *Navicula* are dominant under ionic enrichment and elevated organic load [6, 17].

Green algae (Chlorophyta), such as *Scenedesmus*, *Pediastrum*, and *Coelastrum*, were particularly common at St. 4-St. 5, corresponding with higher concentrations of nitrate (NO₃⁻) and phosphate (PO₄³⁻). Their distribution suggests that these taxa are sensitive indicators of nutrient availability and enrichment. Recent studies emphasize their role as early bioindicators of eutrophication due to their rapid growth and adaptability under nutrient-rich conditions [8, 24]. Despite generally moderate nutrient levels across the study area, episodic peaks of NO₃⁻ and PO₄³⁻, especially at downstream sites, stimulated chlorophyte proliferation, underscoring the system's susceptibility to nutrient-driven changes.

At downstream Site 5, cyanobacteria (Cyanophyta), such as

Microcystis aeruginosa, *Oscillatoria limosa*, and *Pseudanabaena*, were particularly abundant. These species thrive in warm, nutrient-rich, and slow-flowing waters, conditions typically found in the lower reaches of the river [21]. *Microcystis aeruginosa* in particular exhibited high cell densities, raising concerns about the potential for harmful algal blooms (HABs) under sustained eutrophic conditions [25]. The co-occurrence of *Microcystis* and *Oscillatoria* at turbid, nutrient-enriched sites reflects their adaptive ability to regulate buoyancy and efficiently utilize low light, allowing them to dominate under reduced flow and high nutrient conditions [26].

Increased turbidity and elevated nutrient concentrations downstream created favourable conditions for both cyanobacteria and pollution-tolerant diatoms, illustrating a shift toward eutrophic community structure. Additionally, euglenoids, such as *Euglena viridis* and *Trachelomonas*, were mainly observed at the downstream stations, indicating high organic content and reduced oxygen availability. These taxa are recognized indicators of organic pollution, frequently associated with agricultural runoff and wastewater discharge [7, 15]. Their presence further supports the inference of localized organic enrichment and anthropogenic influence in the lower reaches of the Euphrates River.

Notably, the spatial distribution of phytoplankton closely mirrored the physicochemical gradients observed along the river. Upstream sections (St. 1-St. 2) exhibited oligotrophic characteristics dominated by diatoms and generalist green algae, midstream sections (St. 3-St. 4) represented transitional zones influenced by turbidity and silica input, while downstream sections (St. 5) displayed eutrophic conditions characterized by increased nutrient-tolerant cyanobacteria, reduced DO, and elevated BODs. This distribution pattern underscores the strong coupling between nutrient dynamics and community structure, highlighting phytoplankton as reliable bioindicators of water quality and trophic state in the upper Euphrates River.

3.3.1 Seasonal and environmental dynamics

Phytoplankton density and diversity exhibited clear temporal variations corresponding to environmental fluctuations (Figure 3). Cell densities ranged from 289×10^3 cells L^{-1} at St. 1 during winter to 600×10^3 cells L^{-1} at St. 5 in summer, coinciding with higher water temperatures (30–33°C) and nutrient enrichment. Species richness was higher during spring and summer. This coincided with increased photosynthetic activity and nutrient regeneration.

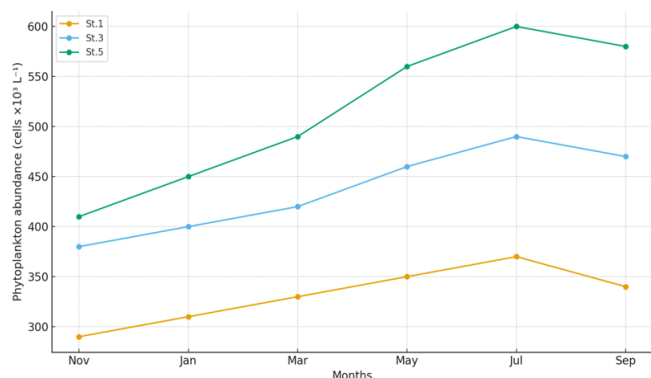


Figure 3. Seasonal variations in total phytoplankton abundance (cells $\times 10^3 L^{-1}$) and species richness across study sites from November 2022 to October 2023

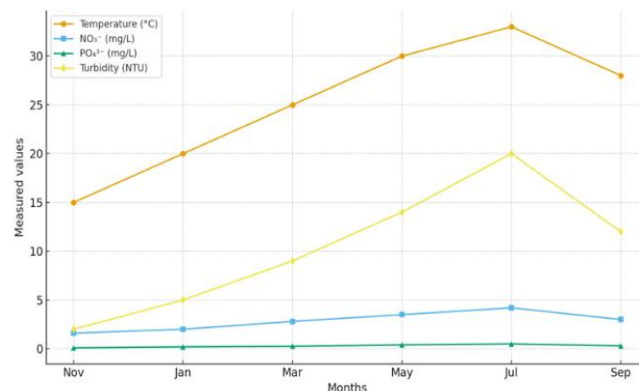


Figure 4. Temporal variations in selected physicochemical parameters (temperature, NO_3^- , PO_4^{3-} , and turbidity) across the five sampling sites, illustrating environmental gradients influencing phytoplankton distribution

Temporal patterns of key physicochemical parameters revealed that water temperature, turbidity, and nitrate (NO_3^-) peaked during summer months, whereas dissolved oxygen (DO) and phosphate (PO_4^{3-}) showed opposite trends (Figure 4). These fluctuations suggest strong seasonal coupling between physical factors and phytoplankton productivity.

3.3.2 Canonical correspondence analysis (CCA) of phytoplankton–environment relationships

As depicted in Figure 5, canonical correspondence analysis (CCA) was conducted to determine how environmental gradients shaped phytoplankton composition. The first two CCA axes indicated 62.4% of the total variance in species–environment relationships, with Axis 1 (38.1%) correlated positively with turbidity, EC, and nitrate, and Axis 2 (24.3%) correlated with pH, dissolved oxygen, and phosphate. Upstream sites (St. 1-St. 2) were associated with higher DO and lower conductivity, which favoured diatom-dominated assemblages (*Cyclotella*, *Fragilaria*, *Navicula*). Midstream sites (St. 3-St. 4) showed strong correlations with turbidity and silica, thus supporting turbulence-tolerant diatoms (*Aulacoseira granulata*). Downstream Site 5 exhibited strong positive correlations with nitrate and phosphate. This explains the dominance of nutrient-tolerant taxa such as *Microcystis aeruginosa*, *Oscillatoria limosa*, and *Scenedesmus quadricauda*.

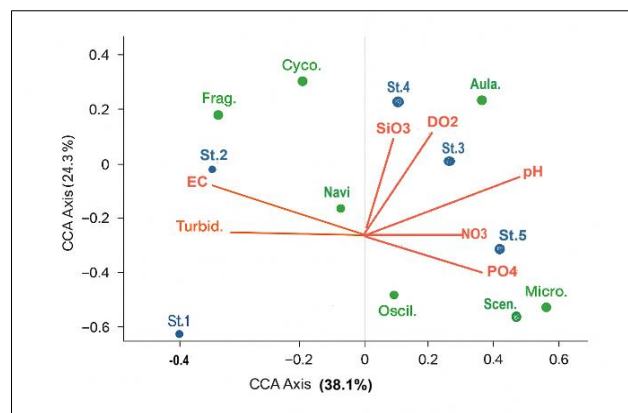


Figure 5. CCA ordination biplot showing the relationship between dominant phytoplankton taxa and key environmental factors

Arrows represent environmental gradients; species and site scores demonstrate clustering according to physicochemical conditions.

These ordination results highlight turbidity, nitrate, and pH as the most influential parameters determining community composition. The downstream shift toward cyanobacterial dominance indicated increasing nutrient enrichment and potential eutrophication risk. From the study, the observed pattern—dominance of diatoms upstream and cyanobacteria downstream is consistent with ecological succession under nutrient enrichment, as reported in similar arid-region rivers [6, 16, 21]. *Nitzschia palea* and *Cyclotella meneghiniana*, dominant in midstream sites, are known indicators of moderate organic loading and turbulence [15]. Conversely, the proliferation of *Microcystis aeruginosa* in downstream stretches reflects eutrophic conditions associated with high NO_3^- and PO_4^{3-} concentrations [25].

The co-occurrence of tolerant euglenoids (*Euglena viridis*, *Trachelomonas*) and high BOD₅ at downstream sites further supports the inference of organic enrichment. These findings align with previous studies of the Euphrates River near Ramadi [20], confirming that anthropogenic pressures, particularly agricultural runoff and domestic effluents, exert strong control over phytoplankton structure.

From the result, upstream sections (St. 1-St. 2) represent relatively oligotrophic conditions dominated by diatoms and generalist green algae. Midstream sections (St. 3-St. 4) reflect transitional zones influenced by turbidity and silica inputs, while the downstream section (St. 5) exhibits eutrophic characteristics, with increased nutrient-tolerant species, reduced DO, and elevated BOD₅. Based on the foregoing, the phytoplankton community structure mirrors the physicochemical gradient from upstream to downstream, serving as a sensitive bioindicator of water quality and ecological integrity in the upper Euphrates River.

4. CONCLUSION

This study evaluated the diversity, spatial, and temporal distribution of phytoplankton in the upper Euphrates River and their relationship with key physicochemical parameters. The assemblages were dominated by Bacillariophyta (47.1%), followed by Chlorophyta (34.8%) and Cyanophyta (12.9%), reflecting a moderately diverse and environmentally responsive community. Environmental gradients exerted a strong influence on phytoplankton composition and density across sites. Higher diatom abundances were observed at midstream sections characterized by silica-rich and turbulent waters, while downstream sections exhibited increased dominance of nutrient- and pollution-tolerant taxa, such as *Microcystis aeruginosa* and *Oscillatoria*, indicating eutrophic and organically enriched conditions associated with agricultural and domestic discharges. Canonical correspondence analysis (CCA) further demonstrated that turbidity, nitrate, and pH were the principal drivers of phytoplankton community structure, together accounting for 62.4% of the total variance in species–environment relationships. These findings emphasize the strong coupling between physicochemical gradients and phytoplankton assemblage dynamics, confirming the ecological sensitivity of these organisms to environmental stressors.

On the basis of the findings from this study, the upper Euphrates River can be characterized as generally oligotrophic to mesotrophic, with localized eutrophic conditions downstream. Phytoplankton therefore serve as reliable bioindicators for monitoring ecological shifts, nutrient

loading, and water quality deterioration in the river system. While the findings provided valuable insights into phytoplankton ecology in the upper Euphrates River, the sampling design may not have captured all microhabitat types, and the 20 µm plankton net likely underestimated smaller or colonial species. Future studies employing finer-mesh sampling, continuous monitoring, and molecular identification are recommended to enhance the accuracy and completeness of community assessments.

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REFERENCES

- [1] Qu Y, Wu N, Guse B, Makarevičiūtė K, Sun X, Fohrer N. (2019). Riverine phytoplankton functional groups response to multiple stressors variously depending on hydrological periods. *Ecological Indicators*, 101: 41-49. <https://doi.org/10.1016/j.ecolind.2018.12.049>
- [2] Li, X., Zhao, Y., Chai, F., Yu, H., Sun, X., Liu, D. (2022). Phytoplankton community structure dynamics in relation to water environmental factors in Zhalong Wetland. *International Journal of Environmental Research and Public Health*, 119(22): 14996. <https://doi.org/10.3390/ijerph192214996>
- [3] Salman, J.M., Jawad, H.J., Nassar, A.J., Hassan, F.M. (2013). A study of phytoplankton communities and related environmental factors in Euphrates River (between two cities: Al-Musayyab and Hindiya), Iraq. *Journal of Environmental Protection*, 4(10). <https://doi.org/10.4236/jep.2013.410123>
- [4] Rusanov, A.G., Bíró, T., Kiss, K.T., Buczkó, K., Grigorszky, I., Hidas, A., Duleba, M., Trábert, Z., Földi, A., Ács, É. (2022). Relative importance of climate and spatial processes in shaping species composition, functional structure and beta diversity of phytoplankton in a large river. *Science of The Total Environment*, 807: 150891. <https://doi.org/10.1016/j.scitotenv.2021.150891>
- [5] Ali, S.F., AL-Shandah, B.T., Ali, H.A., Abdul-Jabar, R.A. (2023). Green algal diversity in Hawija irrigation project/Hawija district, Iraq. *Egyptian Journal of Aquatic Biology & Fisheries*, 27(5): 83-91. <https://doi.org/10.21608/ejabf.2023.317287>
- [6] Ali, H.A., Al-Mahdawi, M.M. (2015). Phytoplankton diversity and pollution index in North Part of Euphrates River, Iraq. *Iraqi Journal of Science*, 56(3B): 2223-2236. <https://www.ijs.uobaghdad.edu.iq/index.php/eijs/article/view/9759>
- [7] Al-Ghanimy, D.B.G., Al-Rekabi, H.K. (2019). A qualitative study of the phytoplankton in the Euphrates River (Middle Euphrates), Iraq. *Plant Archives*, 19(2): 2075-2083.
- [8] Al-Tamimi, A.N.A., Al-Obeidi, N.A. (2025). Biodiversity of phytoplankton (non-diatoms) as bio-indicators in assessing the water quality and trophic status of the Euphrates River between Al-Baghdadi and Al-Ramadi Cities, Western Iraq. *Agronomy Research*. <https://doi.org/10.15159/AR.25.022>

- [9] APHA. (2005). Standard Methods for the Examination of Water and Wastewater. American Public Health Association.
https://books.google.iq/books/about/Standard_Methods_for_the_Examination_of.html?id=buTn1rmfSI4C&redir_esc=y.
- [10] Necchi JR, O. (2016). River Algae. Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-319-31984-1>
- [11] Al-Handal, A.Y., Al-Shaheen, M.A. (2019). Diatoms in the wetlands of Southern Iraq. In *Bibliotheca Diatomologica*.
- [12] Rai, S.K., Chaudhary, L., Ghimire, N.P., Dhakal, S. (2022). Algal Flora of Barju (Chimdi) Taal, Sunsari District, Province 1, Nepal. *Journal of Plant Resources*, 20(1): 20-46. <https://doi.org/10.3126/bdpr.v20i01.56551>
- [13] Ullah, N. (2023). Morpho-taxonomic identification and seasonal correlation between algal diversity and water physico-chemical parameters in District Bajaur Khyber Pakhtunkhwa. *Pakistan Journal of Agricultural Research*, 36(3): 193-206. <https://doi.org/10.17582/journal.pjar/2023/36.3.193.206>
- [14] Ahmad, H.I. (2021). Study of the biological diversity of benthic algae in the Tigris River, Baghdad-Iraq. *IOP Conference Series: Earth and Environmental Science*, 779(1): 012126. <https://doi.org/10.1088/1755-1315/779/1/012126>
- [15] Roy, A., Gogoi, N., Yasmin, F., Farooq, M. (2022). The use of algae for environmental sustainability: Trends and future prospects. *Environmental Science and Pollution Research*, 29(27): 40373-40383. <https://doi.org/10.1007/s11356-022-19636-7>
- [16] Toma, J.J. (2023). Study of Algal Diatoms in some water resources in Shaglaw District. Erbil, Kurdistan Region of Iraq. *Passer Journal of Basic and Applied Sciences*, 5(2): 249-261. <https://doi.org/10.24271/psr.2023.387164.1261>
- [17] Tabassum, S., Kotnala, C.B., Dobriyal, A.K., Salman, M., Bamola, R. (2025). Distribution and dynamics for the ecological assessment of Asan Wetland through periphyton-a water quality indicator. *Frontiers in Environmental Chemistry*, 6: 1529439. <https://doi.org/10.3389/fenvc.2025.1529439>
- [18] Al-Dabbas, M.A., Al-Ali, I.A., Husain, M.M. (2024). Water quality assessment of the Euphrates River from Haditha to Al-Nasiriyah, Iraq. *The Iraqi Geological Journal*, 57(2B). <https://doi.org/10.46717/igi.57.2B.18ms-2024-8-28>
- [19] Abdulmajeed, B.A., Jabar, R.A. (2024). A study of physicochemical parameters, heavy metals and in the Euphrates River, Between the cities of Hit and Ramadi in Anbar Governorate. *IOP Conference Series: Earth and Environmental Science*, 1371(2): 022027. <https://doi.org/10.1088/1755-1315/1371/2/022027>
- [20] Sharqi, M.M., Al-Tamimi, A.A., Hassan, O.M. (2024). Evaluation of Euphrates River water quality on phytoplankton biodiversity in Ramadi, Iraq. *Borneo Journal of Resource Science and Technology*, 14(2): 19-30. <https://doi.org/10.33736/bjrst.6858.2024>
- [21] Chorus, I., Welker, M. (2021). Toxic Cyanobacteria in Water: A Guide to Their Public Health Consequences, Monitoring and Management. CRC Press, London. <https://doi.org/10.1201/9781003081449>
- [22] Ali, S.F., Al-Shandah, B. (2021). Estimation of some plant nutrients and heavy metals in Euphrates River at the cities of Ramadi and Khalidiah. *Pollution Research*, 40(1): 354-361.
- [23] Kuturo, L., Malaza, N., Paulse, A.N., Mpungose, P. (2024). Diatoms as an indicator of water quality in the Kuils River, Western Cape, South Africa. *Applied Biosciences*, 3(4): 517-531. <https://doi.org/10.3390/applbiosci3040033>
- [24] Yang, Q., Zhang, P., Li, X., Yang, S., Chao, X., Liu, H., Ba, S. (2023). Distribution patterns and community assembly processes of eukaryotic microorganisms along an altitudinal gradient in the middle reaches of the Yarlung Zangbo River. *Water Research*, 239: 120047. <https://doi.org/10.1016/j.watres.2023.120047>
- [25] Folcik, A.M., Klemashevich, C., Pillai, S.D. (2021). Response of *Microcystis aeruginosa* and Microcystin-LR to electron beam irradiation doses. *Radiation Physics and Chemistry*, 186: 109534. <https://doi.org/10.1016/j.radphyschem.2021.109534>
- [26] Paerl, H.W., Havens, K.E., Xu, H., Zhu, G., McCarthy, M.J., Newell, S.E., Scott, J.T., Hall, N.S., Otten, T.G., Qin, B. (2020). Mitigating eutrophication and toxic cyanobacterial blooms in large lakes: The evolution of a dual nutrient (N and P) reduction paradigm. *Hydrobiologia*, 847: 4359-4375. <https://doi.org/10.1007/s10750-019-04087-y>