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Bottom-up Controls of Phytoplankton Composition in Tigris River within Baghdad

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Abstract

Phytoplankton, as primary producers, play a fundamental role in aquatic ecosystems by driving the biogeochemical cycling of essential elements such as carbon and forming the base of aquatic food webs. Despite the recognized importance of both organic and inorganic carbon in supporting phytoplankton communities, the specific role of carbon sources in shaping phytoplankton composition in riverine ecosystems remains insufficiently understood. This study aimed to investigate the bottom-up environmental controls on phytoplankton composition in the Tigris River (Baghdad, Iraq), with particular emphasis on the influence of carbon-related variables. A total of 180 phytoplankton taxa were identified and classified into diatom and non-diatom taxa. Diatom accounted for 60% of the total taxa and included Coscinodiscophyceae (6.66%), Bacillariophyceae (45.55%), and Fragilariophyceae (7.77%), whereas non-diatom taxa represented 40%, mainly comprising Chlorophyceae (18.88%), Cyanophyceae (16.11%), Dinophyceae (1.66%), and Euglenophyceae (3.33%). This study revealed distinct responses of phytoplankton groups to environmental variables. Non-diatom taxa exhibited positive correlations with water temperature (WT), dissolved oxygen (DO), dissolved organic carbon (DOC), and (CO_2), while showing a negative correlation to pH. In contrast, diatom taxa were negatively correlated with pH and positively associated with DOC and CO_2, whereas no significant relationships were observed with other measured variables, including electrical conductivity (EC), salinity, nitrate (NO_3^-), and phosphate (PO_4^{-3}). Although NO_3^- and PO_4^{-3} are typically considered key nutrients regulating phytoplankton growth in freshwater ecosystems, their concentrations did not show a significant influence on phytoplankton composition in the study area. Furthermore, constancy index and relative abundance analyses revealed the persistence and dominance of several phytoplankton taxa in the river, classifying them into dominant, abundant, less abundant, and rare species categories. Overall, the results highlight the significant role of carbon-related variables in structuring phytoplankton communities in the Tigris River. These findings contribute to a better understanding of the ecological drivers of phytoplankton dynamics in river ecosystems and provide a valuable basis for future ecological assessments and management strategies.

Introduction

Phytoplankton presence and diversity are pivotal indicators of water quality and ecosystem health. In rivers such as the Tigris, which flows through Baghdad, understanding the factors that influence phytoplankton communities is essential for effective environmental monitoring and management. The Tigris River is one of the most important rivers in the Middle East and forms a major part of the Mesopotamian river basin, supporting ecological diversity, water resources, and human activities across a wide geographical area. Therefore, studying the ecological processes within this river is crucial for understanding the dynamics of freshwater ecosystems in the region (Bachmann et al., 2019).

Phytoplankton composition in rivers is determined by a range of bottom-up controls, including water temperature (WT), dissolved oxygen (DO), pH, nutrient availability, electrical conductivity (EC), salinity, and organic and inorganic carbon sources (Costa et al., 2009; Altman & Paerl, 2012).

Many studies have examined the effects of physical and chemical factors on phytoplankton communities in different aquatic ecosystems in Iraq (Al-Husseini & Alsalman, 2020; Jaafar & Abdulwahhab, 2021; Yaqoob et al., 2023). Similar studies conducted in other major rivers worldwide, such as the Amazon, Yangtze, and Danube Rivers, have also highlighted the importance of environmental variables in shaping phytoplankton community structure and dynamics. Research conducted in several large river systems around the world, including the Amazon, Yangtze, and Danube Rivers, has demonstrated that environmental conditions play a fundamental role in determining phytoplankton community composition and dynamics. Studies from the Yangtze River have reported that seasonal variations in WT, nutrient availability, and hydrological fluctuations strongly influence phytoplankton diversity and succession patterns (Yuan et al., 2025). Similarly, investigations in the Danube River revealed that changes in nutrient inputs, river discharge, and human activities can significantly modify phytoplankton biomass and community structure (Dokulil et al., 2014). In the Amazon River basin, phytoplankton dynamics have been associated with flood pulse cycles, variations in light penetration, and nutrient transport processes, which collectively regulate primary productivity in the system (Kraus et al., 2019). These findings collectively highlight that environmental drivers such as temperature, nutrient concentrations, and hydrological variability are key factors controlling phytoplankton communities in large river ecosystems.

On the other hand, some studies have focused on the impacts of chemical and physical factors, including carbon sources, on phytoplankton biomass, often overlooking the role of carbon sources as an important driver of phytoplankton community composition (Kadhim et al., 2024; Lafta & Hamdan, 2026). Carbon sources play significant roles in freshwater ecosystems, where dissolved organic carbon (DOC) serves as an energy source for microorganisms that support their growth (Johnes et al., 2023). In addition, DOC can bind with metals and pollutants, thereby mitigating their harmful effects (Guo et al., 2020), which represents a key component of dissolved inorganic carbon (DIC), as heterotrophic bacteria decompose DOC and mineralize it into carbon dioxide (CO_2) (Kadhim & Hamdan, 2023). DOC influences microbial activity, nutrient cycling, light penetration, and chemical interactions, while DIC plays a crucial role in pH regulation, photosynthesis, calcification, and overall carbon cycling (He et al., 2020; Yang et al., 2020; Jiménez-Ramos et al., 2022). CO_2 serves as a fundamental substrate for the enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO), which is a key enzyme in photosynthesis and the production of organic matter (Miziorko & Lorimer, 1983; Hamdan et al., 2022). Both DOC and DIC are integral to water quality, each influencing different aspects of aquatic chemistry and biology (Hamdan et al., 2021).

High CO_2 levels may increase phytoplankton primary productivity and photosynthetic activity, which could have an impact on the composition and operation of aquatic food webs (Sun et al., 2022). The balance between carbon production, transformation, and emission is altered by these activities taken together, underscoring the significance of inland waters in regional and global carbon cycles.

Recently, there has been a clear increase in organic and inorganic carbon levels in aquatic ecosystems (Weiss et al., 2018), due to the exposure of aquatic environment, such as the Tigris river to various anthropogenic and natural influences that affect its water quality and biological communities (Kadhim et al., 2024; Al-Sudani, 2021; Altahaan & Dobslaw, 2024). These anthropogenic influences include urban wastewater discharge, agricultural runoff, industrial effluents, and other human activities occurring along the river within Baghdad city, all of which may alter nutrient concentrations, carbon inputs, and overall water chemistry (Shaawi et al., 2024; Alzaidi & Hassan, 2025). Within Baghdad, the Tigris River is exposed to various human pressures including untreated municipal wastewater, hospital and domestic sewage, agricultural drainage, and industrial discharges from nearby facilities. These inputs contribute to increased concentrations of nutrients, organic matter, and other pollutants in the river water (Al-Saedi et al., 2024; Alfalahi & Aldhamin, 2025). Such changes in water chemistry can significantly influence ecological processes and may affect the structure and dynamics of phytoplankton communities by modifying nutrient availability, carbon inputs, and physicochemical conditions of the aquatic environment (Liu et al., 2025). Therefore, our research aimed to investigate the effects of physical and chemical factors on phytoplankton in Tigris River within Baghdad city, with a specific focus on the role of organic and inorganic carbon inputs. By examining the spatial and temporal variations of these factors.

The present study aims to investigate the influence of carbon sources, particularly DOC and CO_2, on phytoplankton composition in the Tigris River. Therefore, the study seeks to understand how the presence of different carbon sources modulates the influence of WT, DO, pH, nutrients, EC, and salinity on phytoplankton communities. Understanding the interactions between these factors is essential for developing comprehensive management strategies aimed at improving water quality and maintaining biodiversity. The insights gained from this research will help to identify critical points of intervention that can

mitigate the negative impacts of pollution and other anthropogenic activities on the river ecosystem.

Materials and Methods

Study Area and Sample Collection

The study was conducted at three sampling stations along the Tigris River within Baghdad city (Figure 1) during the period 2023–2024. Water samples were collected monthly from October to May to investigate phytoplankton communities and associated physicochemical parameters.

The selected sampling stations are located within the central stretch of the Tigris River as it flows through Baghdad. This section of the river was chosen because it represents one of the most densely populated urban areas along the river course, where the aquatic environment is exposed to multiple environmental pressures. In this region, the river receives inputs from agricultural drainage, municipal wastewater, and other anthropogenic activities that may influence water quality and aquatic biological communities. Therefore, this area provides an appropriate setting for examining the response of phytoplankton communities to environmental variables, particularly carbon-related factors.

The three sampling stations were selected to represent different environmental conditions along the Baghdad section of the river. Station selection was based on accessibility, hydrological characteristics, and the presence of potential anthropogenic influences, including urban discharge and agricultural runoff, which may alter the physicochemical properties of the water.

Physical and Chemical Parameters

Surface water samples were collected using clean polyethylene containers. Certain parameters were measured in situ, while others were analyzed in the laboratory to determine chemical properties and to support the qualitative assessment of phytoplankton communities.

Biological Sample

Phytoplankton Sampling

For qualitative analysis, phytoplankton samples were collected using a plankton net with a mesh size of 20 µm. The net was positioned against the direction of water flow and gently moved around the boat for approximately 10–15 minutes to concentrate phytoplankton organisms.

After sampling, the net was carefully retrieved and the concentrated sample was transferred into clean polyethylene bottles. The samples were then transported to the laboratory for further identification and analysis.

Measurements

Physical and Chemical Measurements

Field measurements were conducted using standard methods (APHA, 2005). WT was measured using an AL-Hana HI-98501 thermometer. The pH was determined using an HQ40 HACH multiparameter meter. Calibration of the pH meter was carried out using buffer solutions with pH values of 9, 7, and 4. The probe was immersed in the water sample and the reading was recorded once the measurement stabilized.

DO was determined using the azide modification of the Winkler method, with DO concentrations expressed in mg/L.

CO_2 concentrations were estimated following the method described by Hadi (1981) and approved by Golterman et al. (1978). This involved titrating 100 ml of the water sample with a 0.2N sodium carbonate (Na_2CO_3) solution until pH reached 8.4, then titrating

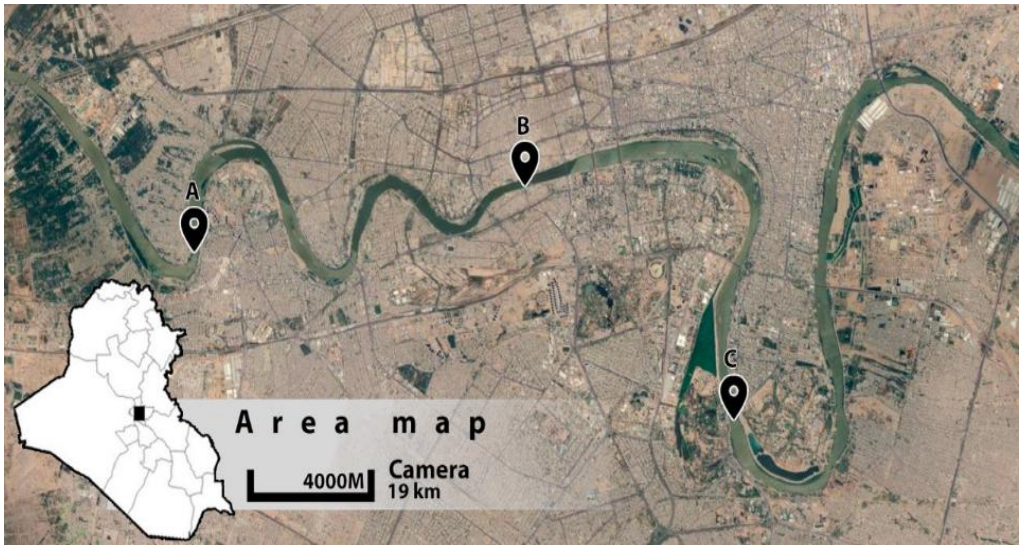

Figure 1. Map showing the study sites (A: AL- AL-Gherai'at, B: AL-Shuhda'a bridge, C: AL-Jadriyah).

another 100 ml with 0.1N hydrochloric acid (HCl) until pH reached 4.2. CO_2 concentration was calculated in µM using the following equation:

$$CO_2 = (A + B \times 4.4) \times 10$$

Where A is the volume of Na_2CO_3 titration, and B is the volume of HCl titration.

NO_3^- was measured by taking 50 ml water sample was treated with 1 ml of 1N HCl. Measurements were conducted using a UV-Visible spectrophotometer (Shimadzu UV-1800, Japan) at 220 nm and 275 nm, with results expressed in mg/L.

PO_4^{-3} was measured by using ascorbic acid method (Lind, 1979). A compound solution was added to a 50 ml filtered sample, forming a blue complex. Optical absorption was measured at 860 nm, with results expressed in mg/L. To measure DOC, samples were acidified to pH 2.0 with sulfuric acid (H_2SO_4) and filtered using a 0.45 µm Millipore filter. In the laboratory, a digestion solution (500 ml distilled water, 10.216 ml potassium dichromate, 167 ml sulfuric acid, and 33.3 ml mercuric sulfate) and an acid reagent solution (540 ml H_2SO_4 and 5.5 g silver sulfate) were prepared. These solutions were mixed in a tube, and 2 ml of the water sample was added. The mixture was digested at 150°C for 120 minutes and analyzed with a colorimeter. Results were reported as Chemical Oxygen Demand (COD) in mg/L and converted to Total Organic Carbon (TOC) using the Plutocalc water program, equating to DOC due to prior filtration (Williams et al., 2010).

Biological Measurements

Phytoplankton Identification

To diagnose non-diatom taxa, temporary slides were prepared and examined using an Olympus CX23 compound microscope at 40x magnification. Diagnosing diatom taxa involved dissolving the organic material with strong nitric acid to clarify their structure, which was then inspected at 100x magnification (Hustedt, 1930; Cleve-Euler, 1955; Huber-Pestalozzi, 1955; Patrick, 1966; Prescott, 1973; Round et al., 1990).

Phytoplankton abundance was determined using sedimentation method described (Furet & Benson-Evans, 1982). For each sampling site, one liter of water sample was collected and preserved with Lugol's iodine solution (1:100). The preserved samples were allowed to settle for 7–10 days to concentrate the phytoplankton. After sedimentation, the supernatant was carefully removed by siphoning, and the remaining concentrated sample was transferred into a graduated cylinder and further concentrated.

The final concentrated sample was examined under a compound microscope. Non-diatom taxa of phytoplankton were counted using a hemocytometer chamber by placing 1 ml of the concentrated sample on the counting slide. Diatom samples were cleaned using nitric acid digestion to remove organic material and then mounted on permanent slides using Canada balsam. The total number of phytoplankton cells was expressed as cells per liter (cell L^{-1}).

Ecological Indices

Constancy Index (CI)

The Constancy Index (S) is determined by the frequency of each species' occurrence using the formula from Myers (1980):

$$S= (n/N) \times 100$$

Where, n is the number of samples in which the species appears. N is the total number of samples.

The results are presented as percentages:

- Constant species: S>50%
- Accessory species: 25% – 50%
- Accidental species: 1% – 25%

Relative Abundance

The Relative Abundance Index (AR) is determined using the formula referenced in the study (Ulrich, 2001):

$$Ra = N/Ns \times 100$$

Where, N is the number of individuals of each taxonomic unit in the sample. Ns is the total number of organisms in the sample.

The results are expressed as percentages:

- Dominant species: (++++) Ra>70%
- Abundant species: (+++) 40% – 70%
- Less Abundant species: (++) 10% – 40%
- Rare species: (+) Ra<10%
- Absent: (–)

Statistical Analysis

Statistical analyses were performed using SPSS. Pearson correlation analysis was applied to evaluate the relationships between phytoplankton groups and the measured environmental variables, including WT, DO, pH, EC, NO_3^- and PO_4^{3-}, DOC, and CO_2. In addition, simple linear regression analysis was used to examine the relationships between phytoplankton composition and the studied environmental variables.

Results and Discussion

Phytoplankton Species Composition

Seven classes were identified, comprising a total of 180 species distributed among 56 genera. Diatom were the most abundant group in terms of both genera and species, accounting for 25 genera and 108 species (60%

of the total). The identified diatom taxa in this study were classified into three classes: Bacillariophyceae, which included 82 species representing 45.55% of the total algae species distributed among 17 genera; Fragilariophyceae, consisting of 5 genera and 14 species (7.77%); and Coscinodiscophyceae, comprising 3 genera and 12 species (6.66%). Diatom taxa represented the dominant group during the study period. Similar findings have been reported in previous studies conducted in the Tigris River, where diatoms were also identified as the dominant phytoplankton group under varying environmental conditions. Investigations carried out in different sections of the Tigris River have shown that diatoms frequently dominate phytoplankton communities due to their ability to tolerate fluctuations in environmental factors such as temperature, nutrient concentrations, and hydrological conditions (Varol & Şen, 2018; Lu et al., 2020; Serôdio & Lavaud, 2022). These observations are consistent with the results of the present study, which also recorded a clear dominance of diatom taxa in the phytoplankton community. Similar patterns of diatom dominance have also been reported in other sections of the Tigris River, where diatoms were identified as the most abundant phytoplankton group under different environmental conditions. This dominance is often attributed to their ecological adaptability and ability to tolerate fluctuations in environmental variables such as temperature, nutrient availability, and hydrological conditions (Varol & Şen, 2018).

This may be attributed to the sufficient availability of silica in the Tigris River (Toma, 2023). In contrast, non-diatom taxa included 32 genera and 72 species, representing 40% of the total phytoplankton. This group included Chlorophyceae, with 38 species belonging to 17 genera (18.88%); Cyanophyceae, with 29 species distributed among 10 genera (16.11%); Euglenophyceae, which included 6 species belonging to 2 genera (3.33%); and Dinophyceae, with 3 species belonging to 3 genera (1.66%) (Table 1).

Ecological Index

According to the constancy index and relative abundance values (Supplementary Table S1), several non-diatom taxa, particularly members of Cyanophyceae, were classified as accidental or rare species, while only a few species were categorized as accessory or less abundant. However, *Oscillatoria formosa* was identified as a constant and abundant species due to its ability to thrive in a wide range of aquatic habitats (Yaqoob et al., 2023; Bishoyi et al., 2024). Among Chlorophyceae, *Pediastrum duplex* was recorded as a constant species, which may be attributed to its ability to reproduce both sexually and asexually and to form colonies capable of tolerating various environmental stresses (McManus et al., 2011). On the other hand, several diatom species were consistently present and abundant during the study period. These included *Cocconeis placentula, Cymatopleura solea, Gyrosigma acuminatum, Navicula angelica, Navicula radiosa, Nitzschia sigmoidea, Diatoma elongatum, Fragilaria capucina, Ulnaria acus, and Ulnaria tabulata.* The dominance of these species may be attributed to their ability to tolerate diverse environmental conditions. This resilience is mainly related to the thickness and robustness of their silica cell walls (Hamm et al., 2003), especially since silica is readily available in the Tigris River (Jassim et al., 2024).

The dominant phytoplankton species identified based on the constancy index and relative abundance are summarized in (Table 2).

Bottom-up Controls of Phytoplankton Composition

The descriptive statistics (minimum, maximum values) of the measured environmental parameters during the study period are summarized in (Table 3), providing an overview of the environmental conditions in the studied sites of the Tigris River.

Table 1: The number of genera, species, and percentage of phytoplankton classes during the study.

	Non-diatom				Diatom		
Types of phytoplankton	Chlorophyceae	Cyanophyceae	Dinophyceae	Euglenophyceae	Coscinodiscophyceae	Bacillariophyceae	Fragilariophyceae
Genus	7	10	3	2	3	17	5
Species	34	29	3	6	12	82	14
Percentage of species%	18.88	16.11	1.66	3.33	6.66	45.55	7.77
Total number of Genus		22				25	
Total species		72				108	
Total percentage of species%		40				60	

The results showed that various variables impacted phytoplankton composition during the study (Figure 2, Table 4). The identified phytoplankton contain two groups; non-diatom taxa were positively affected (WT, DOC, CO_2) (Figure 2 a, h, i), while affected negatively by pH (Figure 2 b). There is no significant effect on phytoplankton by (EC, salinity, NO_3^-, and PO_4^{-3}) (Figure 2 d, e, f, g). Diatom taxa was positively affected by DOC and CO_2, (Figure 3 h, i) while negatively by pH (Figure 3 b), and not influenced by (EC, salinity, NO_3^-, and PO_4^{-3}) (Figure 3 d, e, f, g).

The composition and species richness of phytoplankton communities in aquatic ecosystems are closely related to bottom-up controls. Environmental factors such as WT, pH, DO, nutrient availability, EC, salinity, and carbon sources (DOC and DIC) form the environmental conditions that influence the structure and diversity of phytoplankton communities. Understanding the relationship between phytoplankton species richness and these environmental variables is essential for interpreting the ecological dynamics of aquatic ecosystems (Reynolds, 2006). By exploring this correlation, we can gain valuable insights into how environmental conditions influence diversity of phytoplankton communities, which in turn have far-reaching implications for the overall health and productivity of aquatic ecosystems.

According to the study non-diatom taxa have a positive correlation with WT, while no noticeable influence was noticed on diatom species numbers. With rising WT, the metabolic rate of non-diatom taxa increased, such as growth, reproduction, and cell division rates, leading to an increase in population numbers of algae (Paerl & Huisman, 2008). Moreover,

Table 2. Dominant phytoplankton species recorded at the studied sites of the Tigris River

Species	Group	Gherai'at	Al-Shuhada'a Bridge	Al-Jadriyah
Oscillatoria formosa	Cyanophyceae	Dominant	Abundant	Dominant
Pediastrum duplex	Chlorophyceae	Dominant	Dominant	Dominant
Pediastrum simplex	Chlorophyceae	Dominant	Abundant	Dominant
Pediastrum boryanum	Chlorophyceae	Dominant	Abundant	Abundant
Scenedesmus quadricauda	Chlorophyceae	Dominant	Abundant	Abundant
Closterium microporum	Chlorophyceae	Dominant	Less abundant	–
Euglena acus	Euglenophyceae	Dominant	Abundant	Dominant
Euglena gracilis	Euglenophyceae	Dominant	Rare	Dominant
Euglena minuta	Euglenophyceae	Abundant	Dominant	Abundant
Cyclotella comta	Coscinodiscophyceae	Dominant	Dominant	Abundant
Cocconeis placentula	Bacillariophyceae	Dominant	Dominant	Dominant
Cymatopleura solea	Bacillariophyceae	Dominant	Abundant	Dominant
Cymbella affinis	Bacillariophyceae	Dominant	Dominant	Abundant
Gyrosigma acuminatum	Bacillariophyceae	Dominant	Abundant	Dominant
Gyrosigma macrum	Bacillariophyceae	Dominant	Less abundant	Abundant
Navicula angelica	Bacillariophyceae	Dominant	Dominant	Dominant
Navicula radiosa	Bacillariophyceae	Dominant	Dominant	Dominant
Navicula rhynchocephala	Bacillariophyceae	Dominant	Rare	Rare
Nitzschia longissima	Bacillariophyceae	Dominant	Dominant	Abundant
Nitzschia sigmoidea	Bacillariophyceae	Dominant	Dominant	Dominant
Pinnularia borealis	Bacillariophyceae	Dominant	Less abundant	Rare
Surirella robusta	Bacillariophyceae	Dominant	Abundant	Less abundant
Rhoicosphenia curvata	Bacillariophyceae	Dominant	Less abundant	Less abundant
Diatoma elongatum	Fragilariophyceae	Dominant	Dominant	Dominant
Fragilaria capucina	Fragilariophyceae	Dominant	Dominant	Dominant
Fragilaria crotonensis	Fragilariophyceae	Dominant	Dominant	Abundant
Ulnaria acus	Fragilariophyceae	Dominant	Dominant	Dominant
Ulnaria tabulata	Fragilariophyceae	Dominant	Dominant	Dominant

Table 3. Minimum and maximum values of the measured environmental parameters in the studied sites of the Tigris River

Parameter	Minimum value	Maximum value	Unit
Water Temperature (WT)	9.19	22.00	°C
pH	7.70	8.10	—
Dissolved Oxygen (DO)	5.62	8.45	mg/L
Electrical Conductivity (EC)	905.75	1196.25	µS/cm
Salinity	0.57	0.76	‰
Nitrate (NO_3^-)	0.93	2.61	mg/L
Reactive Phosphate (PO_4^{3-})	0.03	0.14	mg/L
Dissolved Organic Carbon (DOC)	4.11	16.24	mg/L
Carbon Dioxide (CO_2)	115.13	134.44	µM

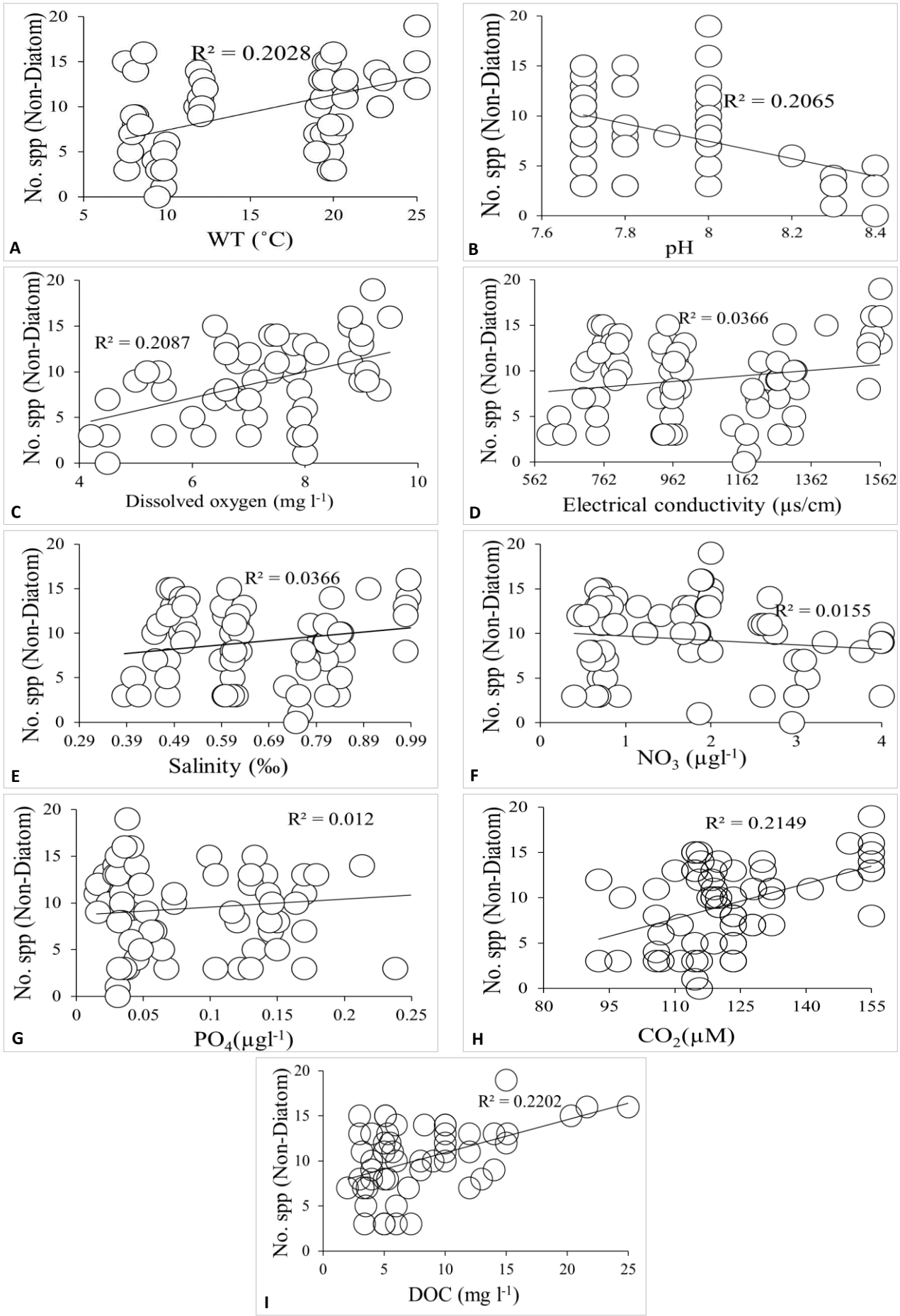

Figure 2. Correlation between different environmental variables and phytoplankton (non-diatom): where: (A-WT, B-pH, C-DO, D- EC, E-salinity, F-NO_3, G-PO_4, H-DOC, I- CO_2).

warmer conditions cause reduce herbivorous grazing activity, that leading to increases in phytoplankton species (Wang et al., 2024). While diatom species can survive under hard condition and can tolerate temperature range (Hamdan, 2026). The negative impact on Non-diatom and diatom taxa species by pH could be attributed to reducing pH levels with increasing CO_2, lead to rising species number of both non-diatom and diatom taxa as a reason of the main CO_2 roles to increase their growth and abundance (Wei et al., 2023).

The results indicated that non-diatom species number correlated positively to DO availability, but diatom species did not correlate. DO is a vital factor for all aquatic organisms, and its availability is strongly influenced by environment factors (Hamdan, 2026). Increased DO concentration supports the thriving and survival of non-diatom species by facilitating various metabolic processes like respiration which in turn increases in phytoplankton species and richness (Wei et al., 2023). In contrast, diatom species demonstrate resilience in challenging conditions. Diatom can tolerate different DO levels due to their ability to use protective mechanisms, such as respire NO_3 in hypoxia and anoxia condition (Merz et al., 2021). Furthermore, diatom taxa can survive under excess amount of DO due to using several mechanisms e.g., by increased the efficiency of their CO_2 concentrating mechanisms (CCMs) (Sun et al., 2022), with this mechanisms diatom can thrive under different environmental stresses.

EC and salinity are critical environmental factors that influence on the composition and distribution of phytoplankton in aquatic ecosystems. Changes in EC and salinity levels can affect competitive interactions, and have cascading effects on the entire aquatic food web (Castillo et al., 2018). On the other hand, and according to our findings, EC and salinity different levels have no significant influences on non-diatom and diatom species numbers, this could be returned for different reasons: (1) aquatic ecosystems are complex and multiple factors interact to determine species composition and abundance, which enables other factors such as DO, pH and carbon sources play a dominant role in shaping species numbers (Resende et al., 2005). (2) Electrical conductivity and salinity may not be limiting factors for non-diatom and diatom taxa due to sufficient for phytoplankton need, that happen as a result of increasing anthropogenic activities that lead to adding EC/salinity amount to the water and keeping them in constant (Lu et al., 2020), (3) some species especially non-diatom taxa has specific adaptations that allow them to thrive in a wide range of environmental conditions, making them less sensitive to changes under high salinity levels like some non-diatom species under high salinity condition can use osmoregulation mechanism by which they can stores some ions such as sodium and potassium within their cells that help them to acclimation to different salinity (Kirst, 1996), (4) diatom taxa may form dormant cyst or use their silica cell wall to withstand and protect their cell from varies condition changes (Stenger-Kovács et al., 2023).

Nutrients are paramount importance for phytoplankton composition. Nutrients such as NO_3^- and PO_4^{-3} in aquatic ecosystems strongly influence the abundance, diversity, and community structure of phytoplankton. However, several studies have shown that in large river systems, nutrient concentrations may not always be the primary limiting factor for phytoplankton growth when nutrient levels remain relatively stable due to continuous external inputs. Under such conditions, other environmental factors such as hydrology, carbon availability, and temperature may play a more dominant role in shaping

Table 4. Statistical results of correlation and regression for bottom-up controls on phytoplankton composition

Variable	Correlation (*r*)	*F*-value$_{(df)}$	*p-value*
Non-diatom			
WT	0.50	$13.23_{(1,71)}$	0.0006***
pH	-0.50	$14.30_{(1,71)}$	0.0003***
DO	0.50	$12.92_{(1,71)}$	0.0007***
EC	0.19	$2.61_{(1,71)}$	0.11
Salinity	0.19	$2.61_{(1,71)}$	0.11
NO_3^{-1}	-0.12	$0.98_{(1,71)}$	0.32
PO_4^{-3}	0.04	$0.13_{(1,71)}$	0.71
DOC	0.50	$14.39_{(1,71)}$	0.0003***
CO_2	0.50	$17.24_{(1,71)}$	0.0001***
Diatom			
WT	0.20	2.97	0.08
pH	-0.50	13.49	0.0005***
DO	-0.21	3.03	0.08
EC	-0.22	3.89	0.05
Salinity	-0.22	3.89	0.05
NO_3^{-1}	-0.13	1.20	0.27
PO_4^{-3}	0.14	1.44	0.23
DOC	0.50	10.20	0.002**
CO_2	0.50	11.14	0.001**

*The significance level is P-value <0.05. **The significance level is P-value <0.01. ***The significance level is P-value <0.001.

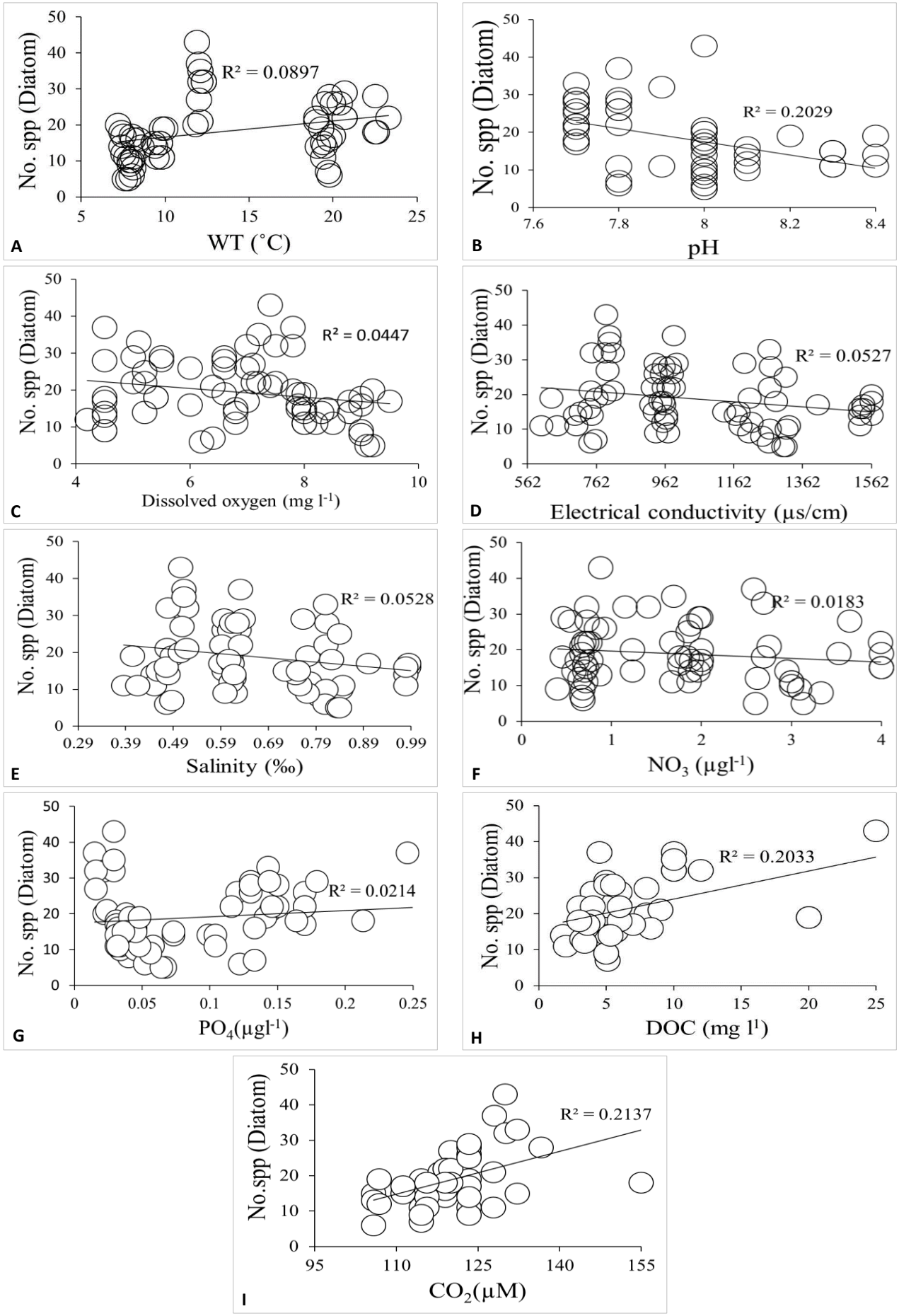

Figure 3. Correlation between different environmental variables and phytoplankton (diatom): where: (A-WT, B- pH, C-DO, D-EC, E- salinity, F-NO_3, G-PO_4, H-DOC, I-CO_2).

phytoplankton community composition (Cvetkoska et al., 2021). On the other hand, our results indicated that there is no significant effect on non-diatom and diatom taxa.

Numerous human activities have an impact on the Tigris River study region in Baghdad, which may have an impact on nutrient dynamics and water quality. The sampling sites, which include Al-Jadriya, Al-Gherai'at and the Al-Shuhada Bridge are located in crowded metropolitan areas that are subject to a variety of pollution sources. Urban surface drainage, business operations, agricultural runoff, and municipal wastewater discharge are some of these sources. In the aquatic environment, NO_3^- and PO_4^{-3} concentrations are comparatively stable and continuously available as a result of these inputs, which add significant amounts of nutrients and organic matter to the river. Phytoplankton growth might not be limited by NO_3^- and PO_4^{-3} in these circumstances (Liu et al., 2009). Nutrient saturation, in which nutrient concentrations are adequate for phytoplankton development throughout the research period, may be the consequence of ongoing external nutrient imports from man-made sources. As a result, changes in nutrient levels might not have a major impact on the composition of phytoplankton (Ma et al., 2024).

Furthermore, the Tigris River's hydrological features might lessen the direct impact of nutrient concentrations on phytoplankton groups. The Tigris River undergoes dilution and mixing processes that can mitigate localized nutrient changes because it is a sizable river system with comparatively strong water flow and constant water renewal. The correlation between phytoplankton dispersion and nutrient concentrations may be weakened by such hydrodynamic conditions (Peierls et al., 1991).

Furthermore, a variety of environmental conditions frequently have an impact on phytoplankton communities in river ecosystems at the same time. When it comes to controlling the makeup of phytoplankton communities, factors including WT, DO, carbon availability (DOC and CO_2), and physicochemical conditions may be more important than nutrients alone. Consequently, the current study's lack of a significant correlation between NO_3^-, PO_4^{-3}, and phytoplankton composition may be due to the combined impacts of ongoing fertilizer imports, river hydrodynamics, and the influence of other environmental factors (Litchman & Klausmeier, 2008).

Additionally, phytoplankton species exhibit varying strategies depending on nutrient availability to survive under different nutrients levels, from these strategies; they can switch between different nutrient transporters and metabolic pathways to optimize nutrient utilization under changing conditions (Stief et al., 2022). They also stored excess amount of nutrient when nutrient levels decline (Zummach et al., 2024). Moreover, diatom taxa can photosynthesize and consume organic matter that allow them to adaptation to different nutrient conditions (Hopkinson et al., 2011).

The functions of DOC and CO_2 are essential and play a significant role in shaping aquatic ecosystem processes and community structure (Hamdan et al., 2018). These variables are frequently recognized as significant participants in the carbon cycle within aquatic settings, extend beyond their chemical effects. According to our study, DOC and CO_2 had positive effects on non-diatom and diatom species numbering. Similar observations have been reported in freshwater ecosystems where elevated concentrations of dissolved organic carbon enhance microbial activity and stimulate phytoplankton growth through increased carbon availability and improved nutrient utilization efficiency (Hamdan & Kadhim, 2025).

DOC is an important sources of organic nutrients, so as for our results, high concentration of DOC broken by bacteria into simpler organic compounds the growth that promoting the growth and diversity of algae (Berggren & Tranvik, 2016). Furthermore, certain diatom taxa are capable of directly utilizing DOC through mixotrophic growth, which involves combining photosynthesis with the absorption of organic carbon. This capability enables them to flourish in environments with elevated DOC levels, resulting in a rise in phytoplankton species richness (Anderson et al., 2008).

DOC is a main sources of CO_2, so with high concentration of DOC, elevated CO_2 concentration enhances the ability of phytoplankton to utilize available nutrients more efficiently (Bach & Taucher, 2019). This can lead to increased growth rates and higher species diversity as different species respond to the improved conditions (Keys et al., 2018). Moreover, High CO_2 concentration shift the species composition of phytoplankton communities. Some species, particularly those that are more efficient at utilizing CO_2, may become more dominant. This can lead to an increase in species diversity, and that can be due to their ability to manage CO_2 levels as a result of their use of specialized mechanism, including concentration mechanism CCM (Giordano et al., 2005; Kumar et al., 2024).

Regression analysis was used to look at the connections between phytoplankton groups and environmental factors, as seen in (Figure 2). The complex character of river ecosystems, where phytoplankton communities are influenced by numerous environmental variables working simultaneously rather than a single one, may be reflected in the relatively low R^2 values seen in (Figure 2). Similar findings have been reported in river ecosystems where phytoplankton dynamics are influenced by multiple interacting environmental factors rather than a single dominant variable (Toma, 2023).

Conclusion

This study highlights the ecological significance of the Tigris River within Baghdad as an important freshwater system influenced by both natural processes

and increasing human activities. The results indicate that carbon sources, particularly DOC and CO_2, play a key role in shaping phytoplankton composition in the river. Both diatom and non-diatom taxa showed a similar positive response to carbon availability, suggesting that carbon acts as an important bottom-up driver of phytoplankton dynamics. However, the two groups differed in their responses to other environmental variables such as temperature, DO, and pH, reflecting differences in their ecological adaptations. Considering the close relationship between carbon cycling in aquatic ecosystems and global change, further long-term studies are recommended to better understand the role of carbon dynamics in regulating phytoplankton communities and ecosystem functioning in the Tigris River.

Ethical Statement

This project received approval from the local ethics committee at the University of Baghdad (No;24-011/3).

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Author Contribution

MH; designed the study, wrote the first draft of the manuscript.

BK; designed the study, carried out the field and lab work, wrote the first draft of the manuscript, wrote the first draft of the manuscript.

Conflict of Interest

We declare that there are no conflicts of interest.

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S U P P L E M E N T A R Y M A T E R I A L S

Supplementary Table 1. Constancy Index (CI) and Relative Abundance (AR) for Zooplankton in the Studied Sites of Tigris River. (Where A indicates constant species comprising more than 50%, B indicates accessory species making up 25-50%, and C indicates accidental species accounting for 1-25%. The abundance categories are as follows: ++++ for dominant species with relative abundance (Ra) > 70%, +++ for abundant species with Ra between 40% - 70%, ++ for less abundant species with Ra between 10% - 40%, + for rare species with Ra < 10%, and - for absent species)

Phytoplankton	AL-Gherai'at		AL-Shuhda'a bridge		AL-Jadriyah	
	CI	AR	CI	AR	CI	AR
Division: Cyanophyta						
Class:Cyanophyceae						
Anabaena affinis(Lemmermann 1898)	-	-	C	+	C	+
Anabaena Sp.	C	+	C	+	C	
Arthrospira platensis (Gomont, 1892)	C	+	C	+	-	-
Aphanocapsa biformis(A.Braun in P. Richter, 1879)	C	+	C	+	C	+
Chroococcus dispersus (Keissler) Lemmermann 1904)	C	+	C	+	C	+
Chroococcus minor (Kützing) Nägeli 1849)	C	+	C	+	C	+
Chroococcus minutus(Stearn 1983)	C	+	C	+	-	-
Chroococcus turgidus (Kützing) Nägeli, 1849)	C	+	C	+	C	+
Lyngbya aestuarii (Liebman ex Gomont 1892)	C	+	C	+	-	-
Lyngbya connectens (Brühl & Biswas 1923)	C	+	C	+	C	+
Lyngbya major (Gomont, 1892)	B	++	B	+++	B	+++
Merismopedia glauca (Ehrenberg) Kützing, 1845*)*	-	-	-	-	C	+
Nostoc Sp.	C	+	C	+	-	-
Oscillatoria amoena (Gomont, 1892)	C	+	B	+++	C	+
Oscillatoria angustissima(West & G.S.West 1897)	C	+	B	+++	B	+++
Oscillatoria Formosa (Bory ex Gomont 1892)	A	++++	A	+++	A	++++
Oscillatoria lacustris (Whitford and Schumacher, 1969)	C	+	C	+	C	+
Oscillatoria lemmermanni(Wołoszyńska 1912)	C	++	B	+++	C	+
Oscillatoria limosa (C.Agardh ex Gomont 1892)		_	B	+++	C	+
Oscillatoria limnetica (Lemmermann 1900)	C	+	-	-	B	+++
Oscillatoria nigra(Vaucher ex Gomont 1892)	B	+++	B	+++	C	+
Spirulina daedaleoides	C	+	C	C	C	+
Spirulina laxa(Smith, G.M.1916)	C	+	-	-	-	-
Spirulina laxissima (G.S.West 1907)	B	+++	C	-	B	++
Spirulina major(Kützing ex Gomont 1892)	-	-	C	+	-	-
Spirulina nordstedii(Gomont, 1892)	C	+	-	-	C	+
Spirulina salsa	-	-	C	+	-	-
Spirulina subtilissima(Kützing ex Gomont 1892)	B	+++	C	+	-	-
Phormidium tenue (Gomont 1892)	B	+++	A	+++	A	+++
Division:Chlorophyta						
Chlorophyceae						
Ankistrodesmus falcatus (Corda) Ralfs 1848)	B	+++	B	+++	B	++
Cladophora lanceolatum	B	+++	C	+	C	+
Chlamydomonas angulosa (O.Dill, 1895)	B	+++	B	++	B	+++
Chlorella vulgaris(Beijerinck 1890)	B	+++	B	++	C	+
Chrysamoeba sp.(G.A.Klebs, 1892)	-	-	-	-	C	+
Closterium microporum (Nägeli, 1855)	A	++++	B	++	-	-
Closterium moniliferum(Ehrenberg ex Ralfs 1848)	-	-	B	++	-	-
Closterium paravalum(Nägeli 1849)	C	+	B	++	C	+
Coelastrum indicum(W.B.Turner 1892)	C	+	B	++	-	-
Coelastrum reticulum(P.A.Dangeard) Senn 1899)	C	+	C	+	C	+
Eudorina sp.(Ehrenberg, 1832)	C	+	C	+	-	-
Haematococcus lacustris(Stearn 1983)	-	-	C	+	C	+
Kentrosphaera gloeophila(Bohlin) Brunnthaler 1915)	C	+	C	+	C	+
Mougeotia scalaris(Hassall 1842)	-	-	-	-	C	+
Oedogonium gracillius(Tiffany, 1934)	C	+	B	++	C	+
Oedogonium Sp.	C	+	C	+	C	+
Pediastrum boryanum (Turpin) Meneghini 1840)	A	++++	B	+++	B	+++
Pediastrum duplex (Meyen 1829)	A	++++	A	++++	A	++++
Pediastrum integrum (Nägeli, 1849)	B	+++	B	+++	B	+++
Pediastrum sculptatum (G.M.Smith 1916)	-	-	C	+	C	+
Pediastrum simplex(Meyen 1829)	A	++++	B	+++	A	+++++
Pediastrum tetras(Ehrenberg) Ralfs 1845)	C	+	B	++	C	+
Scenedesmus acuminatus(Lagerheim) Chodat 1902)	B	++	B	++	C	+
Scenedesmus bijuga(Turpin) Lagerheim 1893)	B	+++	B	+++	B	+++
Scenedesmus bernardii(G.M.Smith) Dedusenko 1953)	B	++	B	++	B	+++
Scenedesmus dimorphus(Turpin) Kützing 1834)	B	+++	B	+++	C	+

S U P P L E M E N T A R Y M A T E R I A L S

Supplementary Table 1. Continued

Phytoplankton	AL-Gherai'at		AL-Shuhda'a bridge		AL-Jadriyah	
	CI	AR	CI	AR	CI	AR
Division:Chlorophyta						
Chlorophyceae						
Scenedesmus hystrix(Lagerheim 1882)	C	+	B	++	C	+
Scenedesmus longus(G.M.Smith 1918)	-	-	B	+++	C	+
Scenedesmus obliquus(Turpin) Kützing 1833)	-	-	B	+++	-	-
Scenedesmus opliensis(P.G.Richter 1895)	-	-	-	-	C	+
Scenedesmus quadricauda(Turpin) Brébisson 1835)	A	++++	B	+++	B	+++
Scenedesmus Sp.	B	++	C	+	C	+
Selenastrum gracile(Reinsch 1866)	C	+	B	++	C	+
Stigeocolonium attenuatum(Hazen) Collins 1909)	-	-	-	-	C	+
Stigeoclonium pychydermum(Prescott, G.W. (1944)	C	+	-	-	-	-
Stigeoclonium subsecundun(Kützing 1843)	C	+	B	++	-	-
Stigeoclonium Sp.	C	+	C	+	-	-
Triploceras sp.(Bailey, 1851)	C	+	C	+	-	-
Division: Dinoflagellata						
Ceratium hirundinella (O.F.Müller) Dujardin, 1841)	B	+++	A	++++	B	+++
Glenodinium borgei (Lemmermann) J.Schiller 1935)	B	+++	C	+	B	+++
Peridinium cinctum (O.F.Müller) Ehrenberg 1832)	-	-	B	+++	B	+++
Division:Euglenophyta						
Euglena acus(O.F.Müller) Ehrenberg, 1830)	A	++++	B	+++	A	++++
Euglena gracilis (Klebs, G. 1883)	A	++++	C	+	A	++++
Euglena minuta(Playfair, G.I. 1921)	B	+++	A	++++	B	+++
Euglena polymorpha (P.A.Dangeard, 1902)	B	+++	B	+++	C	+
Phacus orbicularis (Hübner 1886)	B	+++	B	+++	C	+
Phacus Sp.	C	+	C	+	-	-
Division: Bacillariophyta						
Class: Coscinodiscophyceae (Centric Diatom)						
Cyclotella comta(Ehrenberg) Kützing, 1849)	A	++++	A	++++	B	+++
Cyclotella glomerata(H.Bachmann 1911)	-	-	C	+	**C**	+
Cyclotella meneghiniana(Kützing 1844)	B	++	B	+++	**C**	+
Melosira ambigna (Stearn 1983)	B	++	A	++++	A	++++
Melosira distans(Ehrenberg) Kützing 1844)	A	++++	B	++	C	+++
Melosira granulata(Ehrenberg) Ralfs 1861)	A	++++	B	+++	A	+++
Melosira italica (O.Müller 1906)	-	-	B	+++	C	+
Melosira jurgensi(C.Agardh 1824)	-	-	C	+	C	+
Melosira roseana (Ehrenberg) Grunow, 1882)	B	+++	B	+++	C	+
Melosira varians (C.Agardh 1827)	B	+++	-	-	-	-
Melosira Sp.	C	+	C	+	-	-
Stephanodiscus Astraea(Ehrenberg) Grunow, 1880)	B	++	B	++	B	++
Division: Bacillariophyta						
Class: Bacillariophyceae (Raphid,Pennate Diatom)						
Achnanthes microcephala(Kützing) Grunow 1880)	C	+	B	++	-	-
Achnanthes minutissima(Kützing 1833)	-	-	B	++	C	+
Amphiprora alata (Ehrenberg) Kützing, 1844)	A	++++	B	++	-	-
Amphiprora Sp.	C	+	C	+	A	++
Amphora normani (Rabenhorst, 1864)	B	++	-	-	-	-
Amphora ovalis (Kützing, 1844)	B	++	B	++	C	+
Amphora veneta (Kützing 1844)	B	++	B	++	C	+
Bacillaria paxillifer (O.F.Müller) T.Marsson, 1901)	C	+	C	+	-	-
Calonies amphisbaena (Bory) Cleve 1894)	-	-	C	+	C	+
Calonies permagna (Bailey) Cleve 1894)	C	+	C	+	C	+
Calonies cillicuta	B	+++		++	C	+
Cocconeis pediculus(Ehrenberg, 1838)	A	++++	B	++	B	+++
Cocconeis placentula(Ehrenberg, 1838)	A	++++	A	++++	A	++++
Cymatopleura elliptica(Brébisson) W.Smith 1851)	B	++	B	++	-	-
Cymatopleura salen	B	++	B	++	C	+
Cymatopleura solea (Brébisson) W.Smith 1851)	A	++++	A	+++	A	++++
Cymbella affinis(Kützing 1844)	A	++++	A	++++	B	+++
Cymbella amphicephala(Nägeli ex Kützing) Krammer 2003)	C	+	-	-	-	-
Cymbella aspera(Ehrenberg) Cleve 1894)	C	+	C	+	-	-
Cymbella cymbiformis(C.Agardh, 1830)	C	+	C	+	C	+
Cymbella gracilis(Rabenhorst) Cleve, nom. illeg. 1894)	-	-	C	+	C	+
Cymbella helvetica(Kützing 1844)	B	+++	C	+	-	-

S U P P L E M E N T A R Y M A T E R I A L S

Supplementary Table 1. Continued

Phytoplankton	AL-Gherai'at		AL-Shuhda'a bridge		AL-Jadriyah	
	CI	AR	CI	AR	CI	AR
Division:Chlorophyta						
Chlorophyceae						
Cymbella lacustris(C.Agardh) Cleve 1894)	B	+++	C	+	C	+
Cymbella naviculiforms(Auerswald ex Heiberg 1863)	-	-	C	+	C	+
Cymbella parva(W.Smith) Kirchner 1878)	B	++	C	+	C	+
Cymbella turgida(W.Gregory, nom. illeg. 1856)	-	-	C	+	C	+
Cymbella ventricosa(C.Agardh) C.Agardh 1830)	B	++	B	+++	B	+++
Diploneis interrupta(Kützing) Cleve 1894)	-	-	C	+	-	-
Diploneis ovalis(Hilse) Cleve 1891)	-	-	C	+	-	-
Gomphoneis olivacea(Hornemann) P.A.Dawson ex R.Ross & P.A.Sims 1978)	-	-	B	++	C	+
Gomphonema angustatum(Kützing) Rabenhorst 1864)	B	++	C	+	C	+
Gomphonema constrictum(Ehrenberg 1844)	B	++	C	+	-	-
Gomphonema fanensis(Maillard 1964)	-	-	C	+	C	+
Gomphonema intricatum(Ehrenberg) Cleve 1894)	C	+	-	-	C	+
Gomphonema tergestinum(Grunow) Fricke 1902)	B	++	-	-	-	-
Gyrosigma acuminatum (Kützing) Rabenhorst 1853)	A	++++	A	+++	A	++++
Gyrosigma attenuatum (Kützing) Rabenhorst 1853)	A	++++	B	++	B	++
Gyrosigma macrum(W.Smith) J.W.Griffith & Henfrey 1856*)*	A	++++	B	++	A	+++
Gyrosigma peisonis(Grunow) Hustedt, 1930)	A	++++	B	++	B	+++
Navicula angelica (Ralfs 1861)	A	++++	A	++++	A	++++
Navicula bacilloides(Hustedt 1945)	-	-	C	+	-	-
Navicula bacillum(Ehrenberg 1839)	-	-	-	-	C	+
Navicula cari(Ehrenberg 1836)	B	+++	C	+	C	+
Navicula cincta(Ehrenberg) Ralfs 1861)	C	+	B	+++	B	+++
Navicula cocconsiformis(W.Gregory ex Greville 1855)	-		-	-	C	+
Navicula cryptocephala(Kützing 1844)	A	++++	B	+++	B	+++
Navicula decussis(Østrup 1910)	-	-	C	+	B	+++
Navicula dicephala(Ehrenberg 1838)	B	+++	B	+++	C	+
Navicula fusca(Gregory, 1857)	B	+++	C	+	C	+
Navicula gracilis(Ehrenberg 1832)	B	+++	B	+++	-	-
Navicula gregaria(Donkin 1861)	C	+	-	-	-	-
Navicula grimmei(Krasske 1930)	B	+++	C	+	-	-
Navicula halophile(Grunow) Cleve 1894)	B	+++	-	+	-	-
Navicula phyllepta(Kützing 1844)	C	+	-	-	-	-
Navicula pseudonivalis(W.Bock 1970)	B	+++	-	-	-	-
Navicula pupula(Kützing 1844)	B	+++	-	-	C	+
Navicula radiosa (Kützing 1844)	A	++++	A	++++	A	++++
Navicula rhynchocephala(Kützing 1844)	A	++++	C	+	C	+
Navicula saxophila(W.Bock ex Hustedt 1966)	C	+	C	+	C	+
Navicula seminulum(Grunow 1860)	B	+++	B	+++	C	+
Navicula trivialis(Lange-Bertalot 1980)	B	+++	C	+	-	-
Nitzschia acicularis(Kützing) W.Smith, 1853)	B	+++	B	+++	C	+
Nitzschia amphibia(Grunow 1862)	B	+	B		B	+++
Nitzschia cluassi(Hantzsch 1860)	B	+++	B	+++	-	-
Nitzschia dissipata(Kützing) Rabenhorst 1860)	B	+++	B	+++	C	+
Nitzschia hatizschania (Rabenhorst, 1860)	-	-	C	+	C	+
Nitzschia inconspicua(Grunow 1862)	-	-	-	-	C	+
Nitzschia longissimia (Brébisson) Ralfs, 1861)	A	+++++	A	++++	B	+++
Nitzschia obtuse(W.Smith 1853)	-	-	C	+	-	-
Nitzschia parvala(W.Smith 1853)	B	+++	C	+	C	+
Nitzschia recta(Hantzsch ex Rabenhorst 1862)	C	+	-	-	-	-
Nitzschia romana(Grunow 1881)	B	+++	B	+++	C	+
Nitzschia sigma(Kützing) W.Smith 1853)	B	+++	-	-	-	-
Nitzschia sigmoidea (W.Smith 1853)	A	+++++	A	++++	A	++++
Nitzschia tryblionell(Hantzsch, 1860)	C	+	-	-	C	+
Nitzschia vermicularis(Kützing) Hantzsch 1860)	C	+	B	+++	C	+
Pinnularia borealis(Ehrenberg 1843)	A	++++	B	++	C	+
Pinnularia leptosome(Grunow) Cleve 1895)	C	+	-	-	-	-
Rhoicosphenia curvata(Kützing) Grunow, 1860)	A	++++	B	++	B	++
Surirella capronii(Brébisson & Kitton 1869)	-	-	C	+	-	-
Surirella robusta(Ehrenberg 1841)	A	++++	B	+++	B	++
Surirella Sp.	C	+	-	-	-	-

S U P P L E M E N T A R Y M A T E R I A L S

Supplementary Table 1. Continued

Phytoplankton	AL-Gherai'at		AL-Shuhda'a bridge		AL-Jadriyah	
	CI	AR	CI	AR	CI	AR
Division:Bacillariophyta						
Class: Fragikariophyceae (Araphid,Pennate Diatom)						
Asetrionella Formosa(Hassall, 1850)	B	++	B	++	B	++
Centronella sp.(Voigt 1902)	C	+	-	-	A	+++
Diatoma elongatum (Lyngbye) C.A. Agardh, 1824)	A	++++	A	++++	A	++++
Diatoma vulgare(Grunow, 1862)	A	++++	A	++++	B	+++
Fragilaria brevistriata (Grunow 1885)	B	++	C	+	C	+
Fragilaria capucina (Desmazières, J.B.H.J. 1830)	A	++++	A	++++	A	++++
Fragillaria crotonensis (Kitton 1869)	A	++++	A	++++	B	+++
Fragilaria intermedia(Grunow 1881)	B	+++	B	+++	A	+++
Fragilaria virescens (Ralfs 1843)	B	+++	B	+++	A	+++
Synedra acus (Kützing, 1844)	A	++++	A	++++	A	++++
Synedra pulchell (Kützing, 1844)	-	-	-	-	C	+
Synedra rumpens (Kützing 1844)	B	+++	B	+++	B	+++
Synedra tabulate (Kützing 1844)	A	++++	A	++++	A	++++
Synedra ulna (Ehrenberg, 1836)	B	+++	B	+++	C	+