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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

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Abstract. Given the global climate changes, especially the drought conditions that Iraq's climate has been suffering from in recent years, along with the stifling water scarcity, the current study aimed to focus on developing quantitative and qualitative tools and strategies for phytoplankton (non-diatoms) as vital indicators in order to protect ecosystems, enhance their resilience, and promote sustainability. Four sites were chosen for the most prominent cities. The main site within the river basin for the period from July 2022 to April 2023 to collect water samples and phytoplankton cells (non-diatoms). The current study showed that the water of the Euphrates River at the current study sites is warm, pH neutral, with high basicity and medium hardness, with EC, TDS and turbidity, and the BOD is high, exceeding permissible limits, with good ventilation. Cl and Na salts, nutrients as NO_3, were available in normal proportions, with PO_4 concentrations exceeding the permissible limits due to the river water's impact on agricultural lands around the river basin. During the study, 137 species belonging to five main classes were identified. Chlorophyceae were dominant at a rate of 55%, followed by Cyanophyceae at a rate of 34%, then Euglenophyceae at a rate of 4%, then Pyrrophyceae at a rate of 4%, and Chrysophyceae at a rate of 1%, where the highest density was recorded. For phytoplankton cells (non-diatoms) in site 1 (Al-Baghdadi) 2,438.8 cells L^{-1}, while the lowest density was recorded in site 4 (Al-Ramadi Dam) 1,761.2 cells L^{-1}. The results of biodiversity indices showed that the waters of the Euphrates River have low to moderate biological diversity, little to moderate pollution, and moderate species richness, with high homogeneity in their distribution between sites. The predominant groups of species during the study period were *Oscillatoria formosa*, *Pediastrum simplex, p. duplex*, *Scenedesmus alternate, S. dimorphus, S. quadricauda, S. artcuatus var. platydiscus, microporium crassior*, *Pediastrium boryanum, Coeloastrum microporium, Chrococcus limeticus, C. minor*.

Key words: phytoplankton (non-diatoms), biological indicators, biodiversity indices, upper euphrates river.

INTRODUCTION

Water is of great importance to human life and other living organisms, so it has become necessary to study aquatic ecosystems, chemical, physical and biological factors and organic pollutants in order to determine water quality (Burkhardt et al., 2022).There is a difference between river water and sea water, as rivers are characterized by continuous flow, which leads to continuous mixing of the lower and upper water layers to contribute to the formation of organic nutrients, and this movement is important in the aeration process, which makes rivers with high biological diversity (Sharqi et al., 2024). Phytoplankton live in all aquatic environments, including fresh and salt water, ponds and swamps, which are rich in essential nutrients such as nitrates and phosphates. Algae vary in shapes and sizes, some of which are 1.5 µm and some of which reach 200 m (Allen, 2020. They possess great resistance to environmental variations, including light intensity, temperature and salinity. This is used as a vital indicator for evaluating water quality (Al-Tamaki & Al-Obeidi, 2023). The increased growth of phytoplankton leads to a change in the basic characteristics of the water, causing an unpleasant odor in addition to discoloring the water in green, especially in the summer, as a result of high temperatures and salinity. Some species of floating algae have been used to determine organic pollution occurring in water bodies (Peluso, 2021). Biological pollution in seas and rivers poses a major threat to human health, which contains many living organisms such as pathogenic fungi, bacteria, and worms, and the excretion of their waste is directly depicted, as their reproduction increases with the increase in chemical elements resulting from human activities. Water has the ability to purify itself from impurities, environmental factors, and other living organisms (Al-Dulaimi et al., 2024). Algae have been used as biological indicators since the nineteenth century in terms of environmental variations occurring in algal groups and variations occurring in their reproduction and metabolic and physiological processes. Therefore, they are considered important organisms in determining the quality of aquatic ecosystems (LI et al., 2022). The growth of algae is affected by water pollutants, as they are deprived of access to light as they are autotrophs, leading to a lack of their activity. Pollution also affects the disappearance and appearance of some species of algae, thus affecting their overall density. Most studies of the waters of the upper Euphrates River Basin used diatoms as a biological indicator in determining the quality of river water (Al-Anzy et al., 2023; Al-Tamaki et al., 2023), while the current study is one of the pioneering studies in employing non-diatom phytoplankton as a biological indicator in determining the quality and nutritional status of the waters of the Euphrates River Basin.

MATERIAL AND METHODS

Study Area

Water samples were collected for physical and chemical tests and phytoplankton samples from four sites in the upper Euphrates River between the city of Baghdadi and the city of Ramadi in Anbar Governorate (Iraq) (Fig. 1, Table 1).

These sites were selected according to their population density and human activities for the most important major cities located within the river basin, which are characterized by their agricultural and industrial lands, in addition to the spread of fish farming ponds on the banks of the river. Samples were collected at a rate of one sample per month for a period of ten months, with the average readings calculated to determine the site values, compare them, and discuss them starting from July 2022 to April 2023.

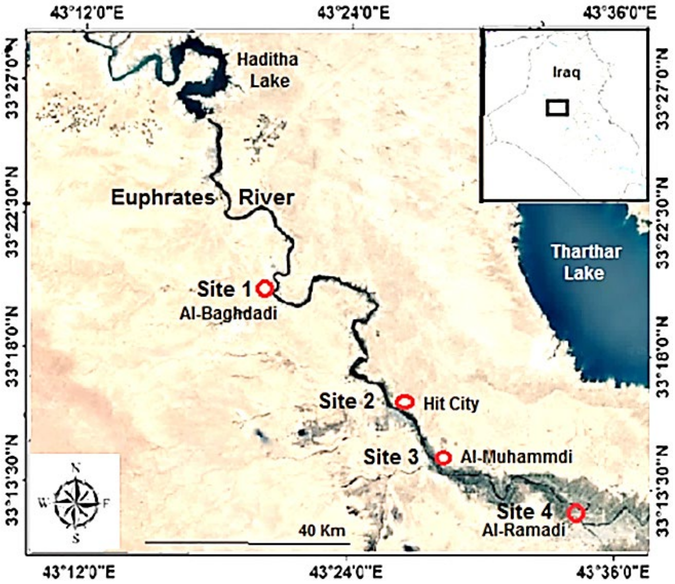

Figure 1. Locations for collecting samples of water from the Euphrates River between two cities of Al-Baghdadi and Al- Ramadi - western Iraq. (Google Earth).

Table 1. Geographic coordinates of sampling sites in the Euphrates River (Google Earth)

Sites	Latitudes (North)			Longitudes (East)		
	°	′	″	°	′	″
1. Al-Baghdadi City	33	52	20	42	31	27
2. Hit City	33	38	44	42	49	32
3. Al-Muhammdi City	33	32	54	42	55	10
4. Al-Ramadi City	33	26	19	43	15	31

Physical and Chemical Parameters analysis

Table 3 indicates the physical and chemical parameters that were measured at the study sites in the waters of the Euphrates River between the cities of Al-Baghdadi and Ramadi. The water temperature was measured using a portable pocket thermometer (Warner- china), while the pH, electrical conductivity (EC), and total dissolved solids (TDS) were measured using the portable digital multimeter (Hach-HQ4od-Germany), and turbidity was measured with a turbidity meter device (Lovibon-Germany). Based on APHA (2017) a group of parameters were measured: Total alkalinity (TH), total Hardness (TH), Calcium (Ca), Magnesium (Mg), Oxygen (O_2), Biological Oxygen Demand (BOD_5), and Nitrate (NO_3).

Phytoplankton (Non-Diatoms) community

Phytoplankton samples were collected using a mesh with a diameter of 26 microns to conduct the qualitative study. While the sedimentation method was used to conduct a quantitative study of phytoplankton cells (Palmer, 1969; Eisenreich, 1975). Phytoplankton cells were counted using the hemocytometer slide method (Martinez et al., 1975).

Phytoplankton cells were examined and identified by compound light microscope at 40X and sometimes at 100X power. A group of sources was used in the classification of phytoplankton cells) Desikachary, 1959; Prescott, 1973; Harrington et al., 2002).

Biodiversity Indices

A set of biodiversity indices was conducted by using the number of species in the sample and their relative density, as well as the variation and presence of species within one sample, which are as follows:

Shannon and Weaver Index (*H*) (Shannon & Weaver, 1949):

$H = \Sigma$ pi ln pi

Biodiversity values range from zero to more than 4 according to the following Table 2.

Table 2. Ranges of Shannon Biodiversity Index values and their relationship to water quality (Shanthala et al., 2009)

Shannon Index score	Biodiversity level	Pollution degree
0.0–1.0	Very Lees	Heavy
1.0–2.0	Lees	Moderate
2.0–3.0	Moderate	Light
3.0–4.5	High	Slight

Richness Index (RI) (Stiling,1996):

RI = (S – 1) / ln N

Evenness Index (E) (McCune & Grace, 2002):

H_{Max} = ln (RI)

E = H / H_{Max}

Jaccard Similarity Index (JI) (Jaccard, 1912):

JI = A / B x100

whereas: S = Number of species in the sample; N = Total number of Species in the samples; Pi = Number of individuals in the sample; A = Number of common species in the between two sites; B = Total number of species in the two sites.

Phytoplankton Trophic Indices

Chlorophyceaen Index = Chlorococcales spp. / Desmidiales spp. (Thunmark, 1945)

Myxophycean Index = Cyanophyta spp. / Desmidiales spp. (Nygaard, 1949).

When the results of the above equations are < 1, the water is Oligotrophic. When the results are > 1, the water is Eutrophic.

Statistical Analysis

Using the statistical program (SPSS, ver. 16) to extract the mean, standard deviation, and the minimum and maximum of the recorded values, in addition to extracting the values of the least significant differences (LSD) through the use of analysis of variance (ANOVA - Analysis of Variance).

RESULTS AND DISCUSSION

Physical and chemical parameters

Table 3 shows the relevant physical and chemical parameters measured at the sites of the Euphrates River between the cities of Al-Baghdadi and Ramadi. The water temperature did not show significant variations, and this may be due to the similarity of the factors that affect the temperature, including water currents, river depths, the shape of the aquatic systems, nutrients, and the lighting factor, which makes non-diatoms algae adapt to different environments and maintain their balance (Al-Tamaki & Al-Obeidi, 2023). The pH values did not show any noticeable local variation, as the highest rate was recorded in the site1 (7.1). This slight variation between the study sites confirms that the water of the Euphrates River has a high regulating capacity because its water contains bicarbonates and carbonates resulting from the erosion of soil containing these materials (Ibo et al., 2020). The total alkalinity values varied locally, with the highest rate recorded at 1,183 mg $CaCo_3$ per L at Site 2 (Hit), which is affected by natural spring water, and the lowest rate recorded at 111 mg $CaCo_3$ per L at Site 3, where the water of the Euphrates River is considered to be lightly alkaline (Snoeck et al., 2022). The highest rate of EC was recorded in the site 1 (1,430) µs cm^{-1}, and the lowest rate 500 µs $cm^{-1}$was recorded in the site 3. The reason for these variations is attributed to the nature of the geological sites, climate elements, where dilution plays an important role in the difference in conductivity during the humid seasons and dry (Sofi et al., 2022). The highest rate of TDS was recorded in site 2 is 5,597 mg L^{-1} and the lowest rate 739 mg L^{-1} in site 3, and its values exceeded the permissible limits (CCME, 2007), a river is characterized by containing many solid dissolved organic and inorganic substances, whether formed naturally or resulting from the waste of anthropogenic, including agricultural and domestic activities, in addition to torrential rains that lead to the washing of the soil and its erosion into the river waters (Xiong et al., 2022).

The water of the Euphrates River in the current study area is considered to be of medium hardness, as its highest rate was 317 mg $CaCO_3$ per L at site 4 (Ramadi), and its values were similar in all sites, with the Ca element predominating over the Mg element, which is one of the characteristics of most Iraqi water bodies (Sharqi et al., 2024). The turbidity values showed clear locational variations, as the highest rate was 8.1 NTU was recorded in site 3, where its values exceeded the permissible limits (CCME, 2007). Perhaps this may be attributed to the abundance of biological activities and chemical fertilizers, and it is agriculture land, which leads to the growth of algae and other organisms such as fungi, bacteria, aquatic plants and zooplankton (Rizani et al., 2022). The Euphrates River waters were characterized during the current study period by recording high concentrations of DO, as its highest rate 10.8 mg L^{-1} of DO was recorded in site 3. While the BOD_5 values varied locally according to the nature of those sites, its values exceeded the permissible limits (CCMW, 2007), where its highest rate was recorded as 11 mg L^{-1} in site 3, due to the high organic load of river water (Lkr et al., 2020).

Cl values exceeded the permissible limits (CCME, 2007), as the highest rate was recorded at 142 mg L^{-1} in the site 2. The reason for the increase is due to its widespread distribution in water systems more than other salts, due to its ease of dissolution and also resulting from waste from factories and homes (Fadel et al., 2021). As for Na, its highest rate was recorded 70.8 mg L^{-1} at the site 4, and its values did not exceed the permissible limits.

NO_3 was available in the river water, with the highest rate recorded at 4.0 mg L^{-1} in sites 1 and 4. This may be attributed to the provision of dissolved oxygen, which leads to the oxidation of nitrite to nitrate (Al-Obeidi and Al-Tamimi, 2024). As for PO_4, its concentrations exceeded the permissible limits (CCME, 2007), with the highest rate recorded at 4.0 mg L^{-1} at site 4 (Ramadi), because this site was affected by organic and inorganic pollutants, as well as agricultural waste such as chemical fertilizers and wastewater waste resulting from restaurants across the river Euphrates (Berkessa et al., 2019; Fan et al., 2022).

Table 3. Physical and chemical factors, biodiversity Indices, and values of the least significant difference between them in the current study sites. (Up : Range and Down : Mean)

Parameters	Site I	Site 2	Site 3	Site 4	*LSD* value
Water temperature (C^o)	5–10	5–10	4–16	5–12	1.078 NS
	8.0	7.8	8.1	8.0	
Electrical conductivity (µ.s cm^{-1})	603–2,935	801–1,349	203–690	523–1,430	174.03 *
	1,400 a	934 b	500 c	1,430 a	
Turbidity (NTU)	3.0–6.0	2.1–10.0	5.0–13.0	5.0–7.0	2.491 *
	4.1 b	6.0 ab	8.1 a	6.0 ab	
Total dissolved sold (mg L^{-1})	542–5,630	525–149	560–1,239	700–890	206.49 *
	1,879 b	5,597 a	739 c		
Total hardness (mg $CaCO_3$ L^{-1})	200–607	194–235	153–290	123–501	136.52 NS
	309	212	311	317	
Total alkalinity (mg $CaCO_3$ L^{-1})	133–1,971	150–2,012	100–127	98–202	12.85 *
	1161 b	1183	111	132 b	
Ca (mg L^{-1})	37–60	98–213	36–201	38–103	33.68 *
	50.3 c	165.0 a	94.1 b	59.8 c	
Mg (mg L^{-1})	22–45	20–50	22–40	20–50	7.31 NS
	32.1	31.3	28.4	34.6	
DO (mg L^{-1})	8.7–12.1	7.2–13.2	9.1–14.2	8.4–12.2	1.045 NS
	10.3	9.8	10.8	10.1	
BOD (mg L^{-1})	6.2–12.1	4.0–10.0	9.0–13.0	5.0–17.0	2.913 *
	8.4 ab	5.9 b	11.0 a	9.8 a	
CL (mg L^{-1}L)	97–120	76–127	19–155	100–203	23.78 *
	103 b	103 b	132 a	142 a	
Na (mg L^{-1}L)	22–62	50–66	60–77	60–78	14.52 *
	50.1 b	59.3 ab	65.3 a	70.8 a	
NO_3 (mg L^{-1}L)	0.9–5.6	0.04–4.1	1.3–2.75	3.1–4.7	1.334 *
	4.00 a	2.49 b	2.31 b	4.0 a	
PO_4 (mg L^{-1}L)	0.16–0.015	0.60–2.23	1.60–6.21	1.10–7.25	1.282 *
	0.18 c	1.60 b	3.60 a	4.0 a	
Shannon index	1.94	1.57	1.56	1.91	0.493 NS
Richness index	12.43 ab	11.30 b	15.13 a	14.45 a	3.066 *
Evenness index	0.97 a	0.85 ab	0.76 b	0.94 a	12.79 *

Means having with the different letters in same row differed significantly; * ($P \leq 0.05$).

Phytoplankton (Non-Diatoms)

Qualitative study. Table 4 shows the density, presence and distribution of phytoplankton (Non-diatom) during the period of the current study. It was noted in this study about the diversity and growth of these algae, where many species dating back to three classes prevailed in all study sites, the largest percentage belonging to the Chlorophyceae at a rate of 55%, and this may be attributed to the sweetness of the water of the Euphrates River (Lu et al., 2022; Al-Anazi et al., 2023) in addition to the geographical location of the study sites, as it is a on the availability of nutrients, which helped the spread and reproduction of many species and their dominance, including *Gloecystis major, Oocystis elliptica, Coelastrum microporium, Pediastrium simplex, Scendesmus quadricauda, S. dimorphus* (Yang et al., 2023), and comes in second place, followed by the Cyanophyceae, with a percentage of 34%, where many species prevailed.

During the study period, including *Oscillatoria tenus, O. nigra, O. Formosa, O. limosa, Mersmopedia elongate, Chrococcus minor, Gomphosphaeria fusca,* and then the Pyrrophyceae by 4%, where two genera were recorded, including *Glenodinium,* which includes four species, and the genus *Peridinium*, which includes two species.

Table 4. Density and distribution of phytoplankton species (Non-diatom) identified in the current study sites

Class: CYANOPHYCEAE	Site 1	Site 2	Site 3	Site 4
Anabaena catenula Ktz Bornet	-	+	+++	+++
A. circinalis Rabenhors*t*	-	+++	-	+
A. limnetica G.M.Smith	-	+	+	+++
Chrococcus limeticus Lemm	+++	+	+++	+
C. minor Ktz Naegli	+++	+	++	+++
C. varius A. Braun	+++	-	++	-
Gloeotheca linearis Naegii	-	-	+	-
G. rupestriis Lung Bornet	+	+	-	+++
Gomphosphaeria fusca Her Naegli	+	++	++	+++
Lyngbya ceylanica Wille	+	++	+++	-
L. lagerhemii Moeb Gomont	-	+	-	+
L. limetica Lemm	-	-	+	-
L.major Meneghini	+	+	++	+++
L. punctate Lemm	+++	-	-	-
L. nigra Agardh	+	-	+++	-
Merismopedia convolute de Brebison	-	-	+	+++
M.elongata Desikachrary	+++	+	+++	+++
Microcystis aeruginosa Kutzing	+++	++	+	+++
Nostoc commune Vacher	-	-	++	-
N. linckia Roth Bornet	-	+	+	+++
Oscillatoria artculata Gardher	+++	-	+++	-
O. annae Van Goor	-	-	++	-
Oscillatoria acutissima Kufferath	+++	++	++	++
Oscillatoriar boryana Bory	+	-	-	+++
O. amoena Ktz Gomont	-	++	+++	-
O. angustissima West &West	+	-	++	+++
O. chalybea Kutz	+	+++	-	+++
O. foreaui Fremy	-	-	-	+
O. formosa Bory	+++	+	+++	+++
O. geminata Meneghinni	++	-	+++	+++
O. irrigua Kuetzig	+++	+	-	-
O. limosa Roth Agardh	+++	+++	+++	+
O. lmnetica Lemm	-	+++	++	-
O. nigra Vaucher	+++	++	++	+++
O. perornata Skuja	-	+	+	+++
O. princeps Vaucher	+++	+	+++	+++
O. splendida Greville	-	+++	++	+
O. tenuis Agardh	-	++	+	+++
O. tenuis var natans Gomont	+++	-	+++	++
Phormidium africanum Lemm.	++	-	+++	++
P. jenkelianum G.Schmidle	-	+	++	++
P. formosum Gomont	++	-	+	+

Table 4 (continued)

P. tenus Menegh Gomont	++	+++	+++	+++
Spirulina gomontii Gutwinski	-	-	+++	-
S. laxa G.M. Smith	++	+++	+++	-
S. major Kuetzing	-	++	++.	+
S. princeps West & West	+++	-	+++	-
Class: CHLOROPHYCEAE				
Ankistrodesmus borunii Naeg	+++	+	-	-
Chlorella ellipsoidea Gernek	-	+++	+++	+++
C. vulgaris Bejerinck	+++	-	+++	++
Cylindrocapsa geminella Wolle	+	-	-	-
Coelastrum microporium Naeg	+++	+	++	+++
C. probiscidium Chan	-	+++	-	+++
C. reticulatum Dang Senn	+++	+	+	++
C. sphaericum Naeg	+++	-	++	-
Crucigenia quadrata Morren	+	+++	++	+
Closterium ehrenbergii Meneghini	-	+++	++	+
C. lineatum Ehrenberg	++	-	++	+++
Cosmarium bioculatum de Brebisson	+++	++	+	+
C. cymatoplerun Nord	+++	-	-	-
C. longiense Biss	-	+	+++	+
C. microsphictum Lemm.	+++	+	+	+
C. obtusatum Schmidle	+++	+++	-	-
C. parvalum ktz.	+++	-	++	+
C. quadrifarum P.Lundell	++	+++	-	+
C. retusum var angustatum West&West	-	-	++	++
Dictyosphaerium pusillum Naeg	++	-	-	-
Eudorina elegans Ehren	+	+++	+++	+++
Gloecystis major Gerneck	++	+++	++	+
Kirchneriella contorta Schmidle	++	-	-	-
Mougeotia microspore Taft	++	-	-	+
Microspora crassior Hansgirg Hazen	+++	+++	+	++
M. elegans Hansg	+	-	+	++
Oocystis apiculate West	+	+++	-	++
O. elliptica West	++	+	++	+
O. natans Lemm.	++	-	++	+
O. pusilla Hansgirg	++	-	++	+
Oedogonium cripsum Hass Wittr	+++	-	-	-
O. gallicum Hirn	+	+++	++	+
O. perfectum Hirn Tiffany	++	+++	++	+
O. varians Wittrock	++	+	+	+++
Pediastum biradiatum Meyen	-	+++	+	-
P. boryanum Turp Meneghini	+++	+++	++++	++
P. clathratum Schr Lemm	+	-	+	-
P. duplex Meyen	++	+++	+	+
P. duplex var cornutum Rciborski	+	-	++	++
P. integrum Naeg	++	+++	-	+
P. simplex Meyen	+++	+++	+	+
P. simplex var granulatum Lemm.	+++	-	++	+++
P. sturmi Rensch	-	-	+	-
P. tetras var. tetrahedronod Corda	++	+++	++	+

Table 4 (continued)

Scenedesmus abundans Kirch	+++	-	+	+++
S. acuminatus Lag Chodat	-	-	+	+
S. alternata Chodatti	++	+++	++	+
S. arcuatus Lemm.	++	+++	+	+
S. arcuatus var platydiscus G.M. Simth	+++	+++	++	++
S. armatus Chodat	+++	-	++	++
S. bijuca Turp Lagher	-	+++	++	++
S. bijga Turp	+++	+++	+	++
S. dimorphus Turp Ktz.	+++	++	+++	++
S. grassus Ktz.	-	++	-	++
S. longus Meyen	+	+++	++	+
S. orbiculare Turp	+++	-	++	+
S. quadricauda Turp de Brebisson	+++	+++	+++	+
Stigeoclonium helveticum Vischer	+	+++	+++	++
S. tenue Ktz.	++	++	++.	++
Spirogyra collinisi Lemm.	+	+++	+++	+++
S. crassa Ktz.	++	++	++	+
S. subsalas Ktz.	++	-	+	+
Staurastrum analinum Cooke	+++	+++	+	++
S. curvatum West	++	-	+++	++
S. kjelmanni Wile	-	-	+++	-
S. pingue Telling	+++	+	++	++
Tetraedron caudatum Cord Hansgirg	-	+	+++	+++
T. minimum A.Braun Hang	+++	+	+	++
T. pentaedruicum West & West	-	+	+	+++
T. regulare Ktz.	+++	++	++	+
T. trigonum Naeg Hansg	+	-	+++	+
Ulothrix cylindricum Presscott	+	++	+	+++
U. pseudoflocca Wille	-	-	+++	+
U. zonata Weber & Mohe	++	-	++	+
Zygnema collinsianum Transeau	+	+	-	+
Z. sterile Transeau	+	+++	++	++
Class: EUGLENOPHYCEAE				
Euglena acus Ehrenberg	++	++	++	++
E. ehrenbergii Korshikov	-	+	-	++
E. minuta Prescott	-	+	++	-
E. oxyuris Sclimardata	-	+	+	+++
Phacus acuminatus Stoken	-	+	+++	+++
P. chloroplastes Prescott	-	+++	++	+
Class : CHRYSOPHYCEAE				
D. tabellariae Lemm.	+	+	-	+
Synura uvella Ehrenberg	+	+	++	+
Class : BYRROPHYCEAE				
Glenodinium borgei Lemm Schiller	+++	-	+++	-
G. cintum Eherberg	++	-	++	++
G. gymondinium Penard	-	+++	+++	++
G. fuscum Her Stein	+	-	++	+++
Peridinium bipes Stein	+++	+	-	++
P. cintum Muell Ehrenberg	+	++	+	-

Note (+ : 1 – 5 Cell mL^{-1}) (++: 5 – 10 Cell mL^{-1}) (+++: ≤ 10 Cell mL^{-1}).

Table 5. Numbers of genera and species of phytoplankton (Non-diamo) in the current study sites

Sites	Chloro.		Cyano.		Eugleno.		Chryso.		Pyrro.		Total	
	G.	Sp.	G.	Sp.	G.	Sp.	G.	Sp.	G.	Sp.	G.	Sp.
1. (AlBaghdadi)	22	62	9	28	1	1	2	2	2	2	36	95
2. (Hit)	18	38	10	30	2	6	2	2	2	2	34	78
3. (Al-Mohamdi)	17	62	11	39	2	5	1	1	2	2	33	109
4. (Al-Ramadi)	18	64	11	32	2	5	2	2	3	2	36	105
Total	75	226	41	129	7	17	7	7	9	8	139	387

The percentage of Euglenophyceae was 4%, and only two genera, including 6 species, were recorded, and the *Euglena acus* was dominant in all study sites. As for the Chrysophyceae, their percentage was 1%, and two genera were recorded, where the type *Synura uvella* was recorded to be dominant in all sites (Table 5 and Fig. 2).

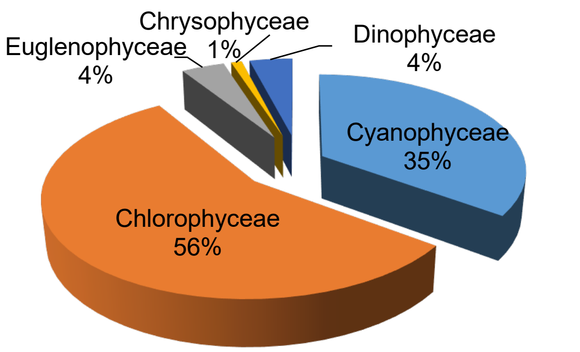

Figure 2. Percentage distribution of phytoplankton species (Non-diatom) according to their main classes.

Quantitative study. The total number of phytoplankton cells varied for the sampling sites (Fig. 3), and this may be due to the difference in geological nature and the extent of its influence on sources of water pollution (Al-Anazi et al., 2023), where the highest rate was 1,767 cell L^{-1} for the Chlorophyceae, while the Chlorophyceae recorded the highest numbers from the algae classes. Cyanophyceae, and this is expected since the water studied is fresh water with a low content of salts (Al-Tamaki & Al-Obeidi, 2023), and the recording of small percentages of the ranks of Euglenophyceae, Chryptophyceae, and Dinophyceae algae is one of the characteristics of fresh water, which many articles have indicated for most Iraqi water bodies (Al-Dulaimi et al., 2024).

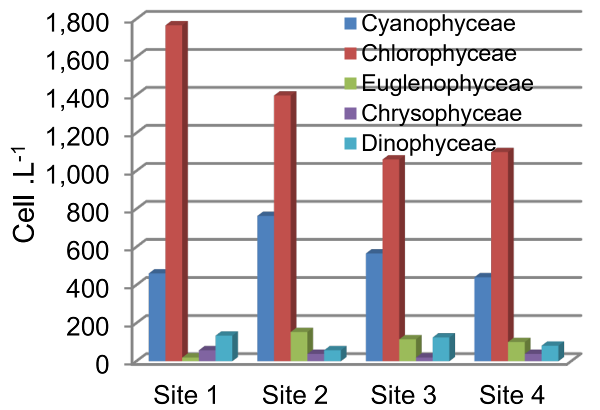

Figure 3. Locational variations in the total number of cells of phytoplankton (non-diatom) classes at sample collection sites during the period of the current study.

Biodiversity Indices

Shannon and Weaver Index (*H*). The values of the Shannon Weaver index of biodiversity converged in all sites of the current study area, where the highest value was recorded in the site 1, 1.94, and the lowest, 1.46, in the site 3 (Fig. 4), and the availability of environmental factors, including light and appropriate temperatures, as well as phosphates and nitrates resulting from the release of organic pollutants that contribute to excessive growth for algae (APHA, 2017). The values of the Shannon Weaver index indicate the existence of inverse relationships between water pollution and biodiversity, leading to variations in algal populations, where sensitive species are replaced by species with greater resistance to pollution in the aquatic environment (Feilong et al., 2020).

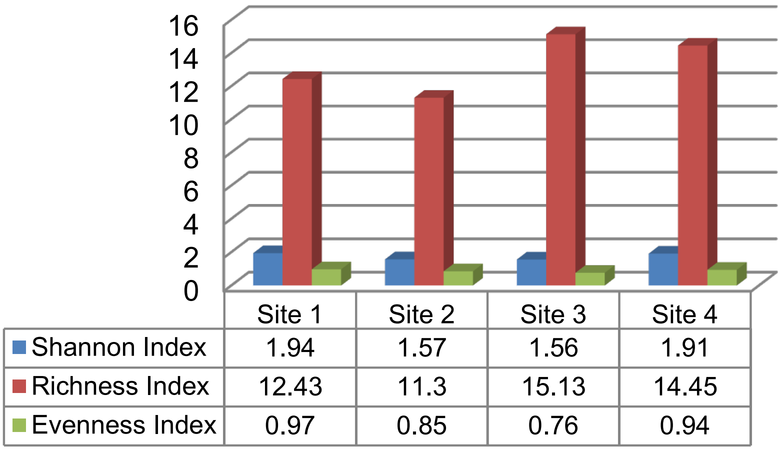

Figure 4. Evaluate the evidence of biodiversity at the sample collection sites during the current study period.

According to the results of the current study, the water of the Euphrates River between Al-Baghdadi and Ramadi Dam can be described as having low biodiversity and moderate water quality (Feilong et al., 2020). The large variation in the relative density of some species of phytoplankton cells negatively affected the decrease in biodiversity values in the river water (Shanthala et al., 2009). Some species of Cyanophyceae and Chlorophyceae recorded cell numbers exceeding 10 cells mL^{-1} with their dominance in all sites, while other species of the same groups recorded low relative density values with their appearance in specific sites, while the Euglenophyceae, Chrysophyceae and Pyrrophyceae recorded a decrease in the relative density of their cell numbers with their fluctuating appearance in the current study sites. The dominant Cyanophyceae species are *Chrococcus limeticus*, *C. minor*, *Gomphosphaeria fusca*, *Lyngbya.major*, *Merismopedia.elongata*, *Microcystis aeruginosa*, *Oscillatoria acutissima, O. formosa, O. limosa, O. nigra, O. princeps, P. tenus.* The dominant types of Chlorophyceae are *Coelastrum microporium*, *C.reticulatum*, *Cosmarium bioculatum, C. microsphictum*, *Eudorina elegans, Gloecystis major, Microspora crassior*, *Oocystis elliptica*, *Pediastrum boryanum*, *Scenedesmus arcuatus, S. arcuatus var. platydiscus, S. dimorphus., Stigeoclonium tenue*, (Table 4).

Richness Index (RI). The richness index refers to the absolute number of taxonomic groups in any given ecological site. The abundance of species indicates the diversity of biological communities in the aquatic environment, as there is a direct relationship between the richness index and the values of biodiversity (Ristanto et al., 2021. A noticeable difference was recorded between the studied sites, as the highest value was recorded in the site 3 (Hit) 15.13, while the lowest value was recorded 11.3. In the site 2 (Fig. 4), these sites are characterized by recreational and heritage sites, including the waterwheels of Hit and the large number of orchards around the river, as they are suitable for agriculture. The values of the rich index varied in the other sites, perhaps due to the diversity of causes of changing the water content of the important nutrients resulting from wastewater and the domestic ones. The Euphrates River waters in the current study area can be described as having moderate species richness (Roşca, 2020).

Evenness Indexs (EI). The value of evenness depends on the Shannon values of biological diversity. Its values range from 0 to 1.0, where high values indicate homogeneity in species from a poorly polluted water body, and vice versa (Pomari et al., 2018) where the highest value was recorded in the site 1 (0.97) and the lowest was recorded in the site 3 (0.76) (Fig. 4). Some species of wandering algae showed dominance, while others appeared, but in a very small percentage. This indicates the presence of changes in the climatic and environmental conditions, as well as the geology of the sites. Therefore, non-diatom wandering algae were described as moderate to highly homogeneous, which indicates that the waters of the Euphrates River are in the current study sites it has moderate water quality (WHO, 2008).

Jaccard Similarity Index (JSI). This index expresses the percentage of similarity in the presence of species and its comparison between each two sites separately, and its values are expressed according to percentages (Al-Tamaki & Al-Obeidi, 2023). The highest similarity value was recorded between the site 3 and 4 (90%), which may be attributed to the closeness of these sites and the similarity of their sources of pollution, while the lowest similarity values were recorded between site 1 and 2 due to the difference in the quality of the water of these sites (Table 6). Similarity ratios are controlled by the geographical and geological characteristics of the site, as well as differences in physical and chemical properties and abiotic factors, which is reflected in the quality and type of water and thus affects the growth process of floating algae (Zhu et al., 2023).

Table 6. Evaluate the Jaccard similarity index between sample collection sites during the period of the current study

Sites	1	2	3
2	61%		
3	78%	73%	
4	76%	75%	90%

Trophic Indices

Chlorophycean index values recorded values higher than 1 in all locations, so the water of the Euphrates River is considered to be oligotrophic and slightly to moderately polluted (Thunmark,1945) (Table 7). Also, the Myxophyceaen index values recorded values higher than 1, so the water of the Euphrates River in the current study sites is considered oligotrophic and slightly to moderately polluted (Nygaard,1949). The application of phytoplankton Trophic Indices in this study was consistent with the results of water quality from environmental factors and evidence of biodiversity in the waters of the Euphrates River in the current study sites.

Table 7. Trophic indices and its relationship to the water quality of the sampling sites during the period of the current study

Sites	Spp. No.			Indices		Water Quality	Trophic Stat
	Chlorococcales	Cyanophyta	Desmidiales	Chlorophycean Index	Mexophycean Index		
Site 1 (Al-Baghdadi)	19	28	10	1.9	2.8	Less to Moderate	Oligotrophic
Site 2 (Hit)	16	29	8	2.0	3.6	Less to Moderate	Oligotrophic
Site 3 (Al-Mohamdi)	23	39	11	2.1	3.5	Less to Moderate	Oligotrophic
Site 4 (Al-Ramadi)	22	33	11	2.0	3.0	Less to Moderate	Oligotrophic

CONCLUSIONS

Through the results of the current study, phytoplankton (Non-diatoms) can be relied upon as effective biological indicators in the waters of the Euphrates River at the current study sites due to their rapid response to changes in aquatic ecosystems. The study showed agreement between environmental factors, evidence of biodiversity, and the nutritional status of river water. Therefore, phytoplankton (Non-diatoms) can be considered as vital monitors due to their sensitivity to changes in water quality, such as nutrient levels, pollutants, and the condition of physical sites, which makes them of high value for monitoring and evaluating the health of the Euphrates River water environment. The study showed that the city of Ramadi has a clear impact on the physical and chemical characteristics of the water of the Euphrates River, which is reflected in the biodiversity of phytoplankton (Non-diatoms). The results of the current study indicate that the Euphrates River waters are exposed to moderate environmental stresses. These results highlight the need for better water management and pollution control, especially in agricultural areas. Overall, this research contributes to providing valuable data for sustainable water use and helps guide future environmental policies for the upper Euphrates River.

REFERENCES

Al-Anzy, D.H., Al-Tamimi, A.A.M & Sharqi, M.M. 2023. Biological and Ecological Monitoring using Epiphytic Diatoms on Tow Aquatic Plants to Estimate the Water Quality of Habbaniyah Lake,Western Iraq. In: *lOP Conference Serier: Earth and Environmental Science* **1262**(2), P022012. doi: 10.1088/1755-1315/1262/2/022012

Al-Obeidi, N.A.S. & Al-Tamimi, A.A.M. 2024. Ecological and Biodiversity Algae (Non-Diatoms) on *Typha Domingensis* Pers. In the Upper Euphrates River Between Haditha Dam and Al-Baghdadi in Western Iraq. *Advanced Studies on Environmental Sustainability (ICES 2023)*, pp. 41–58.

Al-Dulaimi, H.M., Hanaa, A.Y. & Al-Tamimi, A.A.M. 2024. The Effect of Biological and Physicochemical Factors on the Water Quality of the Al-Warar System in the City of Ramadi, Western Iraq. In: *5th International Conference of Modern Technologies in Agricultural Sciences. IOP Conf. Series*: *Earth and Environmental Science* **1371**, 022018.

Al-Tamaki, A.A.M. & Al Obeidi, N.A. 2023. Use of Epiphytic Diatoms in Cyperus Papyrus L. As Bioindicatorus in the Assessment of the Health of the Upper Euphrates River Between the Haditha Dam and Al –Baghdadi, Iraq. In: *IOP Conference Seriers: Earth and Environmental Science* **1222**(1), 012020. IOP Publishing.

Allen, S. 2020. Interannual stability of phytoplankton community composition in the North- East Atlantic. *Mar. Ecol. Prog. Ser.* **6655**, 43–57.

APHA, 2017. American public Health Association. Standerd Methods for the Examinanation of water & waste water 23rd Edition washing ton DC.

Berkessa, Y.W., Mereta, S.T.& Feyisa, F.F. 2019. Simultaneous removal of nitrate and phosphate from wastewater using solid waste from factory. *Applied Water Science* **9**, 1–10.

Burkhardt, F.K., Hayer, J.J., Heinemann, C. & Steinhoff-Wagner, J. 2022. Drinking behavior of dairy cows under commercial farm conditions differs depending on water trough design and cleanliness. *Applied Animal Behaviour Science* **256**, 105752.

CCME, Canada Council of Ministers of the Environment. 2007. Canadian Water Quality Guidelines for the Protection of Aquatic. *Excerpt from publication* No. **1299**, 9 pp.

Desikachary, T.V. 1959. Cyanophyta. Indian council of agriculuture research, New Delhi, 68.

Eisenreich, S.J., Bannerman, R.T. & Armstrong, D. 1975. A simplified phoshours analysis technique. *Environ Letters* **9**(1), 43–53.

Fadel, A., Kanj, M. & Slim, K. 2021. Water quality index variations in a Mediterranean reservoir: a multivariate statistical analysis relating it to different variables over 8 years. *Environ Earth Sci.* **80**(65). doi: 10.1007/s12665-020-09364-x

Fan, X., Gao, S., Zhang, Y., Qin, B., Xu, H. & Ding, S. 2022. Stimulation of high-concentration dissolved nitrogen and reactive phosphorus in Lake Taihu sediments on the initiation and maintenance of cyanobacterial blooms. *Sci. Total Environ* **851**, 158088.

Feilong, A., Florian, Y., Jianghua, A., Shuqing, L., Aimin, Z. & Xioaowei, A. 2020. Human activities fingerprint on multitrophic biodiversity & ecosystem functions across amajor river cathchment in China Glob Chang. *BioI*. **26**.

Harrington, G.A., Cook, P.G. & Herczeg, A.L. 2002. Spatial & temporal variability of ground water in central Australia: *A tracer a approach Ground water* **40**(5), 518–527.

Ibo, E.M., Oriji, M.U. & Umeh, O.R. 2020. Seasonal evaluation of the physicochemical properties. *Kunglige Danske Vidensk, Selskab* **7**, 1–242.

Jaccard, 1912. The Distrbution of the Flora of the apine Zone. *New phytologist*, pp. 37–50.

Li, Z., Ma, Y., Sun, X. & Lu, Y.F. 2022. Ecological health evaluation of River based on phytoplankton biological in tergrity index & water quality index on the impact of anthropogenic pollution: A acase of Ashi River basin Front. *Microbiology* **13**, 942205. doi: 10.3389/fmicb.2022.942205

Lkr, A., Singh, M.R. & Puro, N. 2020. Assessment of water quality status of Doyang River, Nagaland, India, using water Quality Index. *Appl Water Sci.* Sptinger, **10**(46), 1–13. https://link.springer.com/article/10.1007/s13201-019-1133-3

Lu, X.Y, Zhang, Y. & Liu, Y.F. 2022. Differences in planktonic & benthic diatoms reinstorm event in the Songhua River Basin of northeast china. *Ecol. Ind.* **144**, 109547.

Martinez, M.R., Chakroff, R.P. & Pantastica, J.B. 1975 Note on direct phytoplankton counting technique using the haemocytom- eter phil. *Agric*. **59**, 1–12.

McCune, B. & Grace, J.B. 2002. Analysis of ecological communities. MJM Software design. Gelenden Beach OR.

Nygaard, G. 1949. *Hydrobiological studies on some Danish ponds and lakes*. II: The quotient hypothesis and some little known or new phytoplankton organisms. Hardback, 293 pp.

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. *Journal of phycology* **5**, 78–82.

Peluso, J. 2021. Comprehensive assessment of water quality through different approaches: physicochemical and ecotoxicological parameters. *Sci Total Environ.* **800**, 149510. doi: 10.1016/j.scitotenv.2021.149510

Pomari, J., Kane, D. & Nogueira, M. 2018. Application of multplee-use indices to assess reservoiros water quality & the use of plankton community data for production. *Int. J. Hydro*. **2**(2), 173–184. doi: 10.15406/ijh.2018.02.00065

Prescott, G.W. 1973. Algae of the western Great Lake Area. William C. Brown Co. Publishers, Dubque, Lowa.

Ristanto, D., Ambariyanto, A. & Yulianto, B. 2021. Water quality assessment based on national sanitations foundation water quality index during rainy season in Sibelis and Kemiri estuaries Tegal City. *IOP Conf Ser: Earth and Environ Sci.* **750**, 012013. doi: 10.1088/1755-1315

Rizani, S., Feka, F., Fetoshi, O., Durmishi, B., Shala, S., Çadraku, H. & Bytyçi, P. 2022. Application of water quality index for the assessment the water quality in River Lepenci. *Ecol Environ Tech.* **23**, 189–201. doi: 10.12912/27197050/150297

Roșca, O.M. 2020. Impact of anthropogenic activities on water quality parameters of glacial lakes from Rodnei mountains, Romania. *Environ Res.* **182**,109136. doi: 10.1016/j.envres

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. doi: 10.33736/bjrst.6858.2024

Shannon, C.E. & Weaver, W. 1949. *Mathematical Theory of Communitcation*. Univ of llnois press rbuana, 125 pp.

Shanthala, M., Hosmani, S.P. & Hosetti, B.B. 2009. Diversity of phytoplankton in a waste stabilization pond at Shimoga Town, Karnataka State, India. *Environmental Monitoring and Assessment* **151**(1–4), 437–438.

Snoeck, D., Roige, N., Manso, S., Segura, I. & De Belie, N. 2022. The effect of (and the potential of recycled) superabsorbent polymers on the water retention capability and bio receptivity of cementitious materials. *Resours Conserv. Recycl.* **177**, 106016. doi: 10.1016/resconrec.2021.106016

Sofi, M.S., Hamid, A., Bhat, S.U., Rashid, I. & Kuniyal, J.C. 2022. Impact evaluation of the run-of-river hydropower projects on the water quality dynamics of the Sindh River in the Northwestern Himalayas. *Environ Monit Assess.* **194**(9), 626. doi: 10.1007/s10661-022-10303-5

Stiling, P.D. 1996. *Ecology*: *Theory Hall Uppers & application*. 2nd Edition, Prentice-Hall Inc, New Jersey, 539 pp.

Thunmark, S. 1945. Zur Soziologie des susswasserplanktons: eine methodologisch- okologische Studie. *Folia Limnologica Scandinavia* **3**, 1–66.

WHO. 2008. World Health Organization. *International Standaed of Drinking Water*. 3th Edittion, Vol **1**. Recommendation, Geneve, 515 pp.

Xiong, F., Chen, Y., Zhang, S., Xu, Y., Lu, Y., Qu, X., Gao, W., Wu, X., Xin, W., Gang, D.D. & Lin, L.S. 2022. Land use, hydrology, and climate influence water quality of China's largest river. *J Environ Manage* **318**, 115581.

Yang, Q., Zhang, P., Xiaodong Li, X., Yang, S., Xin Chao, X., Liu, H. and Ba, S. 2023. Distribution patterns & community assembly processes of eukaryotic microoganisms along an altitudinal gradient in the middle reaches of the Yarlung Zangbo River. *Water research* **239**, 120047. doi: 10.1016/j.watres.2023.120047

Zhu, A.S., Yuan, Z., Liang, C., Fan, X., Feng, Q., Wu, M. & Li, J.C. 2023. Seasonal s uccession & assembly processes of bacterioplankton communities in a subtropical urban river. *Act. Sci. Circumst* **43**, 461–473.