Int. J. Aquat. Biol. (2023) 11(5): 478-489
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com
© 2023 Iranian Society of Ichthyology

Original Article

Effects of environmental parameters on diatoms community of the Euphrates River system

Huda Hilo Ali[1], Raid Kadhim Abed Al-Asady[2], Sadiq Kadhum Lafta Alzurfi*[3]

[1]Department of Biology, College of Science, University of Misan, Iraq.
[2]Department of Biology, College of Education, University of Al-Qadisiyah, Iraq.
[3]Departments of Ecology and Pollution, College of Science, University of Kufa, Iraq.

Abstract: A study was designed to (1) establish the taxonomy of diatom species in the Euphrates River, and (2) determine the effect of the main environmental factors on diatom community distribution in the Euphrates River. From 14 sites along part of the Euphrates River, samples of diatoms and water were taken during 2016. Diatom samples were collected from the water by phytoplankton nets at a randomly selected site. A total of 96 diatom species were recorded during the study period. Using correlation factor analysis, patterns of diatom species distributions in connection to environmental variables were discovered. Temperature, total suspended solids, total alkalinity, and phosphate (PO_4) were all significantly and strongly linked with diatom species in both habitats (r = 0.85, 0.88, 0.92, and 0.83, respectively). *Fragilaria crotonensis* Kitton 1869 had a higher total number recorded (881.64 cells/l×10^3) during the study period, and site 2 had a higher total number compared with other sites (4845 cells/l×10^3). November had a higher total number recorded compared with other months (13722.64 cells/l×10^3). As a result, we concluded that in lotic systems, environmental conditions can affect the existence and distribution of diatoms.

Article history:
Received 15 July 2023
Accepted 7 September 2023
Available online 25 October 2023

Keywords:
Diatoms
Euphrates
River
Phytoplankton

Introduction

Diatoms are eukaryotic, unicellular, or colonial photoautotrophic microalgae that belong to Bacillariophyta. They stand out due to the peculiar quality of having a silica-based cell wall. The group of diatoms is diverse and can be found in all freshwater and marine ecosystems and wet terrestrial habitats as well as in extreme conditions like sea ice (Arrigo, 2014) and deep marine sediments that are considerably below the photic zone of the ocean (Cahoon et al., 1994). The number of species is thought to range between 100,000 (Mann and Vanormelingen, 2013) and 200,000 (Armbrust, 2009). According to Sabater (2009), diatom cells range in size from 5 µm to more than 1 mm in diameter or length. They can form colonies and live in the water column or attached to substrates, but they are most frequently encountered as solitary cells.

Water, despite being the most plentiful resource on earth, occasionally has a declining natural quality due primarily to human demand in various forms (Falkenmark and Rockström, 2004). The main causes of declining water quality worldwide, including in Iraq, are agricultural intensification, urbanization, and industry as a result of rising human populations and technological development (Alcamo et al., 2007; Nelson et al., 2009). The main cause of water pollution is human activity, which has several negative effects on both the ecosystem and human health (Carr and Neary, 2008). A change in the physical and chemical makeup of the receiving water bodies could result from agricultural runoff and urban pollution finding their way into various aquatic systems (Peters and Meybeck, 2000). It may change the physicochemical characteristics of the water, which therefore influences the mix of living biological communities in the aquatic ecosystem (Karr and Dudley, 1981). The variety of macro-invertebrates, zooplankton, phytoplankton, and other aquatic species are impacted by water pollution (Chapman, 1996). According to

*Correspondence: Sadiq Kadhum Lafta Alzurfi
E-mail: sadiqk.alzurfi@uokufa.edu.iq
DOI: https://doi.org/10.22034/ijab.v11i5.2083

Table 1. Study Sites as displayed by GBS.

Station	East	North
Station 1	44º16 .187´	32º 43.750
Station 2	44º 15. 550	32º 41. 635
Station 3	44º 13. 781´	32º 32. 157
Station 4	44º 17. 234	32º 24. 489
Station 5	44º 21.793	32º 13. 580
Station 6	44º 21. 086	32º 10. 561
Station 7	44º 21. 907	32º 06. 209
Station 8	44º 23. 510	32º 02. 903
Station 9	44º 24. 733	32º 02. 174
Station 10	44º 25. 709	32º 00. 831
Station 11	44º 27. 305	31º 58. 870
Station 12	44º 29. 691	31º 51. 836
Station 13	44º 29. 993	31º 47. 655
Station 14	44º 30. 565	31º 47. 138

several studies done in Iraq (Hassan et al., 2007; Jawad and Alrufaye, 2020; Al-Tamimi and Al-Obeidi, 2021), human-induced water quality changes have an impact on the distribution of diatoms in various aquatic systems. Therefore, this study aimed to (1) establish the taxonomy of diatom species in the Euphrates River, and (2) determine the effect of the main environmental factors on diatom community distribution in the Euphrates River.

Materials and Methods

Study area: The Euphrates River is one of the most significant rivers in eastern and southern Asia. Many barriers have been constructed on this river, such as the Hindiya barrier, at which the river separates into two branches of the Hindiya and the Hilla rivers. When it reaches Kifl city (within the Al-Najaf Province), the Euphrates River branches, namely the Abbasia and Kufa Rivers extend from Kifl city to Al-Diwaniyah city. The length of the river is about 2800 km, which represents inside Iraq about 35% of the total river length, and irrigates wide areas of land of about 765831 km^2, draining an average of 818 m^3/sec (UNESCO, 2002). The Euphrates River undergoes large fluctuations due to its depth. It has a high level during the flooding seasons at the end of March or the beginning of April and a low level in the summer months (Al-Haidarey, 2010). The study area is part of the sedimentary plain in Iraq, which is the result of the sedimentation of the Tigris and Euphrates rivers. Generally, the nature of the surface is characterized by general extension and low diversity of terrain. Although the extension image was visible on the surface, this did not prevent the emergence of some difficulties, which contributed to determining the general trend of the study area and showed some significant increases in the study area due to natural, human, or both factors. The slope of the surface in the study area increases as it rises northward and westward in the marginal area with the western plateau region (Fig. 1).

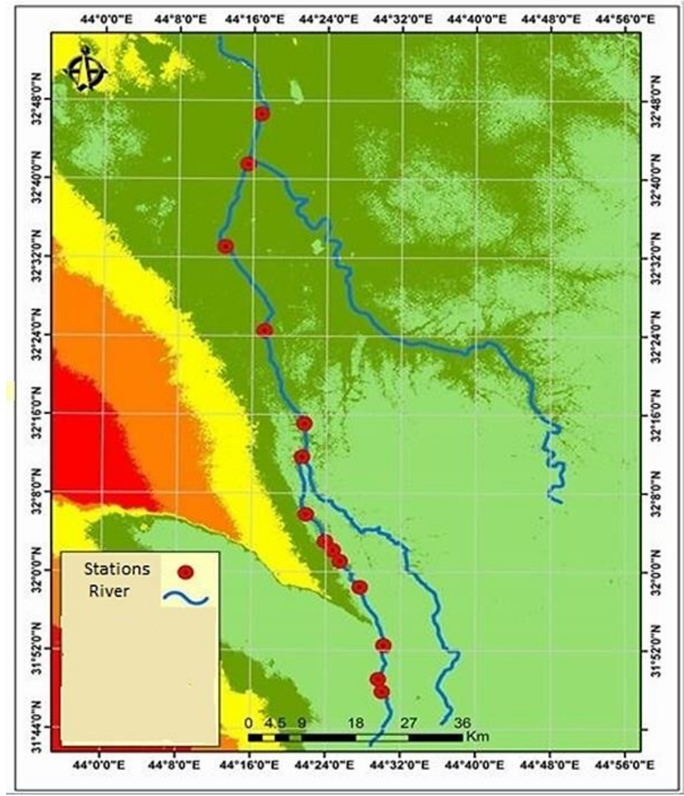

Figure 1. Map showing location sampling sites on the Euphrates River.

Physical and chemical properties: Monthly samples were taken in 2016 from each of the 14 sites from Hindiya Dam to Mishkab Regulator (Table 1). A multi-meter device (WTW, Germany) was used to take in-situ measurements of temperature, pH, and salinity. At each site and a depth of 30 cm below the surface, water samples were taken in 1-liter plastic containers for chemical analysis, and these samples were pooled together for a specific site. Using a

Table 2. Physiochemical parameters of Euphrates River water during the study period.

Months	pH	WT (℃)	AT (℃)	TDS (mg/l)	TSS (mg/l)	Alk. (mg/l)	TH (mg/l)	Ca (mg/l)	Mg (mg/l)
July	7.58±0.03	28.5±0.03	36.1±0.00	566±1.6	40.5±5.8	119±3.5	303±8	114±6	42.3±2
August	7.34±0.036	31.8±0.00	35.4±0.00	521±0.7	29.5±4	118±4.4	290±7	113±4	38.2±1.6
September	7.55±0.05	30.8±0.02	28.7±0.02	406±6.1	22.9±6.6	118±5.4	339±10	120±5	49.4±2.4
October	7.63±0.024	26.3±0.01	27.3±0.00	791±7	29.2±4.2	117±6.3	331±8	118±6	48.3±2.1
November	7.67±0.11	22.6±0.00	18.5±0.00	640±49.4	21.2±2.8	116±7.3	302±9	115±6	42.2±2
December	7.59±0.028	17.8±0.03	14.2±0.00	624±18.4	21.1±3.3	115±8.3	302±7	113±7	43.2±2.1
Mean	7.56±0.11	26.3±5.3	26.7±8.85	591±129	27.4±7.45	117.16±1.47	311.16±19.23	115.5±2.88	43.9±4.14
L.S.D.0.05	0.04	0.02	0.004	17.33	4.5	4.2	6	4	1.5

cadmium column, nutrient samples (NO_2, and NO_3) were analyzed using a cadmium column (Parsons et al., 1984), and PO_4 was assessed following APHA (2010) guidelines. Total alkalinity, total hardness, calcium hardness, TSS, and TDS were measured according to APHA (2010).

Diatom sampling, processing, and analysis: Monthly samples were collected from 14 sites by a standard phytoplankton net (20 µm mesh size). Following that, samples of phytoplankton were put in plastic bottles and preserved by including a small amount of Lugol's solution. A clean glass slide was used, and it was heated to a temperature of 75-80℃. To remove organic matter and clarify the structures of the diatoms, 50 microliters of the sample were added to the slide's center using a micropipette. Nitric acid was then added, and after the acid had completely evaporated, a small amount of Canada balsam was taken and placed on the cover slide (Hadi, 1981).

Statistical analysis: SPSS Version 26 was used to calculate the average and standard error of the mean for the diatom and water quality variables. Using correlation factor analysis, patterns of diatom species distributions in connection to environmental variables were discovered. A one-way ANOVA test, Tukey's multiple comparison test, and Pearson Correlation were used to compare the physicochemical and diatom density between stations and months as well as to analyze the diatom's reaction to environmental conditions and the difference was considered at the level of $P \leq 0.05$.

Results and Discussions

Table 2 shows that the temperature of the water ranged from 17.8°C in December to 31.8°C in August (mean: 26.3±5.3℃). This is consistent with the studies carried out by Al-Zurfi et al. (2018) and Redha and Al-Zurfi (2021). Algae within each community are affected by several physical and chemical factors that affect negatively or positively the distribution, growth, and development of algae. The results of the current study showed clear monthly changes in the water temperature at all the selected stations. Temperature plays a major role in many physical and chemical processes that affect the vital interactions and physiological and metabolic processes carried out by algae, such as growth, photosynthesis, respiration, water absorption, and nutrients (Smith, 2004). The variation in the water temperature is due to the location and the thermal effects of the sun and its transmission through the water column (Zoffoli et al., 2017; Liu et al., 2021). The distribution of organisms in the water body is determined by temperature, which is also one of the primary drivers of water density, which is directly related to salinity (Smith, 2004). This may be due to the nature of the Iraqi climate, as the intensity of sunshine and the length of the day vary in different seasons of the year, as the summer months are distinguished. The length of the photoperiod, the intensity of solar radiation, and the high temperatures (Ali, 2020).

The pH of the water ranged from 7.34 to 7.67 (mean: 7.5±0.1) during the study period (Table 2). The pH level was within acceptable WHO and Iraqi limits. The pH values showed little variation between the months of the study, and the reason for this is probably the narrow range of pH in river water, which may be attributed to the buffer capacity as it resists changes in

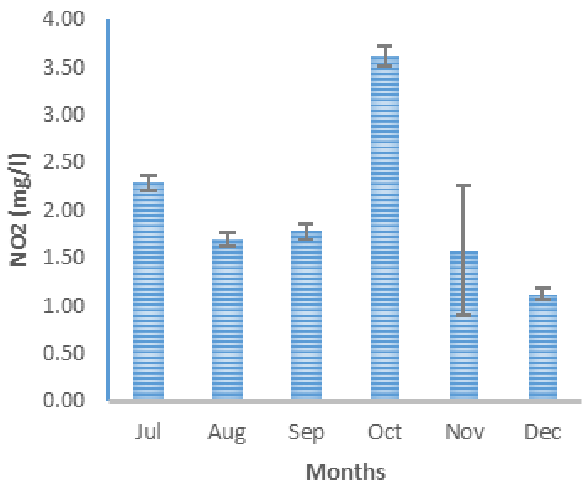

Figure 2. Monthly variations of NO_2 during the study period.

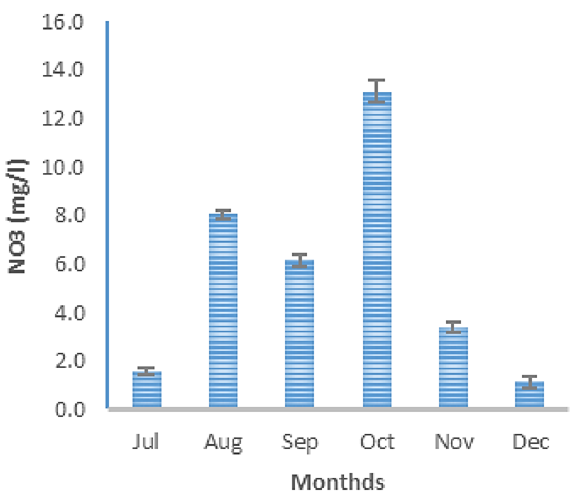

Figure 3. Monthly variations of NO_3 during the study period.

pH (Hynes, 1975). Therefore, the pH values were within a narrow range and did not change very much, and this agreed with many previous studies (Salman et al., 2015; Al-Zurfi et al., 2019).

The TDS ranged from 406 to 791 mg/l (591±129) during September and October, and the TSS ranged from 21.1 to 40.5 mg/l (27.4±7.45) during December and July. The results showed significant differences between the months in both factors (Table 2). TDS levels were high in the summer months. This could be because agricultural waters drain into waterways when they use fertilizers, and water their crops (Al Bomola, 2011). The values of TDS gave a distinction between months and stations, as TDS affected the presence and distribution of algae (Bilanovic et al., 2009), and the abundance of nutrients in the water and

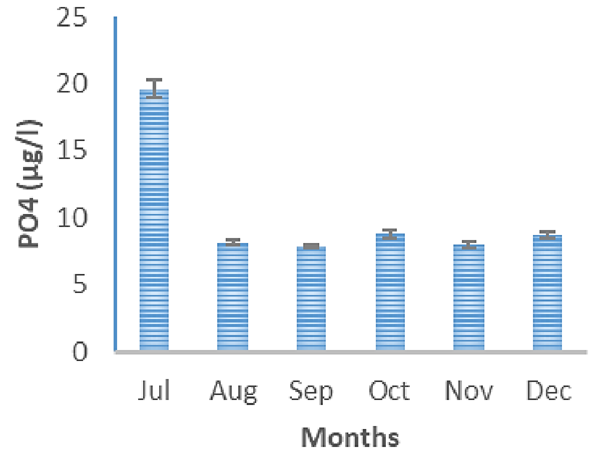

Figure 4. Monthly variations of PO_4 during the study period.

the osmotic activity of algae, which has a major role in the absorption and release of nutrients (Kadono, 1982). The total alkalinity of the water ranged from 115 to 119 mg/l (117.16±1.47) during December and July. This is explained by the fact that the carbonate reactions are affected by the cooler air and water temperatures during the cool season (Abdo, 2005). Alkalinity exhibited a positive correlation with water temperature (r = 0.91) and high negative correlations with TDS and pH (r = -0.44 and -0.36, respectively). The TH of the water ranged from 290 to 339 mg/l (311.16±19.2) during August and September showing significant differences between the months (Table 2).

Calcium levels were high (120 mg/l in September) and low (113 mg/l) in December. While the magnesium content of the water ranged from 38.2 to 49.2 mg/l (43.9± 4.14) during August and September. According to Awdallah et al. (1991), the high Ca^{2+} content in the Euphrates River during September may be caused by the re-dissolution of organisms and suspended materials containing Ca^{2+} in the presence of dissolved CO_2. Figure 2 shows the concentration of nitrite in water samples, where the higher value was recorded in October (3.61 mg/l) and the lower value in December (1.12 mg/l). The results revealed that nitrite concentration was significantly different between months (*P*<0.05) with a higher value in October (13.1 mg/l) and a lower value in December (1.13 mg/l). The results showed that nitrate concentration was significantly different between months (*P*<0.05) (Fig. 3). High values in October may be related to bacterial

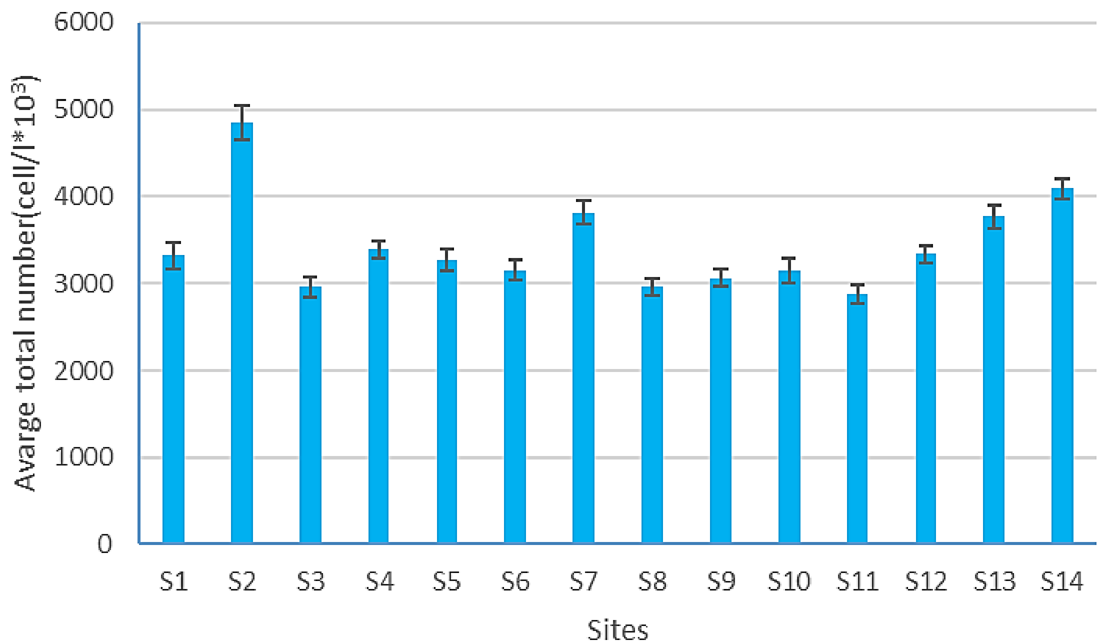

Figure 5. Spatially distributions of diatoms total number at study sites.

activity, decomposition of organic matter, emission of foul odors that indicate the presence of anaerobic decomposition and the presence of H_2S, or a decrease in the uptake by phytoplankton and low water levels, while the lowest value in December may be related to an increase in the uptake by aquatic plants and phytoplankton (Mohammed, 2007; Al-Hamdawe, 2016). These findings are in agreement with the findings of Okbah and ElGohary (2002) and Al-Taee (2017) but contradict with results of Yerli et al. (2012). In aquatic ecosystems, nitrogen is found in both distinct inorganic forms (N_2, NH^{4+}, NO_2, and NO^{-3}) and a variety of organic forms (Wetzel, 2001). The primary form of inorganic nitrogen in the aquatic ecosystem is nitrate (Smith, 2004).

According to the findings, the phosphate ranged from 7.8 to 19.6 μg.l^{-1}. In July, the average value was higher (Fig. 4), but it changed throughout the months because of the breakdown of organic waste and aquatic plants, as well as changes in water level, evaporation, and phytoplankton uptake (Volk and Engelbrecht, 2000; Mokaya et al., 2004). It is lowest in September, and this could be due to an increase in phosphate uptake by aquatic plants or by phosphate adhering to sediments, organic matter, and mineral deposits at the bottom of surface water (Fink et al., 2016). When the pH level is close to natural, phosphorus is strongly linked to sediments by calcium and iron compounds and it is difficult to release (Wauchope et al., 2022). Al-Obaidi et al. (2009) in the southern marshes and Al-Taee (2017) in Bahr Al-Najaf results are in agreement with our findings, however, Gurung et al. (2006) in the Nepal Lakes showed different findings. The results revealed significant variations (P<0.05) between sites and seasons, with summer having a particularly large impact on PO_4 and TP. Both organic and inorganic phosphorus compounds, as well as dissolved or particulate phosphate, can occur. Algae and aquatic plants are the principal sources of phosphate (Mainstone and Parr, 2002). Many natural waters have low phosphorus concentrations, which typically prevent algae growth (Worsfold et al., 2016).

The present study recorded 96 taxa of diatoms during the study period (Table 3) with the highest number of 4845×0^3 cells/l in site 2, while a lower total number of 2871×10^3 cells/l in site 11 (Fig. 5) because of agricultural spills, household, and/or wastewater effluents, or both (Kamel et al., 2022). The plants and animals that make up a living population of water are subject to selective action by water quality, and the changes in them can cause biological indices of water

Table 3. The list of the recorded taxa and their total number of Bacillariophyta (cell/l ×103) in the study sites.

Species	Sites													
	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14
Aulacoseira granulate (Ehrenberg) Simonsen 1979	130	104	0	130	0	0	0	0	0	0	0	0	0	0
A. distans (Ehrenberg) Simonsen 1979	117	0	26	39	26	26	65	13	156	0	26	26	26	0
A. ambigua (Grunow) Simonsen 1979	0	78	65	0	26	39	26	0	65	52	0	13	52	26
A. distans (Ehrenberg) Simonsen 1979	0	117	91	0	13	0	0	0	0	39	0	78	0	39
A. italic (Ehrenberg) Simonsen 1979	662	818	506	247	415	714	454	571	428	558	597	558	350	286
Aulacoseira veraluciaeTremarin ,2014	0	0	0	0	0	0	65	91	52	117	26	130	52	91
Achnanthidium affine (Grunow) Czarnecki 1994	39	0	0	26	0	13	26	0	0	13	26	0	0	389
A. minutissimum (Kützing) Czarnecki 1994	0	0	0	0	0	0	0	0	0	0	26	0	0	0
Achnanthes sp. Bory 1822	0	0	0	0	0	0	0	0	0	0	0	0	0	104
Anomoeoneis capitata Bahls 2017	0	0	13	0	0	0	52	0	0	13	0	13	65	0
A. sphaerophora Pfitzer 1871	0	0	0	0	0	0	13	0	0	0	0	0	0	0
Caloneis ventricosa F. Meister 1912	0	0	0	0	0	0	0	0	0	0	0	13	0	0
Coscinodiscus sp. Ehrenberg, C.G. (1839)	0	0	0	13	0	0	0	13	0	0	39	0	0	13
Cocconeis pediculus Ehrenberg 1838	39	169	350	195	65	39	299	91	26	0	65	130	78	649
C. placentula Ehrenberg 1838	52	156	428	532	117	260	584	286	247	130	143	363	727	221
C. placentula var. euglypta (Ehrenberg) Grunow 1884	0	0	0	0	0	0	0	0	0	0	0	65	0	26
Craticula halophila (Grunow) D.G. 1990	0	0	0	0	0	0	0	0	26	0	26	13	0	0
Cyclotella meneghiniana Kützing 1844	389	221	325	350	441	441	247	312	234	312	273	337	415	156
C. distinguenda Hustedt in Gams 1928	0	0	0	0	0	0	0	0	0	0	0	39	0	0
Cymatopleura elliptica (Brébisson) W.Smith 1851	0	0	13	13	0	13	0	0	0	0	0	0	0	130
Cymbella affinis Kützing 1844	13	13	13	52	52	0	39	26	13	52	52	0	91	0
Cymbella cistula (Ehrenberg) O.Kirchner 1878	0	0	0	26	0	130	52	13	0	0	0	13	26	26
Cymbella lanceolata (C.Agardh) C.Agardh 1830	26	0	0	78	0	26	13	26	13	26	26	0	13	0
Cymbella obtusiuscula Kützing 1844	26	0	0	0	0	0	0	0	0	0	39	0	0	0
Cymbella parva (W.Smith) Kirchner 1878	26	0	0	13	0	0	0	0	0	0	0	0	0	0
Cymbella tumida (Brébisson) Van Heurck 1880	39	13	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella tumidula Grunow in A.W.F.Schmidt 1875	26	0	0	0	0	0	0	0	0	0	0	0	0	0
Cylindrotheca closterium (Ehrenberg) Reimann and J.C.Lewin 1964	0	260	0	0	26	0	0	0	0	65	0	0	0	0
Discostella stelligera (Cleve and Grunow) Houk and Klee 2004	39	0	0	78	117	0	65	78	39	52	26	26	65	273
Diatoma elongata (Lyngbye) C.Agardh 1824	0	13	0	0	13	0	13	13	13	13	26	0	13	26
Diatoma vulgaris Bory 1824	13	0	0	13	26	0	0	13	26	26	39	13	182	13
Diploneis ovalis (Hilse) Cleve 1891	0	0	0	13	0	0	0	0	0	0	0	0	0	0
Encyonema elginense (Krammer) D.G.Mann 1990	0	0	0	0	0	0	0	0	0	0	0	13	0	0
Encyonema sp. Kützing 1834	0	0	0	0	0	0	0	13	0	0	13	0	0	13
Encyonema ventricosum (C.Agardh) Grunow 1875	0	26	0	13	0	0	0	13	39	0	0	13	0	39
Encyonema cespitosum Kützing 1849	0	0	0	26	0	0	0	13	13	0	0	0	0	13
Entomoneis alata (Ehrenberg) Ehrenberg 1845	0	0	0	13	0	26	0	0	0	0	0	0	0	0
Fragilaria capucina Desmazières 1830	0	39	0	26	0	0	0	39	0	0	0	13	0	0
Fragilaria crotonensis Kitton 1869	1272	1713	818	558	1077	584	1090	701	688	1272	805	480	844	441

Table 3. Continued.

Species	Sites													
	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14
Fragilaria capucina var. *vaucheriae* (Kützing) Lange-Bertalot 1980	0	247	0	0	0	0	0	0	0	0	0	0	0	558
Fragilaria vaucheriae (Kützing) J.B.Petersen 1938	0	0	0	0	0	0	0	0	0	0	39	0	0	0
Gomphonema acuminatum Ehrenberg 1832	0	26	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema costulatum Jasnitsky 1936	0	0	13	0	0	0	0	13	0	0	0	0	0	26
Gomphonema angustatum (Kützing) Rabenhorst 1864	0	0	0	0	0	0	0	0	52	0	0	78	65	0
Gomphonella olivacea (Hornemann) Rabenhorst 1853	13	0	0	0	0	65	0	0	0	0	0	0	0	0
Gomphonema grunowii R.M.Patrick and Reimer 1975	0	0	0	13	0	0	0	0	0	0	0	0	26	0
Gomphonema minutum (C.Agardh) C.Agardh 1831	0	0	0	0	0	0	0	0	13	0	0	0	0	0
Gomphonema constrictum Ehrenberg in Kützing 1844	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Gomphoneis sp. (Grunow) Cleve,1894	0	0	0	0	0	0	0	0	0	0	0	26	0	0
Gyrosigma acuminatum (Kützing) Rabenhorst 1853	0	0	13	13	0	0	0	0	26	0	13	0	0	0
Gyrosigma attenuatum (Kützing) Rabenhorst 1853	65	13	0	0	0	0	26	26	0	0	0	26	0	0
Hantzschia zidarovae Bulinová, Kochman 2018	0	0	0	0	0	0	0	0	0	0	13	0	0	0
Halamphora coffeiformis (C.Agardh) Mereschkowsky 1903	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Lindavia comta (Kützing) Nakov et al. 2015	0	13	0	0	0	65	0	26	26	0	0	0	0	0
Licmophora ehrenbergii (Kützing) Grunow 1867	0	0	0	13	0	26	0	13	0	0	0	0	0	0
Licmophora sp. C.Agardh 1827	0	39	26	0	0	13	0	0	0	0	26	0	26	0
Luticola nivalis (Ehrenberg) D.G.Mann 1990	0	0	0	13	0	0	0	0	0	0	0	0	0	0
Mastogloia smithii Thwaites ex W.Smith 1856	26	117	26	130	0	52	52	13	0	65	52	39	65	39
Meridion sp. C.Agardh1824	0	13	0	0	0	0	0	13	13	0	0	13	0	0
Navicula angelica Ralfs in Pritchard 1861	13	13	0	26	13	0	0	0	13	0	13	0	13	0
Navicula cincta (Ehrenberg) Ralfs in Pritchard 1861	39	39	13	0	13	0	13	0	0	0	0	26	0	65
Navicula cryptocephala Kützing 1844	0	0	0	0	0	0	0	0	26	0	0	0	0	0
Navicula tenella Brébisson ex Kützing 1849	0	0	0	0	52	26	0	0	39	39	26	65	0	13
Navicula limnetica Kociolek 2014	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Navicula gregaria Donkin 1861	0	0	0	0	0	0	0	0	0	0	0	0	13	0
Neidium affine (Ehrenberg) Pfitzer 1871	0	0	0	0	0	0	0	0	26	0	0	0	0	0
Nitzschia acicularis (Kützing) W.Smith 1853	0	0	0	0	0	0	52	0	0	0	0	0	0	0
Nitzschia obtusa W.Smith 1853	39	26	0	13	0	39	39	26	13	0	0	26	26	26
Nitzschia clausii Hantzsch 1860	0	0	0	0	0	0	0	0	13	0	0	0	0	0
Nitzschia dissipata (Kützing) Rabenhorst 1860	0	104	0	91	0	0	0	0	0	0	0	0	0	0
Nitzschia gracilis Hantzsch 1860	0	0	0	0	0	0	0	0	0	0	13	0	0	0
Tryblionella hungarica (Grunow) Frenguelli 1942	0	0	0	0	13	0	0	0	0	0	13	0	0	0
Nitzschia linearis W.Smith 1853	0	0	0	0	26	0	0	0	0	0	0	0	0	0
Nitzschia longissima (Brébisson) Ralfs 1861	13	91	26	0	13	0	26	26	0	78	78	26	13	13
Nitzschia palea (Kützing) W.Smith 1856	78	78	26	182	104	117	182	143	182	130	117	169	182	143
Nitzschia pusilla Grunow 1862	0	26	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia fasciculata (Grunow) Grunow 1881	0	0	0	0	0	0	0	0	0	0	0	0	13	0
Nitzschia sigmoidea (Nitzsch) W.Smith 1853	13	39	26	0	26	13	0	13	0	13	0	0	0	26

Table 3. Continued.

Species	Sites													
	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	St.12	St.13	St.14
Tryblionella hantzschiana Grunow 1862	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Nitzschia sp. Hassall 1845	0	0	13	13	0	26	0	0	0	0	13	13	0	0
Nitzschia hantzschiana Rabenhorst 1860	0	0	0	0	0	0	0	0	0	0	0	0	26	0
Pantocsekiella ocellata (Pantocsek) K.T.Kiss and Ács 2016	0	0	0	0	0	0	0	26	0	0	0	0	0	0
Planothidium delicatulum (Kützing) Round and Bukhtiyarova 1996	0	0	0	0	0	0	13	0	0	0	0	0	0	0
Pinnularia cuneola E.Reichardt 1981	0	0	0	0	13	0	0	0	0	0	0	0	0	0
Pinnularia viridis (Nitzsch) Ehrenberg 1843	0	0	0	0	0	0	0	0	13	0	0	0	0	0
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot 1980	0	0	0	0	0	0	0	0	195	0	0	0	0	0
Sellaphora pupula f. *capitata* (Skvortzov and K.I.Meyer) Poulin 1995	0	0	0	0	0	0	0	0	0	0	13	0	0	0
Stauroneis sp. Ehrenberg 1843	0	0	0	0	0	0	0	0	0	0	13	13	0	0
Stephanodiscus hantzschii Grunow in Cleve and Grunow 1880	0	0	26	52	39	13	39	0	26	0	0	13	0	0
Surirella robusta Ehrenberg 1841	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Surirella minuta Brébisson ex Kützing 1849	0	0	0	0	0	65	39	0	26	13	39	0	13	39
Surirella librile (Ehrenberg) Ehrenberg 1845	0	78	0	26	65	0	0	39	78	0	39	26	13	26
Tabellaria sp. (Roth) Kützing 1844	0	0	0	0	325	39	0	0	0	0	0	52	52	0
Tabularia fasciculata (C.Agardh) D.M.Williams and Round 1986	0	0	0	0	26	0	0	0	0	0	0	0	0	0
Ulnaria capitata (Ehrenberg) Compère 2001	0	0	0	26	0	0	0	0	0	0	0	0	0	0
Ulnaria acus (Kützing) Aboal 2003	117	143	104	325	130	234	234	247	208	65	78	376	221	143

Table 4. Correlation between physiochemical properties and Diatoms

Correlations

		pH	WT	AT	TDS	TSS	Alk	TH	Ca	Mg	NO2	NO3	PO4	Diatoms
pH	Pearson Correlation	1	-.542-	-.541-	.295	-.246-	-.365-	.413	.356	.540	.084	-.305-	.122	-.255-
	Sig. (2-tailed)		.266	.267	.571	.639	.477	.415	.489	.269	.874	.556	.818	.626
WT	Pearson Correlation		1	.920**	-.449-	.537	.911*	.247	.368	.070	.382	.482	.197	.682
	Sig. (2-tailed)			.009	.372	.272	.011	.638	.473	.894	.455	.333	.708	.136
AT	Pearson Correlation			1	-.331-	.791	.962**	-.044-	.060	-.195-	.371	.291	.497	.854*
	Sig. (2-tailed)				.522	.061	.002	.934	.910	.711	.468	.576	.316	.030
TDS	Pearson Correlation				1	.043	-.443-	-.020-	-.122-	.072	.588	.363	-.033-	-.419-
	Sig. (2-tailed)					.936	.379	.970	.818	.892	.220	.479	.951	.408
TSS	Pearson Correlation					1	.777	-.176-	-.203-	-.223-	.468	.032	.869*	.881*
	Sig. (2-tailed)						.069	.738	.700	.672	.350	.952	.025	.020
Alk	Pearson Correlation						1	.126	.212	-.011-	.345	.185	.574	.916*
	Sig. (2-tailed)							.812	.686	.984	.504	.726	.233	.010
TH	Pearson Correlation							1	.965**	.981**	.497	.477	-.211-	-.090-
	Sig. (2-tailed)								.002	.001	.315	.339	.688	.865
Ca	Pearson Correlation								1	.910*	.458	.515	-.277-	-.062-
	Sig. (2-tailed)									.012	.360	.295	.596	.907
Mg	Pearson Correlation									1	.462	.377	-.185-	-.169-
	Sig. (2-tailed)										.356	.462	.726	.748
NO2	Pearson Correlation										1	.759	.185	.175
	Sig. (2-tailed)											.080	.726	.740
NO3	Pearson Correlation											1	-.410-	-.160-
	Sig. (2-tailed)												.419	.762
PO4	Pearson Correlation												1	.829*
	Sig. (2-tailed)													.041
Diatoms	Pearson Correlation													1
	Sig. (2-tailed)													

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

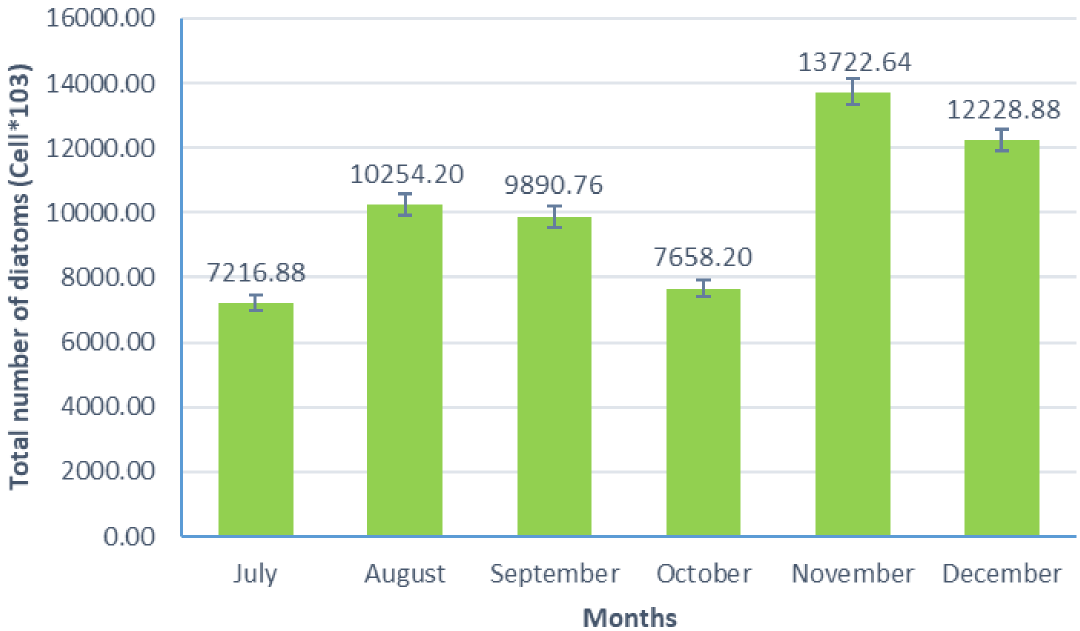

Figure 6. Monthly variations of diatoms total number during study period.

quality (Wu, 1993). November had a higher total number of 13722.64×10^3 cells/l, while July had a lower total number of 7216.88×10^3 cells/l (Fig. 6). Diatoms underwent bi-times total number reduction during July and October and restoration in Euphrates River, once during November and again early winter (December) (Fig. 6). November phytoplankton bloom has occurred as the light became more available, temperatures temperate, and nutrients were available (Libby et al., 2013). In the study period, we discovered that *Fragilaria crotonensis* Kitton (1869) had a higher total number followed by *Aulacoseira italic* (Ehrenberg) Simonsen 1979, *Cocconeis placentula* Ehrenberg 1838, *Ulnaria acus* (Kützing) Aboal 2003, *Cocconeis pediculus* Ehrenberg 1838, and *Nitzschia palea (Kützing)* W.Smith 1856 (Table 3). This may be because cell division happened at a time when the population was predominately made up of tiny cells from the late summer to early fall (Kagami et al., 2006). In oligotropic regions of the Euphrates River, where diatom assemblages resemble those in mesotrophic and eutrophic lakes. *Fragilaria crotonensis* is thought to be a sign that reactive nitrogen levels have risen above the threshold (Wolfe et al., 2006; Spaulding et al., 2015). A significant relation was found between Diatoms' total number and phosphorus (P<0.05; r = 0.83* (Table 4) because phosphorus is an essential component of nucleic acids, phospholipids, and intermediate metabolites, and its availability can affect primary production and the carbon cycle in aquatic environments (Paytan and McLaughlin, 2007).

Nutrients like nitrogen (N), silicon (Si), phosphorus (P), and iron (Fe) can have an impact on diatom growth (Litchman et al., 2006). Phosphorus deficiency has been noted in numerous open ocean places, and P recycling is relatively quick in the ocean (Dyhrman et al., 2007). Orthophosphate anions (Pi) are the most prevalent soluble inorganic form of P taken up by phytoplankton. In response to a P shortage, diatoms can enhance their P absorption (Perry, 1976). Phosphorus limitations have shown the induction of phosphate transporters and alkaline phosphatases, which are linked to an increase in the capacity of P absorption in diatoms (Dyhrman et al., 2012; Lin et al., 2013) In numerous studies, including those on the Tigris and Euphrates rivers (Al-Fatlawi, 2011; Alghanimy, 2015) and other studies on Iraqi marshes (Hammadi et al., 2007; Al-Saadi et al., 2008), diatoms have taken the lead and are a common phenomenon. In research carried out in many parts of the world, including Radwan (2005) in Egypt, Basualto et al. (2006) in Chile, Yerli et al. (2012) in Turkey, and Kumssa and Bekele (2014) in Ethiopia, diatom outperformed other algal groupings. It was concluded that the presence of diatom species in both lotic and lentic habitats was significantly and highly correlated with air temperature, total suspended solids, total alkalinity, and phosphate. We concluded that in lotic systems, environmental conditions can influence the presence and distribution of diatoms.

Acknowledgments
We thank the faculty of sciences at Kufa University for their assistance with the laboratory requirements provided to complete the research.

References

Abdo M.H. (2005). Physico-chemical characteristics of Abu Za’baal ponds. Egyptian Journal of Aquatic Research, 31: 1-15.

Alcamo J., Flörke M., Märker M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. Hydrological Sciences Journal, 52(2): 247-275.

Al-Fatlawi H.J.J. (2011). Ecological, qualitative and quantitative study of algae in Euphrates River between AL-Hindia and AL-Manathera district, Iraq. MSc thesis, College of Science, University of Babylon. 124 p.

Alghanimy D.B.G.S. (2015). Assessment of water quality of Euphrates River (between the cities of Al-Kifl and Al-Shinafiyah) Iraq. Ph.D. Thesis, University of Al-Qadisiyah. 184 p.

Al-Haidarey M.J. (2010). Diurnal variation of heavy metals in Al-Kufa River / Najaf Iraq, 10th Conference of Biogeochemistry of Trace Element, Maxico.

Al-Obaidi G., Salman S., Rubec C. (2009). Key biodiversity areas: Rapid assessment of phytoplankton in the Mesopotamian Marshlands of southern Iraq. BioRisk, 3: 111-126

Al-Saadi H.A., Hassan F.M., Alkam F.M. (2008). Phytoplankton and related nutrients in Sawa Lake, Iraq. Journal of Dohuk University, 11(1): 67-76.

Al-Taee I.A.A. (2017). Algal community, composition and its relation with some environmental variable in Bahr Al-Najaf–Iraq. University of Kufa Journal, 12(3): 112-344.

Al-Tamimi A.N.A., Al-Obeidi N.A. (2021). Water quality assessment by epiphytic diatoms in Euphrates River between Haditha and Al-Baghdadi-Iraq. Annals of the Romanian Society for Cell Biology, 2022-2032.

Armbrust E.V. (2009). The life of diatoms in the world's oceans. Nature, 459(7244): 185-192.

Arrigo K.R. (2014). Sea Ice Ecosystems. Annual Review of Marine Science, 6: 439-467.

Cahoon L.B., Laws R.A., Thomas C.J. (1994). Viable diatoms and chlorophyll a in continental slope sediments off Cape Hatteras, North Carolina. Deep Research Part II 41: 767-782.

Carr G.M., Neary J.P. (2008). Water quality for ecosystem and human health. UNEP/Earthprint

Chapman D.V. (1996). Water quality assessments: A guide to the use of biota, sediments and water in environmental monitoring. CRC Press. 651 p.

Dyhrman S.T., Ammerman J.W., Van Mooy B.A. (2007). Microbes and the marine phosphorus cycle. Oceanography, 20(2): 110-116.

Dyhrman S.T., Jenkins B.D., Rynearson T.A., Saito M.A., Mercier M.L., Alexander H., Heithoff A. (2012). The transcriptome and proteome of the diatom *Thalassiosira pseudonana* reveal a diverse phosphorus stress response. PloS one, 7(3): e33768.

Falkenmark M., Rockström J. (2004). Balancing water for humans and nature: the new approach in ecohydrology. Routledge Press. 247 p.

Fink J.R., Inda A.V., Tiecher T., Barrón V. (2016). Iron oxides and organic matter on soil phosphorus availability. Ciencia e Agrotecnologia, 40: 369-379.

Hadi R.A.M. (1981). Algal studies on the river USK. Ph.D. Thesis, Univ. Collage Cardiff U.K. 220 p.

Hassan F.M., Salah M.S., Salman J.M. (2007). Quantitative and qualitative variability of epiphytic algae on three aquatic plants in Euphrates River, Iraq. Iraqi Journal of Aquaculture, 4(1): 1-16.

Jawad H.J., ALrufaye Z.T.A. (2020). Ecological study of diatoms community of Al Hussainya River in Kerbala City Iraq. In: AIP Conference Proceedings, 2290(1): 020010.

Kamel L.H., Al-Zurfi S.K.L., Mahmood M.B. (2022). Investigation of heavy metals pollution in Euphrates River (Iraq) by using heavy metal pollution index model. In IOP Conference Series: Earth and Environmental Science, 1029(1): 012034.

Karr J.R., Dudley D.R. (1981). Ecological perspective on water quality goals. Environmental Management, 5: 55-68.

Kumssa T., Bekele A. (2014). Attitude and perceptions of local residents toward the protected area of Abijata-Shalla Lakes National Park (ASLNP), Ethiopia. Journal of Ecosystem and Ecography, 4(1): 1.

Libby P.S., Borkman D.G., Geyer W.R., Turner J.T., Costa A.S., Mickelson M.J. (2013). Water Column Monitoring Results. Boston: Massachusetts Water Resources Authority. Report 2013-15. 50 p.

Lin H.Y., Shih C.Y., Liu H.C., Chang J., Chen Y.L., Chen Y.R., Lin H.J. (2013). Identification and characterization of an extracellular alkaline phosphatase in the marine diatom *Phaeodactylum tricornutum*. Marine Biotechnology, 15: 425-436.

Litchman E., Klausmeier C.A., Miller J.R., Schofield O.M., Falkowski P.G. (2006). Multi-nutrient, multi-group model of present and future oceanic phytoplankton communities. Biogeosciences, 3(4): 585-606**.**

Mainstone C.P., Parr W. (2002). Phosphorus in rivers—ecology and management. Science of the total Environment, 282: 25-47.

Mann D.G., Vanormelingen P. (2013). An inordinate fondness? the number, distributions, and origins of diatom species. Journal of Eukaryotic Microbiology, 60: 414-420.

Nelson K.C., Palmer M.A., Pizzuto J.E., Moglen G.E., Angermeier P.L., Hilderbrand R.H., ... Hayhoe K. (2009). Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options. Journal of Applied Ecology, 46(1): 154-163

Parsons T.R., Maita Y., Lalli C.M. (1984). A manual of chemical and biological methods for seawater analysis. Pergamon Press. New York. 173 p.

Paytan A., McLaughlin K. (2007). The oceanic phosphorus cycle. Chemical Reviews, 107(2): 563-576.

Perry M.J. (1976). Phosphate utilization by an oceanic diatom in phosphorus-limited chemostat culture and in the oligotrophic waters of the central North Pacific 1. Limnology and Oceanography, 21(1): 88-107.

Peters N.E., Meybeck M. (2000). Water quality degradation effects on freshwater availability: impacts of human activities. Water International, 25(2): 185-193.

Sabater S. (2009). The diatom cell and its taxonomical entity. Encyclopedia of Inland Waters, 1: 149-156.

Salman H.M., Jasim M.N., Salman J. (2015). A GIS assessment of water quality in Euphrates River/Iraq. Journal of Babylon University/Engineering Sciences, 23: 1-8.

Smith R. (2004). Current methods in aquatic science. University of Waterloo, Canada.

Spaulding S.A., Otu M., Wolfe A.P., Baron J. (2015). Paleolimnological records of nitrogen deposition in shallow, high-elevation lakes of Grand Teton National Park, Wyoming, U.S.A. Arctic, Alpine and Antarctic Research, 47(4): 701-715.

UNESCO (2002). The challenge of achieving gender parity in basic education. Astatistical Review, 2002.

Wauchope-Thompson M.S., Cade-Menun B.J., Baulch H.M. (2022). Phosphorus forms by depth in sediments from the Qu'Appelle lakes, Saskatchewan, Canada. Frontiers in Environmental Science, 10: 928824.

Wolfe A.P., Cooke C.A., Hobbs W.O. (2006). Are current rates of atmospheric nitrogen deposition influencing lakes in the eastern Canadian Arctic? Arctic, Antarctic, and Alpine Research, 38: 465-476.

Wu J.T. (1999). A generic index of diatom assemblages as bioindicator of pollution in the Keelung River of Taiwan. Hydrobiologia, 397: 79-87.

Yerli S.V., Kıvrak E., Gürbüz H., Manav E., Mangıt F., Türkecan O. (2012): Phytoplankton community, nutrients and chlorophyll a in Lake Mogan (Turkey), with comparison between current and old data. – Turkish Journal of Fisheries and Aquatic Sciences, 12: 95-104.