Seasonal species diversity and density of non diatomic phytoplankton from the Tigris River, Baghdad Province, Iraq

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Abstract

Phytoplankton is the subject of great interest because of their role as primary producers in an aquatic ecosystem. The quantitative, qualitative, and diversity studies of phytoplankton may provide good indexes of water quality and the capability of water to sustain heterotrophic communities. Water samples were collected at monthly intervals from four sites of the Tigris River in the Iraqi capital, Baghdad; the study period was one year from January to the end of December 2021. The present investigation aimed at the diversity and total count of non-diatomic phytoplankton. A total of (51) non- diatomic Phytoplankton algal species were identified belonging to 6 classes in all studied stations, 26 species (55.988%) belonged to Chlorophyceae, 18 species (35.657%) to Cyanophyceae, 3 species (6.615%) to Dinophyceae, 2 species (1.28%) to Euglenophyceae and 1 species for each of Zygnematophyceae (0.252%) and Chrysophyceae (0.206%).Chlorophyceae (green algae) remained dominant in all stations during the study period, followed by Cyanophyceae (Blue-green algae). The highest total annual density of phytoplankton during the study period was at Station 2 (1999.1 ind×103L-1), followed by (1655.5 ind×103L-1) at Station 4, and (1560.6 ind×103L-1) at Station 1. The lowest total density was recorded at Station 3 which was (1275.8 ind×103L-1). Seasonally phytoplankton diversity was investigated based on Shannon-Diversity Index. The most diversity index was recorded in Autumn (3.748), in Spring (3.672), followed by (3.473) in Summer and (2.426) in Winter. Eventually, the Shannon index in studying areas within the Tigris River is classified as a good class.

Keywords: *Non-diatomic phytoplankton, Shannon-Diversity Index, Algae total count, Annual density, Tigris River.*

Introduction

Freshwater ecosystems vary in size and composition and contain a large variety of organisms. The environment of the Tigris River is home to diverse fish and plankton species. Phytoplankton is used to indicate the quality of water and pollution status in any water ecosystem since algae are the primary producers in the aquatic environment, they are the base of the food chain, and they play a significant part in water purification and water quality evaluation (Saha et al.2000; Ali et al. 2020).Microalgae are a large group of prokaryotic and eukaryotic photosynthetic organisms that can be found in a variety of forms, including solitary cells, colonies, and long filaments (Chaterjee & Raziuddin, 2006). Microalgae are sources of food, clean energy, and plant fertilizer and include bioactive, antibacterial, and antioxidant chemicals. (Abdulkareem & Anwer2021) Their main habitats are freshwater, brackish, and marine ecosystems make up their primary habitats. They are oligoene microorganisms whose biomass could be converted to potential products such as pigments, fine chemicals, bioactive molecules, and most importantly, biofuels (Spolaore et al., 2006). Some species of green microalgae (e.g., Chlorella vulgaris, Chlorococcum littorale, Botryococcus braunii) have been candidate strains for the production of neutral lipids for conversion to various types of biofuels (e.g., biodiesel, kerosene, gasoline) (Liu et al. 2011). The spatial mapping of phytoplankton assists to determine hotspot areas based on abundance and diversity. Some studies analyze the spatial distribution and diversity of plankton (Farkha ,2006 :Farkha &Fattah,2013; Nassar & Gharib, 2014). Knowledge of phytoplankton distribution concerning the spatial pattern is important to determine the status of the ecosystem structure and functioning.On the other hand, several introduced species have ecological negative effects on ecosystems. Therefore, the identification and qualitative studies of phytoplankton populations not only have an important role in the collection of historical data but are also necessary to understand the polluted and under-stress environment of the aquatic ecosystems (Nasrollahzadeh Saravi et al., 2014). Quantitative and qualitative variables of the phytoplankton are an example of organism's adaptation to the alterations in environment (Kozak 2005). Since algae's diversity and abundance show how physico-chemical variables affect phytoplankton populations cumulatively, total phytoplankton and its composition characterize the trophic conditions of the lakes better than total phosphorus, for example (Brettum & Andersen 2005). A good indicator of energy turnover in aquatic environments is diversity, dominance, a phytoplankton count, and fluctuation in the biotic parameters (Forsberg 1982). A complex pattern of community structure can be established through a variety of interactions that are characterized by species diversity, which reacts to changes in environmental gradients. The variety, , species composition, and population density of phytoplankton are the main topics of our current work. In Iraq, the diversity of freshwater algae was studied by many researchers (Al Hassany et al.,2012; Hassan & Shaawiat,2015; Darweesh,2017; Ali et al., 2018; Albueajee et al., 2020; Ali et al., 2020; Ahmad,2021; Hussein &Alkam,2021; Al-Shandah et al., 2022).

Materials and Methods

Description of The Studied Area

The study area is in the province of Baghdad, the capital of Iraq, between latitude ("54.91'33°18 N) and longitude ("57.86'44°21 E) (Figure 1).

Figure 1: Maps of Iraq, including the province of Baghdad and locations of the study area

The first station (St. 1) is adjacent to the Jadriyah Bridge, the second is about 4 km from the Durah power plant, the third is about 3 km from the last station, and the fourth is about 30 meters from the Al-Tabiqien Bridge.

Sample collection

Water samples were collected monthly from January to the end of December 2021from the higher superficial layer 20-30 cm deep from the river. Samples were kept in a container of cork filled with ice to keep the properties of the samples until being delivered to the laboratory. Samples were then transported to the laboratory for qualitative and quantitative analysis of algae.

Qualitative analysis

Non-diatomic algae were identified by preparing slides and examined under 40 X magnification by using a compound microscope depending on the following references non-diatomic algae were identiffied (Desikachary, 1959; Prescott, 1982; John et al.,2011; Bellinger & Sigee 2015 ; Wehr et al., 2015).

Quantitative analysis

The sedimentation method was used to count the total number of phytoplankton (Furet and Benson, 1982). using Lugol's solution.

Non-diatom phytoplankton was assessed using a hemocytometer; 1 ml of concentrate was placed in the slide chamber and covered with a cover slide; non-diatoms were then recognized and counted under a microscope; the results were represented as an individual per Liter (ind 103L-1). The calculation was done using the following equation:

Number of non-Diatomic phytoplankton = Number of cell counted in one microscope field in 1ml of the original sample × conversion factor

Conversion factor = Number of microscopic field in 1ml of the Concentrated sample × Sample concentration factor

Concentration factor = 0.01ml of sample concentrated from 1000 to 10 ml

No. of microscopic field of 1ml = 1000 mm2 / (volume of concentrated sample in one field of concentrated sample mm2)

Volume of concentrated sample in one field mm2 = area of one microscopic field mm2 × 0.1ml.

Species diversity in the current study area community:

Shannon–Wiener Index was used to study species diversity. The values of this index are divided into five qualitative classes (Marques et al., 2009) (Table 1). Shanon Index is calculated by the following formula:

$$\textit{Shannon Index } (H) = -\Sigma^{s} P_i \ln P_i$$

In the Shannon index, P is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Table 1: Water quality classification, based on Shannon Diversity Index

Rating water quality	Shannon Index
Excellent	>4
Good	3–4
Moderate	2–3
Poor	1–2
bad	0–1

Results and Discussion

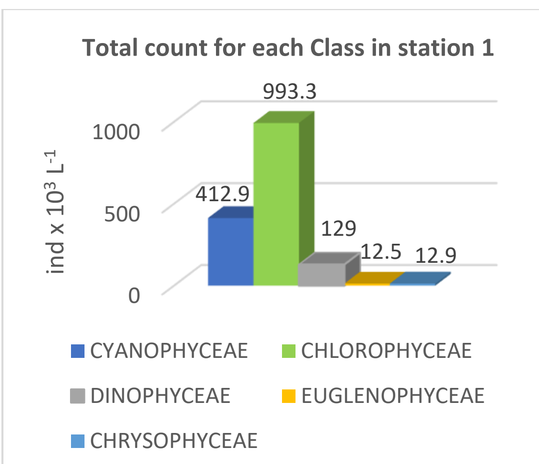
Qualitative and Quantitative (Density and Total count) of non diatomic phytoplankton

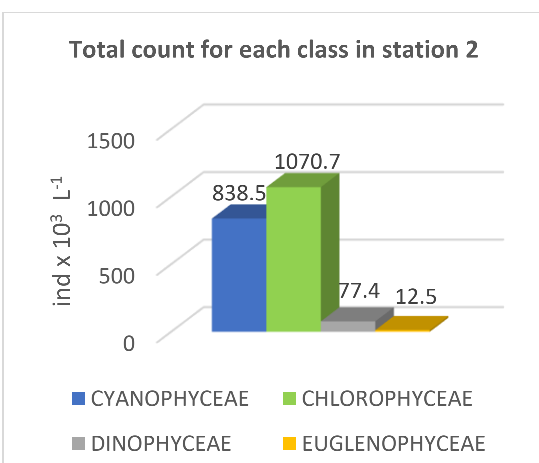
The phytoplankton structure of the Tigris River in the study area was assessed using monthly analyses of non-diatom phytoplankton communities, as well as the variety and density of distinct species. In all of the stations studied, a total of 51 non-diatomic Phytoplankton algal species were identified, 26 species (55.988%) belonging to Chlorophyceae, 18 species (35.657%) to Cyanophyceae, 3 species (6.615%) to Dinophyceae, 2 species (1.28%) to Euglenophyceae, and 1 species each for

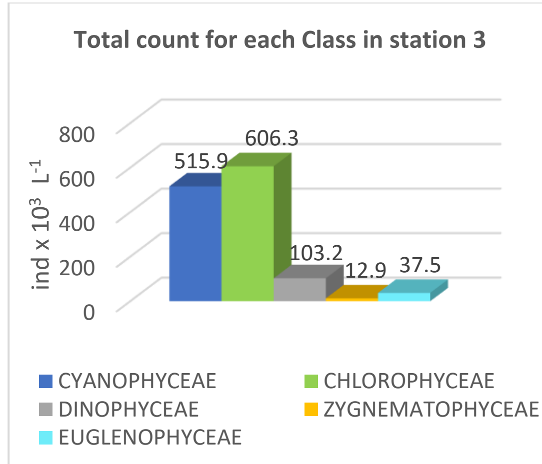
Zygnematophyceae (0.252%) and Chrysophyceae (0.206 %).

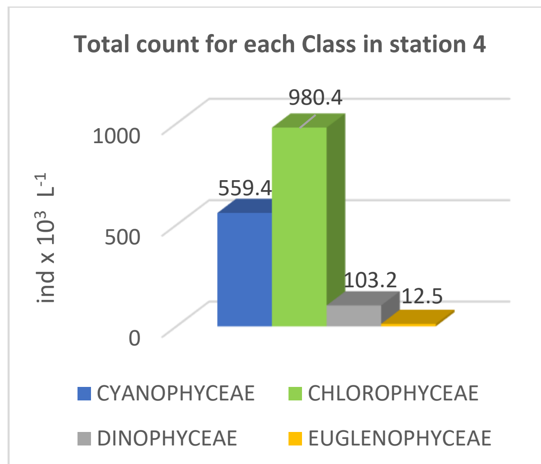
Table 2 and Figures 2, 3, 4, and 5 show that Chlorophyceae dominated all other phytoplankton in all sites. Chlorella vulgaris, Ankistrodesmus falcatus, Scenedesmus quadricauda, Coelastrum astroideum, Kirchneriella obesa, and others were the most prevalent Chlorophyceae species identified at most analyzed stations and in most study seasons, as shown in (Table 2). The qualitative and quantitative characteristics of the species may vary across all stations and seasons due to the mixing of the river water column (Seu-Anoi et al., 2017).

Figure 2: Total count of non-diatom algal Classes in studying stations.









Chlorella vulgaris was determined to be the most dominant Chlorophyceae species at all sites, and the total count of Chlorella vulgaris was recorded in the current study (296.7 ind ×103 L-1, 451.5 ind ×103 L-1, 193.5 ind×103 L-1 and 554.7 ind × 103L-1) for stations 1, 2, 3, and 4 respectively, Kirchneriella obesa (129 ind×103 L-1) was followed by Ankistrodesmus falcatus and Scenedesmus quadricauda (90.3 ind ×103 L-1) for both in station 1. Ankistrodesmus falcatus (167.7 ind×103L-1) and Coalastrum astroideum (64.5ind×103 L-1)Finally, in station 4, Ankistrodesmus falcatus 116.1 ind×103 L-1) was second, Coalastrum astroideum and Scenedesmus quadricauda were third in the total count of algae after Chlorella vulgaris (51.6 ind×103 L-1) .

According to the total count of algal species, Oscillatoria limnetica was followed by Nostoc sp. (38.7ind×103 L-1) and Lyngbya sp. (25.8 ind×103 L-1) at station 1, and Oscillatoria limnetica was followed by Lyngbya perelegans (64.5ind× 103 L-1) and Anabaena sp. (38.7ind×103 L-1) in station 2. Amongst Cyanophyceae, Oscillatoria limnetica was found to be the most dominant species at all stations clearly, the total count of Oscillatoria limnetic recorded 245.2 ind×L-1 , 619.2 ind×103L-1, 361.1 ind×103L-1 and 417.5ind ×103 L-1) for stations 1, 2, 3 and 4 respectively.

In station 1, Oscillatoria limnetica followed by Nostoc sp. (38.7 ind×103 L-1)then Lyngbya sp.(25.8 ind×10 3 L-1) according to the total count of algal species, in station 2 Oscillatoria limnetica followed by Lyngbya perelegans (64.5ind×103 L-1) then Anabaena sp.(38.7ind ×103 L-1), In station 3, Oscillatoria limnetica was followed by Nostoc sp. (51.6 ind ×103 L-1) and Lyngbya perelegans (38.7 ind ×103 L-1), while in station 4, Oscillatoria limnetica× was followed by Anabaena sp. and Lyngbya sp. (25.8 ind ×103 L-1) for both, before a group of species, as shown in Table 2.

The third algal class in this investigation was Dinophyceae (3 species), with Peridinium cinctum, Peridinium sp., and Ceratium hirundinella being the most frequent species detected in most examined stations during the study period (table 2). A variety of physical, chemical, and biological factors influence the distribution and abundance of algae in this system. However, several characteristics, such as alkalinity and phosphate phosphorus, were sensitive to certain concentrations (Chia et al., 2011).

Sensitivity means that as the concentration or levels of the parameters increased or decreased, the number of individuals decreased or increased in the opposite direction. As a result, differences in phytoplankton diversity, total count, and density in the study area are due to these reasons, as well as other hydrological factors such as discharge or water residence time, which are thought to be more important to plan (Jain et al,. 2018).

Table 2: Number of identified phytoplankton in station 1, and their Species and Total count of each Class (ind ×103 L-1)

TAXA	Winter		Spring			Summer			Autumn			Winter	
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	∑ Sum
CYANOPHYCEAE													
Anabaena sp.	-	-	-	-	-	-	12.9	-	-	12.9	-	12.9	12.9
Arthrospira sp.	-	-	-	-	-	-	-	-	12.9		-	-	12.9
Lyngbya perelegans	-	-	-	-	-	-	-	-	-	-	12.9	-	12.9
Lyngbya sp.	-	-	-	-	-	-	-	-	-	-	-	25.8	25.8
Merismopedia gluca (Ehr.) Naeg.	-	-	-	-	12.9	-	-	-			-	-	12.9
Nostoc sp.	-	-	-	-	12.9	-	-	-	12.9	12.9	-	-	38.7
Oscillatoria amphibia	-	-	-	-	12.9	-	-	-	-	-	-	-	12.9

Oscillatoria areli	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Oscillatoria limnetica Lemm.	12.9	12.9	25.8	-	25.8	12.9	12.9	38.7	12.9	25.8	38.7	25.8	245.1
Oscillatoria minima	-	-	-	-	12.9	-	-	-	-	-	-	-	12.9
Spirulia major Kutz.	-	-	-	-	-	-	-	12.9			-	-	12.9
	Total count of Cyanophyceae phytoplankton = **412.8**												
CHLOROPHYCEAE													
Actinastrum hantzschii	-	-	-	-	12.9	-	12.9	-	-	12.9	-	-	38.7
Ankistrodesmus falcatus (Corda.) Ralfs	-		12.9	-	12.9	12.9	12.9	12.9	-			25.8	90.3
Botryococcus braunii Kutz.	-	-	-	-	12.9	-	-	-	-	-	-	-	12.9
Chlorella vulgaris Beyer.	-	51.6	25.8	-	-	-	64.5	64.5	-	77.4	12.9	-	296.7
Coalastrum astroideum	-	-	12.9	-	-	-	-	12.9	12.9	-	-	-	38.7
Crucigenia tetrapedia (Kirch.)West & West.	-	-	-	-	12.9	12.9	-		-	-	-	-	25.8
Kirchneriella obesa	-	-	-	-	116.1		-	12.9	-	-	-	-	129
Monoraphidium corolutum	-	-	-	-	12.9	64.5	-	-	-	-	-	-	77.4
pediastrum simplex	-	-	-	-	12.9	-	-	-	12.9	-	-	-	25.8
Scenedesmus acuminatus	-	-	-	-	12.9	-	-	-	12.9	-	-	-	25.8
Scenedesmus acuminatus var. tetradesmoides	-	-	-	-	12.9	-	-	12.9		-	-	-	25.8
Scenedesmus bijuga	-	-	-	-	12.9	-		-	-	-	-	-	12.9
Scenedesmus dimorphus	-	-	-	-	12.9	-	25.8		12.9	-	-	-	51.6
scenedesmus opoliensis	-	-	-	-	-	-	12.9	-	-	12.9	-	-	25.8
Scenedesmus quadricauda (Turp.) Breb.	-	-	12.9	-	12.9	-	12.9	25.8	12.9	12.9	-	-	90.3
Tetraedron minimum (A.Br.) Hansg	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Tetraedron regulare	-	-	-	-	-	-	-	-	-	-	12.9	-	12.9
	Total count of Chlorophyceae phytoplankton = **993.3**												
DINOPHYCEAE													
Peridinium cinctum (O.F.Müller)	-	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	-	-	116.1
Peridinium sp.	-	-	12.9	-	-	-	-	-	-	-	-	-	12.9
	Total count of Dinophyceae phytoplankton = **129**												
EUGLENOPHYCEAE													

Euglena sp.	-	-	-	-	12.5	-	-	-	-	-	-	-	12.5
	Total count of Euglenophyceae phytoplankton = **12.5**												
CHRYSOPHYCEAE	-	-	-	-	-	-	-	-	-	-	-	-	
Dinobryon divergens	-	-	-	-	12.9	-	-	-	-	-	-	-	12.9
	Total count of Chrysophyceae phytoplankton = **12.9**												
Total count of all Species for each month	**12.9**	**77.4**	**116.1**	**12.9**	**335**	**116.1**	**167.7**	**206.4**	**90.3**	**167.7**	**64.5**	**51.6**	**1418.7**
Total count of all Species for each season	**141.9**		**464**			**490.2**			**322.5**			←	**1418.7**

Number of identified phytoplankton in station 2, and their Species and Total count of each Class (ind ×103 L-1)

TAXA	Winter		Spring			Summer			Autumn			Winter	
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**∑ Sum**
CYANOPHYCEAE													
Anabaena sp.	-	-	-	-	-	12.9		12.9	12.9	-	-	-	38.7
Arthrospira sp.	-	-	-	-	-	-	-	-	12.9	-	-	-	12.9
blue green filament	-	-	-	-	-	-	-	-	-	-	-	12.9	12.9
Chroococcus turgidus	-	-	-	-	12.9	-	-	-	-		-	-	12.9
Lyngbya perelegans	-	-	-	-	-	-	-	-	-	-	64.5	-	64.5
Lyngbya sp.	-	-	-	-	-	-	-	-	-	-	-	12.9	12.9
Merismopedia gluca (Ehr.) Naeg.	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Nostoc sp.	-	-	-	-	-	12.9	-	-	12.9	-	-	-	25.8
Oscillatoria amphibia	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Oscillatoria limnetica Lemm.	77.4	77.4	25.8	25.8	25.8	-	12.9	51.6	64.5	77.4	64.5	116.1	619.2
Spirulina sp.	12.9	-	-	-	-	-	-	-		-	-	-	12.9
	Total count of Cyanophyceae phytoplankton = **838.5**												
CHLOROPHYCEAE													
Actinastrum hantzschii	12.9	-	-	-	-	-	-	-	12.9	-	12.9	-	38.7
Ankistrodesmus falcatus (Corda.) Ralfs	-	-	-	-	-	38.7	-	77.4	12.9	12.9	12.9	12.9	167.7
Botryococcus braunii Kutz.	-	-	-	-	12.9	-	-	-	-	-	-	-	12.9
Chlorella vulgaris Beyer.	-	12.9	-	-	116.1	141.9	38.7			141.9	-	-	451.5

Cladophora frcta	-	-	-	-	-	-	-	-	-	-	12.9	-	12.9
Coelastrum astroideum	-	-	-	-	12.9	-	12.9	12.9	12.9	12.9	-	-	64.5
Crucigenia tetrapedia (Kirch.)West & West.	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
monoraphidium convolutum	-		-	-	51.6	-	-	-	-	-	-	-	51.6
Monoraphidium sp.	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Oosystis sp.	-	12.9	-	-		-	12.9	-	-	12.9	-	-	38.7
Pediastrum duplex var. calthrctum	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Pediastrum simplex	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Scenedesmus acuminatus (Lag.) Chod.	-	-	-	-	12.9	12.9	-	-	-	12.9	-	-	38.7
Scenedesmus acuminatus var. tetradesmoides	-	-	-	-	12.9		-	-	-	-	-	-	12.9
Scenedesmus biguga (Turp.) Lag.	-	-	-	-	-	12.9	12.9	-	-	-	-	-	25.8
Scenedesmus dimorphus	-	-	-	-	-	-	-	25.8	-	-	-	-	25.8
Scenedesmus opoliensis	-	-	-	-	-	-	-	12.9	-	-	-	-	12.9
Scenedesmus quadricauda (Turp.) Breb.	-	-	-	-	12.9		12.9	12.9	-	12.9	-	-	51.6
Tetraedron minimum (A.Br.) Hansg.	-	-	-	-	-	12.9	-	-	-	-	-	-	12.9
	Total count of Chlorophyceae phytoplankton = **1070.7**												
DINOPHYCEAE													
Ceratium hirundinella	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Peridinium cinctum (O.F.Müller)	-	-	-	-	12.9	-	-	12.9	38.7	-	-	-	64.5
	Total count of Dinophyceae phytoplankton = **77.4**												
EUGLENOPHYCEAE													
Euglena sp.	-	-	-	-	12.5	-	-	-	-	-	-	-	12.5
	Total count of Euglenophyceae phytoplankton = **12.5**												
Total count of all Species for each month	**103.2**	**103.2**	**25.8**	**25.8**	**283.4**	**219.3**	**103.2**	**206.4**	**141.9**	**348.3**	**103.2**	**129**	**1792.7**
Total count of all Species for each season	**335.4**		**335**			**528.9**			**593.4**			←	**1792.7**

Number of identified phytoplankton in station 3, and their Species and Total count of each Class (ind ×103 L-1)

TAXA	Winter		Spring			Summer			Autumn			Winter	
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**∑ Sum**
CYANOPHYCEAE													
Anabaena sp.	-	-	-	-	-	12.9	12.9			-	-	-	25.8
Arthrospira sp.	-	-	-	-	-	-	-	-	12.9	-	-	-	12.9
Lyngbya perelegans	-	-	-	-	-	-	-	-	12.9	12.9	12.9	-	38.7
Lyngbya sp.		12.9					-	-	-		-	-	12.9
Nostoc sp.	-	-	-	-	12.9	25.8	-	-	-	12.9	-	-	51.6
Oscillatoria amphibia	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Oscillatoria limnetica Lemm.	58	25.8	25.8	12.9	12.9			51.6	-	64.5	51.6	58	361.1
	Total count of Cyanophyceae phytoplankton **= 515.9**												
CHLOROPHYCEAE													
Ankistrodesmus falcatus (Corda.) Ralfs	-	-	12.9	-	-	12.9	12.9	12.9	-	12.9	12.9	-	77.4
Chlamydomonas sp.	-	-	12.9	-	-	-	-	-	-	-	-	-	12.9
Chlorella vulgaris Beyer.		12.9	-	-	-	12.9	77.4	90.3	-	-	-	-	193.5
Coelastrum astroideum	-	-	-	-	-	12.9		12.9	-	-	-	-	25.8
Coelastrum reticulatum	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Crucigenia tetrapedia (Kirch.)West & West.	-	-	-	-	12.9	12.9	-	-	-		-	-	25.8
Kirchneriella obesa	-	-	-	-		12.9	-	-	-		-	-	12.9
monoraphidium convolutum	-	-	-	-	12.9	-	-	-	-		-	-	12.9
Monoraphidium sp.	-	-	-	-	12.9	-	12.9	-	-	12.9	-	-	38.7
Oosystis sp.	-	-	-	-	-	12.9	-	-	12.9	12.9	-	-	38.7
Pediastrum simplex	-	-	12.9	-	-	-	-	-	-	-	-	-	12.9
Scenedesmus acuminatus (Lag.) Chod.	-	-	-	-	-	12.9	-	-	12.9	-	-	-	25.8
Scenedesmus biguga (Turp.) Lag.	-	-	-	-	-	-	12.9	-		-	-	-	12.9
Scenedesmus dimorphus	-	-	-	-	-	-	12.9	12.9	12.9	-	-	-	38.7
Scenedesmus quadricauda (Turp.) Breb.	-	-	-	-	12.9	-	25.8	25.8		-	-	-	64.5

	Total count of Chlorophyceae phytoplankton = **606.3**												
DINOPHYCEAE													
Peridinium cinctum (O.F.Müller)	12.9	-	12.9	-	12.9	12.9	-	12.9	-	12.9	12.9	-	90.3
Peridinium sp.									12.9				12.9
	Total count of Dinophyceae phytoplankton = **103.2**												
ZYGNEMATOPHYCEAE													
Closterium sp.	-	-	-	-	12.9	-	-	-	-	-	-	-	12.9
	Total count of Zygnematophyceae phytoplankton = **12.9**												
EUGLENOPHYCEAE													
Euglena sp.	-	-	12.5	-	12.5	-	-	-	-	-	-	-	25
Trachelomonas sp.	-	-	-	-	12.5	-	-	-	-	-	-	-	12.5
	Total count of Euglenophyceae phytoplankton = **37.5**												
Total count of all Species for each month	**70.9**	**38.7**	**89.9**	**12.9**	**115.3**	**103.2**	**154.8**	**219.3**	**51.6**	**129**	**77.4**	**58**	**1121**
Total count of all Species for each season	**167.6**		**218.1**			**477.3**			**258**			←	**1121**

Number of identified phytoplankton in station 4, and their Species and Total count of each Class (ind ×103 L-1)

TAXA	**Winter**		**Spring**			**Summer**			**Autumn**			**Winter**	
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**∑ Sum**
CYANOPHYCEAE													
Anabaena sp.	-	-	-	-	-	12.9	-	-	-	-	12.9	-	25.8
Arthrospira sp.	-	-	-	-	-	-	-	-	12.9	-	-	-	12.9
blue green filament	-	-	-	-	-		-	-	-	-	-	12.9	12.9
Lyngbya aus	-	-	-	-	-		-	-	-	12.9	-	-	12.9
Lyngbya sp.	-	-	-	-	-		-	-	-	-	12.9	12.9	25.8
Merismopedia tenuissima	-	-	-	-	-	-	-	-	12.9	-	-	-	12.9
Oscillatoria curviceps	12.9	-	-	-	-	-		12.9		-	-	-	25.8
Oscillatoria limnetica Lemm.	-	51.6	12.9	12.9	25.8	-	12.9	77.4	25.8	159.5	25.8	12.9	417.5
Oscillatoria sp.	-	-	-	-	-	-	-	12.9	-	-	-	-	12.9
	Total count of Cyanophyceae phytoplankton = **559.4**												
CHLOROPHYCEAE													

Actinastrum hantzschii	-	-	-	-	-	12.9	-	-	-	-	-	-	12.9
Ankistrodesmus falcatus (Corda.) Ralfs			12.9		12.9	12.9	25.8	12.9	12.9	12.9	12.9		116.1
Botryococcus braunii Kutz.	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Chlorella vulgaris Beyer.	-	-	-	-	-	64.5	180.6	103.2	193.5	12.9	-	-	554.7
Coalastrum astroideum	-	-	-	-	12.9	12.9	12.9	-		12.9	-	-	51.6
Coelastrum reticulatum	-	-	-	-	12.9		-	-	12.9	-	-	-	25.8
Cosmarium sp.	-	-	-	-	-	12.9	-	-	-	-	-	-	12.9
Crucigenia tetrapedia (Kirch.)West & West.	-	-	-	-	-	-	-	-	-	12.9	-	-	12.9
Glenodinium borgi	-	-	-	-	-	-	12.9	-	-	-	-	-	12.9
monoraphidium convolutum	-	-	-	-	-	-	-	-	-	38.7	-	-	38.7
Monoraphidium sp.	-	-	-	-	12.9	-	-		12.9		-	-	25.8
Oosystis sp.	-	-	-	-		-	-	12.9	-	12.9	-	-	25.8
Pediastrum duplex	-	-	-	-	-	-	-	-	12.9	-	-	-	12.9
Pediastrum simplex	-	-	-	-	-	-	-	-	12.9	-	-	-	12.9
Scenedesmus quadricauda (Turp.) Breb.	-	-	-	-	-	12.9	12.9	-	12.9	12.9	-	-	51.6
	Total count of Chlorophyceae phytoplankton = **980.4**												
EUGLENOPHYCEAE													
Euglena sp.	-	-	-	-	12.5	-	-	-	-	-	-	-	12.5
	Total count of Euglenophyceae phytoplankton = **12.5**												
DINOPHYCEAE													
Peridinium cinctum (O.F.Müller)	-	-	-	12.9	12.9	12.9	12.9	12.9	25.8	-	12.9	-	103.2
	Total count of Dinophyceae phytoplankton = **103.2**												
Total count of all Species for each month	**12.9**	**51.6**	**25.8**	**25.8**	**102.8**	**141.9**	**270.9**	**245.1**	**322.5**	**288.5**	**51.6**	**12.9**	**1552.3**
Total count of all Species for each season	**77.4**		**154.4**			**657.9**			**662.6**			←	**1552.3**

Green algae are the most diverse group of algae, with about 17000 known species (Graham & Wilcox, 2000), followed by Cyanophyceae (Blue-green algae), which are widely occurring throughout freshwater environments, then Dinophyceae, Euglenophyceae, Zygnematophyceae, and finally Chrysophyceae, which were dominant in all stations during the study period (Shuaibm et al., 2017; Srivastava et al. 2018; Kumari et al., 2018). There were the highest and lowest total counts among phytoplankton groups in summer and winter, respectively (Figure 3, Table 2), which were similar to the results of many studies in Iraq and elsewhere on fresh water or salt water, such as(Radhi & Abbas 2009) about zooplankton density in the Euphrates River in Iraq,(Heydari et al., 2018 ; Gulecal & Temel, 2014). There are many reasons for this, but temperature appears to be an important seasonal factor that in studying stations

Station 2 (1999.1 ind ×103 L-1) had the highest total annual density of phytoplankton during the study period, followed by Station 4 (1655.5 ind ×103 L-1), and Station 1 (1560.6 ind ×103 L-1). Station 3 had the lowest overall density, which was 1275.8 ind ×103 L-1, as indicated in table (3) and Figure (4).

Figure 3: Total count of non-diatom algal Classes in four seasons

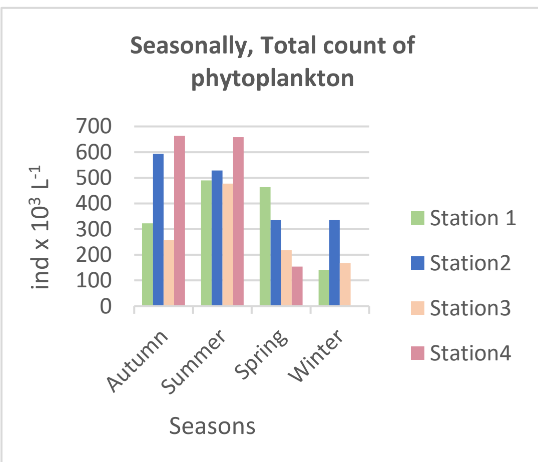
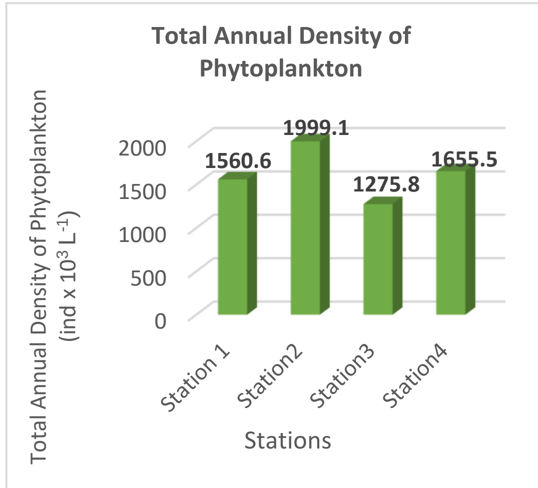


Figure 4: Total annual density of non-diatom algal Classes



According to some experts, temperature has a significant role in variations in phytoplankton population and composition caused by seasonal and temperature changes (Heydari et al., 2018). The high nitrogen and phosphorus concentration, which raises nutrient concentration in the spring and autumn and makes it environmentally predictable, is the cause of the high phytoplankton density (Kozak ,2005). The dominance of these seasons may be due to factors such as salt, pH, increased turbidity, low transparency, strong currents, and clear sunshine in addition to the mild temperature (Adesakin et al., 2019). According to (Giripunje et al., 2013), heterotrophic microbe activities and herbivore activity both had an impact on phytoplankton growth.

Table 3: List of phytoplankton identified in the studying stations. (A) = Annual Density (ind ×103 L-1), (B) = Density percentage (%), (C) = Number of frequency, - = absence.

Stations / Taxa	Station one A	Station one B	Station one C	Station two A	Station two B	Station two C	Station three A	Station three B	Station three C	Station four A	Station four B	Station four C
CYANOPHYCEAE (Total)	**412.9**	**26.458**		**838.5**	**41.944**		**515.9**	**40.437**		**559.4**	**33.790**	
Anabaena sp.	12.9	0.827	3	38.7	1.936	31	25.8	2.022	2	25.8	1.558	2
Arthrospira sp.	12.9	0.827	1	12.9	0.645	1	12.9	1.011	1	12.9	0.779	1
blue green filament	-	-	-	12.9	0.645	1	-	-	-	12.9	0.779	1
Chroococcus turgidus	-	-	-	12.9	0.645	1	-	-	-	-	-	-
Lyngbya aus	-	-	-	-	-	-	-	-	-	12.9	0.779	1
Lyngbya perelegans	12.9	0.827	1	64.5	3.226	1	38.7	3.033	3	-	-	-
Lyngbya sp.	25.8	1.653	1	12.9	0.645	1	12.9	1.011	1	25.8	1.558	2
Merismopedia gluca (Ehr.) Naeg.	12.9	0.827	1	12.9	0.645	1	-	-	-	-	-	-
Merismopedia tenuissima	-	-	-	-	-	-	-	-	-	12.9	0.779	1
Nostoc sp.	38.7	2.480	3	25.8	1.291	2	51.6	4.045	3	-	-	-
Oscillatoria amphibia	12.9	0.827	1	12.9	0.645	1	12.9	1.011	1	-	-	-
Oscillatoria areli	12.9	0.827	1	-	-	-	-	-	-	-	-	-
Oscillatoria curviceps	-	-	-	-	-	-	-	-	-	25.8	1.558	2
Oscillatoria limnetica Lemm.	245.2	15.712	11	619.2	30.974	11	361.1	28.304	9	417.5	25.219	10
Oscillatoria minima	12.9	0.827	1	-	-	-	-	-	-	-	-	-
Oscillatoria sp.	-	-	-	-	-	-	-	-	-	12.9	0.779	1
Spirulia major Kutz.	12.9	0.827	1	-	-	-	-	-	-	-	-	-
Spirulina sp.	-	-	-	12.9	0.645	1	-	-	-	-	-	-
CHLOROPHYCEAE (Total)	**993.3**	**63.649**		**1070.7**	**53.559**		**606.3**	**47.523**		**980.4**	**59.221**	
Actinastrum hantzschii	38.7	2.480	3	38.7	1.936	3	-	-		12.9	0.779	1
Ankistrodesmus falcatus (Corda.) Ralfs	90.3	5.786	6	167.7	8.389	6	77.4	6.067	6	116.1	7.013	8
Botryococcus braunii Kutz.	12.9	0.827	1	12.9	0.645	1	-	-	-	12.9	0.779	1
Chlamydomonas sp.	-	-	-	-	-	-	12.9	1.011	1	-	-	-
Chlorella vulgaris Beyer.	296.7	19.012	6	451.5	22.585	5	193.5	15.167	4	554.7	33.506	5
Cladophora frcta	-	-	-	12.9	0.645	1	-	-		-	-	-
Coalastrum astroideum	38.7	2.480	3	64.5	3.226	5	25.8	2.022	2	51.6	3.117	4
Coelastrum reticulatum	-	-	-	-	-	-	12.9	1.011	1	25.8	1.558	2
Cosmarium sp.	-	-	-	-	-	-	-	-	-	12.9	0.779	1
Crucigenia tetrapedia (Kirch.)West & West.	25.8	1.653	2	12.9	0.645	1	25.8	2.022	2	12.9	0.779	1
Glenodinium borgi	-	-	-	-	-	-	-	-	-	12.9	0.779	1
Kirchneriella obesa	129	8.266	2	-	-	-	12.9	1.011	1	-	-	-
monoraphidium convolutum	77.4	4.960	2	51.6	2.581	1	12.9	1.011	1	38.7	2.338	1
Monoraphidium sp.	-	-	-	12.9	0.645	1	38.7	3.033	3	25.8	1.558	2
Oosystis sp.	-	-	-	38.7	1.936	3	38.7	3.033	3	25.8	1.558	2
Pediastrum duplex	-	-	-	-	-	-	-	-	-	12.9	0.779	1
Pediastrum duplex var. calthrctum	-	-	-	12.9	0.645	1	-	-	-	-	-	-
pediastrum simplex	25.8	1.653	2	12.9	0.645	1	12.9	1.011	1	12.9	0.779	1
Scenedesmus acuminatus (Lag.) Chod.	25.8	1.653	2	38.7	1.936	3	25.8	2.022	2	-	-	-
Scenedesmus acuminatus var. tetradesmoides	25.8	1.653	2	12.9	0.645	1	-	-	-	-	-	-
Scenedesmus biguga (Turp.) Lag.	12.9	0.827	1	25.8	1.291	2	12.9	1.011	1	-	-	-
Scenedesmus dimorphus	51.6	3.306	3	25.8	1.291	2	38.7	3.033	3	-	-	-
scenedesmus opoliensis	25.8	1.653	2	12.9	0.645	1	-	-	-	-	-	-
Scenedesmus quadricauda (Turp.) Breb.	90.3	5.786	6	51.6	2.581	4	64.5	5.056	3	51.6	3.117	4
Tetraedron minimum (A.Br.) Hansg	12.9	0.827	1	12.9	0.645	1	-	-	-	-	-	-
Tetraedron regulare	12.9	0.827	1	-	-	-	-	-	-	-	-	-

CHRYSOPHYCEAE (Total)	**12.9**	**0.827**										
Dinobryon divergens	12.9	0.827	1	-	-	-	-	-	-	-	-	-
DINOPHYCEAE (Total)	**129**	**8.266**		**64.5**	**3.872**		**103.2**	**8.089**		**103.2**	**6.234**	
Ceratium hirundinella	-	-	-	12.9	0.645	1	-	-	-	-	-	-
Peridinium cinctum (O.F.Müller)	116.1	7.439	9	64.5	3.226	3	90.3	7.078	7	103.2	6.234	7
Peridinium sp.	12.9	0.827	1	-	-	-	12.9	1.011	1	-	-	-
EUGLENOPHYCEAE (Total)	**12.5**	**0.801**		**12.5**	**0.625**		**37.5**	**2.939**		**12.5**	**0.755**	
Euglena sp.	12.5	0.801	1	12.5	0.625	1	25	1.960	2	12.5	0.755	1
Trachelomonas sp.	-	-	-	-	-	-	12.5	0.980	1	-	-	-
ZYGNEMATOPHYCEAE (Total)							**12.9**	**1.011**				
Closterium sp.	-	-	-	-	-	-	12.9	1.011	1	-	-	-
Total Annual Density (ind ×10^3 L^{-1})	**1560.6**			**1999.1**			**1275.8**			**1655.5**		

Phytoplankton diversity

The phytoplankton structure of the research area inside the Tigris River was assessed using a monthly analysis of phytoplankton communities (Table 2), as well as the variety and density of distinct species.

In the current study, phytoplankton diversity was explored seasonally using the Shannon-Diversity Index, with the highest diversity index in Autumn (3.748), followed by Spring (3.672), Summer (3.473), and Winter (2.426). (Figure5).

Finally, the Shannon index in the Tigris River study area is mainly categorized in the good class, according to Table (1). The phytoplankton total count and diversity were recorded as a minimum in winter, moderate in spring for diversity, moderate in summer for the total count, and maximum in autumn, as shown in figures 3 and 5. The reason may to, as explained by many different researchers, that temperature was an important factor in fluctuations in the composition of phytoplankton (Heydari et al., 2018).

Figure 5: Seasonal diversity of phytoplankton.

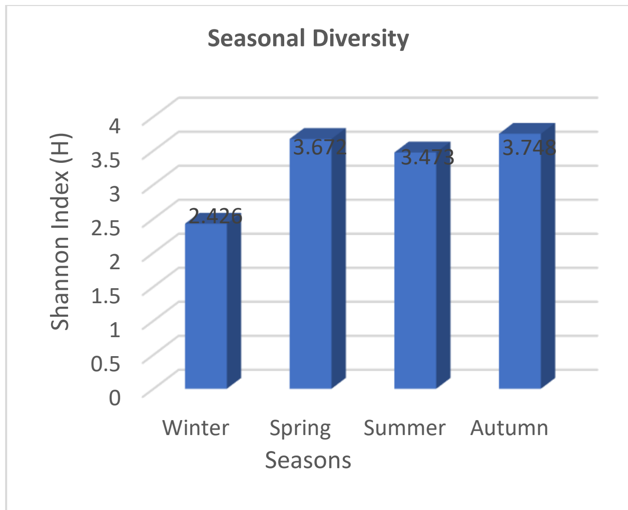
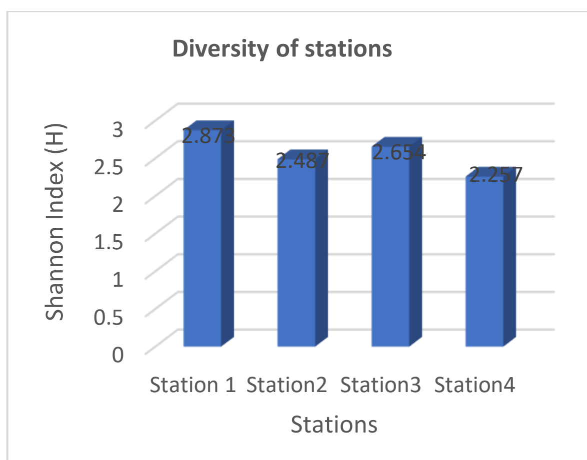


Figure 6: Diversity of phytoplankton within studying stations



In the current study, phytoplankton diversity was investigated using the Shannon-Diversity

Index, with the highest diversity index in station 1 (2.873), followed by station 3 (2.654), station 2 (2.487), and station 4 (2.257) (Figure 6). This could be because this station provides more suitable environmental habits for phytoplankton by increasing decaying organic matter and other factors such as nutrient availability (Nashaat, 2010).

Conclusion

Water ecological health can be determined by investigating phytoplankton communities. A total of 51 non-diatomic freshwater algae species which make up six classifications, Chlorophyceae has the most variety and a high overall population. The variety and abundance of phytoplankton communities essentially reflect the amount of resources available to the ecosystem. The Tigris River's non-diatomic phytoplankton diversity and abundance may be correlated with the water quality indicators, particularly the temperature factor, and nutrients depending on the total number of non-diatomic species present. The Tigris River research area's current fundamental data on the distribution of non-diatomic algae, including total count, annual density, density percentage, and Shannon index, is primarily placed in the good class. The phytoplankton total count and diversity were recorded as a minimum in winter, and maximum in autumn, diversity and dominance would form a useful tool for further ecological assessment and monitoring fresh water in general and for Tigris River in particular.

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