Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(5): 83 – 91 (2023)
www.ejabf.journals.ekb.eg

Green algal diversity in Hawija irrigation project / Hawija district, Iraq

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ARTICLEINFO
ArticleHistory:
Received:Aug. 31, 2023
Accepted: Sept. 9, 2023
Online: Sept. 14, 2023

Keywords:
Green algae,
Diversity index,
Irrigation-project,
Hawija district

ABSTRACT

In freshwater ecosystems, green algae play a key role as a microorganism's component, and the diversity of algae benefits species richness and enhances the importance of these organisms for ecosystem function. The community makeup and pollution levels in the research region can be determined using bio-diversity indices. Due to the limited information clarifying the bio-natural of the irrigation project and the extent of pollution in the study region, this study sought to give information about the planktonic green algae and evaluated them using calculated diversity indices. The study identified 54 phytoplankton green algae species collected from five sites (Mahooz village, Hawija district center, Abbasi sub-district, Zgeaton Valley, and Riyadh district), belonging to 13 families and 20 genera of Chlorophyta from October 2019 to March 2020. To measure algal diversity, four diversity indices were used: Margalef index, Shannon diversity index, Species evenness, and Simpson's diversity index. The algal community structure and pollution index at all sites were depicted using these indices. The study showed that phytoplankton communities are of higher diversity with a moderate pollution level. Phytoplankton grows and increases by responding to some environmental variables, such as nutrient availability, organic matter, and salinity caused by agricultural lands adjacent to the irrigation projects; in addition, it is impacted by the physicochemical factors of the studied region.

INTRODUCTION

Green algae can be found in a variety of habitats, but they are most commonly found in freshwater; a few varieties can also be found in brackish and salt waters, and some are even found on terrestrial ecosystems. The availability of environmental conditions and the trophic level of the ecosystem determine where they are distributed. Green algae are eukaryotic photosynthetic aquatic plants **(Graham *et al.*, 2009)**. Chlorophyta include chlorophylls a and b, which are the main pigments used in photosynthetic reaction and within plastids; they preserve food as starch **(Turmel *et al.*, 2009)**.

Chlorophyta consists of a large number of species, some of which are multicellular and others are unicellular. Some chlorophytes coexist symbiotically with other organisms, and they can be found on land and in fresh and salt water **(Röschold & Leliaert, 2007)**. Diversity indices, which can be reversed to indicate clean or polluted circumstances **(Beak, 1965)**, are essentially a method of assessing bio-quality through the composition of the community **(Washington, 1984)**. Temperature, light, nutrients and other factors have an impact on algal growth **(Xu *et al.*, 2022)**. Any variation in the species diversity and taxonomic makeup of phytoplankton is a result of altered nutrient levels **(Watson *et al.*, 2007)**; these changes are related to variations in the way nutrients are stored, absorbed, grown and lost. Algae and other microorganisms typically respond fast to minor changes in the physical circumstances of their habitat, making them opportunistic species **(Nwankwo, 1988)**. Ecologists and those who monitor natural resources have long been interested in bio-diversity, which is measured by a variety of creatures **(Whittaker, 1972; Peet, 1974)**. A multifold boost in productivity may also be achieved by using algae to improve fertilizer absorption and effectiveness **(Mahapatra *et al*., 2022)**.

Freshwater biodiversity is most likely impacted by eutrophication and harmful algal blooms (HABs), where algal growth exceeds water quality standards and may be toxic to humans and animals. Agricultural land use, environmental changes and climate change continue to pose threats to biodiversity conservation **(Danaher *et al.*, 2022)**. In Iraq, a number of studies have been conducted to addresss the algal diversity in freshwaters **(Al Hassany *et al.*, 2012; Hassan & Shaawiat , 2015; Darweesh , 2017; Ali *et al.*, 2018; Albueajee *et al.*, 2020; Ali *et al.*, 2020; Ahmad , 2021; Hussien & Alkam , 2021)**. The aim of the present study was to evaluate the green algal community structure at all study sites by calculating diversity indices, and using algal biodiversity to detect the algal community structure and pollution level at the Hawija district in Kirkuk province, Iraq.

MATERAIL AND METHODS

Study area

The Hawija irrigation project is situated in the Hawija district/ Kirkuk province, which is 70km southwest of Kirkuk City on the left side of the Lower Zab River. On the western side, it is surrounded by the Abbasi district; while from the eastern side, it is boardered with the Riyadh district. The Hawija irrigation water is one of the major sources of surface water in the Hawija district **(Basem & Ahmad, 2009)**. Five sites were selected as study areas, and water samples were taken for green algal community analysis (Table.1 & Fig. 1).

The Hawija irrigation project is in the Kirkuk province's Hawija district, 70 kilometers southwest of Kirkuk City, on the left bank of the Lower Zab River. Riyadh district borders the project's eastern side, and Abbasi district borders the western side. One of the main sources of surface water in the Hawija district is the irrigation water; this has a 20m^3/ sec water flow rate **(Basem & Ahmad, 2009)**. For the investigation of the green algal community, water samples were collected from five study sites (Table.1 & Fig. 1).

Table 1. The coordinates for the study sites

Site	Longitude	Latitude
St.1: Near Mahooz village	E43°48'06.64"	N35°27'46.75"
St.2: Hawija district center before the river branches distributed into three branches	E43°46'24.40"	N35°19'18.42"
St.3: Abbasi sub-district	E43°45'33.11"	N35°17'52.44"
St.4: It extends from the center of Hawija district and ends at the basin of Zgeaton Valley	E43°47'12.91"	N35°17'56.72"
St.5: It extends from the Hawija district center towards the Riyadh district	E43°47'44.58"	N35°18'22.57"

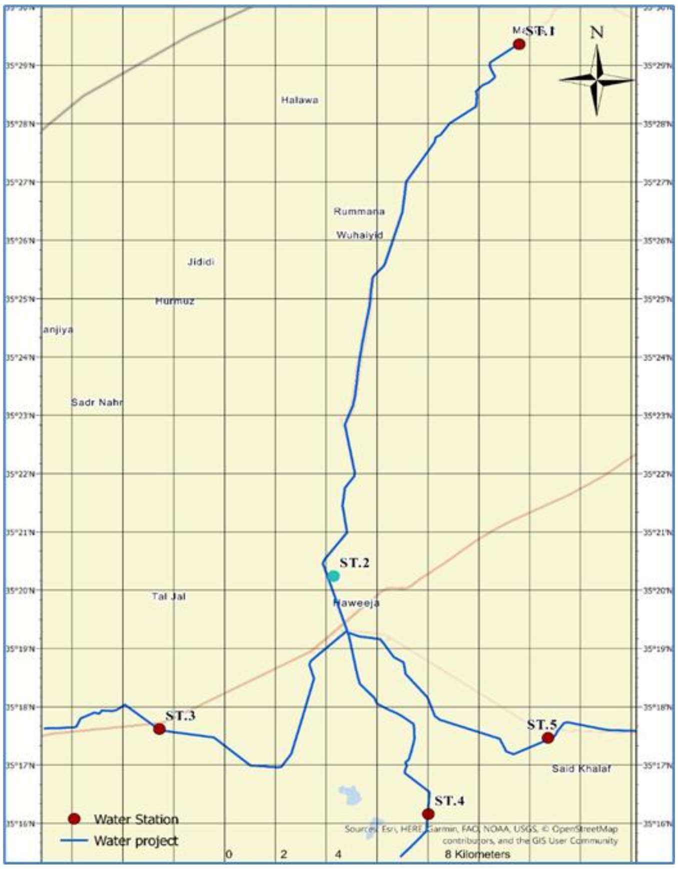

Fig. 1. Sudy sites in the Hawija district

Phytoplankton collection

Samples of phytoplankton were gathered in polypropylene containers, and a few drops of Lugol solution were added. **Furet and Benson- Evans (1982)** described how the phytoplankton count was determined using the sedimentation method. The temporary preparations were used to identify algae, which were examined under an Olympus microscope. According to **Prescott (1972)**, **Wehr and Sheath (2003)**, **Bellinger and Sigee (2010)**, and algae base of **Guiry and Guiry (2020)**, the following equation was used for algae identification.

$D = (S-1)/In(N)$

Where,

S : The species number, and

n : Total number of individuals in the samples.

Shannon's diversity index (1948), which was calculated using the following equation, is marked to the total number of species in the community as follows:

$H = -SUM[(pi) * ln(pi)]$

Where,

H: Shannon index

SUM: Summation

pi: Number of individuals of species

i: Total number of samples.

Evenness index: The relative abundances of species within a community are calculated using the following formula:

$E=H/Hmax$

Where:

E: Evenness.

S: Number of species or species richness, and

Hmax: ln(N) Maximum diversity possible.

The Simpson's diversity index (1949) using to determine which species dominates the sample in the following locations:

$Ds =S(ni\ (ni-1/N\ (n-1)$

Where,

Ds: Bias corrected from Simpson index;

n1: The number of individuals of species, and

N: Total number of species within a community.

The index value decreases as diversity rises.

RESULTS AND DISCUSSION

54 species of green-algae belonging to the 7 orders predominating in the study region were collected. These orders include Chlorellales, Sphaeropleales, Chlamydomonales, Ulotrichales, Cladophorales, Zygmenatales and Desmidiales; they were identified resulting from the diversity of green algae (Table 2 & Fig. 2).

Site 4 had the highest total algae cells count, while Site 5 recorded the lowest values. This variation in the number of genera and species in the water may be attributed to the presence of some pollutants in general at Site 4. As an agricultural area, the study area has easy access to all nutrients and organic materials, and it also receives water from adjacent locations **(Al-Tamimi, 2006; Ahmed, 2021)**. The rate of the river current, the region's geology, sediment bed, human activity, or climatic changes like rains or heavy rains, especially at site 4, have an important effect on phytoplankton community **(Saleh, 2020)**.

Table 2. Green-algae diversity in the Tigris River of Hawija district (orgs. mL^{1-})

No.	Green algal taxa	Number of algae				
		St1	St2	St3	St4	St5
	Phylum: Chlorophyta Class: Trebouxiophyceae Order: Chlorellales Family: Chlorellaceae					
1	*Chlorella vulgaris* Beyerinck	0	3	1	0	0
2	*Actinastrum hantzschii* Lagerheim 1882	4	3	2	3	2
	Family : Oocystaceae					
3	*Oocystis lacustris* Chodat 1897	1	2	3	2	0
4	*Oocystis borgei* Snow 1903	0	0	0	1	0
	Class: Chlorophyceae Order : Sphaeropleales Family: Hydrodictyaceae					
5	*Tetraëdron minimum* (A.Braun) Hansgirg 1889	0	0	0	0	1
6	*Pediastrum duplex* Meyen 1929	0	0	0	2	1
7	*P. boryanum* (Turpin) Meneghini 1840	0	1	1	0	0
8	*P. simplex* Meyen 1829	2	1	0	3	0
9	*P. simplex* var. *duodenarium* (Bailey) Rabenhorst	1	0	0	0	0

No.	Green algal taxa	Number of algae				
		St1	St2	St3	St4	St5
	1868					
10	*P. subgranulatum* (Raciborski) 2001	0	0	1	0	0
11	*Ps.pediastrum boryanum* (Turpin) Hegewald 2005	0	0	1	0	0
12	*Ps.pediastrum boryanum var. longicorne* (Reinsch) Hansgirg 1867	0	2	0	1	1
	Family : Scenedesmaceae					
13	*Scenedesmus acutiformis* Schröder 1897	1	2	1	4	0
14	*S. acutus* Meyen 1829	1	1	1	0	0
15	*S. bijugatus* Kützing 1834	1	0	1	0	0
16	*S. dimorphus* (Turpin) Kützing 1834	4	2	4	2	4
17	*S. ecornis* (Ehrenberg) Chodat 1926	1	1	0	1	0
18	*S. quadricauda* (Turpin) Brébisson 1835	3	2	2	4	2
19	*S. bernardii* Smith 1916	0	0	2	1	0
20	*S. verrucosus* Roll 1925	1	0	0	1	0
21	*S. quadricauda var. bicaudatus* Hansgirg 1890	1	0	0	0	0
22	*Desmodesmus abundans* (Kirchner)Hegewald 2000	0	0	0	1	0
23	*D. communis* Hegewald 2000	1	1	3	4	3
24	*D. armatus* (Chodat).Hegewald 2000	3	0	2	0	0
25	*Coelastrum astroideum* De Notaris 1867	2	3	2	3	4
26	*C. microporum* Nägeli 1855	0	0	1	0	0
27	*Acutodesmusacuminatus* (Lagerheim)P.M.Tsarenk o 2000	1	0	2	0	0
	Family: Selenastraceae					
28	*Monoraphidium caribeum* Hindák 1970	0	0	0	1	0
29	*M. contortum* (Thuret) Komárková-Legnerová 1969	2	3	1	0	1
30	*M. griffithii* (Berkeley) Komárková-Legnerová 1969	3	2	2	4	3
31	*M. komarkovae* Nygaard 1979	1	0	0	1	1
	Order: Chlamydomonadales Family: Goniaceae					
32	*Gonium pectorale* Müller 1773	0	1	0	0	0
	Family: Chlamydomonadaceae					
33	*Chlamydomonas reinhardtii* Dangeard 1888	2	4	2	3	2
34	*Chlamydomonas* sp.	1	2	1	2	2
	Family: Volvocaceae					
35	*Eudorina elegans* Ehrenberg 1832	0	0	0	1	0
36	*Pandorina morum* (Müller) Bory 1826	2	4	3	3	4
	Class: Ulvophyceae Order Ulotrichales Family: Ulotrichaceae					
37	*Ulothrix zonata* (F.Weber & Mohr) Kützing 1833	1	0	2	0	0
38	*Ulothrix* sp.	0	0	0	1	0
	Order : Cladophorales Family : Cladophoraceae					
39	*Cladophora glomerata* (Linnaeus) Kützing 1843	1	2	4	0	0
40	*Cladophora* sp.	1	0	0	0	0
	Phylum : Charophyta Class: Zygnematophyceae Order : Zygnematales Family: Zygnemataceae					
41	*Spirogyra* sp.	1	0	0	0	0
	Order: Desmidiales Family: Closteriaceae					
42	*Closterium tumidum* Johnson 1895	0	1	0	0	0
43	*Closterium acerosum* Ehrenberg ex Ralfs 1848	0	2	1	0	0
44	*C. acutum* Brébisson in Ralfs 1848	3	2	4	3	3

No.	Green algal taxa	Number of algae				
		St1	St2	St3	St4	St5
45	*C. acutum* var. *variabile* (Lemmermann) Willi Krieger 1935	2	2	0	2	2
46	*C. gracile* Brébisson ex Ralfs 1848	1	0	0	1	0
47	*C. kuetzingii* Brébisson 1856	1	0	2	1	0
48	*C. macilentum* Brébisson 1856	0	1	0	1	0
49	*C. setaceum* Ehrenberg ex Ralfs 1848	1	0	0	0	0
	Family: Desmidiaceae					
50	*Staurastrum anatinum* Cooke & Wills 1881	0	0	1	0	0
51	*S. bicorne* Hauptfleisch 1888	0	3	0	0	0
52	*S. johnsonii* West & West 1896	0	0	0	0	1
53	*S. paradoxum* Meyen ex Ralfs 1848	0	3	1	0	0
54	*S. manfeldtii* Delponte 1878	1	1	1	1	0
	Total number of Species	31	27	30	29	17
	Total individuals of phytoplankton /l	52	57	55	58	37

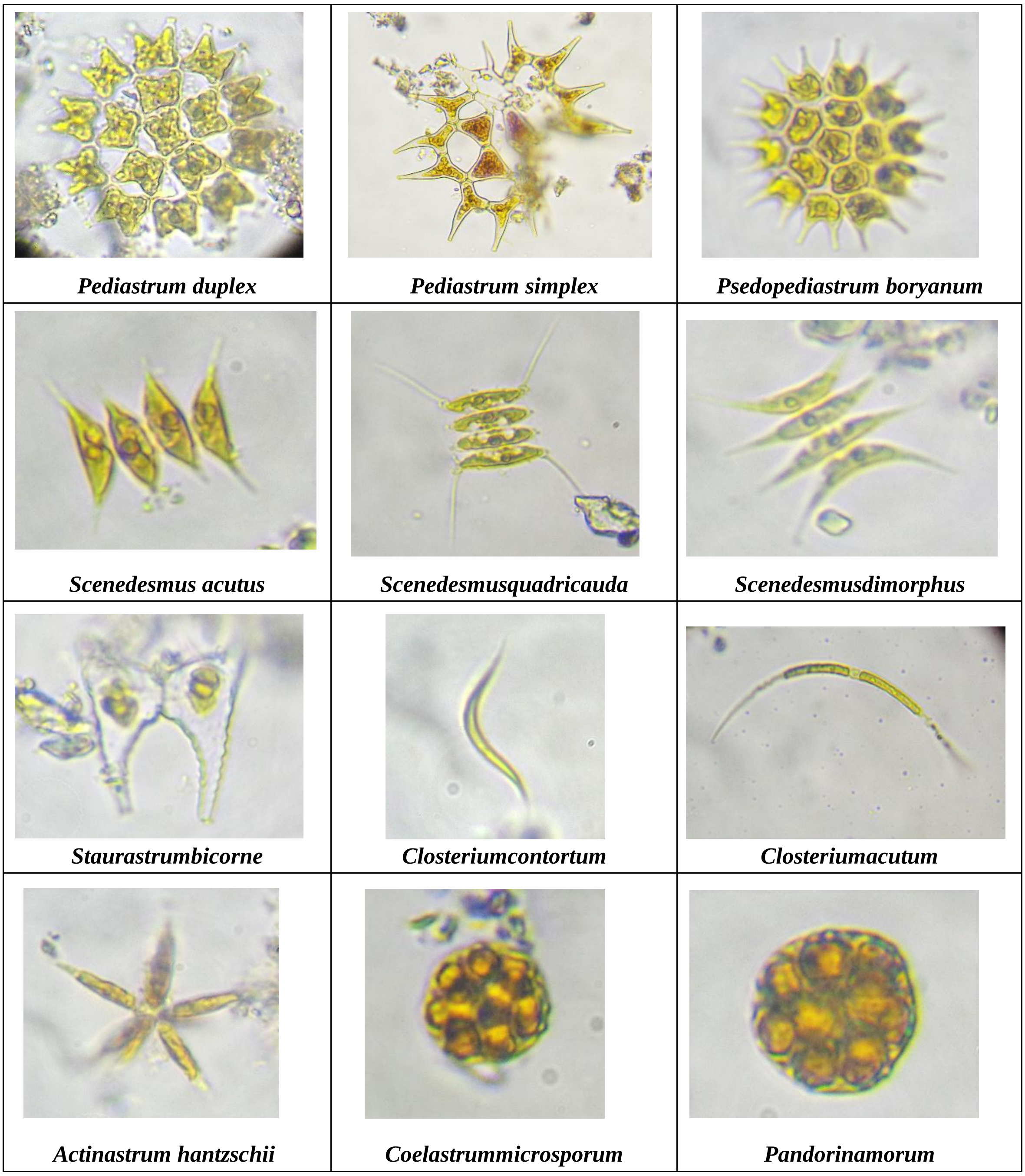

Fig. 2. Photomicrographs of some green algae species recorded at the study sites

The diversity of green algal phytoplankton in the study area was measured using a few biodiversity indices, each of which was tied to a particular data application; the estimated diversity indices are shown in Table (3) and Fig. (3).

Species richness is indicated by **Margalef's indexes (1968)**. The results recorded lower and higher values of 4.431 and 7.5925 at sites 5 and 1, respectively.

Table 3. Diversity indices used for the present study

No	Site	St1	St2	St3	St4	St5
1	Margalef index	7.5925	6.4308	7.2367	6.8958	4.431
2	Shannon -Wiener diversity index	3.46	3.43	3.44	3.33	2.73
3	Evenness index	1	1.03	1.01	0.99	0.96
4	Simpson's diversity index	0.9774	0.9743	0.976	0.9716	0.952
	Total species	31	27	30	29	17
	Total individuals of algae	52	57	55	58	37

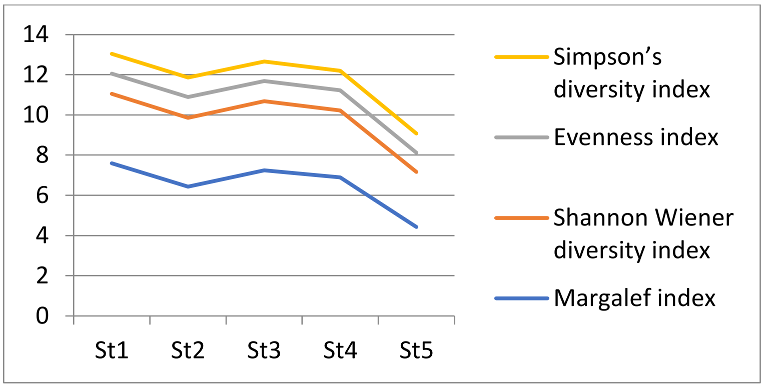

Fig. 3. Green algae diversity indicators in irrigation water from Hawija

The theoretically taxa ranging from 0 to 4 are clarified by the Shannon diversity index or **Shannon-Weiner index (1963)**, which also establishes the level of water contamination. The index takes into account the richness (number of species present) and evenness (diversity) of those species. When examining biodiversity in a variety of polluted and unpolluted areas, values greater than 3 relate to clean water, while values between 1 and 3 are indicative of moderate pollution, and values less than 1 are indicative of seriously polluted ecosystems. The Shannon's diversity index for sites 1, 2, 3, and 4 ranged from 3.33 to 3.46, which is higher than 3 and indicates clean water or low pollution levels, while site 5 exhibits moderate pollution **(Wilhm & Donis, 1968)**. The evenness index value ranges from 0 to 1, with 1 denoting perfect evenness. At sites 5 and 2, the species evenness varied from 0.96 to 1.03, respectively. In monitoring pollution that analyzes the function of phytoplankton species and their aggregation as biological indicators, the Shannon-Wiener index is frequently used. Simple assessments of species richness and dominance are always valuable, and conservation plans can be strengthened by taking into consideration data on patterns of species evenness. **(Stoermer, 1984)**.

The Simpson's Index (1949) measures the bio-diversity of a habitat and considers both the number of species present and the evenness of those species. The results were close to evenness and varied between 0.952 & 0.9774 for sites 5 and 1, respectively. This score rises as richness increases. The river where there is a great diversity of species of algae in general as well as species diversity within the genera is where the measure of biodiversity is most relevant. A reliable index for the bio-monitoring of pollution load is the variety and phytoplankton composition in aquatic ecology **(Venkateshwarlu, 1981)**. Certain phytoplankton species can cause eutrophication, which increases water density and deoxygenation, causing an adverse effect on aquatic life **(Whitton & Patts, 2000)**.

These findings showed that the majority of the studied regions are rich in Scenedesmaceae, which indicates organic contamination; nevertheless, in other locations, Chlamydomonadales and Desmidiales were more prevalent. The distribution of algal phytoplanktonic in rivers and the level of pollution are best understood with an indication of biodiversity.

CONCLUSION

The Shannon diversity index, which is larger than 3 suggested that the algal phytoplankton richness was moderately diverse. The Simpson index rises as richness, or the variety of species present and evenness in the algal community, increases. Freshwater rivers' phytoplankton diversity gives us clues about the condition of the water as a result of environmental parameters or the presence of fertilizers, chemical pesticides that may contain heavy metals and organic materials. All these would contribute to the growth, expansion and diversification of algae depending on the location and the elements and pollutants they contain. It performs a crucial function as a water change monitor. The diversity of algal species and the evaluation of pollution in aquatic ecosystem are both significant tasks for biodiversity indices.Therefore, the application of diversity indices improves the output information of the dataset, which is distinct for each community or sample investigated. H index is strongly influenced by species richness and by rare species, so it is very sensitive to even small diversity changes, and thus is widely used to assess the actual state of environment. While, the D index gives more weight to evenness and dominant species, and is not affected by less abundant elements; therefore, it is utilized to display the direction that ecological diversity is headed in.

Acknowledgments

The authors thank the College of Science and Tikrit University for their support of this work and for providing a variety of resources for the study, which was conducted there.

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