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Seasonal Distribution and Diversity of Epipelic Diatoms in the Lower Zab River

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ABSTRACT

The present study aimed to apply diversity indices to determine the seasonal distribution of epipelic diatom communities in the lower Zab River in Kirkuk Province. Four sites were chosen and subjected to study (Sadr River Bridge, Ashraya Village, Al-Shamit Village, Al-Shak Village), and the sampling was conducted from September 2023 to April 2024. Diatoms dominated the epipelon community; the seasonal distributions of epipelic diatoms were shown in the total numbers at the study sites. The results recorded the lowest rate for both central and pinnate diatoms at site 2 in the spring ($218 \times 10^4/cm^3$) and the highest rate ($512 \times 10^4 /cm^3$) at site 1 in autumn. The dominancy of some epipelic diatomic species was recorded during the study period; these genera were *Nitzschia*, *Navicula*, *Synedra*, *Cymbella*, *Gomphonema*, *Cocconies*, *Gyrosigma*, *Cyclotella*, and *Fragiaria.* The diversity indices such as the richness index, Shannon diversity index, species evenness, and Simpson's diversity index were applied to illustrate the distribution of epipelic diatom community at the study sites. The data obtained would fill the gap in literature, providing adequate information on the topic addressed.

INTRODUCTION

Water quality and the aquatic environment are impacted by pollution from domestic, industrial, and agricultural activities, rendering the water unfit for human use as well as other uses. Pollution also plays a major role in its impact on biodiversity and the alteration of species composition (adaptation of living organisms). The composition of aquatic species may reflect the level and water pollution especially algal blooms **(Rasheed *etal*.,2024)**.

Benthic algae have a vital role in the aquatic ecosystem since they contribute to oxygen production during photosynthesis, nutrient production, and element recycling.They are an important group in aquatic ecosystems, as they constitute a large portion of benthic organisms, approximately 95-90%. Its ability to be present in all kinds of surface waters is its most significant characteristic, which has made it a crucial component in the monitoring of water quality **(Ácset *al*, 2004)**.The most significant factors impacting an epipelic diatom in the aquatic environment are the intensity and duration of lighting, nutrients, temperature, flow rate, grazing, nature of sediments and other environmental factors **(Lili &Lusan, 2010)**. Benthic algae are also used to monitor long-term changes in aquatic ecosystems caused by pollution, and epipelic diatoms are used as indicators of pollutants and their source in the aquatic environment **(Round, 1991)**.

In Iraq, many researches have conducted studies on the diversity of epipelicalgae **(Darweesh,2017; Ali *et al.*, 2018; Hassan*et al.*, 2020; Ahmad,2021;Al-Hasso & Al-Tamimi, 2022**).The study aimed to determine the distribution and quality of benthic diatom communities along the Lower Zab River in the study region and the effect of the seasonal variation on their presence.

MATERIALS AND METHODS

Description of study area

The Lower Zab is the principal river that flows into the Erbil Governorate in northern Iraq, and one of the five tributaries of the Tigris River. The river and its tributaries are located between longitudes 43.39° - 46.26° and latitudes 35.16° - 36.79°. The river originates in northwest Iran, and it flows 402km into Iraq, and its width is 200m **(Al-Lami *et al.*, 2001)**. Four sites were chosen as study regions, and epipelic diatom samples were taken for the study diatoms community analysis (Table1 & Fig. 1).

Table 1. Coordinates for the four study sites

No.	Name of sites	Symbol	Coordination
1	**Sadr River Bridge**	St.1	43° 42′ 41.82″ E 35° 25′ 19.48″ N
2	**Ashraya village**	St.2	43° 37′ 57.69″ E 35° 22′ 06.65″ N
3	**Al-Shamit village**	St.3	43° 31′ 29.42″ E 35° 16′ 33.24″ N

Fig.1. Photographs of the sites in the lower Zab River

Sample collection

Seasonal samples of epipelic algae were collected from autumn 2023 to spring 2024 following the method described by **Eaton and Moss (1966)** for isolation of the epipelic diatoms by using a spatula to scrape off the clay (3-5cm) from the clay's surface in random patterns. The clay was then preserved in polyethylene containers with a little amount of sample water, and before being brought back to the lab, it was shaken and stored in the dark. Diatom species were identified and classified following the method of **Rai *et al*. (2022)**, **Saini *et al*. (2022)** and **Guiry and Guiry(2023)**.

Bio-diversity index

A diversity index is a mathematical measure of species diversity in a community. The calculation of biodiversity indices values is shown in Table (2).

Table 2. Biodiversity indices used in the current study

Index	Formula	Reference
Richness Index (RI)	D = (S-1)/In(N)	Margalef (1969)
Shannon and Weaver Index (H')	$H' = -\sum [(pi) * \ln(pi)]$	Shannon and Weaver (1949)
Evenness index (EI)	E=H´/Hmax	Neves *et al.*(2003)
Simpson's diversity index	$SI = \frac{1}{\sum (Pi)^2}$	Simpson (1949)

RESULTS AND DISCUSSION

The results of epipelic diatoms recorded in the lower Zab River at the study sites was 66 species belonging to 21 genera. The central diatoms species recorded was 6 species belonging to 3 genera, while pinnate diatoms species were 60 species belonging to 18 genera.The total number of centralsdiatoms ranged between 7× 10^4 cell/cm^2- 49× 10^4 cell/cm^2 at site2 and site1 in autumn and spring, respectively, and the total number of the pennate diatoms ranged between 211 ×10^4 cell/cm^2- 463×10^4 cell/cm^2 at site2 and site1 in autumn and spring, respectively (Table3).

Some species recorded the highest number of species and presence at the four sites, such as *A. granulate, C. meneghiniana, F. ulna, S. acus, C. placentula, C. pediculus, Cy. cistula, Cy. aspera, D. vulgare, N.cryptocephala, N.cryptotenella*, *N. rostellata, N.radiosa, Gyr. acuminatum, Gyr. attenuatum Nitz. palea, Nitz. sigma, Nitz. filiformis, Nitz. acicularis, Nitz. gracilis, Suri. robusta , Suri. Ovalis* and *C. sola*, as a result of these species' susceptibility to a wide tolerance of environmental conditions (Table 3).

Table 3. Number of epipelic diatoms (cell*10^4/cm2) according to the sites and seasons studied

Site	S1			S2			S3			S4		
Season / *Algae*	Autum 2023	Winter 2024	Spring 2024	Autum 2023	Winter 2024	Spring 2024	Autum 2023	Winter 2024	Spring 2024	Autum 2023	Winter 2024	Spring 2024
Division: Bacillariophycophyta Class: Bacillariophycophyceae												
Order: Centrales Family: Aulacoseiraceae												
Aulacoseira granulata (Ehrenberg) Simonsen	24	20	12	10	5	2	2	10	12	0	0	0
A. granulata var. *angustissima* (O.Müller) Simonsen	2	4	2	1	2	2	1	2	2	1	1	1
A. ambigua (Grunow) Simonsen	0	0	0	20	11	0	10	5	0	5	8	0
Family: **Stephanodiscaceae**												
Cyclotella meneghiniana Kützing (*Stephanocyclus meneghinianus* (Kützing) Kulikovskiy)*	15	9	8	10	5	2	12	5	2	1	5	8
C. ocellata Pantocsek (*Pantocsekiella ocellata* (Pantocsek) K.T.Kiss and Ács.)*	8	5	2	2	1	1	5	1	5	2	2	1
Family: Coscinodiscaceae												
Coscinodiscus sp.	0	0	0	1	0	0	0	0	0	0	0	0
Total number of Centrales diatoms *(cell*10^{-4}/cm^2)*	**49**	**39**	**24**	**44**	**24**	**7**	**30**	**23**	**21**	**9**	**16**	**11**
Order: Pennales												

Family: Fragilariaceae												
Fragilaria biceps Ehrenberg	1	1	2	3	1	1	2	2	1	0	0	0
F. ulna (Nitzsch) Lange0Bertalot *(Ulnaria ulna* (Nitzsch) Compère)*	20	9	10	18	7	0	18	10	0	9	5	0
F. capucina Desmazières	5	1	0	0	0	0	0	0	0	0	0	0
F. crotonensis Kitton	15	10	0	8	10	0	0	0	0	0	0	0
Synedra acus Kützing *(Ulnaria acus* (Kützing) Aboal.)*	18	12	10	15	10	9	7	5	18	12	5	5
Family: Tabellariaceae												
Diatoma vulgaris Bory	0	0	0	2	1	1	2	1	1	2	1	1
occoneis placentula Ehrenberg	12	10	8	5	8	5	12	5	11	12	8	2
Cocconeis pediculus Ehrenberg	10	5	2	2	5	5	10	2	5	5	10	2
Family: Cymbellaceae												
Cymbella aspera (Ehrenberg) Cleve	12	9	5	3	2	2	10	8	8	5	8	5
C. cistula (Ehrenberg) O.Kirchner	20	18	10	8	8	5	18	11	10	12	10	10
C. tumida (Brébisson) Van Heurck	10	5	5	2	5	2	10	8	5	9	10	10
C. minuta Hilse	2	1	0	2	1	0	1	1	0	0	0	0
C. turgidula Grunow	0	0	0	0	0	0	2	1	0	0	0	0
C. amphicephala Näegeli ex Kützing	1	1	0	1	1	0	2	1	0	0	0	0
Family: Gomphonemataceae												
Gomphonema abbreviatum C.Agardh *(Rhoicosphenia abbreviata* (C.Agardh)*	1	1	0	1	1	0	0	0	0	0	0	0
G. minutum (C.Agardh) C.Agardh	0	0	0	22	18	10	19	11	10	12	15	12
G. insigne W.Gregory	0	0	0	2	5	2	1	1	1	2	1	1
G. affine Kützing	0	0	0	10	8	8	20	18	10	15	11	10
G. truncatum Ehrenberg	0	0	0	0	0	0	0	0	3	0	0	
G. olivaceum (Hornemann) Ehrenberg	20	10	18	12	10	0	18	12	0	15	10	0
G. rhombicum Fricke *(Gomphoneis rhombica* (Fricke) Merino) *	5	2	2	8	5	2	2	2	1	5	1	1
Family: *Achnanthaceae*												
Achnanthes sp.	1	1	0	1	1	0	0	0	0	0	0	0
Family: *Rhopalodiaceae*												
Epithemia adnata (Kützing) Brébisson	2	1	1	1	1	1	2	1	1	0	0	0
Family: *Catenulaceae*												
Amphora veneta Kützing (*Halamphora veneta* (Kützing) Levkov.)*	0	0	0	6	5	0	3	2	0	2	1	0
A. ovalis (Kützing) Kützing	0	0	0	2	1	0	2	2	0	1	1	0
A. copulata (Kützing) Schoeman and Archibald	0	0	0	0	0	0	1	1	0	1	1	0
Family: *Pinnulariaceae*												
Pinnularia gibba (Ehrenberg) Ehrenberg *(Epithemia gibba* (Ehrenberg) Kützing)*	2	2	1	3	2	2	5	2	2	0	0	0
Family: *Naviculaceae*												
Navicula cryptocephala Kützing	12	15	11	12	10	10	12	8	10	12	10	10
N. cryptotenella Lange 0Bertalot	25	22	20	19	15	11	20	18	20	22	18	12
N. radiosa Kützing (*Navicula tripunctata* (O.F.Müller) Bory.)*	18	15	20	19	10	15	20	18	15	19	18	15
N. gregaria Donkin	8	5	2	5	5	11	12	10	10	12	8	5
N. capitatoradiata H.Germain ex Gasse	20	12	10	22	15	18	22	19	11	15	10	12
N. rostellata Kützing	25	20	20	19	18	12	22	18	20	20	15	12
N. veneta Kützing	2	2	0	1	1	0	0	0	0	2	1	0
Navicula sp.	0	0	0	0	0	0				0	0	0
Caloneis permagna (Bailey) Cleve	2	2	1	2	1	1	0	0	0	0	0	0

Gyrosigma acuminatum (Kützing) Rabenhorst	20	15	12	10	5	12	22	15	10	20	18	18
G. attenuatum (Kützing) Rabenhorst	18	10	10	15	10	5	15	8	10	18	12	10
Family: *Pleurosigmataceae*												
Pleurosigma elongatum W.Smith	0	2	0	0	1	0	0	0	0	0	0	0
Family: *Sellaphoraceae*												
Sellaphora pupula (Kützing) Mereschkovsky	1	1	1	1	1	1	1	1	1	1	1	1
Family: *Bacillariaceae*												
Nitzschia reversa W.Smith	0	0	0	1	1	0	2	1	0	2	1	0
Nitz. filiformis (W.Smith) Van Heurck	15	12	11	10	8	8	18	12	10	8	5	10
Nitz.intermedia Hantzsch ex Cleve and Grunow	3	2	2	1	1	2	3	2	2	1	1	2
Nitz. palea (Kützing) W.Smith	26	20	22	19	18	22	20	25	18	20	15	22
Nitz. sigma (Kützing) W.Smith	25	22	18	0	0	0	19	15	10	12	10	10
Nitz. sigmoidea (Nitzsch) W.Smith	12	10	5	10	8	8	0	0	0	12	10	15
Nitz. acicularis (Kützing) W.Smith	20	15	12	10	11	5	10	8	8	15	10	12
Nitz. linearis W.Smith	0	0	0	0	0	0	0	0	0	1	0	0
Nitz. gracilis Hantzsch	20	12	10	12	9	5	18	15	10	15	12	10
Nitz. dissipata (Kützing) Rabenhorst	5	3	2	2	2	1	5	2	2	3	1	2
Nitz. obtusa W.Smith	8	5	0	5	2	0	2	2	0	0	0	0
Nitz. umbonata (Ehrenberg) Lange0Bertalot	2	2	1	1	1	2	2	2	1	1	1	2
Nitz. amphibia Grunow	2	2	1	0	0	0	0	0	0	0	0	0
Nitz. agnita Hustedt	0	0	0	0	0	0	0			0	0	0
Hantzschia amphioxys (Ehrenberg) Grunow	2	2	1	1	2	2	0	0	0	1	1	1
Family: *Surirellaceae*												
Surirella robusta Ehrenberg	5	2	2	3	2	2	8	5	2	8	8	5
S. ovalis Brébisson	5	3	2	1	2	2	1	1	1	2	1	1
S. capronii Brébisson and Kitton (*Iconella capronii* (Brébisson and Kitton) Ruck and Nakov)*	3	2	0	0	0	0	2	2	0	2	1	0
Cymatopleura solea (Brébisson) W.Smith (*Surirella librile* (Ehrenberg) Ehrenberg.)*	2	2	1	2	1	1	1	2	1	3	2	2
C. elliptica (Brébisson) W.Smith	0	0	0	0	0	0	1	0	0	1	0	0
Total number of Pennales diatoms *(cell*10^{-4}/cm^2)*	**463**	**336**	**271**	**340**	**276**	**211**	**425**	**316**	**260**	**367**	**288**	**248**
Total number (cell*10^{-4}/cm^2)	**512**	**375**	**295**	**384**	**300**	**218**	**455**	**339**	**281**	**376**	**304**	**259**

Diatoms are predominating in epipelic algae, a feature that has been shown in many researches **(Darweesh, 2017; Hassan *et al*., 2020; Ahmad, 2021; Al-Hasso & Al-Tamimi, 2022**).

Epipelic diatoms have been utilized as indicators of pollution in the aquatic environment since they are impacted in multiple ways. They cannot grow because of the lack of sunshine, or pollution can alter the physical and chemical conditions that prevent growth and reproduction. The polluted species are proliferating and expanding. Additionally, they alter species, making some less prevalent and dominant, which affects the overall aggregation of algae in the water system. This caused a variation among the study's four sites and seasons **(Mahmood *et al*., 2021)**.

The variety of diatoms in the water's surface body is impacted by variations in salinity, nutrient availability, and sediment quality. Some species may be absent or might lack at different times of the seasons because of impure conditions brought on by the river's increased water discharge and flow velocity **(Kadhim *et al.,* 2013)**. The exposure of sites to pollution has an impact on the particular structure of the diatoms attached to the sediments since sediments serve as a storehouse for the byproducts of both natural and human activities **(Alwan &Saeed, 2024)**.

Compared to other algae at the bottom, they are more resistant, tolerant, and effective against water currents. They are more stable on benthic sediments, have adhesion to submersible surfaces, and are more suited to the environmental conditions at the bottom **(Davies *et al*., 2009)**. **Al-Taee (2010)** noted that there is also an increase in the grazing rate and flow velocity that moves the bottom sediments, increasing the turbidity and obstructing the light necessary for diatom growth.

Ali *et al.* (2023) mentioned that the community makeup and pollution levels in the research region can be determined using bio-diversity indices. Moreover, diversity indices consider the relative abundances of various species, offering more information on the makeup of communities than just species richness.

The results of the study in Table (4) show that the lowest value of the richness species index (D) for epipelic diatoms in the Lower Zab River was 8.09 at site 4 in spring, and the highest value (10.93) recorded at site1 was in autumn. Higher richness levels are indicative of greater diversity, which indicates that the Zab River's waters have a high level of diversity.

Table 4. Evaluation of biodiversity index of epipelic diatoms at the study sites

Diversity index	Season											
	St.1			St.2			St.3			St.4		
	Autum 2023	Winter 2024	Spring 2024	Autum 2023	Winter 2024	Spring 2024	Autum 2023	Winter 2024	Spring 2024	Autum 2023	Winter 2024	Spring 2024
Richness index(D)	**10.93**	10.42	8.45	10.62	10.81	8.49	10.60	10.71	8.09	9.82	9.50	**8.09**
Shannon and weaver index (H)	3.82	3.77	3.51	3.78	3.79	3.51	**3.84**	3.75	3.51	3.72	3.63	**3.46**
Evenness index(E)	0.89	0.90	**0.89**	0.90	**0.91**	0.90	**0.91**	**0.89**	0.90	**0.91**	**0.89**	0.90
Simpson's diversity index	**0.97**	0.92	**0.95**	0.96	**0.97**	0.95	**0.97**	0.96	0.96	**0.97**	0.96	0.96

Shannon and Weaver index (H) values for epipelic diatom ranged between 3.46-3.84 at site4 and 3 in spring and autumn, receptivity (Table 4). According to the Shannon diversity index results, the study area's diversity is high, and certain species of epipelic diatoms do not predominate. This suggests that the environmental conditions are favorable for the growth and diversity of the epipelic algae, which in turn determines the level of water contamination **(Jonge, 1995)**.While, evenness index (E) values were recorded between 0.89 at site1, 3 and 4 in spring and winter, respectively, and 0.91 at sites 2, 3 and 4 in winter and autumn; according to the evenness index of species, the epipelic algae are not under any environmental stress or pressure.

The difference in values of the index of algae stuck to the mud may be due to the speed of water flow, as it can cause a change at the depth and in the geology of the surface and bottom of the river, and this leads to a change in species. It may also be due to the dominance of a certain species over other species **(Merican *et al*., 2006)**.

Simpson's diversity index (D) is a measure of diversity which takes into account both species richness (the number of species present) and species evenness (the relative abundance of each species). The results of Simpson index values ranged from 0.92 at site 1 in autumn to 9.97 at sites 2,3, 4 in autumn, winter, respectively. This score rises as richness increases; the river where the measure of biodiversity is most meaningful is the one with a high species diversity within the genera and a wide variety of algal species overall.

CONCLUSION

The diversity of the epipelic diatoms can provide information on the ecological status of the water or the presence of pollutants. It serves as an essential water change monitor.Applying diversity indices enhances the dataset's output information, which varies depending on the community or sample under investigation. A Shannon diversity score greater than three indicated a relatively diverse epipelic diatom richness. Richness, or the variety of species present and evenness in the algal population, increases with an increase in the Simpson index.

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