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Epilithic Diatoms Diversity in the Lower Zab River Within Kirkuk Province

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ABSTRACT

This study was conducted in the Lower Zab River, Kirkuk Province, from October 2024 to March 2025 to assess epilithic diatom diversity as an indicator of river water quality. Epilithic diatom samples were collected by scraping submerged rock surfaces at four study sites (S1: Sadr River Bridge, S2: Ashraya, S3: Al Shamit, S4: Al Shak villages). Biodiversity indices including richness index (RI), Shannon Wiener index (H′), evenness index (EI), and Simpson's diversity index (D) were calculated. Pennate diatoms dominated the community (90.86%), while centric forms accounted for 7.14%. Diatom abundance ranged from 1.58×10^6 to 2.14×10^6 cells mL^{-1}. The dominant species included *Cymbella cistula*, *Gomphonema minutum*, *G. olivaceum*, *Nitzschia palea*, and *Navicula capitatoradiata*, highlighting their ecological significance. Shannon Wiener index (H′) values ranged from 2.834 to 3.200, and Simpson's index (D) from 0.932 to 0.954, both reflecting moderate to high diversity. Evenness index (EI) values (0.880–0.893) indicated stable community structure and high species distribution uniformity. Overall, the results demonstrate that epilithic diatom communities in the Lower Zab River exhibit high diversity, suggesting that the river can be categorized as a high biodiversity system with slightly polluted water quality.

INTRODUCTION

Epilithic diatoms are unicellular, benthic, photosynthetic microalgae that attach to submerged lithic substrates and form vital components of freshwater ecosystems **(Prahardika *et al.*, 2022)**. As primary producers, they contribute substantially to periphytic biomass and play a central role in nutrient cycling, oxygen production, and the foundation of aquatic food webs. They are also widely recognized as reliable bioindicators of water quality due to their rapid response to ecological changes **(Taurozz *et al.,* 2024)**. Epilithic diatoms exhibit high taxonomic and functional diversity, with community structure influenced by a variety of physicochemical parameters such as nutrient availability, pH, temperature, light intensity, and current flow **(Luostarinen *et al.*, 2023)**.

Rivers, as dynamic lotic systems, provide heterogeneous habitats for diatom colonization, where both spatial and temporal variability strongly shape epilithic assemblages **(Shibabaw *et al.*, 2020)**. Assessing epilithic diatom diversity not only supports monitoring of ecological status but also enhances understanding of ecosystem functioning, particularly under anthropogenic pressures such as urbanization, agricultural runoff, and hydrological alterations **(Stenger Kovács *et al.,* 2014)**. Given their ecological sensitivity and taxonomic richness, the distribution patterns and diversity of epilithic diatoms in riverine habitats are essential for developing effective freshwater management and conservation strategies **(Shin *et al.,* 2022; Bashir & Ali, 2024; Jasim & Ali, 2024)**.

MATERIALS AND METHODS

Study area

The Lower Zab is one of the main tributaries of the Tigris River and serves as the primary source of potable water in Kirkuk Province, in addition to other uses **(Saeedrashed & Guven, 2013; Mariam *et al.,* 2025)**. Fig. (1) and Table (1) present the four study sites located along the Lower Zab.

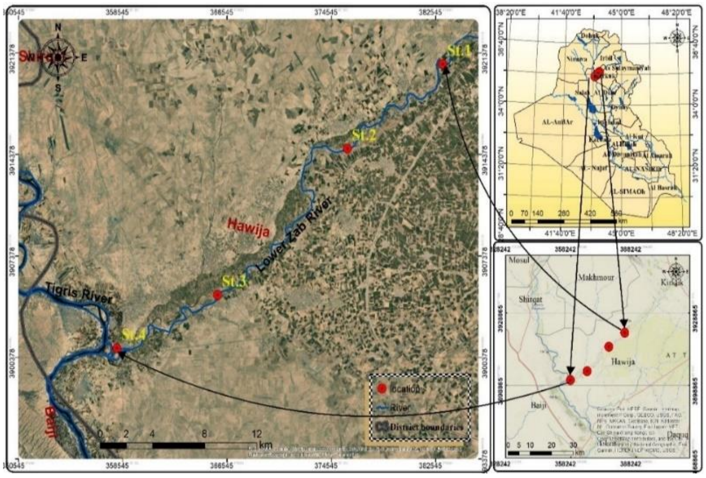

Fig. 1. Study sites **(Bashir & Ali, 2024)**

Table 1. The coordination of the study sites along the river

No.	Sites	GPS coordinate
1	S1: Sadr river-bridge	43° 42′ 41.82″ E, 35° 25′ 19.48″ N
2	S2: Ashraya-village	43° 37′ 57.69″ E, 35° 22′ 06.65″ N
3	S3: Al-Shamit-village	43° 31′ 29.42″ E, 35° 16′ 33.24″ N
4	S4: Al-Shak-village	43° 26′ 26.03″ E, 35° 14′ 31.65″ N

Epilithic diatom samples: Collection and preparation

Epilithic diatom samples were collected monthly from four sites between October 2024 and March 2025 (six months), with three replicates per site. Samples were taken from submerged rocks (10– 15cm in size) at depths of 15– 30cm below the water surface, during early morning hours. Rocks covered with mud or macrophytes were excluded to avoid contamination with epipelic or epiphytic diatoms. Diatoms were scraped from the upper rock surfaces using hard-bristled toothbrushes or sharp blades, pooled from 4–6 rocks (depending on size), and transferred into sterile containers **(Reavie & Smol, 1998; Castilejo *et al.*, 2018)**. Samples were rinsed with distilled water, preserved with Lugol's solution, and transported to the laboratory.

Laboratory analysis

In the laboratory, samples were cleaned using sodium hypochlorite and distilled water, then centrifuged at 1,000 rpm for 5–10 minutes. Permanent slides were prepared by digestion with nitric acid following **Lange-Bertalot *et al.* (2017)** and **Afifah *et al.* (2021)**. Diatoms were identified and examined under an Olympus microscope at 40× magnification. Taxonomic identification was based on the studies of **Taylor *et al.* (2007)**, **Lavoie and Hamilton (2008)**, **Saini *et al.* (2022)** and **Guiry and Guiry (2024)**.

Diversity indices

To characterize community structure at each site (Table 2), several biodiversity indices were calculated, including species richness (RI), Shannon–Wiener index (H′), species evenness (EI), and Simpson's diversity index. These indices are widely applied in the bioassessment of water quality **(Stevenson *et al.*, 2010)**.

Table 2. Biological diversity indices used in the current study

Index	Equation	Abbreviations	Reference
Richness Index (RI)	D = (S-1)/In(N)	S = Total number of species, n = Total number of individuals in the sample.	Margalef (1969)
Shannon-Wiener Index (H')	H′ = -Σ [(pi) * ln(pi)]	H=Shannon index, SUM=Summation, pi= Number of individuals of species, i/total number of samples.	Shannon (1948)
Evenness index (EI)	E=H′/Hmax	H=Shannon index, Hmax = ln(N) Maximum diversity possible, and E= Evenness.	Neves *et al.* (2003)
Simpson's diversity index (D)	$SI = \frac{1}{\sum(Pi)^2}$	**SI** =Simpson's Diversity Index, ∑ = Sum of all values, **Pi** =Proportion of individuals belonging to species *i* in the dataset.	Simpson (1949)

RESULTS AND DISCUSSION

A total of 56 species of epilithic diatoms were identified across the four study sites in the Lower Zab River, Kirkuk Province (Table 3). Of these, centric diatoms accounted for 7.14%, while pennate diatoms dominated with 90.86% during the study period. Site 4 exhibited the highest species richness (37 species) and abundance (214×10^4 cells mL^{-1}), whereas Site 3 recorded the lowest richness (25 species) and abundance (158×10^4 cells mL^{-1}) (Fig. 2). *Nitzschia palea* was among the most frequently occurring taxa, present at all sites and particularly abundant at S1 and S2, reflecting its tolerance to eutrophic and organic-rich conditions **(Tokatlı *et al.*, 2022)**.

Table 3. Types of epilithic diatoms at the studied sites (cells*10^4 mL^{-1})

Diatoms algae	S1	S2	S3	S4
Division: Bacillariophycophyta				
Class: Bacillariophycophyceae				
Order: Centrales				
Family: Aulacoseiraceae				
Aulacoseira granulata (Ehrenberg) Simonsen	22	0	0	12
A. ambigua (Grunow) Simonsen	0	18	10	0
Family: Stephanodiscaceae				
Cyclotella meneghiniana Kützing (*Stephanocyclus meneghinianus* (Kützing) Kulikovskiy)*	12	8	0	6
C. ocellata Pantocsek (*Pantocsekiella ocellata* (Pantocsek) K.T.Kiss & Ács.)*	0	2	0	0
Order: Pennales				
Family: Fragilariaceae				
Fragilaria biceps Ehrenberg	0	1	0	0
F. ulna (Nitzsch) Lange-Bertalot (*Ulnaria ulna* (Nitzsch) Compère) *	15	12	10	0
F. capucina Desmazières	0	0	0	2
Synedra acus Kützing (*Ulnaria acus* (Kützing) Aboal.) *	0	12	10	0
Family: Tabellariaceae				
Diatoma vulgaris Bory	1	2	0	2
Cocconeis placentula Ehrenberg	10	8	6	11
C. pediculus Ehrenberg	8	0	0	0
Family: Cymbellaceae				
Cymbella cistula (Ehrenberg) O.Kirchner	22	10	12	8
C. tumida (Brébisson) Van Heurck	8	4	4	11
C. turgidula Grunow	0	1	1	2
C.silesiaca Bleisch	0	0	1	1
C. cespitosa (Kützing) Brun (*Encyonema cespitosum* Kützing)*	0	0	1	1
C. ventricosa (C.Agardh) C.Agardh (*Encyonema ventricosum* (C.Agardh) Grunow)*	0	0	0	1
Placoneis elginensis (W.Gregory) E.J.Cox	0	1	0	0
P. clementis (Grunow) E.J.Cox	0	1	0	0
Family: Gomphonemataceae				
Gomphonema abbreviatum C.Agardh (*Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot)*	2	0	2	0
G. minutum (C.Agardh) C.Agardh	20	15	12	10
G. insigne W.Gregory	1	3	2	1
G. affine Kützing	1	0	2	12
G. truncatum Ehrenberg	2	0	0	2
G. olivaceum (Hornemann) Ehrenberg	15	11	10	8
G. rhombicum Fricke (*Gomphoneis rhombica* (Fricke) Merino) *	3	2	2	0
G. venustum S.I.Passy, Kociolek & R.L.Lowe	1	1	1	1
G. pumilum (Grunow) E.Reichardt & Lange-Bertalot	1	1	0	1
G. parvulum (Kützing) Kützing	0	0	1	0
Family: Achnanthaceae				
Achnanthes sp.	0	2	2	0
Family: Rhopalodiaceae				

Epithemia adnata (Kützing) Brébisson	0	0	0	1
Family: Catenulaceae				
Amphora veneta Kützing (*Halamphora veneta* (Kützing) Levkov.)*	2	0	0	0
A. copulata (Kützing) Schoeman & Archibald	0	0	0	2
Family: Pinnulariaceae				
Pinnularia gibba (Ehrenberg) Ehrenberg (*Epithemia gibba* (Ehrenberg) Kützing)*	3	0	0	2
Family: Naviculaceae				
Navicula cryptocephala Kützing	18	15	0	0
N. cryptotenella Lange-Bertalot	21	20	0	15
N. radiosa Kützing (*Navicula tripunctata* (O.F.Müller) Bory.)*	12	18	12	9
N. gregaria Donkin	0	3	4	0
N. capitatoradiata H.Germain ex Gasse	22	20	15	18
N. rostellata Kützing	0	0	1	1
Gyrosigma acuminatum (Kützing) Rabenhorst	0	0	0	3
G. attenuatum (Kützing) Rabenhorst	21	18	0	15
Family: Bacillariaceae				
Nitz. palea (Kützing) W.Smith.	25	20	22	18
Nitz. filiformis (W.Smith) Van Heurck	10	15	0	12
Nitz.intermedia Hantzsch ex Cleve & Grunow	0	1	0	2
Nitz. sigmoidea (Nitzsch) W.Smith	0	0	0	5
Nitz. acicularis (Kützing) W.Smith	18	15	12	8
Nitz. linearis W.Smith	0	0	0	1
Nitz. gracilis Hantzsch	0	0	0	5
Nitz. dissipata (Kützing) Rabenhorst	0	0	0	3
Nitz. obtusa W.Smith	2	2	0	0
Nitz. umbonata (Ehrenberg) Lange Bertalot	0	0	0	1
Family: Surirellaceae				
Surirella robusta Ehrenberg	8	6	3	0
S. ovalis Brébisson	1	0	0	1
Total species	**30**	**32**	**25**	**37**
Total individuals of algae	**307**	**268**	**158**	**214**

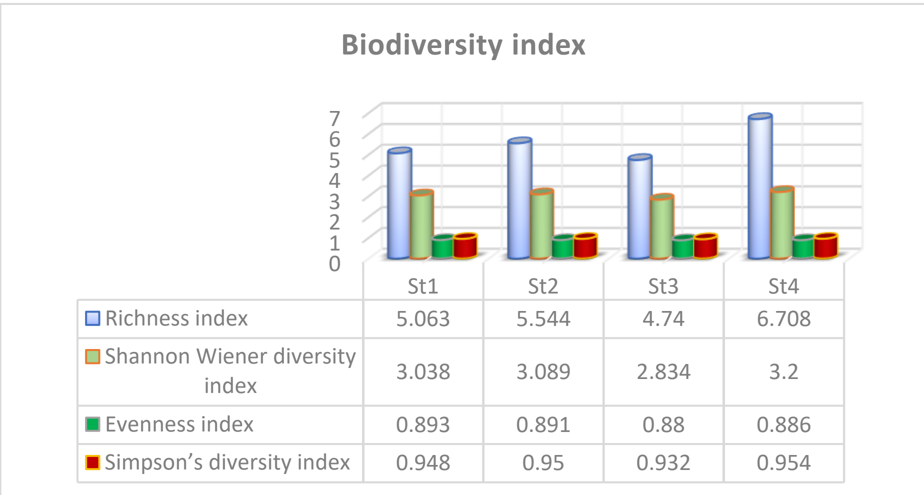

Fig. 2. Bio-diversity indices values of the present sites

Shannon–Wiener index (H′) values ranged from 2.834 at S3 to 3.200 at S4, indicating moderately high diversity across the river, with S4 supporting the most ecologically stable assemblage (Table 4). These findings are consistent with those of

Jasim and Ali (2024), who reported that the Lower Zab River sustains high biodiversity and is characterized as slightly polluted.

Table 5. Shannon-Wiener index with pollution levels **(Hosmani & Hosetti, 2009)**

Shannon-Wiener values	Diversity & pollution levels
0.00-1.0	Very low diversity & heavy-pollution
1.0-2.0	Low diversity & moderate-pollution
2.0-3.0	Moderate diversity & light-pollution
3.0-4.5	High diversity & Slight-pollution

The evenness index values ranged between 0.880-0.893 at S3 and S1, respectively, which reflects a stable ecosystem and high evenness **(Magurran, 2021)**, indicating an equal distribution of individuals among species (Table 5). This trend is reinforced by Simpson's index, which was the highest at S4 (0.954), indicating a balanced distribution of species with no single taxon dominating excessively.

Table 5. Evenness index criteria

Index values	Explanation of evenness
$E < 0.4$	Low
$0.4 \leq E \leq 0.6$	Moderate
$E > 0.6$	High

The dominant genera observed—*Gomphonema, Navicula, Cymbella,* and *Nitzschia*—are typical of freshwater benthic diatom communities in moderately impacted riverine systems **(Najeeb *et al.*, 2025; Naz *et al.*, 2025)**. In this study, for example, *Gomphonema olivaceum, Nitzschia palea,* and *Navicula capitatoradiata* were consistently recorded at all sites with relatively high abundances, suggesting their adaptability to variable hydrological and nutrient conditions. The increase in diatom richness and diversity from S3 to S4 may be linked to improved water quality or greater habitat complexity in downstream regions, possibly due to reduced anthropogenic pressure or enhanced substrate availability **(Tiwari *et al.*, 2024; Mahmood *et al.*, 2025)**. In contrast, the lower richness at S3 likely reflects localized stressors such as agricultural runoff or channel modifications, which typically reduce sensitive taxa and favor pollution-tolerant species **(Virta *et al.*, 2019; Taher & Saeed, 2022)**.

The dominance of *Cyclotella meneghiniana* at S1 and S2 is notable, as this species is often associated with nutrient enrichment and moderate organic loading, conditions commonly linked to urban or agricultural discharges **(Dienye *et al.*, 2023; Rasheed *et al.*, 2024)**. Overall, the spatial variation in diatom assemblages across sites reflects a gradient in water quality and ecological conditions along the river, with S4 representing the most favorable habitat for diverse diatom communities. These findings underscore the effectiveness of epilithic diatoms as bioindicators for ecological assessment in freshwater ecosystems.

CONCLUSIONS

The diversity of epilithic diatoms provides valuable insight into the ecological status of aquatic systems and the presence of pollutants, as these organisms reproduce rapidly and respond sensitively to environmental changes, making them reliable bioindicators of water quality. The application of diversity indices further enhances interpretation by capturing variations in community structure across sites. Results from this study indicate that epilithic diatom communities in the Lower Zab River display relatively high diversity. Based on the applied indices, this section of the river can be classified as a high-biodiversity system with slightly polluted water.

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