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Diatom flora of Lake Iro (Southern Chad): Preliminary observations

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Abstract

Diatoms are microscopic yellow-brown algae widely distributed in aquatic environments, where they play a key role in trophic networks and primary productivity. This study aims to better characterize the current diatom assemblages of Lake Iro, located in southern Chad, a region previously unexplored from a limnological perspective. A taxonomic inventory was conducted based on seven samples collected from different substrates (sediments, plankton, macrophytes), complemented by *in situ* measurements of hydrochemical parameters (temperature, pH, conductivity, and dissolved oxygen).

The results reveal low species diversity, dominated by *Aulacoseira granulata*, a typical freshwater species that thrives in alkaline, well-mixed waters. The highest diversity indices were observed in samples collected from macrophytes. As the first study of Lake Iro, this work highlights the need for additional, especially seasonal, investigations to better understand the ecological dynamics of this Sahelian lake system.

Keywords: Diatoms; Lake Iro; Diversity; Assemblages; Chad; Bioindicators; Hydrochemistry

1. Introduction

Diatoms are a major group of unicellular photosynthetic algae, characterized by a siliceous frustule intricately ornamented with species-specific patterns. They are ubiquitous in aquatic environments, where they play a fundamental role in the biogeochemical cycles of carbon and silica (Kemp et al., 2006; Smetacek, 1999). It is estimated that diatoms contribute to approximately 20% of global primary productivity and account for nearly one-quarter of the inorganic carbon fixed annually in the world's oceans (Richardson & Jackson, 2007).

Due to their high sensitivity to physico-chemical parameters such as temperature, pH, nutrient concentration, and conductivity, diatoms are widely used today as bioindicators of water quality, particularly in studies of eutrophication, acidification, and anthropogenic impacts on aquatic ecosystems (Smol & Stoermer, 2010). Their rapid response to environmental fluctuations makes them especially useful for short- and medium-term ecological monitoring.

In Central Africa, the shallow lakes of the Sahelian and Sudanian zones are fragile ecosystems subject to intense climatic and hydrological pressures (Nguetsop et al., 2013). Among these, Lake Iro—located in the Moyen-Chari region of southern Chad—remains poorly documented, especially concerning its phytoplanktonic communities. To date, no comprehensive study has been conducted on the current diatom assemblages of this lake. This knowledge gap is

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particularly noteworthy given that Lake Iro, likely of impact-crater origin (Rochette et al., 2024), shares certain features with other major Chadian lakes such as Lake Fitri and Lake Chad, which have been the subject of extensive diatomological studies (Servant-Vildary, 1978; Remadji, 2019).

The present study aims to address this gap by conducting a taxonomic inventory of the current diatom flora in Lake Iro, while also characterizing species diversity and distribution across different substrates (sediments, macrophytes, and plankton). In parallel, *in situ* measurements of hydrochemical parameters (pH, temperature, conductivity, and dissolved oxygen) are used to assess the environmental conditions influencing these biological communities. The objective is to provide a first ecological characterization of diatom assemblages in Lake Iro, in order to better understand their structure, dynamics, and potential bioindicator value in a Sahelian lacustrine context.

This study represents a novel contribution to the understanding of lake ecosystems in Chad and may serve as a basis for future limnological, ecological, or paleoenvironmental research in this largely unexplored region.

1.1. Study Area

Lake Iro is located in the Moyen-Chari region of southern Chad (10°06′N, 19°25′E), near the town of Kyabé. It covers an area of approximately 100 km^2, with a maximum depth of 4 meters during the high-water period. The water level fluctuates seasonally, with a range of about 2.5 meters between July (minimum) and October (maximum).

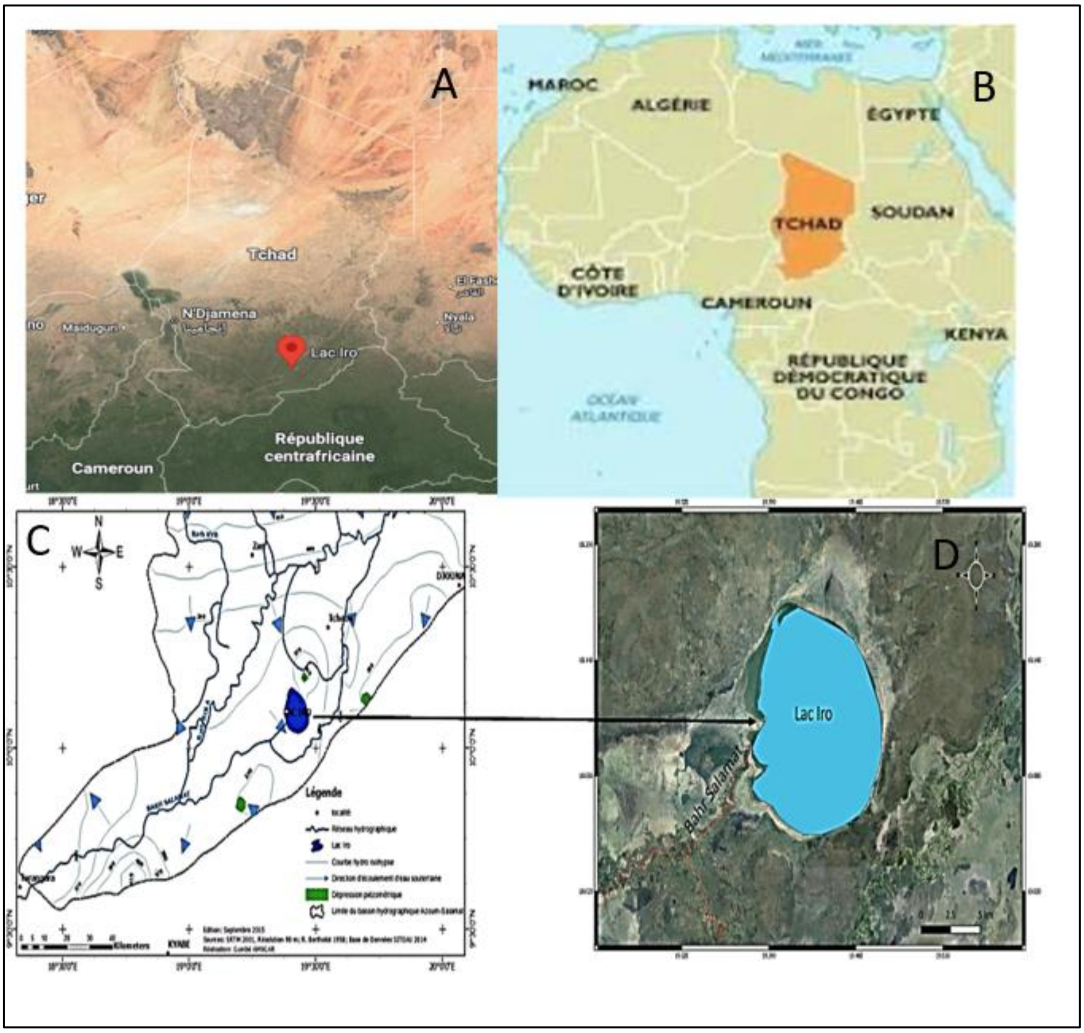

Figure 1 A) Map of showing the location of lake Iro with a red star (source: Google Earth); B) Map of Africa showing Chad highlighted in colored background; C) Satellite photo of Lake Iro showing its market contours (source: Google Earth); D) Map of Lake Iro's catchment area

This lake, circular and homogeneous in shape, is thought to be of impact crater origin (Doumnang & Rochette, pers. comm.). It is fed by rainfall and floodwaters from the Bahr Salamat *via* the Iro River, a diversion channel located west of the lake. During the rainy season, Lake Iro and the Bahr Salamat merge to form a vast floodplain (Pias & Barbery, 1965).

The Bahr Salamat watershed extends over approximately 195,000 km^2 and receives hydrological inputs as far as western Darfur (Poulin, 2018). The regional climate is sahelo-sudanian type, with a rainy season from May to October (500–900 mm/year), followed by a prolonged dry season.

Soils surrounding the lake are dominated by hydromorphic vertisols, which are favorable for recession agriculture. The vegetation is typical of Sudanian savannas, mainly composed of *Acacia seyal, Combretum glutinosum, Terminalia avicennioides*, and herbaceous steppe formations (Gillet, 1969).

2. Matérials and Methods

2.1. Sampling

Twelve samples were collected in 2015 and 2016 from various substrates: surface water, superficial sediments, aquatic macrophytes, and plankton. Of these, seven contained a sufficient concentration of diatoms to be analyzed.

Hydrochemical parameters including temperature, conductivity, salinity, dissolved oxygen, and oxygen saturation were measured *in situ* using a portable multiparameter probe.

2.2. Sample Preparation

Samples were processed following the standard sediment treatment protocol for diatom analysis (Battarbee et al., 2001). Organic matter was removed using heated hydrogen peroxide (H_2O_2, 33%), followed by treatment with hot hydrochloric acid (HCl, 10%) to eliminate carbonates.

A small volume (~200 µL) of the cleaned sample was evaporated onto coverslips and mounted onto microscope slides using a high refractive index synthetic resin (Naphrax®).

2.3. Microscopic Observation and Taxonomic Identification

Observations were performed at ×1000 magnification using a Nikon Eclipse 80i microscope equipped with differential interference contrast (DIC) optics. For each sample, a minimum of 500 diatom valves were counted along randomly selected transects.

Taxonomic identification was based primarily on the floras of Krammer & Lange-Bertalot (1986, 1988) and Gasse (1986), with nomenclature verified according to recent revisions by Guiry & Guiry (2022).

2.4. Ecological Indices

Shannon-Weaver diversity indices and Pielou's evenness indices were calculated for each sample based on the relative abundances of identified diatom species.

3. Results and Discussion

3.1. Environmental Parameters

Measurements of physico-chemical parameters evidenced that the Lake Iro is a freshwater lake with conductivity ranging between 163.3 and 180 $\mu S \cdot cm^{-1}$. Surface water temperatures were relatively high at the time of sampling, varying between 28°C and 33°C. Oxygen saturation ranged from 10.7% to 71.8%, while dissolved oxygen concentrations varied between 0.61 and 5.33 mg/L.

3.2. Diatom Flora

In Lake Iro, a total of 32 taxa belonging to 19 genera were identified (see species list). The lake is characterized by a very low abundance of diatoms. Among the twelve samples collected, only seven were quantitatively analyzed due to sufficient diatom content. These included (Figure 2):

- Two sediment samples: Iro 1-15(S) and Iro 2-15(S), where the total number of counted individuals did not exceed 50;
- Three plankton net samples: Iro 1-15(F), Iro 6-16(F), and Iro 9-16(F);
- Two macrophyte samples: Iro 2-15m and Iro 8-15m.

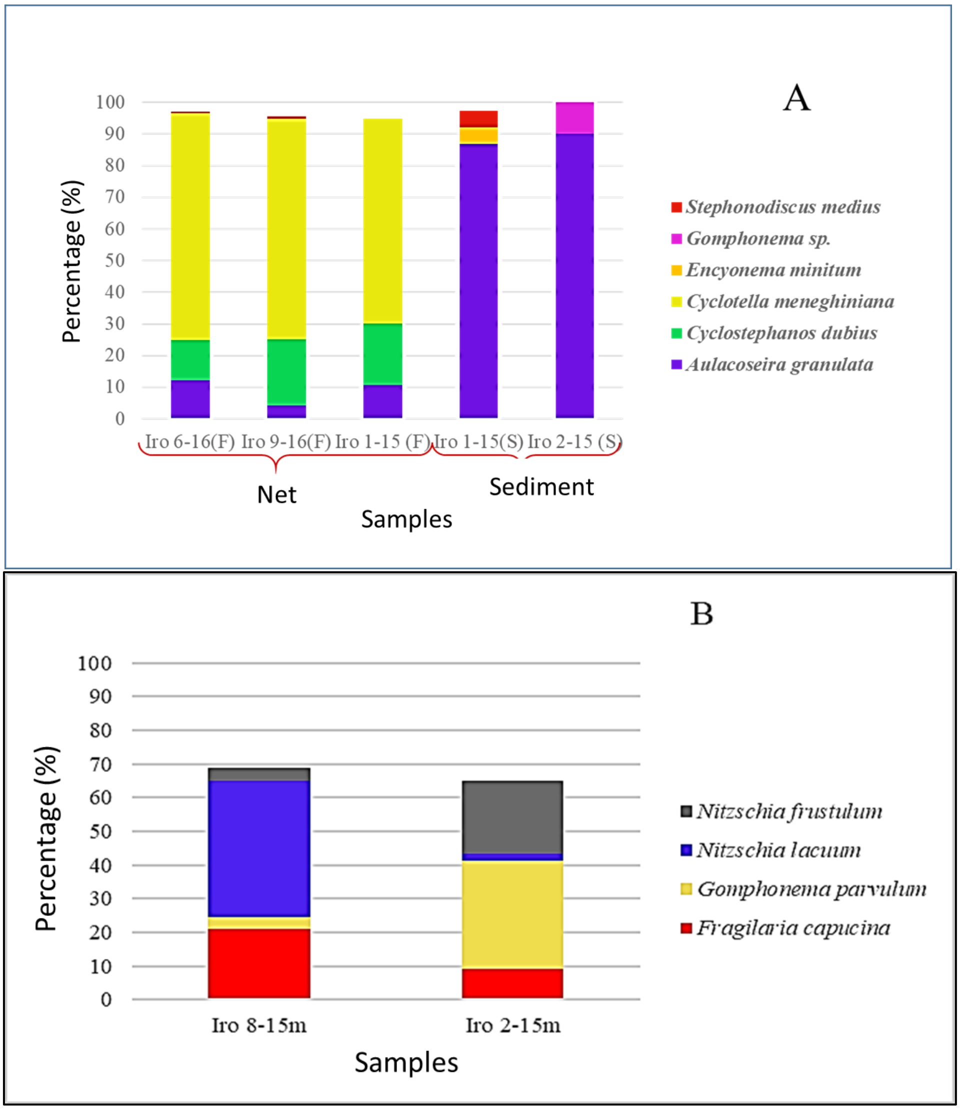

Figure 2 Relative abundance of dominant diatom species in sediment and net samples (A), and in samples collected from macrophytes (B)

Analysis of Figure 2A showed that *Aulacoseira granulata* was nearly monospecific in the sediment samples Iro 1-15(S) and Iro 2-15(S), with relative abundances of 86.8% and 90%, respectively. *Aulacoseira granulata* is generally described as characteristic of alkaline freshwater environments, developing optimally at pH levels between 7.8 and 8.2 (Cholnoky, 1970). This species is associated with shallow, non-stratified lakes that undergo strong seasonal variations in surface area and depth depending on water inputs. It is commonly recorded in both West and East African lakes (Gasse, 1986), *and* also frequently observed in sedimentary archives, being an indicator of lacustrine conditions in past environmental contexts (Gasse, 2000). This species dominates the sediments of Lake Chad (Servant-Vildary, 1978; Sylvestre et al., 2019), and was also prevalent in Lake Yoa sediments during the mid-Holocene (Kröpelin et al., 2008).

Stephanocyclus meneghinianus (formerly *Cyclotella meneghiniana*) was highly represented in the three net samples, with relative abundances of 64.9% in Iro 1-15(F), 71.6% in Iro 6-16(F), and 69.7% in Iro 9-16(F). It was followed by *Cyclostephanos dubius*, accounting for 19.2%, 12.8%, and 20.8% in the same samples. *Aulacoseira granulata* was also present at 10.8% in Iro 1-15(F) and 12.2% in Iro 6-16(F).

Macrophyte samples exhibited a different species composition (Figure 2B). In Iro 2-15m, *Gomphonema parvulum* was dominant (32.1%), followed by *Nitzschia frustulum* (21.9%) and *Encyonema silesiacum* (10.7%). In Iro 8-15m, *Nitzschia lacuum* represented 40.3% of the assemblage, followed by *Fragilaria capucina* (20.1%) and *Discostella stelligera* (10.6%). Figure 1 presents several species frequently observed across the analyzed samples.

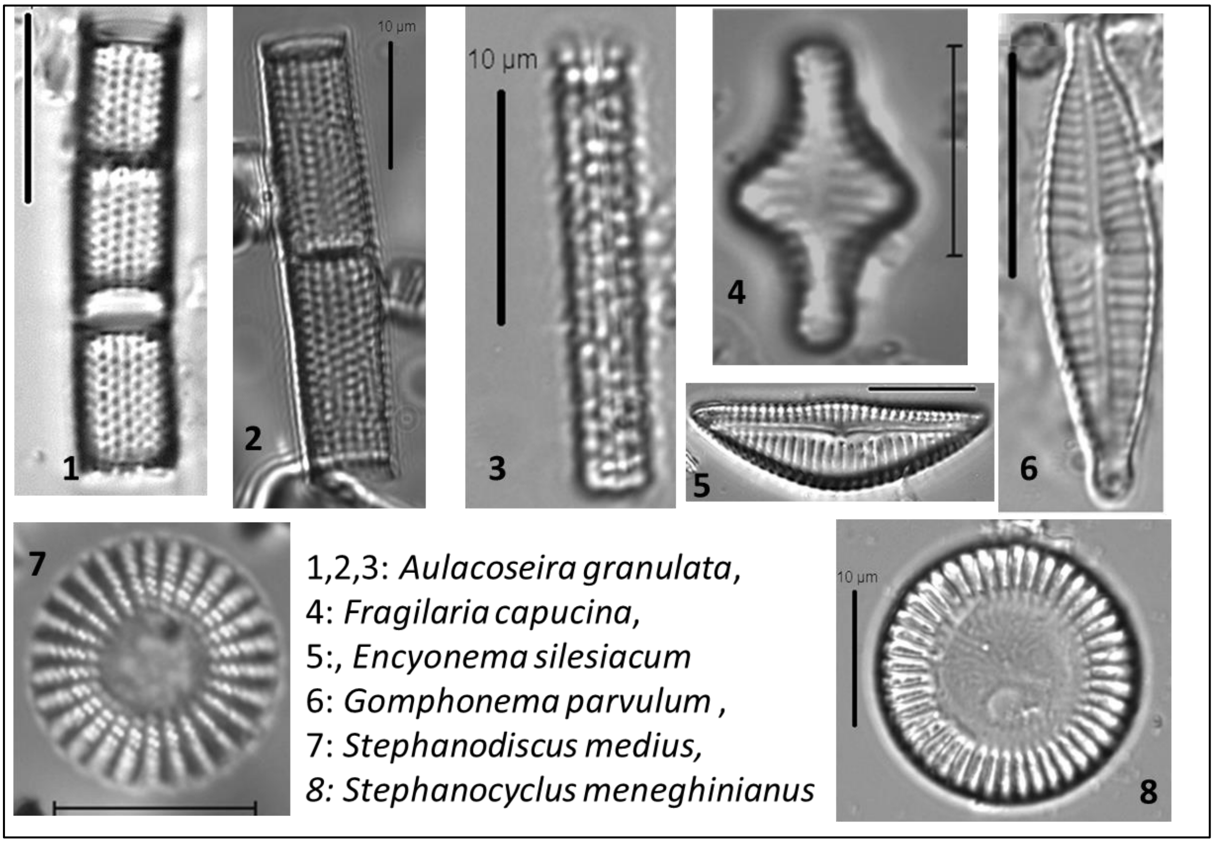

Figure 1 Light microscope photographs of dominant diatom species from Lake Iro.

3.3. Diatom Abundance

The evaluation of diatom content in sediment samples revealed a very low abundance of diatoms in Lake Iro. The concentration of diatom valves ranged from 8 × 10^6 to 10 × 10^6 valves per gram of dry sediment, regardless of the sampling site or substrate type (Table 1). For the sediment samples Iro 1-15(S) and Iro 2-15(S), valve concentration was not measured; however, complete scanning of the microscope slides from these two samples yielded only 48 valves in total.

Diatom content was also not measured in the macrophyte samples due to insufficient dry weight at the time of preparation. As a result, only the net-collected samples were quantified for diatom abundance.

Table 1 Lake Iro: Quantitative assessment of diatom valve concentration per sample.

	Moyenne/Champs	Moyenne x nbre de champs sur la lamelle	Volume de dilution (ml)	Volume éch. Lamelle (ml)	Poids sec échantillon (g)	Concentration x10^6 en valves/ g de sédiment sec
Iro 6-16(F)	3	23232	50	0,2	0,67	8
Iro 9-16(F)	3	23232	50	0,2	0,58	10
Iro 1-15 (F)	1,6	12390,4	10	0,2	0,28	2

Several hypotheses may explain this very low, or even near-absence, of diatoms in the lake:

The first hypothesis relates to the sampling method. Net sampling introduces uncertainty regarding the quantity of material collected. In the field, large volumes of water were filtered without precise quantification. The assessment of sample richness was based on the coloration of the filtered water in the collection bottles, a subjective estimate that could have resulted in insufficient sampling effort.

However, even sediment samples collected at the water–sediment interface also showed low diatom content, suggesting that the second hypothesis, which concerns the lake's hydrochemical characteristics, might be relevant. Lake Iro shares similar water chemistry with other regional lakes such as Lake Chad and Lake Fitri, with pH values ranging between 7.45 and 8.47, and conductivity values between 166 and 180 $\mu S \cdot cm^{-1}$ (Rirongarti, 2019).

3.4. Diversity Indices

Shannon diversity index values ranged from 0.47 to 2.73, while Pielou's evenness index values ranged from 0.38 to 0.75. Only the samples collected from macrophytes showed relatively high values. Specifically, samples Iro 2-15m and Iro 8-15m had Shannon indices of 2.70 and 2.73, and evenness indices of 0.75 and 0.68, respectively.

In contrast, the net samples Iro 6-16(F), Iro 9-16(F), and Iro 1-15(F) had lower values, with Shannon indices ranging between 1.34 and 1.59, and evenness values between 0.39 and 0.42.

The sediment samples Iro 1-15(S) and Iro 2-15(S) exhibited the lowest values for both Shannon diversity and evenness indices.

4. Conclusion

The analysis of diatom assemblages in Lake Iro reveals a low-diversity flora, dominated by *Aulacoseira granulata*, a species typical of shallow freshwater environments. This species is often associated with alkaline, well-mixed waters, which is consistent with the physico-chemical parameters measured in the lake (alkaline pH, moderate conductivity, and high water temperature).

Despite the taxonomic richness observed (32 taxa across 19 genera), the low diatom abundance, particularly in sediment and macrophyte samples, limits the ecological interpretation of these results. This scarcity may be attributed to a combination of methodological factors (under-sampling, sample dilution, lack of accurate volume quantification) and environmental conditions (turbidity, nutrient availability, competition with other algal groups).

Diversity indices (Shannon) reflect an unbalanced community structure, with strong dominance of a few planktonic species, especially in net samples, and slightly higher richness only observed in macrophyte-associated samples.

This study represents a first descriptive assessment of present-day diatoms in Lake Iro, a system previously unexplored from a scientific perspective. It highlights the need for more standardized sampling protocols and seasonal monitoring to better capture the spatial and temporal dynamics of diatom communities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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Species list

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- *Craticula subminuscula* (Manguin) C.E.Wetzel & Ector 2015
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- *Cyclotella cyclopuncta* Håkansson & J.R.Carter 1990
- *Diadesmis confervacea* Kützing 1844
- *Discostella stelligera* (Cleve & Grunow) Houk & Klee 2004
- *Discostella woltereckii* (Hustedt) Houk & Klee 2004
- *Encyonema minutum* (Hilse) D.G.Mann 1990
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- *Gomphonema parvulum* (Kützing) Kützing 1849
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- *Stephanodiscus minutulus* (Kützing) Cleve & Möller 1882