Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 191 (2025) 55098_55107

ISSN: 2229-712X

Diatomic Flora of the Djubudjubu Stream in the Kisangani Region

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ARTICLE INFO

Article history:
Received: 15 May 2025;
Received in revised form: 20 June 2025;
Accepted: 23 July 2025;

Keywords
Diatoms,
Specific Relative Abundances,
Specific Diversity,
Similarity,
Stream,
Djubudjubu,
Kisangani

ABSTRACT
This study concerned the study of the diatomic flora of the Djubudjubu stream in the urban region of Kisangani (Tshopo/ DRC). Samples were taken at the source, in the middle and at the outfall of the stream. The results obtained revealed a great diversity of 119 species, 38 genera distributed in 24 families. The source contained many species (51 species) than the other stations. The Shannon and Weaver biodiversity indices revealed a great diversity. The Evenness index showed an equipartition of species. The species *Pinnularia* sp8 and *Nitzschia palea* are the most abundant (13.68 and 10.25% respectively). The specific relative abundance is very high at the source (42.69%) than at the other stations. The different groupings of species and samples depend on their environment having similar ecological conditions at the different stations.

I. Introduction

Diatoms are highly diverse, unicellular brown algae that are widely distributed across the globe in oceans and continental surface waters. The role played by these microscopic algae has been proven in several domains of life. In fact, diatoms are used as bioindicators of water quality (Prygiel and Coste, 1993). Knowledge of the ecology of thousands of diatom species has led to their widespread use as biological indicators of running water quality in Europe. They are widely used to assess more or less precisely the physicochemical parameters of water such as pH (Battarbee and Charles, 1986; Charles *et al*., 1991), pollution (Sladecek, 1986), salinity (Servant-vildary and Roux, 1990) and Gasse, 2002), etc. Diatoms can fossilize under favorable conditions after cell death due to certain specific biological characteristics, including their siliceous skeleton. This allows them to reconstruct aquatic paleoenvironments in their deposition sites (Stager and Anfang-Sutter, 1999 and Nguestop *et al*., 2004). They are used in the diagnosis of drowning in forensic medicine (Ludes and Coste, 2004). These organisms, sometimes invasive, are increasingly used in criminology, genetics, hydrology, nanotechnology, paleoecology as well as for the production of biofuels (Ector, 2017).

However, there is little research on diatoms in Central Africa in general and in the Democratic Republic of Congo in particular. Researchers give little importance to these microorganisms and more interest to higher plants. Nevertheless, some investigations have been carried out in the rivers of the DRC, the results of which have been published by a few authors. Among the rare cases, we can cite some research carried out in the 20th century by Duvigneaud & Symoens (1949), Kufferath (1956b), Cholnoky (1970), Compère & Symoens (1987), Compère & Symoens (1988), Compère (1989), Golama (1992), Compère (1995) and Golama (1996). Interest in algal flora began with the Belgian-Congolese Boyekoli Ebale Congo expedition in 2010, which covered 250 km of the Congo River and some tributaries between Kisangani and Bumba (Cocquyt and Taylor, 2015; Cocquyt and Taylor, 2016; Karthick *et al*., 2016; Cocquyt *et al*., 2016). Cocquyt and Lokele (2019) recently identified a species *Geissleria lubiluensis* sp. nov. from the Lobilo River in the Yangambi region.

In view of these realities, it is appropriate to conduct investigations to understand the diversity of diatoms in the waters of the DRC in general and in particular in the Kisangani region.

II. Materials and Methods

2.1. Study environment

The city of Kisangani (0° 31′ 09″ North, 25° 11′ 46″ East) is located in the center of the Congo Basin forest, at the confluence of the Lindi, Tshopo, and Congo rivers. Kisangani's low temperature range is characteristic of a tropical climate. The hot season extends from January to March (average temperatures above 30°C). July to November correspond to the coldest period (average temperature below 22°C). The city of Kisangani experiences extreme seasonal variations in monthly rainfall. It can be seen that the greatest rainfall accumulation occurs during the 31 days centered around October 25, with an average total accumulation of 167 millimeters.

The Djubudjubu stream in the Kisangani region of Tshopo Province. This watercourse, located in an urban environment, begins in the commune of Makiso and flows into the Tshopo River through the communes of Tshopo and Mangobo (figure 1). 3.04 km long, its geographical

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coordinates are:

- latitude: 0°32'4.92" North
- longitude: 25°10'33.24" East

2.2. Method

Samples were collected during the rainy season in November 2015 and 2016. The samples consisted of phytoplankton, epipsammons, and epiphytons (on *Pennisetum* sp., *Eicornia crassipes*, *Vossia cuspidata*, and *Comelina diffusa*). They were collected:

- at the source (Lat. 0.521092 and Long. 25.179837), characterized by *Vossia cuspidata* vegetation, dwellings (disposal of various waste), and fish ponds, are located in the Makiso commune in downtown Kisangani.
- in the middle, crossing the Tshopo communes, which have a high population density. There are small gardens, but more household waste and fecal matter are disposed of there;
- at the outfall, the Tshopo and Mangobo communes, which have very high population densities in the city of Kisangani. The dominant vegetation consists of *Eicornia crassipes*, *Vossia cuspidata*, and *Comelina diffusa*. There are also nearby dwellings that frequently defecate and dispose of household waste there.

They were preserved in plastic jars after fixation with 70-degree ethanol and labeled LND0046, LND0047, LND0048, LND0049, LND0050, LND0051, LND0171, LND0172, LND0174, LND0175, LND0177, and LND0178. They underwent oxidation with 30% hydrogen peroxide. After centrifugation to remove the peroxide, permanent slides were prepared for observation and identification of the diatoms under an electron microscope.

The taxonomic identification and ecological classification of diatoms were based mainly on the work of Krammer & Lange-Bertalot (1986, 1988, 1991) and Taylor & Cocquyt (2016) as well as certain sites such as https://www.algaebase.org and https:///www.diatoms.org.

2.3. Data Analysis

After counting the valves, the relative abundance of species (Pi = ni/N where ni is the number of species of rank i, and N the total number of species counted) was determined. Diatom diversity at the surveyed sites was determined in terms of species richness (SR), Shannon and Weaver's (1949) H' index, and Evenness index E (H' / log2 of S, where S is the number of species or subspecific taxa). The two aforementioned indices were used to express, respectively, the numerical importance of taxa and the even distribution of numbers among the inventoried taxa in order to compare the diversity of diatom populations at different sites (Dajoz, 2000).

Correspondence Factor Analysis (CFA) was used to detect major axes of variation in the data to be analyzed based on the numbers of different specific taxa in the different samples. It should be noted that in this study, individuals with at least 2% specific relative abundance at least one sample were considered.

The Jaccard similarity index (I = Nc / (N1 + N2 - Nc with Nc the number of taxa common to both stations 1 and 2, N1 and N2 the number of taxa present at stations 1 and 2 respectively) was used to determine a comparison between two sites, as it assesses the resemblance between two surveys by calculating the ratio between species common to both surveys and those specific to each survey.

III. Results

3.1. Physicochemical parameters

The results of the physicochemical parameters measurements show that the water temperature of the Djubudjubu stream during this season varies between 24.01 and 24.29°C (an average of 24.14±0.48°C). The highest temperature was recorded in the middle waters compared to all stations (24.29±0.34°C), while it was lower in the source waters (24.01±0.39°C). The temperature differences between the stations were due to the exposure of each station to solar radiation.

The pH values indicate that the waters of this stream are generally slightly acidic with pH values ranging from 6.31 to 6.50 (i.e. 6.43±0.22 on average), the waters of the middle being more acidic than those of the other stations (i.e. 6.31±0.13 on average) while those of the outfall are the least acidic of all (i.e. 6.50±0.18 on average) due to the action of the temperature hydrolyzing the rock on which these waters flow. Concerning electrical conductivity, it is generally high in the waters of Djubudjubu with values between 198.44 and 233.56 µS/cm (i.e. 218.33±66.04 µS/cm on average) being higher in the waters of the source than in those of the other stations (i.e. 233.56±68.83 µS/cm on average) but low in those of the outfall (i.e. 198.44±59.93 µS/cm on average). The observed differences are explained by the action of temperature leading to the mineralization of organic matter. As for the dissolved oxygen content, the waters of this stream contain levels ranging from 0.44 to 4.63 mg/L (i.e. 2.16±2.10 mg/L on average), the waters of the outfall containing more oxygen than those of the other stations (i.e. 4.63±1.52 mg/L on average) while those of the source have less (i.e. 0.44±0.04 mg/L on average). The differences observed are caused by exposure to mixing winds (Table 1).

Table 1. Physicochemical parameters of the waters of Djubudjubu

Parameters	Temp (°C)	pH	Cond (µS/cm)	DO (mg/L)
Source	24,01±0,39	6,44±0,25	233,56±68,83	0,44±0,04
Middle	24,29±0,34	6,31±0,13	216,52±62,15	2,09±1,44
Outfall	24,21±0,62	6,50±0,18	198,44±59,93	4,63±1,52
River	24,14±0,48	6,43±0,22	218,33±66,04	2,16±2,10

3.2. Diatom flora and community structure

Counting diatom valves (with at least 2% cumulative relative abundance in at least one sample) showed that *Pinnularia* sp8 was more abundant than the others (13.68%), followed by species such as *Nitzschia palea* (10.25%), *Navicula cryptocephala* (8.00%), *Hantzschia amphioxys* (7.91%), *Pinnularia brauniana* (5.98%), *Diadesmis* sp2 (4.41%), *Eunotia* sp7 (4.36%), *Halamphora submontana* (2.91%), *Gyorisgma scalproides* (2.64%), *Luticola* sp1 (2.43%), and *Gomphonema augur* var. *turris* (2.11%) (figure 2).

The variations at the station level are such that there is a high abundance in the source waters than in those of the other stations (i.e. 42.69%) followed by the middle waters (i.e. 31.10%) while those of the outfall have less (26.21%) (figure 3).

The results of species identification in this stream revealed 119 species distributed in 38 genera belonging to 24 different families. Of these species, we can cite *Achnanthes inflata* (Kützing) Grunow of the family Achnanthaceae Kützing, *Achnanthidium exiguum* (Grunow) Czarnecki Achnanthidiaceae D.G. Mann, *Aulacoseira granulata*

(Ehrenberg) Simonsen of Aulacoseiraceae R.M. Crawford, *Caloneis bacillum* (Grunow) Cleve, *Cavinula lilandae* Cocquyt, de Haan & J.C. Taylor from Cavinulaceae D.G. Mann, *Cocconeis placentula* Ehrenberg from Cocconeidaceae Kützing, *Craticula cuspidata* (Kützing) D.G. Mann from Stauroneidaceae D.G. Mann, *Cyclotella atomus* Hustedt from Stephanodiscaceae Glezer & Makarova, *Diadesmis confervacea* Kützing from Diadesmidaceae D.G. Mann, *Diploneis subovalis* Cleve of the Diploneidaceae D.G. Mann, *Encyonopsis frequentis* Krammer of the Cymbellaceae Greville, *Eolimna subminuscula* (Manguin) Gerd Moser, Lange-Bertalot & Metzeltin, *Eunotia flexuosa* (Brébisson ex. Kützing) Kützing from Eunotiaceae Kützing, *Fallacia pygmaea* (Kützing) Stickle & D.G. Mann from Sellaphoraceae Mereschkowsky, *Frustulia saxonica* Rabenhorst from Amphipleuraceae Grunow, *Gomphonema affine* Kützing from Gomphonemataceae Kützing, *Gyrosigma scalproides* (Rabenhorst) Cleve from Pleurosigmataceae Mereschkowsky, *Halamphora submontana* (Hustedt) Levkov from Catenulaceae Mereschkowsky, *Hantzschia amphioxys* (Ehrenberg) Grunow from Bacillariaceae Ehrenberg, *Lemnicola hungarica* (Grunow) Round & Achnanthaceae Bassoon Kützing, *Luticola mutica* (Kützing) D.G. Mann from Diadesmidaceae D.G. Mann, *Navicula cryptotenella* Lange-Bertalot from Naviculaceae Kützing, *Neidium affine* (Ehrenberg) Pfitzer from Neidiaceae Mereschkowsky, *Nitzschia palea* (Kützing) W. Smith and *Nitzschia amphibia* Grunow from Bacillariaceae Ehrenberg, *Orthoseira roeseana* (Rabenhorst), Pfizer from Orthoseiraceae R.M. Crawford, *Pinnularia amabilis* Krammer from Pinnulariaceae D. G. Mann, *Placoneis elginensis* (W.Gregory) E.J. Stauroneidaceae D.G. Mann, *Stenopterobia delicatissima* (F.W. Lewis) Brébisson ex Van Heurck des Surirellaceae Kützing…. Some taxa such as *Achnanthes*, *Adlafia*, *Caloneis*, *Cavinula*, *Diadesmis*, *Eunotia*, *Gyrosigma*, *Fragilaria*, *Hantzschia*, *Luticola*, *Navicymbula*, *Nitzschia*, *Pinnularia*, *Placoneis*, *Pseudofallacia*, and *Rhopalodia* could not be determined to species. These will be determined in further research. Families with many species are Bacillariaceae (20.17%), Pinnulariaceae (16.81%), Diadesmidaceae (10.92%), Cymbellaceae (7.56%), Gomphonemataceae (6.72%), Naviculaceae, and Stauroneidaceae (5.88% each). Other families have less than 5.00% species.

This specific richness varies from one station to another. Indeed, it varies from 27 to 51 species, the source containing more species than the other stations while the environment has fewer. The observed differences are explained by the intensity of anthropogenic activities first in the environment and then at the outfall compared to the source. The Shannon and Weaver index (H') varies from 2.23 to 2.84 showing a large in the waters of this stream being higher at the outfall than at the other stations followed by the source. An equidistribution is revealed by the Evenness index (E) with values varying from 0.63 to 0.83, being higher at the outfall than at the other stations followed by the environment (Table 2).

Table 2. Spatial variation of species richness (SR), Shannon and Weaver index (H') and Evenness index (E) along the Djubudjubu stream.

Stations	SR	Shannon and Weaver index (H')	Evenness index (E)
Source	51±15	2,69±0,41	0,63±0,05
Middle	27±15	2,23±0,47	0,72±0,08
Outfall	28±6	2,84±0,33	0,83±0,07

Jaccard similarity showed that samples LND0046 and LND0047 are very close (high similarity), likely from sites with very similar ecological conditions (same substrate type, same pollution level, etc.). LND0048, LND0049, LND0050, and LND0051 form a coherent cluster, indicating a group of ecologically homogeneous samples. LND0174, LND0175, and LND0178 also converge at a high level of similarity; this may be a more natural or contrasting area, depending on the species present. LND0171, LND0172, and LND0177 form another distinct group, moderately similar to each other but more distant from the others. Hierarchical analysis based on diatom community similarity (Figure 4) reveals several ecologically coherent groups. Sites LND0046 and LND0047 show strong similarity, suggesting similar environmental conditions. Conversely, LND0178 is clearly distinct, indicating a specific composition or a different, perhaps more altered or particular, environment.

Observation of this dendrogram shows that the outfall and the source are grouped together first, with a high similarity (approximately 0.60). This means that they share similar ecological characteristics (biological composition, physicochemical parameters, etc.). However, the environment is more distant, linked to the outfall-source group with a lower similarity (approximately 0.37). This indicates a more marked ecological difference.

From an ecological perspective, the outfall and the source could have similar conditions (e.g., water quality, low anthropogenic impact, or similar biological composition). As for the environment, it could present disruptive factors (e.g., pollution, anthropogenic pressure, stagnation, physicochemical variations) explaining its isolation in the dendrogram (figure 5).

Concerning Correspondence Factor Analysis (AFC) of species, the graph representing diatom species in a factorial plane formed by axis 1 (43.79%) and axis 2 (17.93%). These two axes together explain 61.72% of the variance, which is satisfactory for an ecological interpretation. Axis 1 (43.79%) seems to structure the species according to a trophic or pollution gradient with species such as *Nitszchia paleacea* (NIPL), *Pseudofallacia insociabilis* (PSIN), *Orthoseira roeseana* (ORRO), *Eolimna subminuscula* (EOSU), *Gomphonema augur* var. *turris* (GAVT), *Achnanthidium exiguum* (ACEX), *Luticola* sp1 (LUS1), *Diadesmis confervacea* (DICO) and *Nitzschia* cf. *bacata* (NICB) often associated with oligotrophic (nutrient-poor), more natural, or little disturbed environments. In addition, for the same axis (right), we have species like *Halamphora submontana* (HASU), *Humidophila contenta* (HUCO), *Nitzschia amphibia* (NIAM), *Hantzschia* sp1 (HAS1), *Gomphonema pseudoaugur* (GOPS), *Humidophila contenta* var. *constricta* (HCVC), *Sellaphora pupula* (SEPU), *Placoneis exigua* (PLEX), *Encyonopsis microcephala* (ENMI) are known for their tolerance to organic pollution or rich (eutrophic) environments. Axis 2 (17.93%) could reflect a secondary gradient (e.g., current speed, oxygenation, pH) with species such as *Lemnicola hungarica* (LEHU), *Sellaphora pupula* (SEPU), *Placoneis exigua* (PLEX) … generally tolerant, sometimes indifferent to physicochemical variations (at the top of the axis). Species such as *Hantzschia* sp1 (HAS1), *Nitzschia amphibia* (NIAM) and *Diadesmis confervacea* (DICO) may indicate highly disturbed environments, perhaps organically loaded or anoxic. In the center of the graph, species very close to the center are *Nitzschia* cf. *bacata* (NICB), *Nitzschia* sp1 (NIS1), *Craticula cuspidata* (CRCU)… are generalist or ubiquitous species, present in several types of habitats without marked ecological value (figure 6a).

Concerning the samples, the AFC analysis shows that axis 1 (26.08%) expresses the largest part of the variation. It could reflect a trophic gradient (from oligotrophic to eutrophic zones) or an organic pollution gradient, depending on the dominant species in each sample. Thus, at the top left, we have the ecologically close samples LND0050, LND0051, LND0049, probably from moderately disturbed to rich environments, with indicator diatoms of average quality. At the bottom left of this axis we have samples LND0047 and LND0178 (genera *Nitzschia*, *Hantzschia*… potentially altered areas, rich in pollutant-tolerant species, perhaps eutrophic or weakly oxygenated conditions. Axis 2 (47.61%) expresses another important part of the variability, perhaps linked to oxygenation, current speed, or conductivity. At the top right sample LND0172 is far from the others and may indicate a specific profile, possibly of good ecological quality or influenced by a factor (source, low organic load, etc.). At the bottom right, samples LND0174 and LND0175 are also isolated, potentially very different conditions, e.g., high organic pollution or physical modification of the environment. In short, the arrangement of the points shows that some sites share a similar floristic composition, suggesting close water quality (e.g., LND0051, LND0049, LND0177). Samples scattered on the edges (LND0047, LND0175, LND0172) indicate contrasting or even extreme ecological conditions. The separation on the horizontal axis may be related to a pollution gradient (phosphates, nitrates, BOD), while the vertical axis may reflect hydrology (flowing *vs*. stagnant water, sunlight level or pH) (Figure 6b).

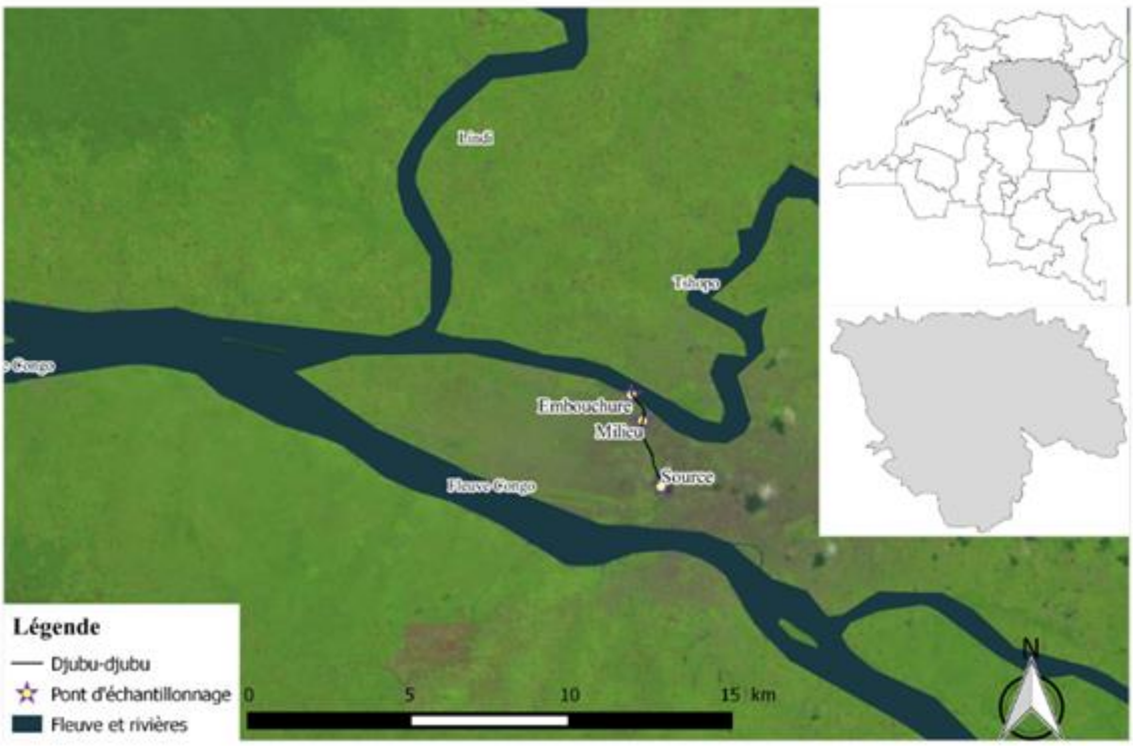
At the station level, axis 1 (61.20%) and axis 2 (25.06%) account for more than 86% of the variance, which is excellent: the representation is faithful to the data structure. The Source is associated with NACR (*Navicula cryptocephala*), indicating that this species is strongly represented at the source. The Middle is associated with NIPA (*Nitzschia palea*) and PIS8 (*Pinnularia* sp8); these are species tolerant to organic pollution, suggesting an anthropogenic impact or moderate eutrophication in the middle of the river. The outfall shows a certain ecological resemblance with the middle. NACR (*Navicula cryptocephala*) is an indicator of good ecological conditions, well correlated with the Source. NIPA, PIS8 (*Pinnularia* sp8), HASU (*Halamphora submontana*), GAVT (*Gomphonema augur* var. *turris*) are species often associated with nutrient-enriched or disturbed environments, characteristic of downstream areas. Other species are ubiquitous and can be found in all stations. These are species such as *Aulacoseira ambigua* (AUAM), *Luticola mutica* (LUMU), *Sellaphora pupula* (SEPU), *Halamphora submontana* (HASU), *Nitzschia paleacea* (NPAC), *Humidophila contenta* (HUCO), *Diadesmis* sp2 (DIS2), *Gyrosigma scalproides* (GYSC), *Gomphonema parvulum* (GOPA), *Eunotia* sp7 (EUS7). This graph suggests an ecological gradation from the source to the downstream, with a decrease in ecological quality from the source site towards the middle and the outfall, illustrated by the diatomic composition (figure 7). These observations support the use of diatoms as effective bioindicators of freshwater quality, their composition reflecting environmental variations along the river.

3.4. Discussions

The study of the diatom flora of the Djubudjubu stream revealed the existence of great diversity, with species richness and relative abundance varying from one station to another. Concerning the physicochemical parameters, Salam *et al*. (2024) observed that the variation of physicochemical parameters (salinity, pH and dissolved oxygen) is significantly influenced by the season but also by the stations. They found that salinity, pH and dissolved oxygen are significantly influenced by the season while these variations are not significant between stations. The assemblages formed and the similarities reflect the physicochemical variation along this stream. Compared to the present study, a total of 150 diatom species were observed belonging to 70 genera was inventoried in a study conducted in Senegal and Gambia (Senegambia). The microflora is dominated everywhere by *Cyclotella striata* except in Néma Ba where it admits *Nitzschia granulata* as co-dominant. Euryhaline species dominate everywhere and confirm the dual marine/freshwater influence, the degree of which has varied over time and space (Gueye & Sow, 2023). Gueye *et al*. (2022) inventoried 89 species and varieties of diatoms belonging to 48 genera. The most represented genera are *Nitzschia* (11 species), *Coscinodiscus* (7 species), *Amphora* and *Navicula* (4 species each). Some freshwater species encountered are represented mainly by *Cyclotella meneghiniana* and the genera *Aulacoseira* (*Aulacoseira ambigua*, *A. granulata* and *A. distans*), *Cocconeis placentula*, *Cyclotella meneghiniana*, *Craticula cuspidata*, *Nitzschia* (*Nitzschia palea*, *N. amphibia* and *N. sigma*), *Navicula cryptocephala*, *Pinnularia gibba*…. The difference with the present study is explained by the difference in climatic conditions determining the physicochemical variables in the waters marine. However, some species such as *Aulacoseira ambigua*, A. *granulata*, *Cyclotella meneghiniana*, *Craticula cuspidata*, *Nitzschia palea*, *N. amphibia* and *N. sigma*, *Navicula cryptocephala*… were also identified in the waters of Djubudjubu where the diatom samples for this investigation came from. The type of substrate on which benthic diatoms develop is also a physical parameter that structures the composition of the communities (Rimet, 2020). The observed differences are due to the climates (temperate and tropical) which determine the physicochemical parameters of the watercourses in each region. The specific richness and relative specific abundance of diatoms depend on decomposing organic matter that adapts to pollution. For this purpose, α-meso/polysaprobic species such as *Nitzchia palea*, *Gomphonema parvulum*, *G. gracile*, *Hantzschia amphioxys*, *Pinnularia subcapitata* are found at different stations where the waters are eutrophic as reported by Leland and Porter (2000). They are also explained by the regions and seasons studies as well as other parameters such as nutrient and organic matter contents, water flow speed having a negative impact on the colonization of substrates which have an influence on the diversity, relative abundance and assemblages of diatoms as well as their spatial distribution (Leland and Porter, op.cit.). The study conducted by Gallut *et al*. (2024) revealed spatial variability (phytoplankton communities in heterogeneous harbor) and temporal variability of phytoplankton communities (variable from one year to another). These results are explained by the presence of certain nutrients as well as the increase or decrease in salinity and temperature and dependent on the circulation of water masses. In a study of the relationship between the carbonate system and the phytoplankton community in the Gulf of Guinea-Africa, it was proven that physical (temperature, salinity) and chemical (total alkalinity, dissolved inorganic carbon, pH) parameters influenced, in general, less than 50% of the population phytoplankton of the Gulf coastal zone and in particular, the Bacillariophyta population when the variability of physicochemical parameters increases (Koffi *et al*., 2024). Salam *et al*. (2024) counted 189 species of diatoms whose specific richness and abundance vary according to the season in the Marine Protected Areas in Senegal where, for all stations and seasons combined, Bacillariophytes represented 189 species. Khaoula *et al*. (2023) identified 24 species of phytoplankton among which 31% of diatoms in Lake Tonga in Algeria. Amaral *et al*. (2024) identified 221 species of diatoms at the infrageneric level. *Pinnularia* was the most representative genus in terms of number of species (28 spp.), followed by *Eunotia* (25 spp.), *Gomphonema* (17 spp.), *Nitzschia* (14 spp.) and *Navicula* (11 spp.) in the Cascavel River in southern Brazil.

3.5. Conclusion

Investigations carried out on the diatomic flora of the Djubudjubu stream located in an urban environment reveal a great richness and diversity of species forming this group of organisms in response to the environmental conditions prevailing along this watercourse at each station.



USGS 2024

Fig. 1. Map of the Djubudjubu stream

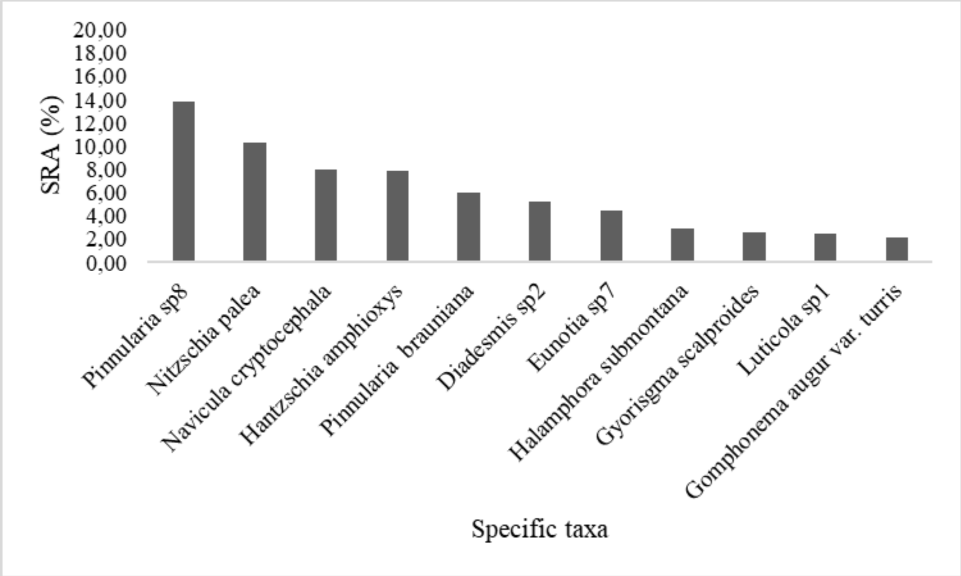


Fig. 2. Specific relative abundances of diatoms from Djubudjubu

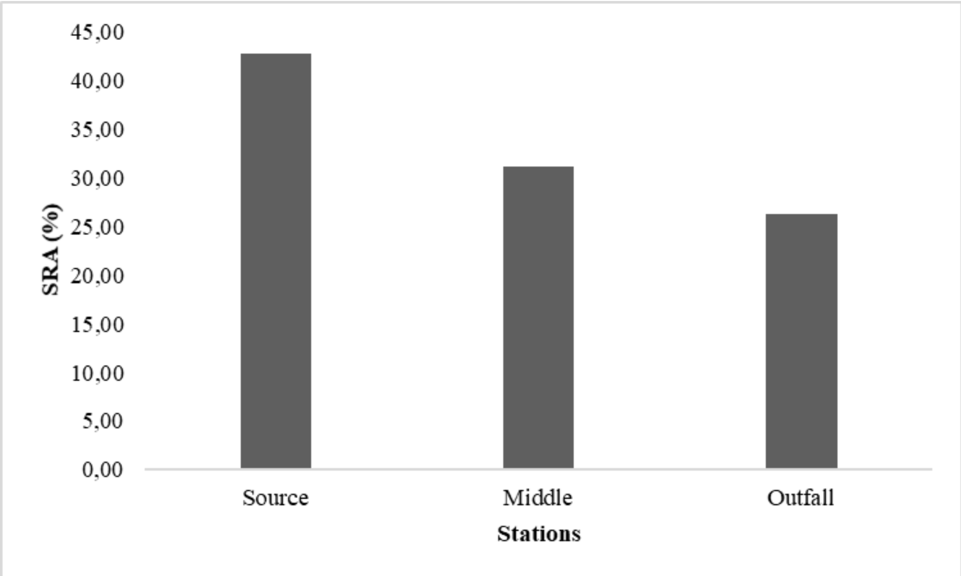


Fig. 3. Variation of specific relative abundances (SRA) at the station level.

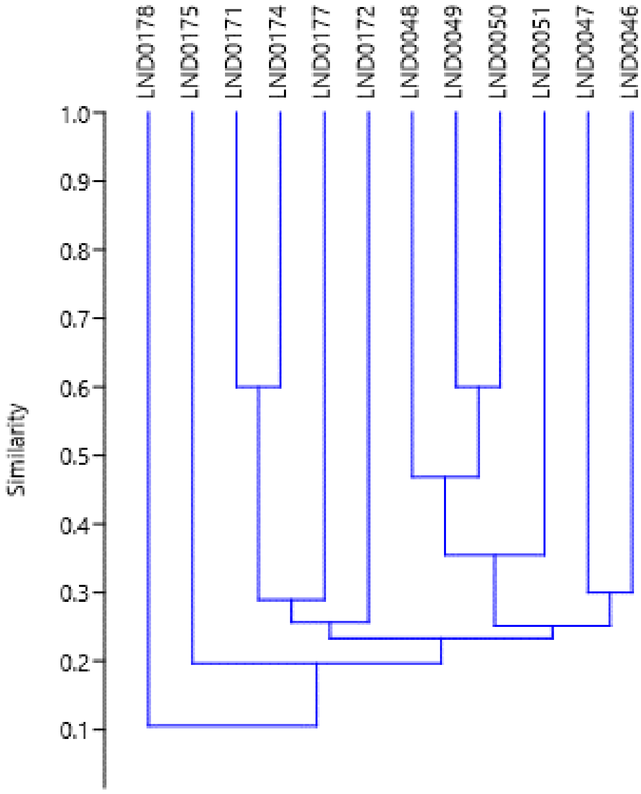


Fig. 4. Jaccard similarity of diatom samples.

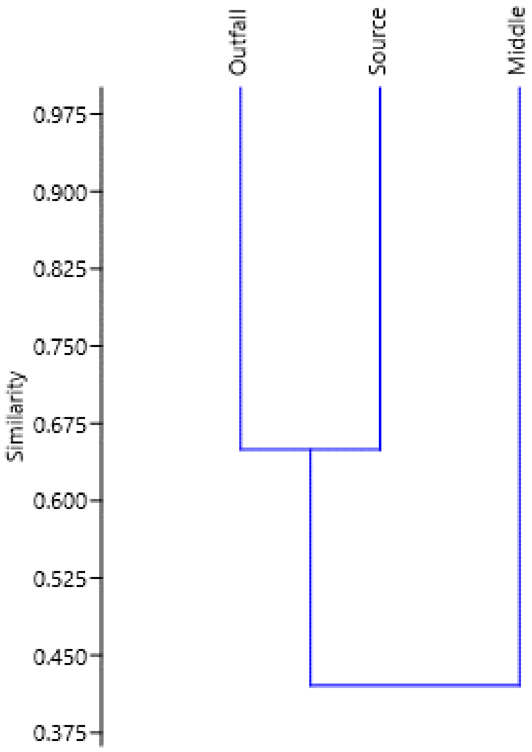
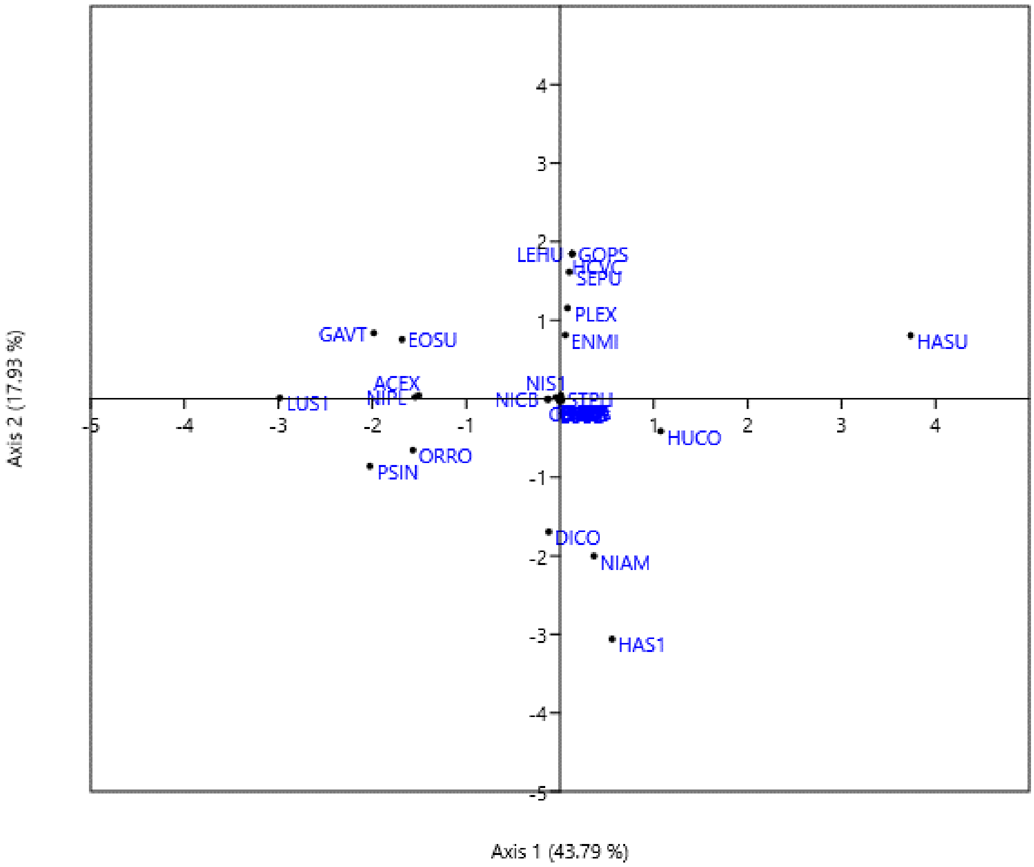


Fig. 5. Jaccard similarity of diatoms at station level.

a. Species of diatoms (axes 1 and 2 : 61,72 %)



b. Samples of diatoms (axes 1 and 2 : 61,72 %)

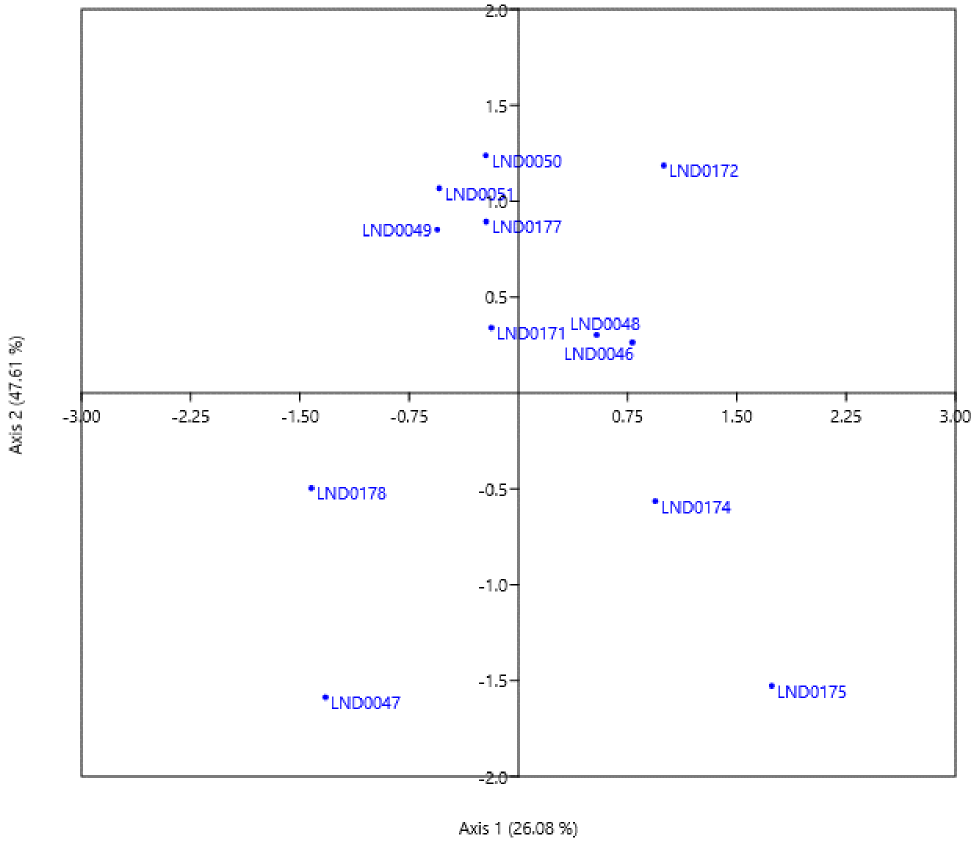


Fig. 6. Correspondence Factor Analysis (CFA) : a. diatoms. b. samples from Djubudjubu.

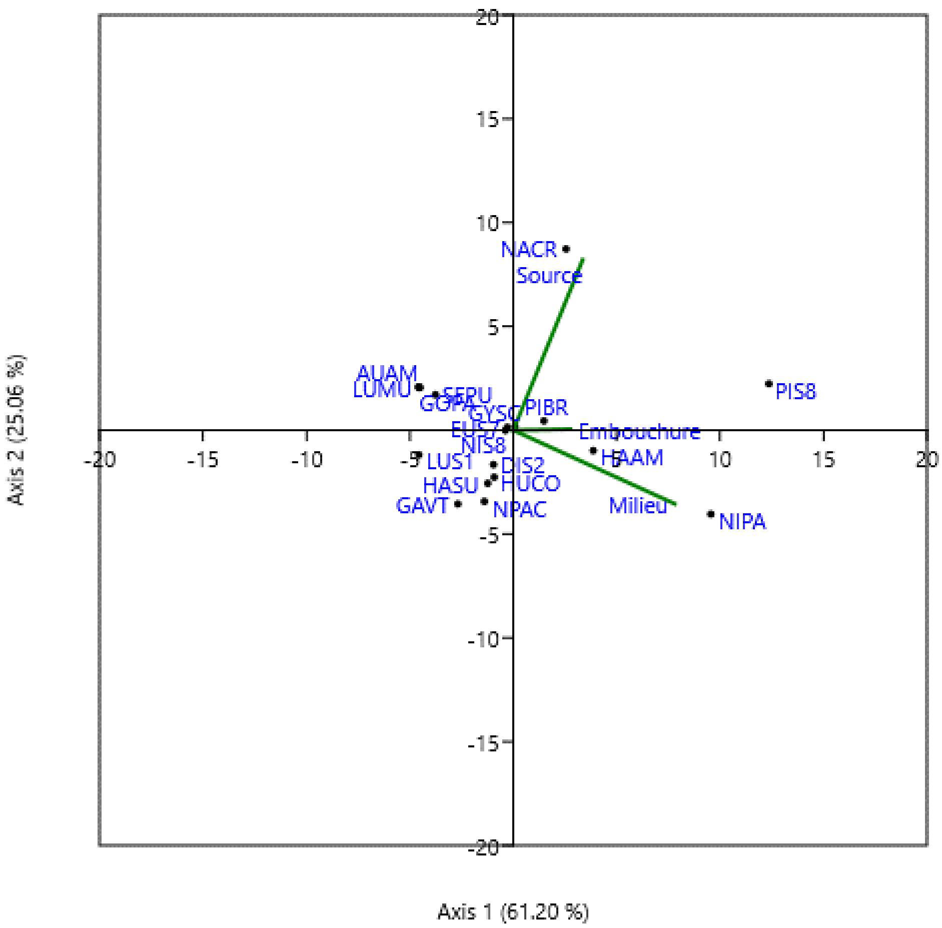


Fig. 7. Correspondence Factor Analysis (CFA) of diatoms at the station level

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