



Diatoms Flora from a Shallow Reservoir in Ivory Coast

**Blé Alexis Tardy Kouassi^{1*}, Koffi Komoé², Marie Paulette Adon³
and Allassane Ouattara⁴**

¹*UFR Biological Sciences, Peleforo Gon Coulibaly University, P. O. Box 1328, Korhogo, Côte d'Ivoire.*

²*Laboratory of Botany, Félix Houphouët-Boigny University, P. O. Box 1328, Korhogo, Abidjan, Côte d'Ivoire.*

³*Laboratory of Hydrobiology and Fishery Resources, Jean Lorougnon Guede University, P. O. Box 150, Daloa, Côte d'Ivoire.*

⁴*Laboratory of Environment and Aquatic Biology, Nangui Abrogoua University, 02 P. O. Box 801, Abidjan, Côte d'Ivoire.*

Authors' contributions

This work was carried out in collaboration among all authors. Authors BATK and KK designed the study, performed the fields analysis, wrote the protocol and the first draft of the manuscript. Authors MPA and AO managed the identification of Diatoms taxa. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2021/v27i230360

Editor(s):

(1) Prof. Prinya Chindapasirt, Khon Kaen University, Thailand.

Reviewers:

(1) Pablio Henrique Costa dos Santos, Federal University of Pará, Brazil.

(2) Camila Leão Roland, Universidade Federal Fluminense, Brazil.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/67287>

Received 17 February 2021

Accepted 14 April 2021

Published 22 April 2021

Original Research Article

ABSTRACT

The diatoms flora of Adzopé Reservoir in Côte d'Ivoire was investigated from January to December 2005. The species composition of the assemblage was compiled, accompanied by illustrations. Forty-one taxa were identified in the temporal survey. Five taxa (16.3%) were new for Côte d'Ivoire. Eleven common species, 9 occasional taxa and 11 rare taxa were also recorded. No spatial variations in the taxonomic composition of the populations of diatoms were found. Variations were encountered in the seasonal analysis. Variation in the dimensions of some identified taxa have been observed. The species richness of Diatoms in the Adzopé Reservoir was in relation with water current velocity.

*Corresponding author: E-mail: alexis1tardy@yahoo.fr;

Keywords: Diatoms; taxonomy; reservoir; Adzopé; Ivory Coast.

1. INTRODUCTION

Diatoms are unicellular, eukaryotic algae, best known for their characteristic silica-based cell wall called a frustule. They might be solitary or colonial, with some diatoms remaining suspended within the aquatic habitat while other forms of diatoms are settled within the sediment, where they are a major food source for grazing protozoa and animals [1]. Fast-reproducing organisms, most diatoms are widespread on different substrates and are closely associated with a certain microbiotope. Due to their sessile nature and fast growth rate [2], diatoms are very useful for studying the impact of various forms of pollution such as the discharge of waste water, treated sewage effluents and organic and inorganic nutrients [3]. They may promptly indicate adverse changes in main biotopic conditions determined by natural environmental processes and anthropogenic impact [4]. They are so valuable indicators of environmental conditions because they respond directly and sensitively to many physical, chemical, and biological changes in aquatic ecosystems [5-7]. Due to this, Diatoms have proven to be extremely powerful tools to explore and interpret many ecological conditions. They are also used for monitoring the environmental conditions of water in many countries in Europe [8].

Although diatoms are recognized as being the best bioindicators [9], little is known about Diatoms in Adzopé reservoir in Côte d'Ivoire. This reservoir, surrounded by urban development, is a shallow raw potable water reservoir, influenced by a diverse variety of anthropogenic activities. The aim of this study is to provide a taxonomic and floristic account, and to try to understand the species richness of the Adzopé Reservoir diatoms.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The area has four seasons as shown in Fig. 1: the long dry season (December-February), the long rainy season (March-July); the short dry season (August) and the short rainy season (September-November) [10]. The reservoir as shown in Fig. 2, located at 6°06'N and 3°51'E, lies in an urban area of the city of Adzopé, in the south-east of Côte d'Ivoire that belongs to the subequatorial zone [11]. It has a surface area of

61.44 ha. The reservoir has a maximum depth of 7 m and a length of about 2 km. It has no permanent inflowing streams, but there is an overflow channel at its southern end. The sources of water inputs are seasonal, usually being direct precipitation in the form of rainfall.

The reservoir was built in 1977 for water supplementation. Two sampling stations (St1 and St2) were sampled according to the longitudinal gradient as shown in Fig. 2.

2.2 Physicochemical Parameters

Some physicochemical measurements were made in the field immediately after each sample was collected. The Conductimeter Aqualitic CD24 was used to assess water temperature and conductivity. Dissolved oxygen was measured with the Oxymeter Aqualitic OX24, and pH with the pHmeter Aqualitic, pH24. For nutrients (orthophosphates and nitrates), subsamples of 30 ml were collected and refrigerated for later analysis according to the standard methods AFNOR T90-23 and T90-110. The water transparency (Z_{SD}) and the the water current velocity were measured *in situ*, using a white Secchi disk and a Lightweight Current meter model 106 respectively.

2.3 Sampling, Preparation, and Data Analysis

Diatoms communities were assessed both by sampling natural (stones and leaves of *Nymphaea lotus*) and artificial (glass fragments and pieces of wood) substrates located at well-illuminated places. Algae were removed monthly by scraping the substrates with razor blades. Other samples were collected with 20 μ m mesh plankton net at surface level. Diatom valves were cleaned by hot nitric acid in order to remove the organic material and were embedded in Naphrax resin. For qualitative analysis an Olympus BX40 microscope, equipped with a Canon camera was used. Species were identified according to the relevant taxonomic guides [12-17].

In average, 50 organisms were used for measurements. The frequency of each species present was determined according to [18]. Three frequency groups were distinguished according to value of frequency (F) : 1) common species (F > 50%) ; 2) occasional species (25% < F < 50 %) ; 3) rare species (F < 25%)..

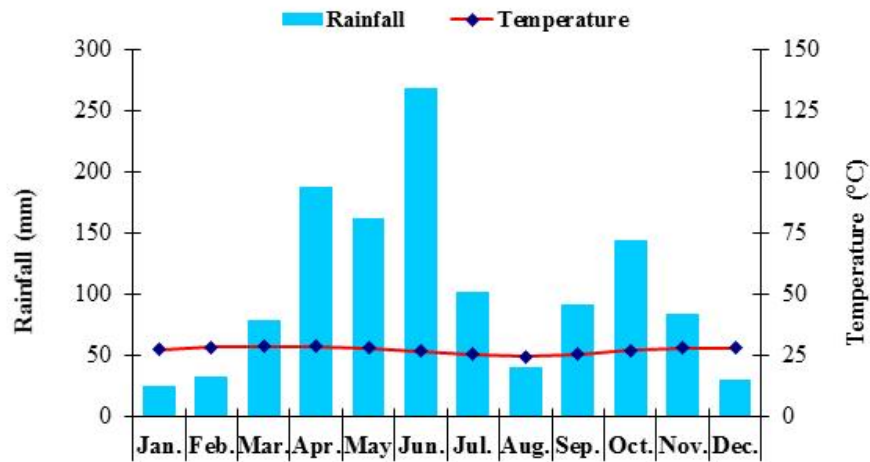


Fig. 1. Climate graph of Adzopé area

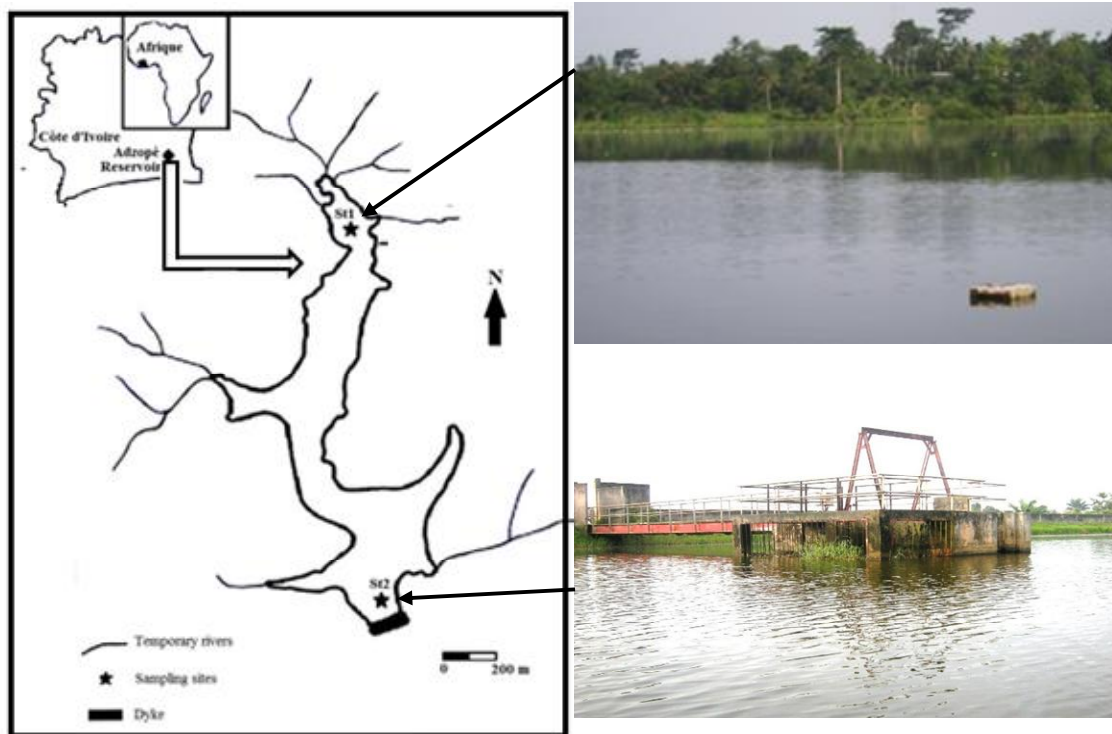


Fig. 2. Localization of Adzopé reservoir with sampling sites

In taxonomic part, for each taxon, the latin name with authors name (s), a year of description and reference to the illustration (s) in the iconographic part are given. The morphology (Morph.) in which the length and width of valves, the number of striae or fibulae are also given. The habitat in which the taxon has been harvested is given (planktic, epilithic, epiphytic,)

based on own observations is presented in Ecology (Ecol.) section. Finally, the stations where the taxon is observed and the geographic distribution of each taxon are also given in Distribution (Distr.) section. Taxa indicated by an asterisk are reported for the first time in Côte d'Ivoire. The taxa are arranged following the classification of [19].

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physicochemical parameters

The physicochemical parameters at the two sampling stations (St1 and St2) throughout the seasons are summarized in Table 1.

The reservoir water temperature fluctuated between 23.3 °C during the short dry season and 30.13 °C during the short rainy season. The conductivity exhibited a low fluctuation throughout the seasons. Its values varied from 190.44 $\mu\text{S}\cdot\text{cm}^{-1}$ in long dry season to 164.78 $\mu\text{S}\cdot\text{cm}^{-1}$ during long rainy season. The lowest average value of dissolved oxygen (1.99 $\text{mg}\cdot\text{L}^{-1}$) was measured during the long dry season, then the highest (4.37 $\text{mg}\cdot\text{L}^{-1}$) was in the long rainy season. The measured pH varied around the neutral value 7. The lowest average values of pH were obtained during short dry season. The water transparency was essentially low (ZSD min = 35.69 cm, ZSD max = 80 cm), probably reflecting the high turbidity of the lake. The highest water transparency values were measured during the short dry season. The lowest water current velocity value (0.08 $\text{m}^3\cdot\text{S}$) was measured during the long dry season, then the highest (0.38 $\text{m}^3\cdot\text{S}$) was in the long rainy season. The Reservoir is characterized by high concentrations of nitrate and orthophosphates. The maximum concentration of nitrates (NO_3^-) and orthophosphates (PO_4^{3-}) values were 2.54 $\text{mg}\cdot\text{L}^{-1}$ and 1.68 $\text{mg}\cdot\text{L}^{-1}$, respectively. The minimum values of these parameters were below the limit of detection.

3.1.2 Taxonomy

The Following taxa were identified

Class: Coscinodiscophyceae Round & R.M.Crawford

Order: Aulacoseirales R.M.Crawford
Family: Aulacoseiraceae R.M.Crawford
Genus: *Aulacoseira* Thwaites

Aulacoseira granulata (Ehrenberg) Simonsen, 1979 (Fig. 3).

Morph.: Valves diameter: 3-5 μm , mantle height 15-26 μm ; mantle with areolae curved to the right or straight and parallel to perivalvar axis ; **Ecol.:** Planktic, epipellic and epilithic **Distr.:** St1 & St2, Cosmopolitan.

Aulacoseira granulata* var. *angustissima (O.F. Müller) Simonsen, 1979 (Fig. 4).

Frustule identical to *Aulacoseira granulata* but terminal valves with 1 or 2 spines very long, almost equal in length to the valve mantle ; Planktic, epipellic and epilithic ; **Distr.:** St1 & St2, Cosmopolitan.

Class: Bacillariophyceae Haeckel
Order: Lcmophorales Round
Family: Ulnariaceae E.J.Cox
Genus: *Ulnaria* (Kützing) Compère

***Ulnaria biceps* (Kützing) Compère 2001** (Fig. 5)

Morph.: Valve length: 150-220 μm , width: 7-9 μm , 7-9 striae in 10 μm . **Ecol.:** Planktic, epipellic, epiphytic ; **Distr.:** St2, Subcosmopolitan.

***Ulnaria ulna* (Nitzsch) Compère 2001** (Figs. 6-7)

Morph.: Valve length: 94-110 μm , width: 4-6 μm , 12-13 striae in 10 μm . **Ecol.:** Planktic, epilithic, epiphytic ; **Distr.:** St1 & St2, Cosmopolitan.

Order: Eunotiales Silva
Family: Eunotiaceae Kützing
Genus: *Eunotia* Ehrenberg

***Eunotia bilunaris* (Ehrenberg) Schaarschmidt 1880** (Fig. 8)

Morph.: Valve length: 40-45 μm , width: 3-4 μm , 24-26 striae in 10 μm ; **Ecol.:** Planktic, epilithic ; **Distr.:** St2 , Cosmopolitan.

***Eunotia minor* (Kützing) Grunow in Van Heurck 1881** (Fig. 9)

Morph.: Valve length: 30-50 μm , width: 5-6 μm , 13-17 striae in 10 μm . **Ecol.:** Planktic, epilithic, epiphytic ; **Distr.:** St1 & St2 , Cosmopolitan.

***Eunotia pectinalis* (Kützing) Rabenhorst 1864** (Fig. 10)

Morph.: Valve length: 92-96 μm , width: 12-14 μm , 10-12 striae in 10 μm . **Ecol.:** planktic, epilithic & epiphytic; **Distr.:** St1 & St2, Cosmopolitan.

***Eunotia soleirolii* (Kützing) Rabenhorst 1864** (Fig. 11)

Morph.: Valves linear, slightly arcuate, Valve length: 33-37 μm , width: 4-5 μm , 17-19 striae in 10

µm. **Ecol.:** planktic, epilithic & epiphytic; **Distr.:** St1 & St2, Cosmopolitan.

Order: Cymbellales D.G.Mann
Family: Gomphonemataceae Kützing
Genus: *Encyonema* Kützing

***Encyonema elginense* (Krammer) D.G.Mann in Round, R.M.Crawford & D.G.Mann 1990** (Fig. 12)

Morph.: Valve length: 32-60 µm, width: 8-16 µm, 7-10 striae in 10 µm. **Ecol.:** epilithic; **Distr.:** St2, Cosmopolitan.

***Encyonema silesiacum* (Bleisch) D.G.Mann in Round, R.M.Crawford & D.G.Mann 1990** (Fig. 13-15)

Morph.: Valve length: 28-45 µm, width: 8-11 µm, 11-12 striae in 10 µm. **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

***Encyonema cf. gracilis* (Ehrenberg) Kützing** (fig. 16)

Morph.: Valve length: 52-60 µm, width: 8-10 µm, 9-10 dorsal striae in 10 µm, 13-15 ventral striae in 10 µm. **Ecol.:** epilithic; **Distr.:** St2.

Genus : *Gomphonema* Ehrenberg

***Gomphonema affine* Kützing 1844** (Fig. 17-19)

Morph.: Valve length: 30-47 µm, width: 8-10 µm, 10-13 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan

****Gomphonema brasiliense* Grunow 1878** (Fig. 20)

Morph.: Valve length: 28-35 µm, width: 4-6 µm, 12-13 striae in 10 µm. **Ecol.:** epilithic; **Distr.:** St2, paleotropical.

****Gomphonema dichotomum* Kützing 1834** (Fig. 21)

Morph.: Valve length: 75-90 µm, width: µm, 9-14 striae in 10 µm. **Ecol.:** epilithic; **Distribution:** St2, Cosmopolitan.

***Gomphonema gracile* Ehrenberg 1838** (Fig. 22)

Morph.: Valve length: 45-78 µm, width: 8-12 µm, 10-13 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

***Gomphonema olivaceum* (Hornemann) Kützing 1838** (Fig. 23)

Morph.: Valve length: 32-38 µm, width: 10-12 µm, 13 striae in 10 µm; **Ecol.:** epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

***Gomphonema parvulum* (Kützing) Kützing 1849** (Fig. 24-26)

Morph.: Valve length: 19-25 µm, width: 6-8 µm, 14-16 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

Gomphonema sp.1 (Fig. 27)

Morph.: Valve length: 30-35 µm, width: 5-6 µm, 10-11 striae in 10 µm; **Ecol.:** epilithic, epiphytic, **Distr.:** St2.

Gomphonema sp.2 (Fig. 28)

Morph.: Valve length: 51-58 µm, width: 9-13 µm, 11 striae in 10 µm; **Ecol.:** epilithic, epiphytic, **Distr.:** St1 & St2

Genus : *Placoneis* Mereschkowsky

****Placoneis pseudanglica* E.J.Cox 1988** (Fig. 29)

Morph.: Valve length: 30-34 µm, width: 10-13 µm, 14-15 striae in 10 µm. **Ecol.:** epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

Order: Naviculales Bessey

Family: Diploneidaceae D.G.Mann

Genus: *Diploneis* Ehrenberg ex Cleve

****Diploneis subovalis* Cleve 1894** (Fig. 30)

Morph.: Valve length: 19-25 µm, width: 9-12 µm, 24 striae in 10 µm; **Ecol.:** epilithic, epiphytic, **Distr.:** St2, Subcosmopolitan.

Family: Naviculaceae Kützing

Genus: *Caloneis* Cleve

****Caloneis lauta* J.R.Carter 1981** (Fig. 31)

Morph.: Valve length: 24-26 µm, width: 6-8 µm, 24 striae in 10 µm; **Ecol.:** epilithic, epiphytic, **Distr.:** St2, Cosmopolitan.

Genus: *Navicula* Bory

Table 1. Physicochemical parameters during the study

Sampling station	Season	Temperature (°C)	Conductivity (µS.cm ⁻¹)	Dissolved oxygen (mg.L ⁻¹)	pH	Transparency (cm)	Nitrates (mg.L ⁻¹)	Orthophosphates (mg.L ⁻¹)	Current velocity (m ³ .S ⁻¹)
St1	LDS	27.66	170.4	3.31	8.21	60	0.8	0.17	0.08
	LRS	26.4	171	3.61	7.2	35,69	0.4	-	0.38
	SDS	23.3	182.1	2.17	7.4	80	0.6	0.15	0.28
	SRS	29.31	181.44	3.09	7.39	42.33	-	0.04	0.22
St2	LDS	29.76	190.44	1.99	8.2	53.33	2.54	0.28	0.18
	LRS	27.9	164.78	4.37	7.56	40.8	0.40	-	0.32
	SDS	25.6	183.6	2.02	6.1	62	1.1	1.68	0.28
	SRS	30.13	176	3.2	7.56	51.34	0.5	0.11	0.24

Table 2. List of taxa observed in the Adzopé Reservoir (F: species occurrence frequency, * presence, LDS: long dry season, LRS: long rainy season, SDS: short dry season, SRS: short rainy season, Dist.: Distribution, Plan. Plankthic, Epil.: Epilithic, Epip.:Epiphytic)

	St1	St2	Dist.	F	Plan.	Epil.	Epip.	LDS	LRS	SDS	SRS
<i>Aulacoseira granulata</i>	*	*	C	1	*	*	*	*			*
<i>Aulacoseira granulata</i> var. <i>angustissima</i>	*	*	C	1		*	*	*		*	
<i>Ulnaria biceps</i>		*	Sc	3	*	*	*	*			*
<i>Ulnaria ulna</i>	*	*	C	2	*	*	*	*		*	
<i>Eunotia bilunaris</i>		*	C	3		*		*	*	*	*
<i>Eunotia minor</i>	*	*	C	2	*	*	*	*		*	
<i>Eunotia pectinalis</i>	*	*	C	2		*	*	*	*		*
<i>Eunotia soleirolii</i>	*	*	C	3	*	*	*	*	*	*	*
<i>Encyonema elginense</i>		*	C	1		*		*	*	*	*
<i>Encyonema silesiacum</i>	*	*	C	3	*	*	*	*		*	
<i>Encyonema</i> cf. <i>gracilis</i>		*		1		*					
<i>Gomphonema affine</i>	*	*	Sc	3	*	*	*	*		*	*
<i>Gomphonema brasiliense</i>		*	P	3	*	*		*		*	*
<i>Gomphonema dichotomum</i>		*	C	2		*					
<i>Gomphonema gracile</i>	*	*	C	3	*	*	*	*		*	
<i>Gomphonema olivaceum</i>	*	*	C	2		*	*	*	*	*	*
<i>Gomphonema parvulum</i>	*	*	C	1	*	*	*	*			
<i>Gomphonema</i> sp.1	*	*		2		*	*	*		*	*

	St1	St2	Dist.	F	Plan.	Epil.	Epip.	LDS	LRS	SDS	SRS
<i>Gomphonema</i> sp.2		*		1		*	*	*		*	
<i>Placoneis pseudanglica</i>	*	*	C	1	*	*	*	*	*		*
<i>Diploneis subovalis</i>		*	Sc	1		*	*	*	*	*	*
<i>Caloneis lauta</i>		*	C	1		*	*	*	*	*	*
<i>Navicula cryptocephala</i>	*	*	C	3	*	*	*	*		*	
<i>Pinnularia acrosphaeria</i>	*	*	C	1	*	*	*	*		*	
<i>Pinnularia divergens</i>	*	*	C	1	*	*	*	*			
<i>Pinnularia interrupta</i>	*	*	C	2	*	*	*	*		*	
<i>Pinnularia microstauron</i>	*	*	C	2	*	*	*	*		*	
<i>Sellaphora pupula</i>	*	*	C	2		*	*	*	*	*	*
<i>Amphora</i> cf. <i>fogediana</i>		*	C	1	*	*	*	*	*		
<i>Nitzschia amphibia</i>	*	*	C	3	*	*	*	*	*	*	*
<i>Nitzschia palea</i>	*	*	C	3	*	*	*	*	*	*	*
	21	31			21	31	26	29	12	22	16

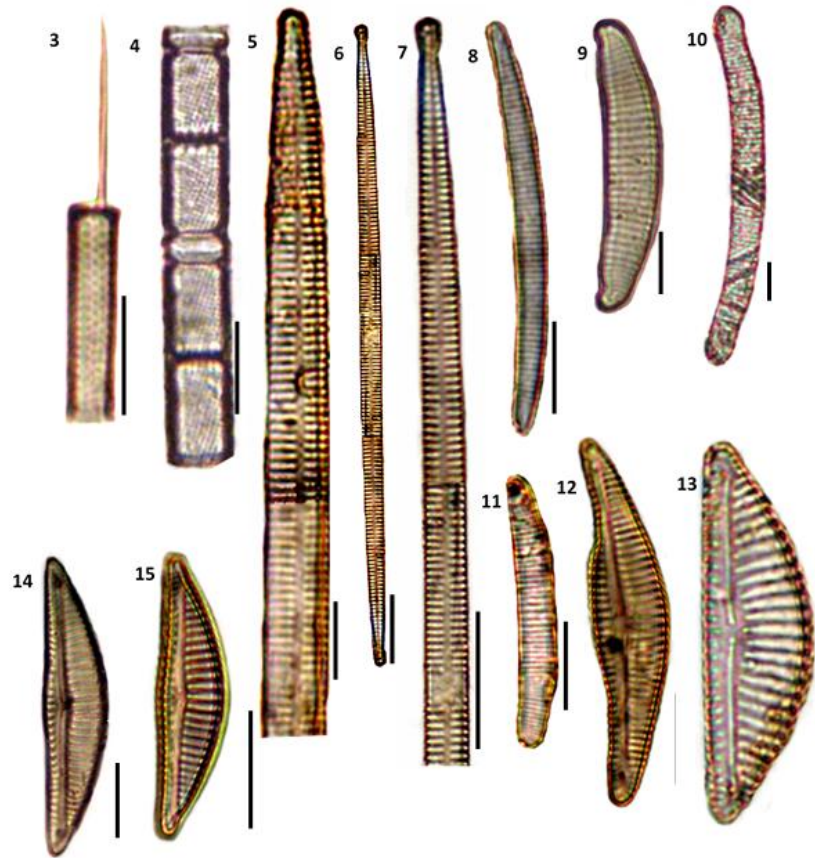


Fig. 3. *Aulacoseira granulata*, 4-*Aulacoseira granulata* var. *angustissima*, 5-*Ulnaria biceps*, 6-7-*Ulnaria ulna*, 8- *Eunotia bilunaris*, 9-*Eunotia minor*, 10-*Eunotia pectinalis*, 11-*Eunotia soleirolii*, 12-*Encyonema elginense*, 13-15-*Encyonema silesiacum*

***Navicula cryptocephala* Kützing 1844** (Figs. 32-33)

Morph.: Valve length: 28-35 µm, width: 6-7 µm, 16-17 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

Family: Pinnulariaceae D.G. Mann

Genus: *Pinnularia* Ehrenberg nom. cons.

***Pinnularia acrosphaeria* W. Smith, 1853** (Fig. 34)

Morph.: Valve length: 50-80 µm, width: 10-12 µm, 13-14 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

***Pinnularia divergens* W. Smith 1853** (Fig. 35)

Morph.: Valve length: 100-110 µm, width: 14-15 µm, 13-14 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

***Pinnularia interrupta* W. Smith 1853** (Fig. 36)

Morph.: Valve length: 40-52 µm, width: 6-7 µm, 13-14 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

***Pinnularia microstauron* (Ehrenberg) Cleve 1891** (Fig. 37)

Morph.: Valve length: 54-60 µm, width: 11-12 µm, 13-14 striae in 10 µm; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

Family: Sellaphoraceae Mereschkowsky

Genus: *Sellaphora* Mereschkowsky

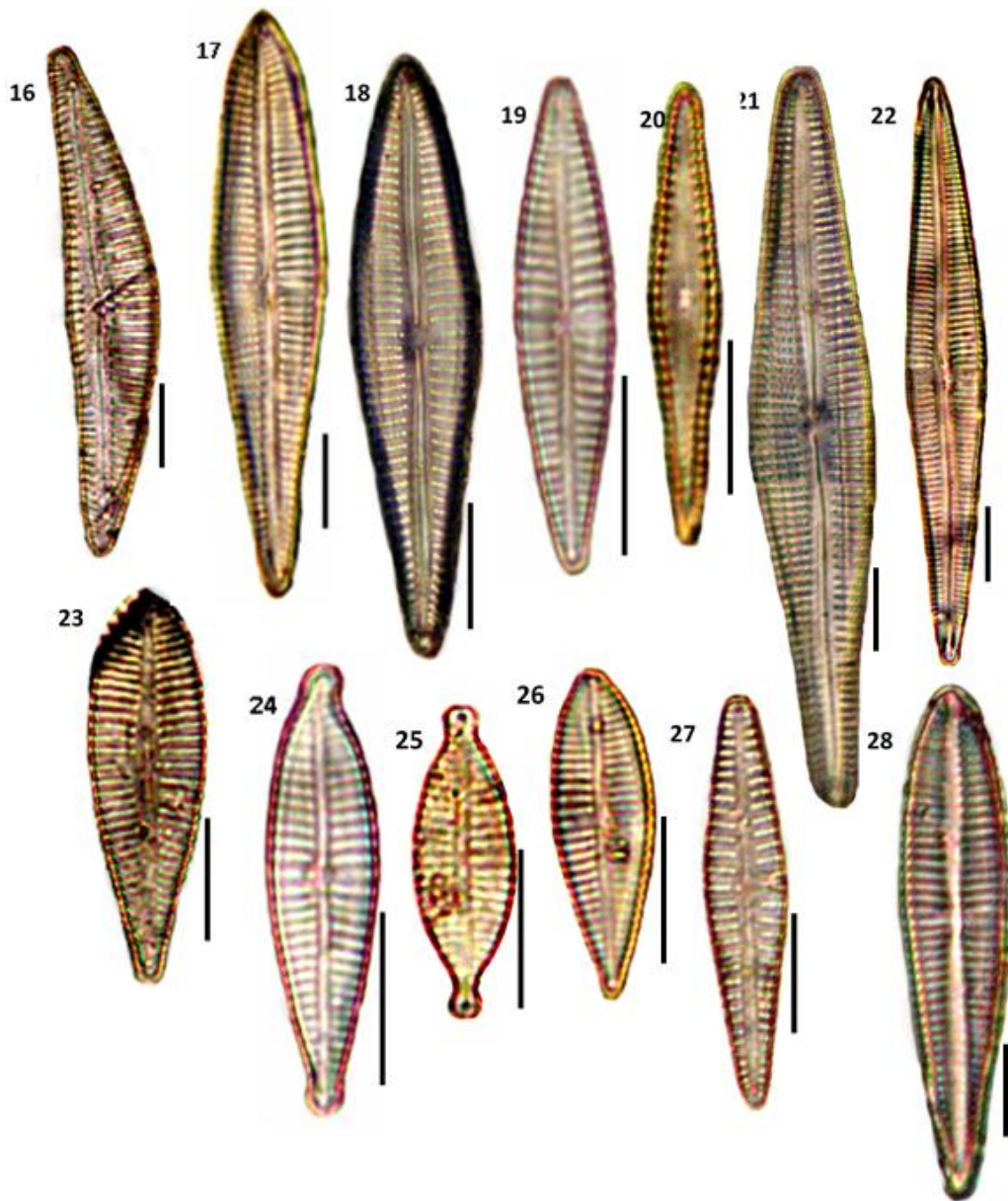


Fig. 16. *Encyonema cf. gracilis*, 17-19-*Gomphonema affine*, 20-*Gomphonema brasiliense*, 21-*Gomphonema dichotomum*, 22-*Gomphonema gracile*, 23-*Gomphonema olivaceum*, 24-26-*Gomphonema parvulum*, 27-*Gomphonema sp.1*, 28-*Gomphonema sp.2*

***Sellaphora pupula* (Kützing) Mereschkowsky 1902** (Fig. 38)

Morph.: Valve length: 25-30 μm , width: 8-10 μm , 20-25 striae in 10 μm ; **Ecol.:** planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

Order: Thalassiophysales D.G. Mann
Family: Catenulaceae Mereschkowsky
Genus: *Amphora* Ehrenberg ex Kützing

***Amphora cf. fagediana* Krammer 1985** (Fig. 39)

Morph.: Valve length: 20-25 μm , width: 10-14 μm ; **Ecol.:** planktic, epilithic, epiphytic,

Distr.: St2.

Order: Bacillariales Hendey
Family: Bacillariaceae Ehrenberg
Genus: *Nitzschia* Hassall

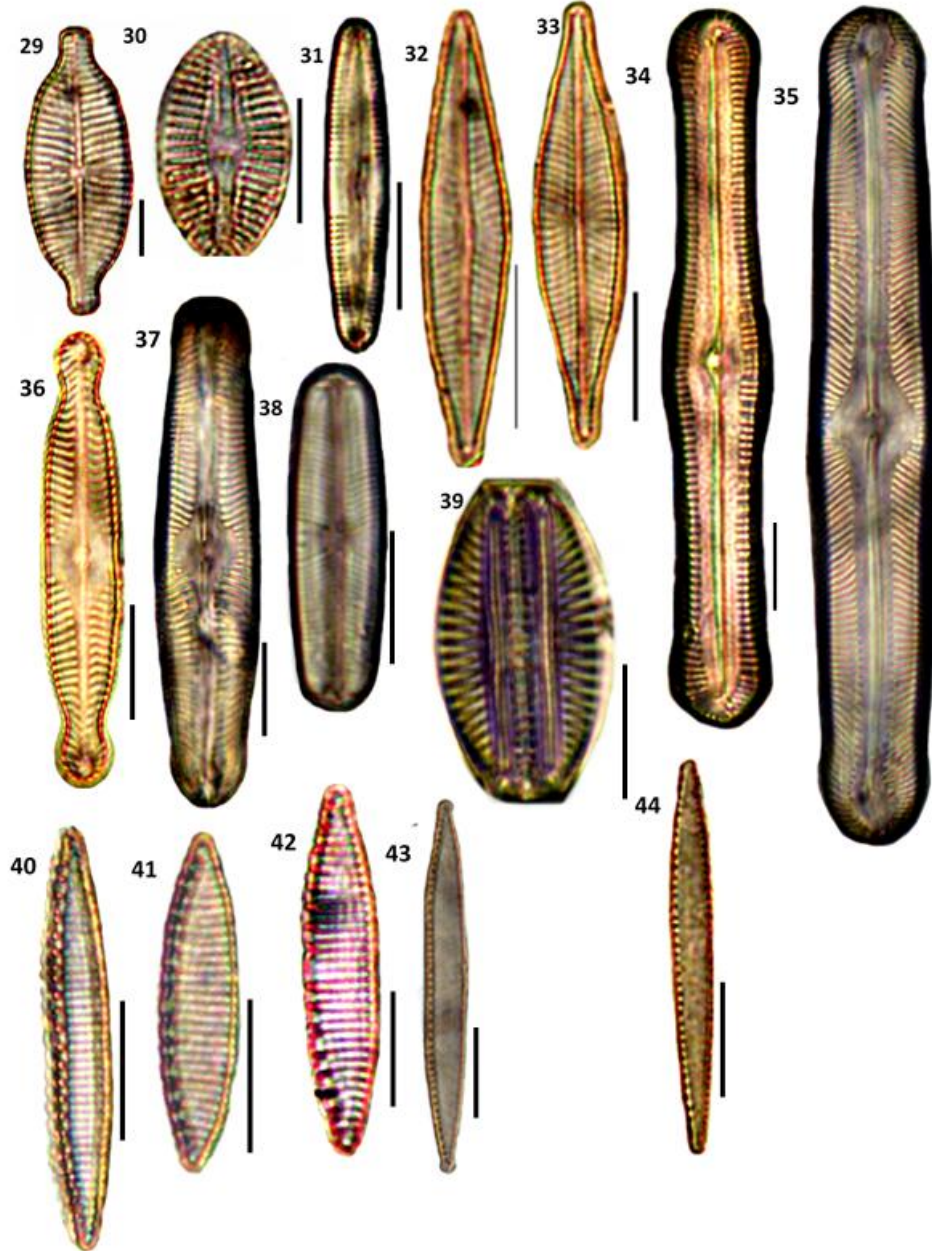


Fig. 29. *Placoneis pseudanglica*, 30-*Diploneis subovalis*, 31-*Caloneis lauta*, 32-33-*Navicula cryptocephala*, 34-*Pinnularia acrosphaeria*, 35-*Pinnularia divergens*, 36-*Pinnularia interrupta*, 37-*Pinnularia microstauron*, 38-*Sellaphora pupula*, 39-*Amphora fagediana*, 40-42-*Nitzschia amphibia*, 43-44-*Nitzschia palea*

Nitzschia amphibia Grunow 1862 (Fig. 40-42)

Morph.: Valve length: 20-28 μm , width: 4-5 μm , 17-19 striae in 10 μm ; 8-9 fibulae in 10 μm ;
Ecol.: planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

Nitzschia palea (Kützing) W.Smith 1856 (Fig. 43-44)

Morph.: Valve length: 21-35 μm , width: 4-5 μm , 8-9 fibulae in 10 μm ;
Ecol.: planktic, epilithic, epiphytic, **Distr.:** St1 & St2, Cosmopolitan.

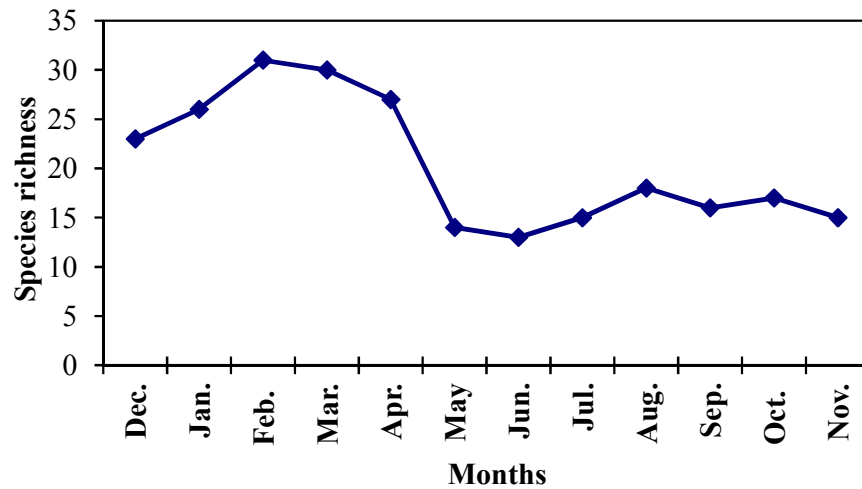


Fig. 45. Temporal sequence of species richness

3.1.3 Algae composition

In the samples from the Adzopé Reservoir, a total of 120 taxa were identified belonging to 5 phyla, of which 44 belonged to Euglenozoa. The Euglenozoa and Chlorophyta were the most diversified groups with 40.19% and 36.3% respectively of total species, followed by the Ochrophyta (17.86%) and the Cyanobacteria (10.71%). The Myzozoa were the least diversified group.

According to Diatoms the 31 identified taxa (Table 2) were distributed amongst 2 class, 7 order, 11 families and 13 genera. Five species and subspecies were recorded for the first time in Côte d'Ivoire. The majority of taxa are cosmopolitan. The highest diatoms species rate was observed on substrates, which were epilithic (100%) or epiphytic (84%).

The distribution of taxa at station level showed that the greatest number of diatoms (31) was recorded at station 2 further downstream. Based on the species occurrence frequency, 11 rare, 9 occasional, and 11 common species were found. The time sequence of species richness of the Diatoms was presented in Fig. 45, which highlights its dominance during dry seasons. Species richness was weakly represented during rainy seasons. The highest species richness (31) was obtained in February during the long dry season; the lowest (13) was registered in June during the long rainy season. Species richness of diatoms was correlated with water current velocity. In the dry season, when low water

current velocity was measured ($0.08 \text{ m}^3 \cdot \text{S}$), 29 taxa were observed. During the rainy season, when the highest water current velocity was measured ($0.38 \text{ m}^3 \cdot \text{S}$), 12 of taxa were obtained.

3.2 Discussion

Based on the threshold values for different trophic states suggested by [20], the measured Secchi disk transparency for the Adzopé Reservoir and the nutrient charges places it in a eutrophic category.

The taxa collected are both planktic and periphytic with a high rate for periphytic taxa. The highest rate of periphytic taxa is due to the fact that many diatoms have specialized structures for fixation to substratum, such as short or long mucilaginous peduncles as in species of *Gomphonema*, production of mucilaginous matrices as in *Cymbella*, and *Navicula*, and star or branch-shaped colonies fixed at the base as in *Eunotia* and *Fragilaria* [21]. These specialized structures confer a competitive advantage on diatoms in more stressful ambient conditions imposed by current speed and discharge [22]. Many tycho plankton species like *Ulnaria biceps*, *Pinnularia acrosphaeria*, *Nitzschia amphibia*, *Nitzschia palea* and *Gomphonema parvulum* are common to all the habitats explored. The big size of these diatoms and their way of life in banded colonies predispose them to uprooting, which would explain their presence in phytoplankton. According to [23], the ability of algae to remain attached to the substrate during an increase in flow varies depending on their size, morphology

and their mode of attachment. On the other hand, Diatoms of small sizes remain attached to substrates despite an increase in flow rate during long rainy season and are therefore difficult to tear off by the current [24], unlike those of large size. Our observations corroborate those of [25] on the ecology of Diatoms in the Walloon region (Belgium).

Seasonal variations in the diatoms composition can be explained by the stability of the water column and nutrients. Indeed, the highest species richness in the Adzopé reservoir, mainly during dry season seems to be associated with increasing of nutrients and the long period of water retention during long dry season in the reservoirs providing excellent conditions of temperature and irradiation [26] and promoting biological processes such as complete cycles of reproduction and development of algae [27]. Decreasing of species richness with the rainy season might be attributable to the reduced nutrient charge, dilutional effects of rain [28] and the water current velocity.

Variation in the dimensions of some identified taxa have been observed, and this phenomenon can be explained as a type of ecomorphological adaptation to the habitats studied. For instance, *Pinnularia acrosphaeria* have a valve length of 50-80 μm , while [29] stated that valve length ranges 44-65 μm . However, it is still compatible with data available in [27] (57-82,6 μm). On the other hand, the measured lengths in this study are less than that obtained by [30] in Guinea (80-150 μm). In addition, *Gomphonema dichotomum* in the current study is biggest in length than findings published in the literature, i.e. 75-90 μm vs. 25-60 μm in [31]. Nevertheless, [32] pointed out that the valve length of this specie ranges 25-80 μm . The dimensions of *Pinnularia microstauron* (Length: 54-50 μm , Width: 11-12 μm), *Sellaphora pupula* (Length: 25-30 μm , Width: 8-10 μm) are similarly incompatible with the literature [30].

4. CONCLUSION

It is concluded that variation in the dimensions of some identified taxa have been observed. The species richness of Diatoms in the Adzopé Reservoir was in relation with water current velocity. Seasonal variations in the diatoms composition can be explained by the stability of the water column and nutrients. Indeed, the highest species richness in the Adzopé reservoir, mainly during dry season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mann DG, Droop SJM. Biodiversity, biogeography and conservation of diatoms. *Hydrobiologia*. 1996;336:19-32.
2. Stenvenson RJ, Lowe RL. Sampling and interpretation of algal patterns for water quality assessment. *In*: Ison BG editor. Rational for sampling and interpretation of ecological data in the assessment of fresh water ecosystem. Philadelphia, American Society for Testing and Materials. 1996; 118-149.
3. Hürlimann J, Schanz F. The effect of artificial ammonium enhancement on riverine periphytic diatom communities. *Aquatic Sciences*. 1993;55(1):40-64.
4. Stenger-Kovács C, Tóth L, Tóth F, Hajnal E, Padisák J. Stream order-dependent diversity metrics of epilithic diatom assemblages. *Hydrobiologia*. 2014;721: 67-75.
5. Round FE, Crawford RM, Mann DG. The Diatoms, Biology and Morphology of the Genera. Cambridge University Press, Cambridge; 1990.
6. Stoermer EF, Smol JP. The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, Cambridge; 1999.
7. Reynolds CS. The Ecology of Phytoplankton. Cambridge University Press, Cambridge; 2006.
8. Whitton BA, Rott E, Friedrich G. Use of Algae for Monitoring Rivers, Proceedings of International Symposium. Universität Innsbruck, Innsbruck; 1991.
9. Prygiel J, Coste M. Use of diatomic indices to measure the water quality of the Artois-Picardie basin: results and prospects. *Annales de Limnologie*. 1993;29(3-4):225-267
10. Kouassi BAT, Ouattara A, DA KP. Euglenozoa occurring in Adzopé Reservoir, Côte d'Ivoire. *Turkish Journal of Botany*. 2013;37:1176-1187.
11. Iltis A, Lévêque C. Physical and chemical characteristics of rivers from Ivory Coast. *Revue d'Hydrobiologie Tropicale*. 1982; 15:115-130.
12. Krammer K, Lange-Bertalot H. Bacillariophyceae: Naviculaceae. *In*: Ettl H,

- Gerloff J, Heying H, Mollenhauer D, editors. Süßwasserflora von Mitteleuropa. Stuttgart, Fischer. 1986;2(1):1-876.
13. Krammer K, Lange-Bertalot H. Bacillariophyceae: Bacillariaceae, epithemiaceae, surirellaceae. In: Ettl H, Gerloff J, Heying H, Mollenhauer D, editors. Süßwasserflora von Mitteleuropa. Stuttgart, Fischer. 1998;2(2):1-596.
 14. Lange-Bertalot H, Navicula *sensu stricto*, 10 Genera separated from *Navicula sensu lato*, *Frustulia*. In: Lange-Bertalot H editor. Diatoms of the European Inland waters and comparable habitats. Liechtenstein: Gantner ARG & Verlag KG. 2001;1-526.
 15. Krammer K. *Cymbella*. In: Lange-Bertalot H editor. Diatoms of European Inland Waters and Comparable Habitats. Liechtenstein: Gantner ARG & Verlag KG. 2002;1-584.
 16. Rumeau A, Coste M. Introduction to the taxonomy of freshwater diatoms. Practical use of a generic diatomic index. Bulletin Français de Pêche et de Pisciculture. 1988;309:1-69.
 17. Foged N. Freshwater diatoms from Ghana. Biologiske Skrifter Kongelige Danske Videnskaberne Selskab. 1996;15(1):1-169.
 18. Dajoz R. Précis d'Écologie. 7ème éd. Paris, Éditions Dunod; 2000.
 19. Guiry MD, Guiry GM. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway; 2021. Accessed 15 February 2021. Available: <https://www.algaebase.org>
 20. Forsberg C, Ryding SO. Eutrophication parameters and trophic state indices in 30 Swedish waster receiving lakes. Archiv für Hydrobiologie. 1980;89:189-207.
 21. Round F E. Diatoms in river water-monitoring studies. Journal of Applied Phycology. 1991;3:129-145.
 22. Biggs BJF. Patterns in benthic algal of streams. In: Stevenson RJ, Bothwell ML, Lowe RL, editors. Algal ecology freshwater benthic ecosystems, San Diego, Academic Press. 1996;31-56.
 23. Peterson GP, Stevenson RJ. Post-spate development of epilittic algal communities in different current environments. Canadian Journal of Botanic. 1990;68: 2092-2102.
 24. Lavoie I, Vincent W F, Pienitz R, Painchaud J. Effect of flow on the temporal dynamics of periphytic algae in a river influenced by agricultural activities. Revue des Sciences de l'eau. 2003;16:55-77.
 25. Fabri R, Leclercq L. Ecological study of rivers in the north of the Ardennes massif (Belgium): flora and vegetation of diatoms and physico-chemistry of water. Robertville, Station Scientifique Hautes-Fagnes; 1984.
 26. Bouvy M, Ba N, Ka S, Sane S, Pagano M, Arfi R. Phytoplankton community structure and species assemblage succession in a shallow tropical lake (Lake Guiers, Senegal). Aquatic Microbial Ecology. 2006; 45:147-161.
 27. Ouattara A, Podoor N, Teugels GG, Gourène G. Microalgae from two rivers (Bia et Agnébi) in Ivory Coast. Systematics and Geography of Plants. 2000;70:315-372.
 28. Kouassi BAT, Komoé K, Adon MP, Ouattara A, Cyanobacteria from a shallow Reservoir in Côte d'Ivoire. Journal of Biodiversity and Environmental Sciences. 2015;7(5):136-149.
 29. Cocquyt C., Diatoms from the Northern Basin of Lake Tanganyika. J. Camer ed., Berlin; 1998.
 30. Compère P, Riaux-Gobin C. Diatomées de quelques biotopes marins, saumâtres et dulçaquicoles de Guinée (Afrique occidentale). Systematics and Geography of Plants. 2009;79:33-66.
 31. Boyer CS. Synopsis of North American Diatomaceae, Part II. - Naviculatae, Surirellatae. Actes de l'Académie des Sciences Naturelles de Philadelphie. 1927; 79:229-583.
 32. Compère P. Algae from Lac Tchad region. IV-Diatomophyceae, Cahiers de l'O.R.S.T.O.M., Série Hydrobiologie. 1975; 9(4):203-290.

© 2021 Kouassi et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/67287>