

New epilithic Naviculales (Bacillariophyta) from Ivory Coast

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Abstract

Epilithic diatom of the Ivory Coast is very poorly understood, aims of this study are: to document the epilithic diatom diversity from Naviculales. In this study, the epilithic diatoms in the samples collected from ten stations on the Me River between February and July 2012. A total of 56 Naviculales new taxa in 8 families were recorded. The taxonomic composition observed was dominated by Naviculaceae and Pinnulariaceae.

Keywords: Diatoms, Epilithic, Flora, Naviculales, Ivory Coast

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Introduction

Aquatic ecosystems of fluvial types are characterized by the existence of an upstream-downstream gradient from the hydrological point of view or a spatial variation of the hydromorphological characteristics (current, flow, width and depth) (Malavoi and Souchon, 2002). These hydromorphological variations along the upstream-downstream gradient are accompanied by variability in the physico-chemical parameters of water, essential for biological organisms, especially diatoms. Studies on diatom taxonomy only in the African tropics are less numerous than in temperate zones (Metzeltin and Lange-Bertalot, 1998 and 2007, Descy and Sarmiento, 2008; Wetzel *et al.*, 2011). Available data on the diatoms of African rivers and streams are old and limited to the works of Zanon (1941) in French West Africa, Foged (1966) in Ghana, Foged (1986) in the Gambia, Cholnoky (1968) in central Africa, Carter and Denny (1982) in Sierra Leone. The most extensive data on diatom taxonomy were conducted on lake ecosystems. We can mention the work of Compère (1975a, 1975b 1975c and 1975d) on Lake Chad, from Compère (1991) on Lake Guiers, Cocquyt (1998) on Lake Tanganyika, Couté and Iltis (1985). In Ivory Coast, references have been very useful for taxonomic determinations:

Bourrelly (1961) on the Ébrié lagoon, Da (1986, 1992 and 2007), Ouattara *et al.*, (2000 and 2001), Niamien-Ébrottié *et al.* (2008), Kouassi (2013), Kouassi *et al.* (2010), Salla

(2015), Komoé *et al.* (2009) in the lagoon complex of Grand-Lahou and Seu-Anoï (2012), in the lagoon complexes (Aby, Ébrié and Grand-Lahou).

Order Naviculales Bessey emend. Mann and Round *et al.* (1990) is characterized by solitary or chain-forming cells with one, two or four lamina-shaped chloroplasts, rarely H-shaped or discoid. The central nucleus is rarely eccentric. The frustules are isovalvar with simple or loculated areolae occluded by hymenes. The raphe is central or slightly eccentric, straight or sigmoid,

Studies specific of taxa from the order Naviculales from Ivory Coast water environments almost does not exist. The diatoms communities from the Agnéby and Mé river watersheds, Ivory Coast (N'guessan *et al.*, 2014) note the presence of a large number of species of this order.

In this paper, we describe the new epilithic Naviculales of the river Mé would contribute to the knowledge of diatoms in Ivory Coast.

Material and methods

The Mé River (3°14' W, 6°40' N) is located in the south of Ivory Coast). Mé River rises in the North of Adzopé flows into the Poto lagoon in the North of Grand Bassam with a catchment area of 4,300 km². This part of Ivory Coast, located on Precambrian substrates, is covered by swamps and rainforests (Avenard *et al.*, 1971). A preliminary study of the river systems based on geological, topological and land cover

data allowed the selection of the study sites, taking into account their accessibility

The material analyzed and interpreted in the present study was collected in the Mé River (Fig. 1 and Table 1). Ten stations were visited, in February and July 2012. Diatoms were sampled on glass slides (76×26×1 mm) previously immersed during a period of 30 days. Ten slides were maintained in a cage made of polystyrene (38×13×6 cm), in the photic zone. After the immersion

period, the cage was removed from the river; the glass slides were scraped using a razor blade and the biofilm was poured into a vial with distilled water and a few drops of 10% formalin. Samples for diatom analysis were cleaned using hydrogen peroxide (H₂O₂; 30%) and hydrochloric acid (HCl; 35%) and mounted on slides with Naphrax according to (AFNOR, NF EN 13946 (2003)).

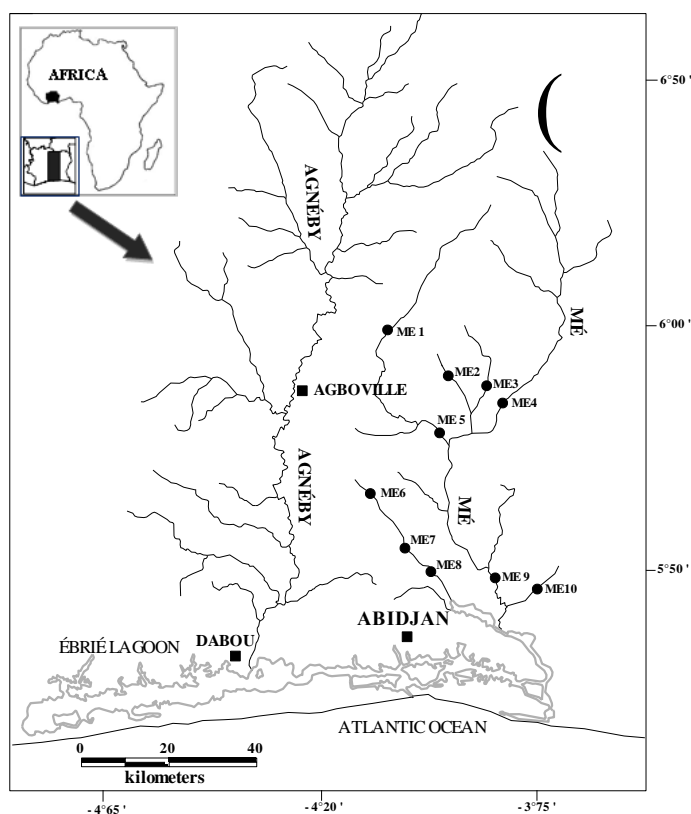


Figure 1: Study area and location of sampling sites of river Me in Ivory Coast.

Diatoms were identified using light microscopy (LM) (Leica-DMRB) at a specific or infraspecific level according to Foged (1966, 1986), Carter and Denny (1982, 1987, 1992), Krammer

and Lange-Bertalot (1986, 1988, 1991a, b), Simonsen (1987), Levkov (2009), Lange-Bertalot *et al.* (2011), Krammer (2000, 2002, 2003, and Lange-Bertalot (2001) (Figs. 2-57). In average, 50

organisms were used for measurements. The frequency of each species present was determined according to Dajoz (2000). Three frequency groups were distinguished according to value of

Dajoz (2000) Common species (1), $F > 50\%$; occasional species (2), $25\% < F < 50\%$; rare species (3), $F < 25\%$.

$$\frac{F_i \times 100}{F_t}$$

Table 1: List of sampling stations along the Mé River, Ivory Coast.

Site code	Geographic coordinates	River or tributary	Locality
ME1	5°59'4.5"N-4°02'42.3"W	Mafou	Mafou-Boudépé road
ME2	5°52'40.9"N-3°54'37.8"W	Mambé	Abié-Lobo Opé road
ME3	5°52'27.9"N- 3°51'03.4"W	Mansan	Lobo Opé-Lobo Akoudzin road
ME4	5°50'25.5"N-3°49'01.4"W	Mé	Lobo Akoudzin-Kodioussou road
ME5	5°47'19.0"N-3°57'46.0"W	Mafou	Azaguié-Yakassémé road
ME6	5°38'15.1"N- 4°02'38.3"W	Abé	800 m from Azaguié corridor
ME7	5°31'34.7"N-4°02'49.7"W	Bété	800 m from Attiékoï
ME8	5°29'33.1"N-3°57'14.4"W	Bété	Bridge of Ahoué. Abobo-Baoulé- Ahoué road
ME9	5°28'26.3"N-3°50'00.9"W	Mé	5 km d'Ahoutoué Axe Ahoué-Ahoutoué
ME10	5°29'41.5"N-3°49'00.0"W	Ahoutoué	3.5 km from Ahoutoué-Ahoutoué-N'zodji road

Results and discussion

Light microscopy micrographs of diatoms were showed in Figures 2-57.

Order: Naviculales

Family: Brachysiraceae

Brachysira exilis* (Kützing) Round and D.G. Mann (1981) (Fig. 2**)



Description. L: 32.8 μm; W: 5.9 μm. Distribution and examined site: Accidentel, ME10.

Brachysira neoexilis* Lange-Bertalot and Gerd (1994) (Fig. 3**)

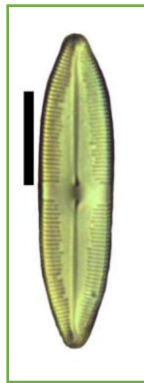


Description. L: 21.3 μm ; W: 4.4 μm .
Distribution and examined site:
Accidental, ME8

Order: Naviculales

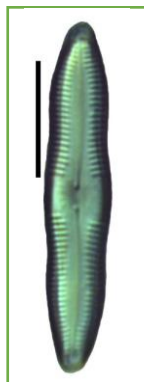
Family: Naviculaceae

**Caloneis incognita* Hustedt (1910)
(Fig. 4)



Description. L: 33.5-44.8 μm ; W: 8.8-10.8 μm ; Str: 1 9-21/10 μm .
Distribution and examined site:
Accidental, ME1, ME2 and ME6.

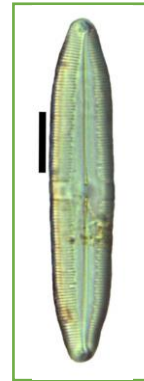
**Caloneis inflata* (Hustedt) Metzeltin
and Lange-Bertalot (2007) (Fig. 5)



Description. L: 27.4-31.1 μm ; W: 5.4-5.6 μm ; Str: 21-22/10 μm .
Distribution and examined site: Accidental, ME7
and ME9.

**Caloneis stauroneiformis*

(Amossé) Metzeltin and Lange-Bertalot
(2002) (Fig. 6)

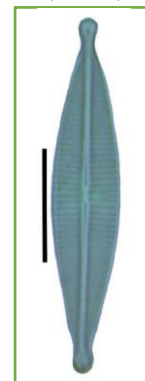


Description. L: 47.2-57.7 μm ; W: 9.3-10.5 μm ; Str: 19-20/10 μm .
Distribution and examined site:

Order: Naviculales

Family: Stauroneidaceae

**Craticula halophila* (Grunow) Mann
Round *et al.* (1990) (Fig. 7)

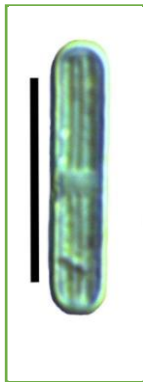


Description. L: 31.2-49.1 μm ; W: 6.9-10.3 μm ; Str: 19-20/10 μm .
Distribution and examined site: Accidental, stations
ME8

Order: Naviculales

Family: Diadesmidaceae

**Diadesmis contenta* var. *biceps*
(Grunow) P.B.Hamilton 1992 (**Fig. 8**)

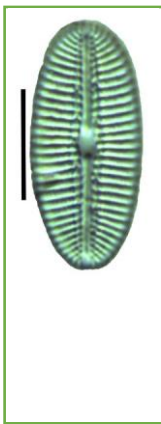


Description. L: 8.6-13.5 μm ; W: 2.2-2.9 μm . Distribution and examined site: Accidental, except ME5 and ME7.

Order: Naviculales

Family: Diploneidaceae

**Diploneis pseudovalis* Hustedt (1930)
(**Fig. 9**)

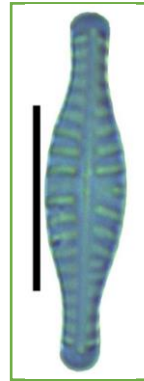


Description. L: 16.3-29.1 μm ; W: 9.2-13.3 μm ; Str: 8-13/10 μm . Distribution and examined site: Accessoiry, ME1, ME2, ME3 et ME10.

Order: Naviculales

Family: Naviculaceae

**Hippodonta capitata* (Ehrenberg)
Lange-Bertalot, Metzeltin & Witkowski
(1996) (**Fig. 10**)

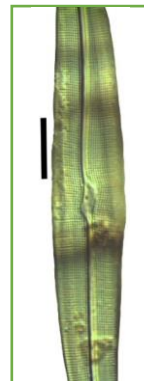


Description. L: 17,8-19,23 μm ; W 4,7-4,9 μm ; Str: 12-13/10 μm . Distribution and examined site: Accessoiry, ME12, ME14 et ME15.

Order: Naviculales

Family: Naviculaceae

**Gyrosigma reimeri* Sterrenburg (1994)
(**Fig. 11**)

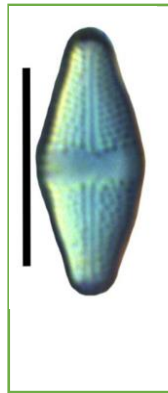


Description. L: 65.3-79.1 μm ; W: 13.3-14.1 μm ; Str: 22-24/10 μm . Distribution and examined site: accidental, all stations except ME1.

Order: Naviculales

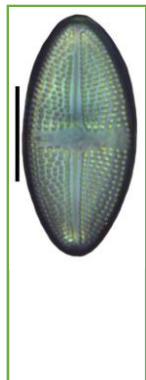
Family: Diadesmidaceae

Luticola acidoclinata* Lange-Bertalot and Metzeltin (1996) (Fig. 12**)

Family : Naviculaceae

Description. L: 10.9-17.2 μm ; W: 5.7-6.9 μm ; Str: 20-25/10 μm . Distribution and examined site: Accidental, ME3, ME6 and ME10.

Luticola dupaliformis* (Hustedt) D.G. Mann Round *et al.* (1990) (Fig. 13**)

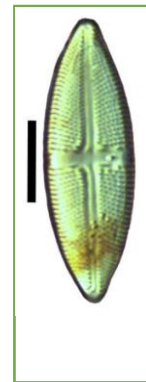


Description. L: 26.1 μm ; W: 12.3 μm ; Str: 17/10 μm . Distribution and examined site: Accidental, ME10.

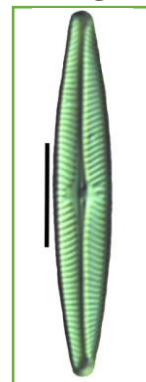
Luticola suecorum* (Carlson) Van de Vijver Van de Vijver and Mataloni (2008) (Fig. 14**)

Description. L : 28.5-32.8 μm ; W : 8.9-9.1 μm ; Str : 18-20/10 μm . Distribution and examined site : Accidental, ME1 et ME8.

Order: Naviculales



Navicula capitatoradiata* Germain Gasse (1986) (Fig. 15**)



Description. L: 44.1-47.6 μm ; W: 4.5-7.8 μm ; Str: 14-15/10 μm . Distribution and examined site: Accidental, ME6, ME8 et ME10.

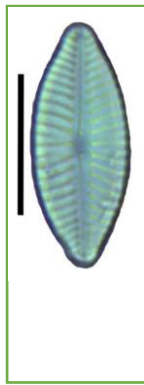
Navicula erifuga* Lange-Bertalot Krammer and Lange-Bertalot (1985) (Fig. 16**)



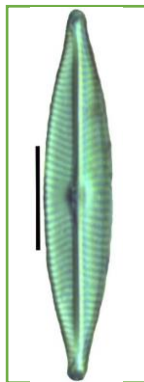
Description. L: 5.2-6.1 μm ; W: 36.2-40.1 μm ; Str: 11-14/10 μm . Distribution and examined site: Accidental, ME3, ME7, ME9 and ME10.

Navicula hambergi* Hustedt Hustedt (1924) (Fig. 17**)

Description. L: 12.3-17.5 μm ; W: 5.8-7.4 μm ; Str: 13-18/10 μm . Distribution and examined site: Accidental, ME1 et ME10.

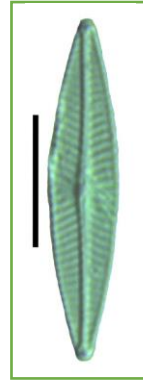


Navicula notha* Wallace Wallace (1960) (Fig. 18**)



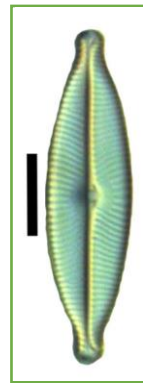
Description. L: 33.1-37.21 μm ; W: 5.6-7.4 μm ; Str: 12-13/10 μm . Distribution and examined site: Accidental, ME9.

Navicula radiosafallax* Lange-Bertalot Lange-Bertalot (1993) (Fig. 19**)



Description. L: 23.3-30.1 μm ; W: 4.6-6.3 μm ; Str: 13-15/10 μm . Distribution and examined site: Accidental, ME3 and ME6.

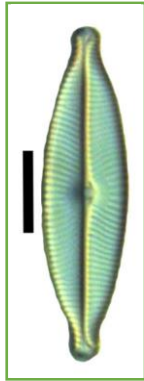
Navicula rostellata* Kützing Kützing (1844) (Figure 20**)



Description. L: 37.4-45.7 μm ; W: 7.6-9.4 μm ; Str: 11-15/10 μm . Distribution and examined site: Accidental, ME2, ME3, ME4, ME6, ME7, ME8, ME9 et ME10.

Navicula similis* Krasske var. *strigosa* Hustedt Hustedt (1937) (Fig. 21**)

Description. L: 14.1-15.7 μm ; W: 4.8-5.7 μm ; Str: 17-19/10 μm . Distribution and examined site: Accidental, ME3, ME4, ME6, ME8, ME9 and ME10.

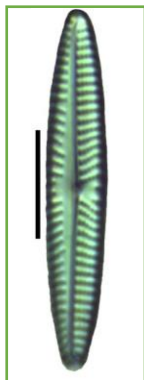


**Navicula subtilissima* Cleve Cleve (1891) (Fig. 22)



Description. L: 12.1-21.8 μm ; W: 3.1-5.1 μm . Distribution and examined site: Accidental, except ME4 and ME7 stations.

**Navicula symmetrica* Patrick Patrick (1944) (Fig. 23)

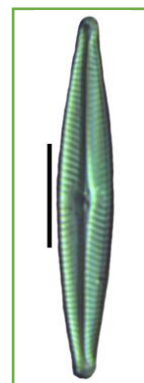


Description. L: 28.6-34.4 μm ; W: 5.1-5.4 μm ; Str: 10-14/10 μm . Distribution

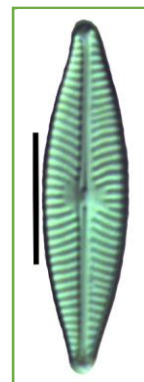
and examined site: Accidental, ME4 and ME10.

**Navicula tenella* Brébisson Kützing (1849) (Fig. 24)

Description. L: 29.4-44.51 μm ; W: 5.2-7.1 μm ; Str: 13-16/ 10 μm . Distribution and examined site: Accidental, ME5, ME9 and ME10

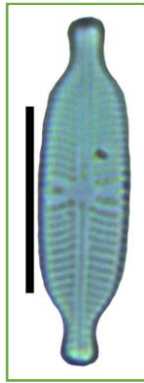


**Navicula veneta* Kützing Kützing (1844) (Fig. 25)



Description. L: 20.4-27.7 μm ; W: 5.4-6.3 μm ; Str: 13-14/ 10 μm . Distribution and examined site: Accidental, ME1, ME3, ME4, ME5 and ME10.

**Naviculadicta absoluta* (Hustedt) Lange-Bertalot Lange-Bertalot and Moser (1994) (Fig. 26)

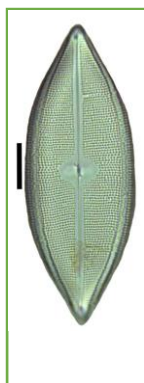


Description. L: 19.1 μm ; W: 5.1 μm ;
Str: 20 /10 μm . Distribution and
examined site: Accidental, ME6.

Order: Naviculales

Family: Neidiaceae

**Neidium amphigomphus* (Ehrenberg)
Pfitzer Pfitzer (1871) (**Fig. 27**)



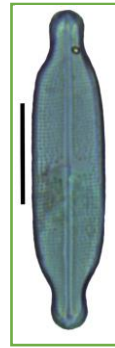
Description. L: 57.6-108.2 μm ; W:
16.9-28.4 μm ; Str: 18-19/10 μm .
Distribution and examined site:
Accidental, ME1, ME3, ME6, ME7,
ME8, ME9 and ME10.

**Neidium productum* (W. Smith) Cleve
(1894) (**Fig. 28**)

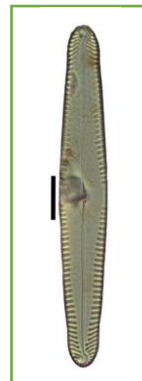
Description. L: 30.7-32.2 μm ; W: 6.7-
7.7 μm ; Str: 26-28/10 μm . Distribution
and examined site: Accidental, ME3
and ME9.

Order: Naviculales

Family : Pinnulariaceae

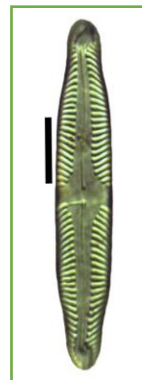


**Pinnularia angustistriata* Metzeltin &
Krammer (1998) (**Fig. 29**)



Description. L: 78.1 μm ; W: 12.1 μm ;
Str: 9/10 μm . Distribution and
examined site: Incidental, ME9.

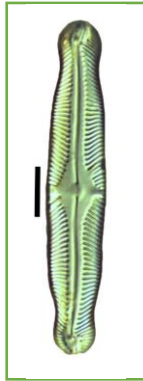
**Pinnularia divergens* W. Smith
(1853) (**Fig. 30**)



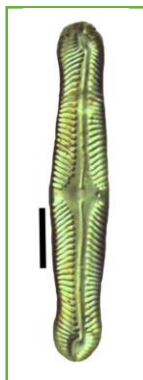
Description. L: 24.8 μm ; W: 10.2 μm ;
Str: 9/10 μm . Distribution and
examined site: Incidental, ME3.

**Pinnularia divergens* var. *media*
Krammer (2000) (Fig. 31)

Description. L: 71.2 μm ; W: 12.7 μm ;
Str: 12/10 μm . Distribution and
examined site: Incidental, ME10.



**Pinnularia divergens* var.
madagascariensis Metzeltin & Lange-
Bertalot (2002) (Fig. 32)



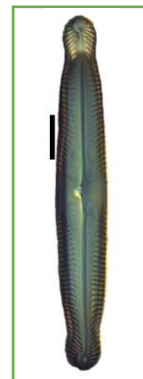
Description. L: 59.1-83.9 μm ; W: 11.2-
12.4 μm ; Str: 23-26/10 μm . Distribution
and examined site: Incidental, ME6.

**Pinnularia gibba* Ehrenberg var.
gibba Ehrenberg (1843) (Fig. 33)



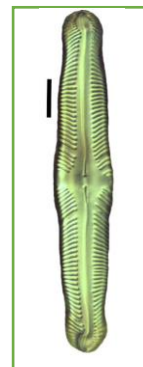
Description. L: 29.7-88.2 μm ; W: 7.6-
9.2 μm ; Str: 9-11/10 μm . Distribution
and examined site: Incidental, ME5 and
ME8.

**Pinnularia gibba* var. *subundulata*
(Mayer) Frenguelli (1933) (Fig. 34)



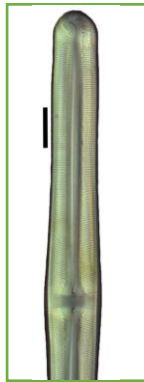
Description. L: 76.2-79.8 μm ; W: 10.8-
11.3 μm ; Str: 9/10 μm . Distribution
and examined site: Incidental, ME5.

**Pinnularia graciloides* Hustedt (1937)
(Fig. 35)



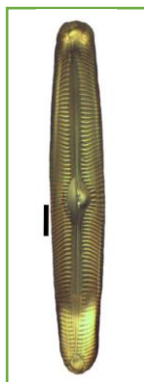
Description. L: 60.3-90.7 μm ; W: 9.4-15.1 μm ; Str: 10-12/10 μm . Distribution and examined site: Incidental, ME2.

**Pinnularia hartleyana* var. *orientalis* Metzeltin and Lange-Bertalot (2002) (Fig. 36)



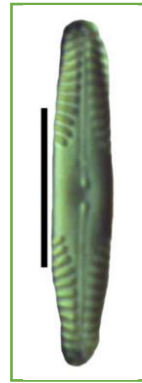
Description. L: 143.8 μm ; W: 15.5 μm ; Str: 18/10 μm . Distribution and examined site: Incidental, ME8.

**Pinnularia insignis* Metzeltin and Lange-Bertalot (2002) (Fig. 37)



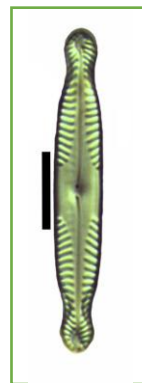
Description. L: 133.7 μm ; W: 18.4 μm ; Str: 7/10 μm . Distribution and examined site: Incidental, ME10.

**Pinnularia interrupta* var. *joculata* Manguin Bourrelly and Manguin (1952) (Fig. 38)



Description. L: 21.5-22.1 μm ; W: 4.7 μm ; Str: 16/10 μm . Distribution and examined site: Incidental, ME6.

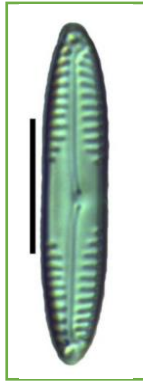
**Pinnularia latarea* Krammer (2000) (Fig. 39)



Description. L: 27.4-53.4 μm ; W: 5.6-8.7 μm ; Str: 12-13/10 μm . Distribution and examined site: Incidental, ME3, ME5, ME8, ME9 and ME10.

**Pinnularia molaris* (Grunow) Cleve (1895) (Fig. 40)

Description. L: 18.8-25.6 μm ; W: 4.7-4.9 μm ; Str: 14-15/10 μm . Distribution and examined site: Accidental, ME2.

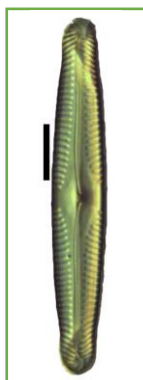


**Pinnularia subgibba* var. *subgibba*
Krammer (1992) (Fig. 41)

Description. L: 45.5-77.8 μm ; W: 7.2-10.5 μm ; Str: 7-12/10 μm . Distribution and examined site: Incidental, all site except ME1, ME4 and ME5.

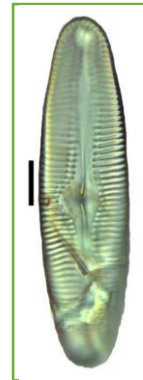


**Pinnularia subgibba* var. *undulata*
Krammer (1992) (Fig. 42)



Description. L: 15.8-23.6 μm ; W: 4.2-6.1 μm ; Str: 23-26/10 μm . Distribution and examined site: Incidental, ME5.

**Pinnularia subsolaris* (Grunow)
Cleve (1895) (Fig. 43)

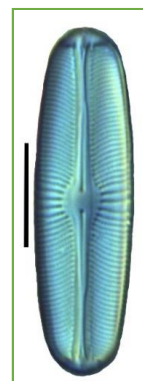


Description. L: 50.9 μm ; W: 19.8 μm ; Str: 8 /10 μm . Distribution and examined site: Incidental, ME8.

Order: Naviculales

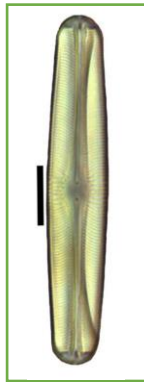
Family: Sellaphoraceae

**Sellaphora madagascariensis*
Metzeltin and Lange-Bertalot (2002)
(Fig. 44)



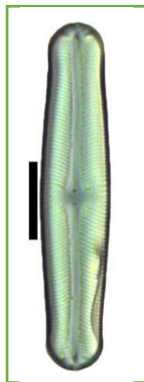
Description. L: 27.3-39.1 μm ; W: 9.1-10.7 μm ; Str: 17-21/10 μm . Distribution and examined site: Incidental, ME3 and ME10.

**Sellaphora parapupula* Lange-Bertalot and Metzeltin (1996) (Fig. 45)



Description. L: 58.5 μm ; W: 10.9 μm ; Str: 17/10 μm . **Distribution and examined site:** Incidental, ME10.

**Sellaphora platycephala* Otto Müller (1910) (Fig. 46)



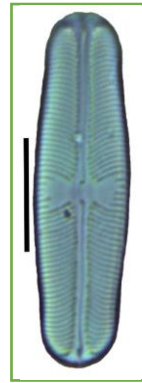
Description. L: 35.9-46.2 μm ; W: 8.2-9.3 μm ; Str: 19-21/10 μm . **Distribution and examined site:** Incidental, ME8.

**Sellaphora rectangularis* (W. Gregory) Lange-Bertalot and Metzeltin (1996) (Fig. 47)

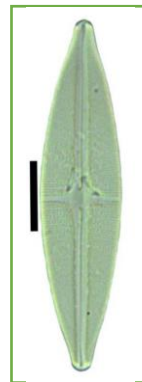
Description. L: 20.7-36.8 μm ; W: 5.8-9.1 μm ; Str: 19-24/10 μm . **Distribution and examined site:** Constant, all site except ME9.

Order: Naviculales

Family : Stauroneidaceae

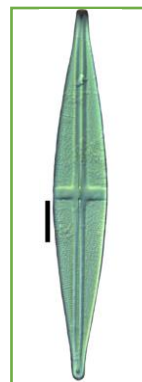


**Stauroneis akrosoensis* Foged (1966) (Fig. 48)



Description. L: 14.7-16.4 μm ; W: 14.4-14.8 μm ; Str: 20-27/10 μm . **Distribution and examined site:** Incidental, ME8 and ME10.

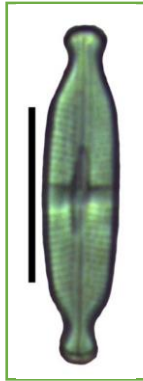
**Stauroneis gracilis* Ehrenberg (1843) (Fig. 49)



Description. L: 58.8-90.57 μm ; W: 12.1-12.9 μm ; Str: 20-21/10 μm .

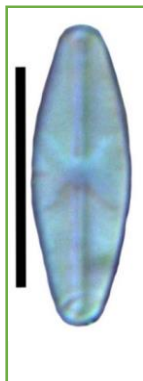
Distribution and examined site:
Accidental, ME5 and ME8.

**Stauroneis kriegeri* R.M. Patrick
(1945) (Fig. 50)



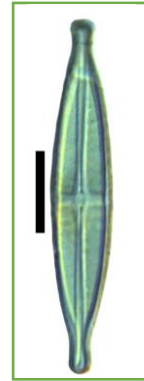
Description. L: 18.01-20.02 μm ; W: 4.5-4.7 μm ; Str: 22-30/10 μm .
Distribution and examined site:
Incidental ME4, ME9 and M10.

**Stauroneis nana* Hustedt (1957) (Fig. 51)



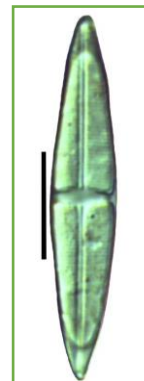
Description. L: 10.7-16.38 μm ; W: 4.2-4.6 μm ; Str: 7-10/10 μm .
Distribution and examined site: Incidental, ME1 and ME3.

**Stauroneis neohyalina* Lange-Bertalot
and Krammer (1996) (Fig. 52)



Description. L: 43.1 μm ; W: 7.2 μm .
Distribution and examined site:
Incidental, ME3.

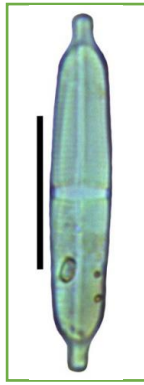
**Stauroneis reicheltii* Heiden Schmidt
(1903) (Fig. 53)



Description. L: 21.3-34.3 μm ; W: 5.6-6.8 μm ; Str: 20-30/10 μm .
Distribution and examined site: Incidental, ME4, ME9 and ME10.

**Stauroneis separanda* Lange-Bertalot
& Werum (2004) (Fig. 54)

Description. L: 23.4-23.6 μm ; W: 4.7-4.8 μm ; Str: 28-29/10 μm .
Distribution and examined site: Incidental, ME8 and ME10.

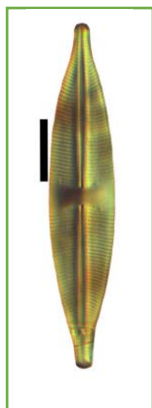


**Stauroneis siberica* Lange-Bertalot and Krammer (1996) (Fig. 55)



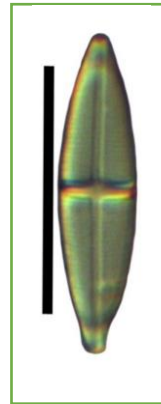
Description. L: 57.1-63.8 μm ; W: 13.1-14.7 μm ; Str: 30/10 μm . Distribution and examined site: Incidental, ME3 and ME4.

**Stauroneis slateri* Foged (1966) (Fig. 56)



Description. L: 58.8 μm ; W: 12.1 μm ; Str: 16/10 μm . Distribution and examined site: Incidental, ME8.

**Stauroneis tenera* Hustedt (1937) (Fig. 57)



Description. L: 12.9 μm ; W: 3.4 μm ; Str: 30 /10 μm . Distribution and examined site: Incidental, ME10.

A total of 56 taxa at the species and variety levels distributed in 32 genera were encountered. divided into 11 orders, 23 families. Pinnularia (15 taxa), Navicula (11 taxa), Stauroneis (10 taxa), Sellaphora (4 taxa), Luticola (3 taxa), Caloneis (3 taxa), Brachysira (2 taxa), Neidium (2 taxa), Craticula (1 taxa), Diadesmis (1 taxa), Diploneis (1 taxa), Gyrosigma (1 taxa), Hippodonta (1 taxa) and Naviculadicta (1 taxa) were recorded. The taxa belonging to the species Pinnularia, Navicula and Stauroneis were found to be more significant than the other diatoms in terms of diversity. The diatom taxa *Sellaphora rectangularis*, *Navicula subtilissima* *Navicula rostellata* were regularly recorded in all stations throughout the study. Navicula is

cosmopolitan (Pala *et al.*, 2018). The taxa identified in Ivory Coast showed considerable different to the diatoms identified in another country (Caglar *et al.*, 2017; Caglar *et al.*, 2019; Caglar *et al.*, 2020; Caglar *et al.*, 2021). On the other hand, a significant number of navicula has been observed by (Pala *al.*, 2017) in HazarLake/Elazig-Turkey.

Conclusion

The new navicula epilithic diatoms flora of the Mé river included 56 taxa and grouped into 8 families. The most representative families were naviculaceae, and pinnulariaceae.

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