Freshwater diatoms in the Democratic Republic of the Congo: a historical overview of the research and publications

Christine Cocquyt¹, Edit Lokele Ndjombo²,³, Simon Tutu Tsamemba³, Hippolyte Nshimba Seya wa Malale⁴

¹ Research Department, Meise Botanic Garden, Nieuwelaan 38, 1860, Meise, Belgium ² Institut Facultaire des Sciences Agronomiques de Yangambi, Kisangani, DR Congo ³ Faculté de Gestion des Ressources Naturelles et Renouvelables, Université de Kisangani, DR Congo ⁴ Faculté des Sciences, Université de Kisangani, DR Congo

Corresponding author: Christine Cocquyt (christine.cocquyt@botanicgardenmeise.be)

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Abstract
An overview of the diatom research in the DR Congo is given based on literature data starting in 1938 with the work of Zanon and excluding the East African Lakes as these were already discussed in previous papers. For each literature record the diatom genera mentioned are presented as well as all diatom taxa described from the Congo as new. In total, 106 new taxa were documented, of which *Nitzschia* with 40 taxa is the most important genus followed by *Navicula* s.l. and *Pinnularia* and with 15 and 13 taxa respectively. Particular attention was paid to the local research of students found in unpublished theses at bachelor, licentiate, master and PhD level. Diatom records in these works are almost all restricted to genus level, although in the last decade an attempt to delimit species can be observed. This accompanies the renewed taxonomic interest in the Congo basin during the last decade. Renewed taxonomic interest can also be seen in the genera: the first period being situated during the lumping period, while more recent works follow the current taxonomic classification, for example *Navicula* s.l. versus *Navicula*, *Cavinula*, *Craticula*, *Diadesmis*, *Geissleria*, *Humidophila*, *Luticola*, etc.

Keywords
Algae, Bacillariophyta, Congo basin, tropical Africa, Zaire
Introduction

In the Democratic Republic of the Congo (DR Congo), research in the field of plant biology mostly concerned the study of terrestrial forest ecosystems (Anonymous 2012; Wasseige et al. 2014), while the interest given to the aquatic environments was mainly limited to ichthyology and fisheries (e.g. Chapman 2001; Paugy et al. 2011; Snoeks et al. 2011), fish being an important source of protein for local populations. Only a few publications are available in the field of microscopic algae, and diatoms in particular, from inland aquatic environments in DR Congo.

Early publications on freshwater algae in tropical Africa focused on the great lakes of the Albertine rift: Malawi (Nyassa/Nyasa), Tanganyika (Tanganika) and Victoria (Victoria Nyanzae) (e.g. Müller 1904a, b, 1905, 1910; West 1907). A review of the studies that have been carried out on these large lakes and the lentic and lotic ecosystems of East Africa is given by Cocquyt (2006) and Taylor and Cocquyt (2015).

The present paper aims to give an overview of the research that has been conducted in the DR Congo or that has investigated Congolese material, not only found in international publications, but also by means of local publications as well as unpublished theses at different levels (bachelor, licentiate, master and PhD).

Material and methods

Initially international publications on algae, and more specifically on the diatoms, of DR Congo (formerly Belgian Congo between 1908 and 1960, and the Republic of Zaire between 1971 and 1997) were searched for on the Web of Science and in the available international literature. Subsequently, inquiries were made regarding papers that were published locally in journals of the different universities in DR Congo and in final reports of national and international projects. The last step was to retrieve all theses, PhD level and other dissertations (licentiate, bachelor and master level) from universities and scientific institutions in DR Congo. Licentiate is an academic degree below that of a PhD, used in Belgium (and the DR Congo), and obtained after a university study of 4 to 5 years. In the Bachelor-Master structure, it is the degree that corresponds to (almost) a Master.

Results and discussion

A brief overview follows on the diatom research conducted on materials collected in DR Congo, including the former Congo and the Republic of Zaire, as found in mainstream literature, thus taking into consideration only published work accessible to the international scientific community.

The diatoms of Lake Kivu and its surroundings were first documented by Zanon (1938). From this region he reported 263 taxa belonging to 33 genera. Of these taxa, 16 were new to science of which 9 were *Pinnularia* Ehrenberg, the others belonging
to the genera *Cocconeis* Ehrenberg, *Cymbella* C. Agardh, *Eunotia* Ehrenberg, *Neidium* Pfitzer and *Synedra* Ehrenberg (for details see Table 1). However, we must point out that most of the genera names mentioned in this paper are in the broad sense (sensu lato) as they very probably combine several genera after the changes initiated in recent diatom classification (Round et al. 1990, and subsequent later taxonomic publications). These systematic changes were initially based on knowledge acquired through what were relatively new technologies at the time such as the scanning electron microscope and more recently molecular analyses.

Zanon (1938) described *Pinnularia borealis* var. *congolensis* Zanon (on page 641) with a drawing (fig. 27) from a puddle on the Karisimbi volcano in the region Lake Kivu and mentioned this taxon name also (on page 545) in his species list of the diatoms from the region of Lake Kivu. However, in the same publication Zanon (1938) wrote *Pinnularia borealis* var. *africana* v. n. (on page 556) and *Pinnularia congolensis* n. sp. (on page 571) and in the species list he mentioned sample nr 5 from a puddle on the Karisimbi volcano and sample nr 21 from a puddle from Nanindjha respectively. However, no description is given for these two taxa, consequently both names have to be considered nomina nuda and therefore invalidly published. Two decades later Cholnoky (1957) elevated the validly described *Pinnularia borealis* var. *congolensis* to species level: *Pinnularia congolensis* (Zanon) Cholnoky.

Zanon’s research was followed in the middle of the 20th century by that of Hustedt (1949) who published a treatise on the diatoms of the “Parc national Albert”, nowadays the Virunga National Park, which was created in 1925 and among the first protected areas in Africa. Among the 55 new taxa that Hustedt (1949) described, 25 belong to the genus *Nitzschia* Hassall, 11 to *Navicula* Bory and 6 to *Eunotia*. The other taxa are from more than 10 other genera including *Achnanthes* Bory, *Amphora* Ehrenberg, *Caloneis* Cleve, *Cymbella*, *Fragilaria* Lyngbye, *Gomphonema* Ehrenberg, *Pinnularia*, *Stauroneis* Ehrenberg, *Stephanodiscus* Ehrenberg and *Surirella* Turpin (for details see Table 1).

Further studies which included diatoms, were carried out in the Kivu region in the 1950’s by Kufferath (1957). This author reported on diatoms from cataracts on the Rusizi River, which forms the overflow of Lake Kivu to Lake Tanganyika, near Bugarama. Although this village is located in Rwanda, formerly Ruanda-Urundi, we have included the new diatoms reported from the cataracts as the Rusizi River forms the border between DR Congo and Rwanda. Of the 59 taxa mentioned by Kufferath (1957), twelve were described as new to science (Table 1): five *Nitzschia*, two *Hantzschia* Grunow, two *Navicula*, one *Cymbellonitzschia* Hustedt, one *Gomphonema* and one *Pseudo-eunotia* Grunow. The other genera reported by Kufferath (1957) are *Amphora*, *Anomooneis* Pfitzer, *Cocconeis*, *Cymatopleura* W. Smith, *Cymbella*, *Gomphocymbella* O. Müller, *Mastogloia* (Thwaites) W. Smith, *Rhopalodia* O. Müller, *Rhoicosphenia* Grunow and *Synedra*.

At the beginning of the 21st century research on algae of Lake Kivu continued with the work of Sarmento (2006) and Sarmento et al. (2012). Although not concerning the DR Congo, it is noteworthy to mention the papers of Mpawenayo (1985, 1996) as these concerned diatoms from rivers in the Burundian part of the Rusizi plain. The
Table 1. New diatom taxa described from DR Congo, their references, geography, habitat and possible synonyms.

| Taxon n                | Publication                  | Page | Plate | fig.  | Province     | Region       | Waterbody       | Synonym                           |
|------------------------|-----------------------------|------|-------|-------|--------------|--------------|-----------------|-----------------------------------|
| Achnanthes atomus var. congolensis Hustedt*** | Hustedt 1949 | 74–75 | 2     | 35, 36 | North-Kivu   | Bugazia      | Lake Edward     | Achnanthes congolensis Hustedt     |
| Achnanthes pseudogrimmi Cholnoky* | Cholnoky 1970 | 11–2 | 1     | 1–3   | Zambia       | 10 km from Kansenga | Lake Chali |                    |
| Amphora thermalis Hustedt* | Hustedt 1949 | 111–112 | 11   | 1–3   | North-Kivu   | Mar-ya-Moto  | hot springs     | Halamphora thermalis (Hustedt) Levkov |
| Amphora submontana Hustedt* | Hustedt 1949 | 112–113 | 11   | 4     | North-Kivu   | Butembo      | Mosenda river mouth in Lake Edward | Halamphora submontana (Hustedt) Levkov |
| Cavirola lalandei Cocquyt, M. de Haan & J. C. Taylor | Cocquyt et al. 2013 | 158  | 2     | 11–16, 16–21 | Tshopo        | Lilanda      | Baombe stream   |                                   |
| Cocconeis cistina Zanon* | Zanon 1938 | 598  | 6     |       | South-Kivu   | Kivu         | stream         | Cocconeis cistina Schoeman       |
| Cocconeis scortaetaze Zanon* | Zanon 1938 | 598–599 | 7   |       | South-Kivu   | Kivu         | stream         |                                   |
| Coscinodiscus antiquus [var. minor] f. banaensis Kufferath* | Kufferath 1956 | 43   | 3     | 1     | Bas-Congo    | Banana       | creek near the ocean |                                   |
| Coscinodiscus minoratus Kufferath* | Kufferath 1956 | 45   | 3     | 2     | Bas-Congo    | Banana       | creek near the ocean |                                   |
| Cymbella naviculoides Hustedt* | Hustedt 1949 | 113–114 | 10   | 9–13  | North-Kivu   | Karisimbi    | pond at 3800 m | Cymbella naviculoides (Hustedt) Krammer |
| Cymbella norvegica var. parva Zanon* | Zanon 1938 | 605–606 | 38  |       | North-Kivu   | Karisimbi    | puddle at 3900 m |                                   |
| Cymbellonitzschia carvarorum Kufferath* | Kufferath 1957 | 20–21 | 41   |       | Rwanda       | Bugarama     | rapids on the Rusizi river |                                   |
| Eunotia damasii Hustedt* | Hustedt 1949 | 67–68 | 3     | 1–12  | North-Kivu   | Karisimbi    | crater lake at 3800 m | Eunotia damasii (Hustedt) |                                   |
| Eunotia fuseyi J.C. Taylor & Cocquyt | Taylor et al. 2016a | 305  | 11–14 |       | Tshopo        | Yangubu      | Lobaye river | Eunotia fuseyi (J.C. Taylor & Cocquyt) J.C. Taylor & Cocquyt |
| Eunotia leonardii J.C. Taylor & Cocquyt | Taylor et al. 2016a | 295  | 6–10  |       | Tshopo        | Yangubu      | Lobaye river |                                   |
| Eunotia montana Hustedt* | Hustedt 1949 | 66–67 | 3     | 13–23 | North-Kivu   | Kando        | lake           |                                   |
| Eunotia rudis Cocquyt & M.de Haan | Cocquyt et al. 2016b | 75–76 | 2–24  |       | Tshopo        | Yangambi     | Lomami river   |                                   |
| Eunotia safettax Zanon* | Zanon 1938 | 595–596 | 3   |       | North-Kivu   | Karisimbi    | puddle at 2000 m |                                   |
| Eunotia pseudofusiformis Hustedt | Hustedt 1949 | 71–72 | 2     | 16–18 | North-Kivu   | Karisimbi    | crater lake    |                                   |
| Frustulia africana Cocquyt* | Hustedt 1949 | 62   | 2     | 29–34 | North-Kivu   | Bugazia, Kamande | Lake Edward | Staurastrum africana (Hustedt) D.M. Williams & Round |
| Geiszleria lubiluensis Cocquyt & Lokele | Cocquyt and Lokele 2019 | 243–244 | 1–4, 6–17 |       | Tshopo        | Yangambi     | Lubila river   |                                   |
| Gomphonema aequatoriale Hustedt* | Hustedt 1949 | 119–120 | 10   | 6–8   | North-Kivu   | Kamande      | Lake Edward   | Gomphonema aequatoriale (Hustedt) |                                   |
| Gomphonema constrictum [var. capitata] f. bipunctata Kufferath* | Kufferath 1957 | 30–31 | 38   |       | Rwanda       | Bugarama     | rapids on the Rusizi river |                                   |
| Gomphonema grande B. Karthick, Kociolek, J.C. Taylor & Cocquyt | Karthick et al. 2016 | 188  | 1–24  |       | Tshopo        | Yangubu      | Lomami river   |                                   |
| Gomphonema sairensis Compère* | Compère 1995 | 32   | 1–14  |       | Tshopo        | Kisangani    | Tshopo waterfalls |                                   |
| Taxon                        | Publication | Page | Plate | fig. | Province | Region | Waterbody                          | Synonym                              |
|-----------------------------|-------------|------|-------|------|----------|--------|------------------------------------|--------------------------------------|
| Hantzschia ruziziensis      | Kufferath   | 34   | 53    |      | Rwanda   | Bugarama| rapids on the Rusizi river         |                                      |
| Hantzschia uncinata         | Kufferath   | 34–35| 45    |      | Rwanda   | Bugarama| rapids on the Rusizi river         |                                      |
| Melosira mareri             | Kufferath   | 42   | 2     | 5    | Bas-Congo| Banana  | ocean – brackish-water             |                                      |
| Navicula barriarica         | Hustedt     | 97   | 4     | 14–17| North-Kivu| Kamande| Lake Edward, Mosenda river mouth  |                                      |
| Navicula congolensis        | Hustedt     | 86   | 4     | 23, 24| North-Kivu| Gando  | pond                               |                                      |
| Navicula dartevellei        | Kufferath   | 23   | 25    |      | Rwanda   | Bugarama| rapids on the Rusizi river         |                                      |
| Navicula falcata            | Hustedt     | 88   | 4     | 25, 26| North-Kivu| Gando  | lake                               |                                      |
| Navicula fraxima            | Hustedt     | 90   | 4     | 29, 30| North-Kivu| Kamande| crater                             | Mayamaea grumiformis (Hustedt) Lange-Bertalot |
| Navicula nanteri            | Kufferath   | 23–24| 26    |      | Rwanda   | Bugarama| rapids on the Rusizi river         |                                      |
| Navicula molariformis       | Hustedt     | 86–87| 5     | 9    | North-Kivu| Kamande| Lakes Edward, Mosenda              | Navicula molariformis (Hustedt) Lange-Bertalot |
| Navicula muraliformis       | Hustedt     | 85–86| 4     | 31, 32| North-Kivu| Kavisimbi| crater lake                         | Mayamaea muraliformis (Hustedt) Lange-Bertalot |
| Navicula multivora          | Hustedt     | 82   | 4     | 33–36| North-Kivu| Kamande| Lakes Kivi (Bera), Ndiala         | Luticola mutionoides (Hustedt) D.G. Mann |
| Navicula nuchigodii         | Taylor et al. 2016b | 202 |       | 1–22, 34–51| Tshopo | Yangubu| Lomami river                      |                                      |
| Navicula subcontinent var. africana | Hustedt     | 85   | 4     | 27, 28| North-Kivu| Kisinga-Channel (Uganda) |                                      |
| Navicula submolesta         | Hustedt     | 86   | 5     | 16–18| North-Kivu| Gando  | puddle                            | Navicula submolesta (Hustedt) Lange-Bertalot |
| Navicula zanonii            | Hustedt     | 92–93| 5     | 1–5  | North-Kivu| Gander | Lakes Edward, Kivi                 |                                      |
| Neidium iridis var. parallela | Zanon 1938 | 619 |       | 1    | North-Kivu| Karisimbi| puddle at 3900 m                  |                                      |
| Nitzschia accommodate       | Hustedt     | 139  | 12    | 27–31, 34, 35| North-Kivu| Ngoma| Lake Kivi                         |                                      |
| Nitzschia adapta            | Hustedt     | 135  | 12    | 3–6  | North-Kivu| Kamandee | Lakes Edward, Kibuga, Ndiala    |                                      |
| Nitzschia aquilis           | Hustedt     | 135–136| 12    | 7, 8 | North-Kivu| Bugazia| Lake Edward                      |                                      |
| Nitzschia amphisonoides     | Hustedt     | 140  | 13    | 65–72| North-Kivu| Kamande, Bugazia| Lake Edward             |                                      |
| Nitzschia buccata \ lineari | Hustedt     | 149  | 13    | 17–20| North-Kivu| Kamande| Lake Edward                      |                                      |
| Taxon                               | Publication | Page | Plate | fig. | Province | Region          | Waterbody                                | Synonym                              |
|------------------------------------|-------------|------|-------|------|----------|-----------------|------------------------------------------|---------------------------------------|
| *Nitzschia baculumata* Kufferath*  | Kufferath 1956 | 55   | 7     | 3    | Bas-Congo | Banana          | ocean – brackish-water                   |                                       |
| *Nitzschia bicinctigera* Kufferath*| Kufferath 1957 | 36–37 | 57    |      | Rwanda    | Bugarama        | rapids on the Rusizi river               |                                       |
| *Nitzschia caparti* Kufferath*     | Kufferath 1948 | 8    |       | 17   | Equateur  | Makana (Nouvelle-Anvers) | Congo River                            |                                       |
| *Nitzschia confinis* Hustedt*      | Hustedt 1949 | 145  | 11, 13| 49–54, | North-Kivu, South-Kivu | Ngoma, Keshe-ro, Kishushu, Nyamirundi | Lakes Kivu, Ndalaga                     |                                       |
| *Nitzschia congolensis* Hustedt*   | Hustedt 1949 | 134  | 12    | 15, 16| North-Kivu  | Kamande, Vitsilumbi | Lake Edward                            |                                       |
| *Nitzschia conumennata* Hustedt*   | Hustedt 1949 | 134–135 | 12 | 1, 2 | North-Kivu | Smliki | Lake Edward        |                                       |
| *Nitzschia curvirectangularis* Kufferath* | Kufferath 1956 | 55   | 5    | 8    | Bas-Congo | Banana          | ocean – brackish-water                   |                                       |
| *Nitzschia diurna* Hustedt*        | Hustedt 1949 | 139  | 12    | 32, 33| South-Kivu | Nyamirundi | Lake Kivu                     |                                       |
| *Nitzschia elliptica* Hustedt      | Hustedt 1949 | 148–149 | 13 | 32–34 | North-Kivu | May-ya-Moto | hot springs            |                                       |
| *Nitzschia epiphytocerca* Hustedt* | Hustedt 1949 | 144–145 | 13 | 48–55 | North-Kivu | Smliki | Lakes Edward, Kivu   |                                       |
| *Nitzschia fusiformata* Kufferath* | Kufferath 1956 | 56   | 5    | 9    | Bas-Congo | Banana          | creek near the ocean                     |                                       |
| *Nitzschia hexagonata* Kufferath*  | Kufferath 1956 | 56   | 2    | 10A, B | Bas-Congo | Banana          | creek near the ocean                     |                                       |
| *Nitzschia hexagonata f. minutissima* Kufferath* | Kufferath 1956 | 56   | 1, 2 | 12C, 9, 12A–E | Bas-Congo | Banana          | ocean – brackish-water                   |                                       |
| *Nitzschia inflatea* Kufferath*    | Kufferath 1957 | 38   | 64   |      | Rwanda    | Bugarama        | rapids on the Rusizi river               |                                       |
| *Nitzschia intermissa* Hustedt*    | Hustedt 1949 | 136  | 12    | 11–14 | North-Kivu, South-Kivu | Kamande, Katana | Lake Edward, Machus-waterfall near Lake Kivu |                                       |
| *Nitzschia latens* Hustedt*        | Hustedt 1949 | 148  | 13    | 30–31 | North-Kivu | May-ya-Moto | hot springs            |                                       |
| *Nitzschia mammiferus* Kufferath*  | Kufferath 1956 | 57   | 6    | 4, 5 | Bas-Congo | Banana          | ocean – brackish-water                   |                                       |
| *Nitzschia marci* Kufferath*       | Kufferath 1956 | 58   | 5    | 11   | Bas-Congo | Banana          | creek near the ocean                     |                                       |
| *Nitzschia mediterrani* Hustedt*   | Hustedt 1949 | 149  | 13    | 21–24 | South-Kivu | Nyamirundi | Lake Kivu                     |                                       |
| *Nitzschia microscula* Kufferath*  | Kufferath 1956 | 58   | 5    | 4    | Bas-Congo | Banana          | creek near the ocean                     |                                       |
| *Nitzschia obliquata* Hustedt*     | Hustedt 1949 | 148  | 13    | 25   | North-Kivu | Kamande        | Lake Edward                            |                                       |
| *Nitzschia oholeta* Hustedt*       | Hustedt 1949 | 146  | 13    | 94–99 | North-Kivu | Kamande, Bugazia | Lake Edward                            |                                       |
| *Nitzschia ogivalis* Kufferath*    | Kufferath 1957 | 40–41 | 56   |      | Rwanda    | Bugarama        | rapids on the Rusizi river               |                                       |
| *Nitzschia pala var. tropica* Hustedt* | Hustedt 1949 | 147  | 13    | 26–29 | North-Kivu | Kamande, Bugazia, Gando | Lakes Edward, Kivu, Kibuga, Ndalaga ponds |                                       |
| Taxon                          | Publication      | Page | fig. | Plate | fig. | Province   | Region   | Waterbody                  | Synonym                                                                 |
|-------------------------------|------------------|------|------|-------|------|------------|----------|---------------------------|-------------------------------------------------------------------------|
| Nitzschia pseudopectinalis    | Kufferath 1957   | 43   | 73   | 70a   | b    | Rwanda     | Bugarama | rapids on the Rusizi river |                                                                        |
| Nitzschia pseudostriata       | Kufferath 1957   | 43   | 15   | 35–38 |      | South-Kivu | Kamana   | Lake Edward               |                                                                        |
| Nitzschia robusta             | Hustedt 1949     | 141  | 13   | 1–4   | 1–4  | North-Kivu | Bugarama | Machusa-waterfall near Lake Edward |                                                                        |
| Nitzschia spiculoides         | Hustedt 1949     | 136  | 13   | 5–6   | 5–6  | North-Kivu | Katana   | Lakes Kibuga, Machusa-waterfall near Lake Edward |                                                                        |
| Nitzschia spiculum            | Hustedt 1949     | 136  | 13   | 1–4   | 1–4  | North-Kivu | Katana   | Lakes Kibuga, Machusa-waterfall near Lake Edward |                                                                        |
| Nitzschia spirilliformis      | Kufferath 1956   | 58   | 6, 7 | 3–1   | 3–1  | Bas-Congo  | Banana   | ocean – brackish-water    |                                                                        |
| Nitzschia stricta             | Hustedt 1949     | 136  | 12   | 9–10  | 9–10 | North-Kivu | Kamanda   | Lake Edward               |                                                                        |
| Nitzschia subcommunis         | Hustedt 1949     | 146  | 11   | 11–13 | 11–13| North-Kivu | Katana   | Lakes Kibuga, Machusa-waterfall near Lake Edward |                                                                        |
| Nitzschia tarda               | Hustedt 1949     | 138–139 | 12 | 24–25 | 24–25| North-Kivu | Kamanda   | Lakes Kibuga, Machusa-waterfall near Lake Edward |                                                                        |
| Nitzschia tropica             | Hustedt 1949     | 147  | 11   | 65    | 65   | North-Kivu | Kamanda   | Lake Kibuga               |                                                                        |
| Nitzschia umbilicata          | Hustedt 1949     | 129–130 | 11 | 1–4   | 1–4  | North-Kivu | Kamanda   | Lake Kibuga               |                                                                        |
| Tryblionella umbilicata       | Hustedt 1949     | 129–130 | 11 | 1–4   | 1–4  | North-Kivu | Kamanda   | Lake Kibuga               |                                                                        |
| Pinnularia alpina var.        | Zanon 1938       | 642–643 | 29 | 5–6   | 5–6  | North-Kivu | Karimbi   | puddle at 3900 m          |                                                                        |
| Pinnularia borealis var.      | Zanon 1938       | 641  | 27   | 64–57 | 64–57| North-Kivu | Karimbi   | puddle at 3900 m          |                                                                        |
| Pinnularia fusiformis         | Zanon 1938       | 645–646 | 24 | 30–48 | 30–48| North-Kivu | Karimbi   | puddle at 3900 m          |                                                                        |
| Pinnularia lata var.          | Zanon 1938       | 642  | 28   | 16–25 | 16–25| North-Kivu | Karimbi   | puddle at 3900 m          |                                                                        |
| Pinnularia lineolata          | Zanon 1938       | 647–648 | 23 | 250–500| 250–500| North-Kivu | Karimbi   | puddle at 3900 m          |                                                                        |
| Pinnularia scaettae           | Zanon 1938       | 648  | 21   | 65–48 | 65–48| North-Kivu | Karimbi   | puddle at 3900 m          |                                                                        |
| Taxon | Publication | Page | Plate | fig. | Province | Region | Waterbody | Synonym |
|-------|-------------|------|-------|------|----------|--------|-----------|---------|
| *Pinnularia* *scaettae* var. *krasskei* | Zanon* | 648  | 22    | 4    | North-Kivu, South-Kivu | Bambu mud | pond at 3900 m |  |
| *Pinnularia* *symoensii* | Cholnoky* | 51   | 2     | 4    | Zambia | || |
| *Pinnularia* *tropica* | Hustedt | 108–109 | 7 | 1–12 | North-Kivu | Karisimbi | pond at 3900 m |  |
| *Pinnularia* *valida* | Hustedt* | 106  | 22    | 2    | North-Kivu | Karisimbi | pond at 3900 m |  |
| *Pseudo-eunotia* *ruziziensis* | Kufferath* | 224  | 8–13  | 40   | Rwanda | Bugarama | peat lake at 3900 m, peat bog at 2160 m, puddle at 1500 m |  |
| *Stauroneis* *subobtusa* | Hustedt* | 22   | 2–5   | 25   | Kivu | || ***  |
| *Stauroneis* *zairensis* | Compère* | 224  | 8–13  | 40   | Kinshasa | Bugarama, Pili-Pili, Ndahile | bugarama peat bog, charred wood |  |
| *Stephanodiscus* *damasii* | Hustedt* | 57–58 | 40   | 5    | Kivu | || |
| *Synedra* *bananaensis* | Kufferath* | 49   | 8     | 8    | Bas-Congo | Banana ocean – brackish-water |  |
| *Synedra* *famelica* var. *enflata* | Zanon* | 586–587 | 11 | 14   | North-Kivu, Uganda | Mubumba, Nyanzaghi | pond at 3900 m, pond at 2160 m, peat bog at 1500 m |  |

* : taxon status uncertain (unassessed) in DiatomBase (30 September 2019); ** : taxon not found in DiatomBase (30 September 2019); *** : taxon status unaccepted (synonym) in DiatomBase (30 September 2019).
Rusizi River divides its plain in two parts, the river forming the border between DR Congo and Burundi.

We have not included the research conducted on diatoms of Lake Tanganyika because this ancient lake, located on the territory of four African countries (DR Congo, Burundi, Tanzania and Zambia), does not fall within the scope of this paper. Moreover, there are a number of reports regarding this lake which have been produced in the last decades (e.g. Cocquyt 1998, 2006).

Very little research has been done on freshwater algae from the remaining part of DR Congo (see also Taylor and Cocquyt 2015). For Kongo Central (called Bas-Congo in the colonial time and between 1997 and 2015, and Bas-Zaïre between 1965 and 1997) of note are the publications of Kufferath who reported eight taxa near Mateba Island (Kufferath 1956a) and 44 taxa, of which eleven species and two forms were new to science, at Banana Beach (Kufferath 1956b) (for details see Table 1): one Coscinodiscus Ehrenberg, one Craspedodiscus Ehrenberg, one Melosira C. Agardh, nine Nitzschia and one Synedra. It should be noted that some marine species are included in the results of these surveys, which is not surprising as the two localities are close to the mouth of the Congo River into the Atlantic Ocean. In 1948, Kufferath reported on the plankton of the Congo River near Makanza, formerly called New Antwerp, halfway between Kisangani and Kinshasa in the Equateur province. Among the 25 taxa Kufferath (1948) reported one new Nitzschia species (Table 1). He named this species after André Capart (1914–1991), who was the Director of the Royal Belgian Institute of Natural Sciences between 1958 and 1978. Therefore the specific epithet should be written as capartii. In the second half of the 20th century Cholnoky published three works on tropical African diatoms. Besides diatoms from Mount Kenya (Cholnoky 1960) and the Rwenzori mountains in Uganda (Cholnoky 1964), he studied the diatoms from the Bangweulu swamps (Cholnoky 1970) and reported on 92 specific and infraspecific taxa including three new species, one Achnanthes, one Pinnularia and one Surirella (Table 1). Although these swamps are located in Zambia we include these here as the swamps are situated in the upper Congo River basin and close to the border with DR Congo. Two decades later, Compère (1989) described a new Stauroeis from a fishpond in Kinshasa (Table 1).

The first investigation of the Tshopo province was carried out in the mid 1950’s (Demalsy 1957) on diatoms growing epiphytically on Azolla Lamarck (aquatic ferns of the family Salviniaeae) in the vicinity of Yangambi. The dominant genera were Eunotia, Cocconeis and Achnanthes; the other genera mentioned are: Bacillaria Ehrenberg, Caloneis, Coscinodiscus Ehrenberg, Cyclotella Kützing ex Brébisson, Diatoma Bory, Diploneis (Ehrenberg) Cleve, Epithemia Kützing, Frustulia Rabenhorst, Gomphonema, Gyrosigma Hassall, Cymbella, Navicula, Nitzschia, Pleurostaurum (Rabenhorst) C. Jannisch, Pinnularia, Stauroeis, Surirella, Synedra and some other centric diatoms. Diatom research in the Tshopo province was started again at the end of the 20th century, as is shown in the publication record. The Congo River as well as localities downstream the Lindi River, a major tributary of the Congo river, the Tshopo River and several small rivers and ponds in Kisangani were studied by Golama (1991, 1992, 1996), who
reported 278 diatom taxa excluding desmids (group of green algae) and euglenophytes. In the same period a new *Gomphonema* species, *G. zairense* Compère, was described from the Tshopo River (Compère 1995) (Table 1).

Two decades later, renewed interest in diatom research in the region of Kisangani and Yangambi was initiated by the Boyekoli Ebale Congo 2010 expedition, an expedition that covered 250 km of the Congo River between Kisangani and Bumba and downstream some of its major tributaries (e.g. Cocquyt et al. 2013, 2016; Cocquyt and Taylor 2015). This research resulted in the description of several new diatom species belonging to the genera *Cavinula* D.G. Mann & Stickle, *Eunotia*, *Gomphonema*, *Navicula* and *Iconella* Jurilj (as *Surirella*) (for details see Table 1). *Cavinula lilandae* Cocquyt & M. de Haan (Cocquyt et al. 2013), a diatom from sandy substrata, for example, was described from a stream near the village of Lilanda located close to the western border of the Yangambi Biosphere Reserve. *Gomphonema grande* B. Karthick, Kociolek, J.C. Taylor & Cocquyt (Karthick et al. 2016) and *Navicula nielsfogedii* J.C. Taylor & Cocquyt (Taylor et al. 2016a) were described from an epiphytic sample taken in the Lomami River about 33 km as the crow flies from its confluence with the Congo River. This *N. nielsfogedii*, which may be conspecific with *N. fuerbornii f. africana* Foged described from Ghana (Foged 1966), has a distribution that is not restricted to the Congo, but to tropical and sub-tropical Africa (Taylor et al. 2016). The genus *Eunotia* is not only abundant in the acid streams and rivers from the Congo basin, but it is also a very diverse genus. Up to the present four new taxa have been described from the Yangambi Biosphere Reserve and its surroundings: *E. pierrefuseyi* (J.C. Taylor & Cocquyt) J.C. Taylor and Cocquyt, *E. leonardii* J.C. Taylor & Cocquyt, *E. rudis* Cocquyt & M. de Haan and *Geissleria lubiluensis* Cocquyt & Lokele (Table 1) (Cocquyt et al. 2016; Taylor et al. 2016b; Cocquyt and Lokele 2019; Taylor and Cocquyt 2019). Moreover, *Eunotia enigmatica* L.F. Costa & C.E. Wetzel a species recently described from the Amazon basin (Costa et al. 2017a, b) and another South American species, *Encyonopsis frequentis* Krammer (Krammer 1997) were observed in the Congo basin (Cocquyt et al. 2019).

However, what is not apparent from the above cited publications is that diatom research was also conducted in the region of Kisangani, Tshopo province, in the decades between the publication of the paper by Demalsy (1957) and those of Golama (1991, 1992, 1996). In the 1980’s several students completed their theses on diatoms at the University of Kisangani (UNIKIS): Golama in 1980, Dhed’a in 1981, Mbuyu and Mwilambwe in 1983, Kasereka, Kwere and Mbiya in 1984 (Table 2). The results of Golama on diatoms of the Lindi River and the Simi-Simi pond, and of Dhed’a, on diatoms of the Kabondo River and ponds near Botumbe, were published in the “Annales de la Faculté des Sciences de Kisangani”, the local journal of the University of Kisangani (Golama et al. 1983). A total of 21 genera were reported: *Asterionella* Hassall, *Caloneis*, *Ceratoneis* Ehrenberg, *Cocconeis*, *Coscinodiscus* (mentioned as *Cosnodiscus*), *Cylindrotheca* Rabenhorst, *Cymbella*, *Diatoma*, *Epithemia*, *Eunotia*, *Fragilaria*, *Frustulia*, *Gomphonema*, *Gyrosigma*, *Navicula*, *Nitzschia*, *Pinnularia*, *Rhopalodia*, *Surirella*, *Synedra*, *Tabelaria* Ehrenberg ex Kützing (Golama et al. 1983). The Lindi River and the Simi-Simi pond were the most diverse each with 16 genera; 7 genera were reported from ponds near Botumbe, 5 from the Kabondo River and 3 from a pond at Lumbulumbu.
A pond (étang du Grand-séminaire) in Kisangani, dominated by *Closterium Nitzsch ex Ralfs* (Desmidiales), was also investigated. It is located 4.5 km from the old road to Buta in the north of the city. Mbuyu (Table 2) reported twelve diatom genera in samples from the dry and the wet season in 1983. *Surirella* was only observed in the wet season, while *Amphipleura Kützing, Cymbella, Epithemia, Fragilaria, Melosira, Navicula, Nitzschia, Pinnularia, Rhicosphenia, Synedra* and *Tabellaria* were observed both in the dry and the wet season. Kasereka (Table 2) studied the algal flora of the Djubudjubu River, where he mentioned the following diatom genera from 27 samples taken between 10 March and 3 May 1984: *Asterionella, Nitzschia* in the plankton, *Fragilaria, Gomphosphaeria, Navicula and Pinnularia* in the benthos, *Cocconeis, Cymbella, Fragilaria, Gomphonema, Navicula, Nitzschia, Pinnularia, Surirella and Synedra* in the epilithon. Diatoms of the genera *Gomphonema* and *Navicula* were the most abundant. Kwere (Table 2) reported on algae present in the purification ponds of the water treatment plant of the Régideso in Kisangani. Seven diatom genera were mentioned, *Navicula, Nitzschia and Pinnularia* were dominant, *Asterionella, Fragilaria, Gomphonema, Melosira, Surirella and Synedra* were also recorded. Mbiya (Table 2) studied the algal flora of the Makiso River in the urban subregion of Kisangani. In epilithic samples eight genera were reported (*Cocconeis, Cymbella, Gomphonema, Navicula, Nitzschia, Pinnularia, Surirella and Synedra*) and only four were found in the benthos (*Navicula, Nitzschia, Pinnularia, and Synedra*).

Golama and Richell-Maurer (1983) reported on fish stomach contents from several fish species captured in the Lindi and the Congo River near Kisangani. *Melosira* was found to be dominant in the stomach contents of *Citharinus* sp., a tropical African lutefish, and *Labeo* sp., a genus of carp, while *Cymbella* and *Navicula* were found in *Distichodus* sp., an African ray-finned fish. In addition to diatoms belonging to these three genera, 15 other genera were reported: *Amphora, Amphipleura, Arcella Ehrenberg, Cocconeis, Caloneis, Cymatopleura, Cylindrotheca, Diatoma, Fragilaria, Gomphonema, Gyrosigma, Nitzschia, Pinnularia, Surirella and Synedra*.

The Boyekoli Ebale Congo 2010 expedition, together with initiatives taken by the VLIR-UOS at the University of Kisangani and the FORETS project at Yangambi, encouraged a number of students to choose diatom related subjects for their theses. In 2013, two students investigated the diatoms of some fish ponds at NgeneNgene, about 20 km from the city center of Kisangani. One thesis concentrated on the diatoms in the phytoplankton (Mosunga), the other on the benthos and the epiphyton (Mukinzi) (Table 2). These two students tried to delineate taxa within diatom genera. However, as the available literature or diatom floras for tropical Africa were scarce or not available to the students, a name could not be given to most of the taxa. In the phytoplankton samples 27 taxa were reported belonging to *Asterionella, Aulacoseira Thwaites, Cyclotella, Cymbella, Encyonema Kützing, Eunotia, Fragilariforma D.M. Williams & Round, Frustulia, Gomphonema, Navicula, Nitzschia, Pinnularia, Sellaphora Mereschkowsky, Stenopeterobia* (Brébisson) Van Heurck and *Surirella*. For the benthos and epiphyton a total of 13 taxa were reported (12 for the benthos, 9 epiphytic on *Nymphaea lotus* L. and 6 epiphytic on *Azolla pinnata* R. Brown). Most were the same genera as reported in the plankton, however *Asterionella and Cymbella* were not present in the periphytic samples while *Cymatopleura* was present but not in the plankton.
Table 2. List of diatom-related theses authored by students in DR Congo with the academic year of submission, the student’s full name and affiliation (UNIKIS: Université de Kisangani; IFA: Institut Facultaire des Sciences Agronomiques de Yangambi; UOB: Université officielle de Bukavu), the academic degree and the title of the dissertation. A bachelor’s dissertation from the Thomas More University of Applied Sciences (Thomas More) in Belgium is added. A translation of the original French/Dutch title into English is given in italics. (*: not yet submitted).

| Year | Institution | Full name | Degree | Title thesis |
|------|-------------|-----------|--------|--------------|
| 1980 | UNIKIS      | Anicet Go- lama Swana Rakata | licentiate | Étude comparative de la flore algologique de la rivière Lindi et de l’étang de Simi-Simi (Haute-Zaïre) en relation avec quelques facteurs du milieu. |
| 1981 | UNIKIS      | Benoît Djef’a Djiallo | licentiate | Inventaire algologique des étangs de Botumbe et de la rivière Kabondo. |
| 1983 | UNIKIS      | Mwilambwe Mbiyu Wu Kibwe | licentiate | Flore algale des réservoirs d’eau douce, étude des algues d’un étang à Kisangani. |
| 1984 | UNIKIS      | Mbiya Mutombo Mudima Kasereka Katsumugene | licentiate | Contribution à l’étude de la flore algale d’une rivière de la sous-région urbaine de Kisangani: Makiso. |
| 1984 | UNIKIS      | Kwere Kwere Muhangana | licentiate | Étude des algues des bassins d’épuration de l’usine de traitement des eaux à la Régideso Kisangani. |
| 2013 | UNIKIS      | Julienne Mukiriza Manyambu | licentiate | Contribution à l’étude des diatomées benthiques et périphytiques des étangs Ngene-Ngene aux environs de Kisangani (R.D. Congo). |
| 2013 | UNIKIS      | Solange Mosungo Bosamba | licentiate | Étude sur la composition des diatomées phytoplanktoniques des étangs de Ngene-Ngene situés en milieu périphérique de Kisangani. |
| 2014 | UOB         | S. Ombezi | licentiate | Evaluation de la qualité de l’eau de la rivière Nyanuhinga (l’un des affluents Nord-Ouest du Lac Kivu) par les indices diatomiques. |
| 2018 | UOB         | MwamiBantu Mulini Cédric-Dubois | bachelor | Diversité algale et caractéristiques physico-chimiques des eaux thermales de la rivière Mayi ya Moto, Nyangezi, Sud-Kivu. |
| 2019 | UNIKIS      | Alain Okito Mosindo | master | Étude des diatomées épiphytiques isolées des herbes et plantes aquatiques fraîches de la région de Yangambi en République Démocratique du Congo (RDC). |
| 2019 | Thomas More | Zoë Madder | bachelor | Een onderzoek naar de evolutie van waterkwaliteit in de regio Eala, Kisangani en Yangambi (DR Congo) doorheen de 20ste eeuw. |
| 2019* | IFA         | Nelly Acel Yapersi | bachelor | Identification des diatomées du cours d’eau Makiso dans la région de Kisangani en saison sèche et saison des pluies. |
| 2019* | IFA         | Francis Nzanzu Vosi | bachelor | La flore des diatomées du cours d’eau Lokuti dans la région de Yangambi en saison sèche et saison des pluies. |
| 2019* | IFA         | Daniel Mabele Boyoma | bachelor | Identification des diatomées du cours d’eau Loile dans la région de Yangambi en saison sèche et saison des pluies. |
| 2019* | UNIKIS      | Dorcas Basuma Sakina | licentiate | Identification des diatomées du cours d’eau Lokwae dans la région de Kisangani en saison sèche et saison des pluies. |
Okito studied diatoms present on herbarium material of aquatic plants collected during the 20th century in the Central Forest phytogeographic region (VI) according to the classification of Robyns (Robyns 1948; Bamps 1968) and kept at the Herbarium of Yangambi (YBI) (Table 2). In a similar fashion to the students Mosunga and Mukinzi, Okito tried to distinguish the different species, without, however, giving a name to most of them. This resulted in 104 specific and infra specific taxa, belonging to 34 genera with *Eunotia*, *Frustulia* and *Desmogonium* Ehrenberg as most dominant. The other observed genera were *Achnanthes*, *Achnanthidium* Kützing, *Actinella* F.W. Lewis, *Amphora*, *Aulacoseira*, *Bacillaria*, *Brachysira* Kützing, *Caloneis*, *Cavinula*, *Cocconeis*, *Cyclotella*, *Cymbopleura* (Krammer) Krammer, *Diploneis*, *Encyonema* cf. *Fistulifera* Lange-Bertalot, *Geissleria* Lange-Bertalot & Metzeltin, *Halamphora* (Cleve) Levkov, *Humidophila* (Lange-Bertalot & Werum) Lowe, *Kociolek, Johansen, Van de Vijver, Lange-Bertalot & Kopalová, Iconella*, *Mayamaea* Lange-Bertalot, *Navicula*, *Nupela* Vyverman & Compère, *Staurosira* Ehrenberg, *Staurosirella* D.M. Williams & Round.
During the academic year 2017–2018 several other students started studying diatoms in rivers in the Tshopo province. Although most are not finished at the time of publication of the present paper, the preliminary titles of these theses (bachelor, licenti-ate or master level) are included in Table 2.

Algological investigations, other than on Lake Kivu, continue in the South Kivu province through student theses (Table 2). Muliri (Table 2) for example reported on 18 diatom genera from the thermal water of the Mayi ya Moto River. From the genera cited (Achnanthes, Actinella, Aulacoseira, Bacillaria, Cocconeis, Cyclotella, Diadesmis, Diatoma, Encyonopsis, Fragilaria, Fragilariforma, Melosira, Navicula, Nitzschia, Stephano-discus, Synedra, Tabellaria and Thalassiosira Cleve) we can conclude that more recent literature (e.g., Round et al. 1990, and subsequent later taxonomic publications) is already being used. For example the genera Diadesmis and Encyonopsis are used which were before lumped with the genera Navicula and Cymbella respectively.

Up to now a total of 106 new diatoms (specific and infraspecific taxa) have been described from DR Congo, with a peak (51 taxa) at the end of the 1940’s (Fig. 1). Of the 21 genera (s.l.), Nitzschia is by far the genus with the highest numbers of new taxa described from DR Congo (40), followed by Pinnularia (12) (Fig. 2). Navicula s.l. has 15 taxa, but includes at least two Craticula, one Cavicula, one Geissleria, one Luticola and one Mayamaea species. Although the genus Eunotia is well represented in the acid rivers of DR Congo, it only comes in fourth place with 7 new species described. However, the renewed interest in the diatom biodiversity in DR Congo will certainly increase the number of new diatom species to be discovered, including several Eunotia as evidenced by ongoing investigations (unpubl. data). Of interest are the similarities and differences with the neo-tropical (South America) diatom flora as evidenced by the presence of Eunotia enigmatica L.F. Costa & C.E. Wetzel and Encyonopsis frequentis Krammer (Cocquyt et al. 2019) in DR Congo.

Figure 1. Number of new diatom taxa (specific and infraspecific) described from DR Congo per decade.
Figure 2. Pie diagram showing the relative abundance of the 21 genera (s.l.) to which the newly described species and infraspecific taxa from the DR Congo belong, *Nitzschia* being the most important, followed by *Pinnularia* and *Navicula* s.l.

It is worth noting that almost all of the new diatoms (see Table 1) described from DR Congo have the taxon status uncertain (unassessed) in DiatomBase. Only twelve taxa have the taxon status accepted; these include nine species described from DR Congo in the 21st century (Cocquyt et al. 2013; Cocquyt and Taylor 2015; Cocquyt et al. 2016; Karthick et al. 2016; Taylor et al. 2016a, b; Cocquyt and Lokele 2019) as well as *Eunotia pseudoflexuosa* Hustedt, *Nitzschia elliptica* Hustedt and *Pinnularia tropica* Hustedt. All three aforementioned species were described in a publication in which Hustedt described a total of 50 new taxa from the “Parc national Albert” (Hustedt 1949). Although *Nitzschia epiphyticoides* Hustedt was thoroughly studied (Cocquyt et al. 2012) it still has the status uncertain (unassessed) in DiatomBase (Kociolek et al. 2019).

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