ГОДИШНИК НА СОФИЙСКИЯ УНИВЕРСИТЕТ „СВ. КЛИМЕНТ ОХРИДСКИ“
БИОЛОГИЧЕСКИ ФАКУЛТЕТ
Книга 2 - Ботаника
Том 104, 2020

ANNUAL OF SOFIA UNIVERSITY “ST. KLIMENT OHRIDSKI”
FACULTY OF BIOLOGY
Book 2 - Botany
Volume 104, 2020

CHECKLIST OF CYANOPROKARYOTES AND ALGAE IN THE LARGE TROPICAL RIVER CONGO (AFRICA)

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Abstract. This study presents data on the floristic composition of cyanoprokaryotes/ cyanobacteria and algae in the tropical River Congo, the second longest river in Africa after the Nile, which at global scale is the second most important river after Amazon in terms of drainage basin size and freshwater discharge. The results in this paper are based only on the materials collected from the mainstem of the middle part of the River Congo, in a stretch of 1,450 km, in two sampling campaigns conducted in contrasting hydrologic conditions: in the high water (HW) period, in December 2013 (33 sites), and in the low, falling water (FW) period in June 2014 (38 sites). Totally 520 taxa of 7 divisions (Cyanoprokaryota - 76, Cryptophyta - 1, Euglenophyta -17, Pyrrhophyta - 8, Chlorophyta - 108, Streptophyta - 38, Ochrophyta - 272: 242 Bacillariophyceae, 24 Chrysophyceae, 1 Synurophyceae, 3 Tribophyceae and 2 Eustigmatophyceae), were identified in the phytoplankton samples but few of them (16) were strictly tropical. Algal diversity was higher during the FW (431 taxa) compared with HW (314 taxa) and floristic similarity between both periods was only 57% based on 213 common taxa. According to the frequency of distribution, most of the phytoplankters occurred rarely and only two diatoms were found in all sites during both studied periods: *Aulacoseira ambigua* and *Nitzschia lancettula.* They were followed by the widespreadAulacoseira *agassizii, A. granulata* var. *angustissima, Nitzschia* cf. *lacuum, Staurosirella leptostauron* and *Staurosirella pinnata.*

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Cyanoprokaryotes and chlorophytes were found along the whole river flow, but with different species composition.

Key words: algal distribution, diversity, phytoplankton, potamoplankton, tropical algae

INTRODUCTION

The knowledge on the phytoplankton of one of the most important large world rivers, the tropical Congo River, which provides freshwater resources for millions of people in central Africa (Oberg et al. 2009) and is the major transport arteria of DR Congo is quite scarce. Only recently data on potamoplankton structure, dynamics and main driving forces in the Middle Congo River became available (Descy et al. 2016). The results obtained by high-performance liquid chromatography analysis of chlorophyll a (Chi a) and marker pigments, and to the primary production measurements made by using the 13C incubation technique, demonstrated a pronounced difference in phytoplankton composition, biomass and production in the periods of high waters (HW) and low, falling waters (FW) (op. cit.). For example, in the mainstem concentrations of Chi a varied between 0.07 and 1.77 ^g L 1 in HW conditions, and between 1.13 and 7.68 ^g L 1 in FW conditions. Based on marker pigment concentration, green algae (both chlorophytes and streptophytes) dominated in the mainstem in HW, whereas diatoms dominated in FW; cryptophytes and cyanobacteria were more abundant but still relatively low in the FW period, both in the tributaries and in the main channel (Descy et al. 2016). Daily integrated production measured in the mainstem varied between 64.3 and 434.1 mg C m 2 d ay 1 in FW conditions and between 51.5 and 247.6 mg C mm-2 d ay 1 in HW (op. cit.). Phytoplankton growth in the Congo River can take place in the main channel, with hydrological processes allowing maintenance of phytoplankton biomass even during HW (Descy et al. 2016). The relative contribution to phytoplankton biomass from tributaries (mostly black waters) and from a few permanent lakes was low, and the main confluences resulted in phytoplankton dilution. This result is in contrast to other tropical river systems where connectivity with the floodplain and the presence of natural lakes and man made reservoirs play a prominent role in the recruitment of phytoplankton to the main river (Descy et al. 2016). At the same time, the presence of phytoplankton developing in the main river channel is in accordance with data on its formation in the lowest natural part of the temperate large European Danube River (Stoyneva & Draganov 1991; Stoyneva 1994) and its tributary Tisa/Tisza (Istvanovics et al. 2010, 2011,2012).

Regarding the river phytoplankton composition, D escy et a l . (2016) published the most frequent 25 phytoplankton taxa from different taxonomic groups in the Middle Congo mainstem: *Aphanocapsa* spp., *Aphanothece* spp., *Limnococcus limneticus, Planktolyngbya* spp. (cyanobacteria/cyanoprokaryotes), *Actinastrum*

rhaphidioides, Coelastrum spp., *Coenochloris* spp., *Desmodesmus magnus, D. perforatus, Scenedesmus communis, S. oahuensis, Planktosphaeria gelatinosa* (chlorophytes), *Closterium* spp., *Hyalotheca* cf. *mucosa* (streptophytes), *Euglena*

spp., *Strombomonas* spp. (euglenophytes), *Salpingoeca* spp. (chrysophytes), *Aulacoseira granulata* (including var. *angustissima), A. agassizii, Cyclostephanos invisitatus, Cyclotella* spp., *Discostella pseudostelligera, Staurosirella* spp. and *Thalassiosira rudolfii* (diatoms). However, "studies of African phytoplankton should not only list the major components, but also all the accompanying taxa in order to provide better knowledge on their distribution and biogeography" (Lemoalle et al. 1981, p. 38). Regarding this, John (1986, p. 160) noted that "the correct identification of taxa in many groups is becoming increasingly a specialist task ...". Former studies on algae of the R. Congo basin reported floristic composition of both periphyton and plankton from the mainstem and some tributaries, but on relatively small sectors and dealt with specific taxonomic groups *(e.g.* Kufferath 1948; Golama 1991,1996; Verheyen et al. 2017). The aim of the present paper is to present data on the total species composition of the Congo River phytoplankton, in a stretch of 1,450 km corresponding to the Middle Congo River, in contrasting hydrologic conditions, which could serve as a basis for future tracking of the algal biodiversity in this important large tropical river.

MATERIAL AND METHODS

Study site

The Congo River (formerly known as the Zaire River) stretches from the Great Rift Valley in Eastern Africa to the Atlantic Ocean in the west **(Fig. 1).** It is the second longest river in Africa after the Nile, with a length of about 4,300 km (Oberg et al. 2009; Van den Bossche & Bernacsek 1990 - cit. acc. to http s://en.wikipedia.org/wiki/Congo_River). The Congo is also the second largest river in the world by discharge volume, following only the Amazon: the discharge at its mouth ranges from 23,000 to 75,000 $m^3 sec^{-1}$, with an average of 41,000 $m^3 sec^{-1}$ (Van den Bossche & Bernacsek 1990 - cit. acc. to http s://en.wikipedia.org/wiki/Congo_River). The drainage basin has been estimated to cover about 4 million km^2 (Beadle 1974; Van den Bossche & Bernacsek 1990 - cit. acc. to http s://en.wikipedia.org/wiki/ Congo River; Oberg et al. 2009). The river runs between 7 0N and 12 0S, mostly through a flooded forest region, draining the largest expanse of lowland tropical forest in Africa (Beadle 1974; Bwangoy et al. 2010). Congo River crosses twice the equator. In this way the dry season on the northern part of the basin is compensated by the rainy season on the southern part of the basin, and vice versa, leading to a regulation of seasonal water high tv ariations, which are small (3-4 m) in the main river bed (Runge 2008).

Sampling

Sampling details and main water characteristics have already been published by Descy et al. (2016): two sampling campaigns were carried out in the Middle Congo River, between Kisangani and Kinshasa **(Fig. 1),** in the high water (HW) period, in December 2013 (75 sites), and in the falling water (FW) period in June 2014 (89

sites). The sampling was carried out using a 28 ^m plankton net in the main river bed of the Congo River and in tributaries, as well as in the outlet of one of the two main lakes (Lake Tumba). A few additional samples were collected on

Fig. 1. Location of sampling sites in the Congo River at the scale of the whole basin overlain on elevation. Inset: Location of the Congo River basin in Africa. Map was generated with ArcGIS_ using publically available spatial datasets (after Desc y et a l. 2 0 1 6).

the lower stretch of the mainstem downstream of the confluence with the Kasai River in May 2015 (FW period). Here we report only results from the River Congo mainstem (38 sites in FW and 33 sites in HW), as most of time only one sample was available from the lakes and tributaries.

Algal identification

The main part of the work on the algal biodiversity was done using conventional light microscopy with magnification 100x and immersion on non-permanent slides on microscopes Motic BA 4000 microscope with camera Moticam 2000, and on Motic B1 microscope with camera Moticam 2.0 mp, supplied by Motic Images 2 Plus and

Motic Images 3 Plus software programs, respectively. Only Bacillariophyceae were identified on permanent slides mounted with Naphrax after peroxide digestion on Leitz Diaplan standard microscope, equipped with a Euromex camera using the Image Focus 4 software. Identification of some diatoms was checked by Priscila Trema rin (Universidade Federal do Parana, Curitiba, Brazil) using SEM.

The work is based on main standard floras *(e.g.* Ettl 1978; Starmach 1983, 1985; Krammer & Lange-Bertalot 1991, 1997a,b, 2004; Komarek & Fott 1983; Komarek & Anagn ostidis 1999, 2005; Tsarenko et al. 2011; Wehret al. 2015; Moestrup & Calado 2018) and numerous relevant current taxonomic papers consid ering data in Algae Base (Guiry & Guiry 2020), Diatom Base (Kocioleketa l. 2020), and Cyano DB (Hauer & Komarek 2020).

Estimation of frequency of distribution and floristic similarity For better understanding of the horizontal distribution of the species and their role in the phytoplankton, for each species the frequency quotient (FQ standardly calculated as per cent of the number of sites in which it was found vs total number of checked sites), was estimated separately for each of both studied periods (HW and FW) and as their average for the river phytoplankton. Estimated FQs were grouped in five classes through 20%: I - 1-20%, II - 21-40%, III - 41-60%, IV - 61-80%, and V - 81-100% (Stoyneva & Draganov 1991).

Floristic similarity between both studied periods was estimated according to Sorensen's Similaritylndex (SSI, Sorensen 1948).

RESULTS AND DISCUSSION

The results from taxonomical identification of the phytoplankton algae in both studied periods are summarized in **Table 1.** There, some of the most popular common former Latin names are kept as synonyms.

In total, 520 taxa from 7 divisions have been identified in the phytoplankton of the Congo River **(Table 1),** some of which are illustrated on **Figs 1-82.** The distribution of all taxa by phyla is: Cyanoprokaryota - 76, Cryptophyta - 1, Euglenophyta -17, Pyrrhophyta - 8, Chlorophyta - 108, Streptophyta - 38, Ochrophyta - 272 (Bacillariophyceae - 242, Chrysophyceae - 24, Synurophyceae - 1, Tribophyceae
- 3, Eustigmatophyceae - *2)* - **Fig. 83.** Thus, Ochrophyta represented 52% of all phytoplankton diversity. Among them the richest were diatoms (Bacillariophyceae), which formed 47% of all biodiversity and clearly prevailed over all other

Table 1. Checklist of phytoplanktonic algae of the Congo River (2013-2014) with indication of their frequency quotients in low (FQLW) and high (FQHW) waters.

Taxa/Frequency quotients	FQ L W	FQ H W
CYANOPROKARYOTA		
Anathece cf. *bachmannii* (Komärek & Cronberg) Komärek,		

Kastovsky & Jezberovä (Syn. *Aphanothece* cf. *bachmanii* Komärkovä-Legnerovä & G.Cronberg)

Anathece clathrata (W. etG. S. West) Komärek, Kastovsky et Jezberova 3

Anathece endophytica (W. & G. S. West) Komärek, Kastovsky & Jezberovä (Syn. *Aphanothece endophytica* (West & G. S. West) J. Komärkovä-Legnerovä & G. Cronberg) 3

Anathece smithii (Komärkovä-Legnerovä & Cronberg) Komärek, Kastovsky & Jezberovä 3

Aphanocapsa conferta (W. et G. S. West) Komärkovä-Leg nerovä et Cronberg 3 3

Aphanocapsa elachista W. et G. S. West 9 *Aphanocapsa grevillei* (Berkeley) Rabenhorst 5

Aphanocapsa holsatica (Lemmermann) Cronberg et Komärek 9

Aphanocapsa incerta (Lemmermann) Cronberg et Komärek 9 8 *Aphanocapsa koordersii* KM.Str0m 39 18 *Aphanocapsa planctonica* (Smith) Komärek et Anagnostidis 6 *Aphanocapsa* spp. 3 5 *Aphanothece elabens* (Brebisson ex Meneghini) Elenkin 42 26 *Aphanothece microscopica* Nägeli 9 *Aphanothece stagnina* (Sprengel) A. Braun in Rabenhorst 12 3 *Aphanothece* sp. 3 *Chroococcus cohaerens* (Brebisson) Nägeli 6 *Chroococcus dispersus* (Keissler) Lemmermann 3 3

Chroococcus cf. *distans* (G. M. Smith) Komärkovä-Legne rovä & Cronberg 3

Chroococcus minimus (Keissler) Lemmermann 5 *Chroococcus minor* (Kützing) Nägeli 3 *Chroococcus minutus* (Kützing) Nägeli 12 3 *Chroococcus planctonicus* Bethge 3

Taxa/Frequency quotients FQ L W FQ H W *Chroococcus* cf. *polyedriformis* Schmidle 3 *Chroococcus vacuolatus* Skuja 3 *Coelosphaerium kützingianum* Nägeli 5 *Cyanodictyon* cf. *tubiforme* Cronberg 3 *Cyanodictyon* cf. *iac* Cronberg et Komärek 3 3

Eucapsis aphanocapsoides (Skuja) Komárek & Hindák in Komárek et al. (Syn. *Chroococcus aphanocapsoides* Skuja) 3 3

Geitleribactron subaequale (Geitler) Komárek 3 3 *Gomontiella* sp. 3

Horrmoscilla sp. 3

Jaaginema cf. *perfilievii* (Anissimova) Anagnostidis & Komárek (Syn. *Oscillatoria* cf. *perfilievii* Anissimova) 0 3 3

Leptolyngbya cf. *valderiana* (Gomont) Anagnostidis et Komárek 3

Leptolyngbya foveolarum (Gomont)

Leptolyngbya sp. 15 13

Limnococcus limneticus (Lemmermann) Komárková, Jezberová, 0. Komárek et Zapomelová 52 8

Limnolyngbya circumcreta (G. S. West) X. Li & R. Li 6 21 *Limnolyngbya* cf. *circumcreta* (G. S. West) X. Li & R. Li 12 8 *Lyngbya martensiana* Meneghini ex Gomont 3 *Merismopedia glauca* (Ehrenberg) Kützing 6 *Merismopedia punctata* Meyen, nom. Illeg. 3 *Merismopedia tenuissima* Lemmermann 3 *Merismopedia warmingiana* (Lagerheim) Forti 3 *Microcystis cf. aeruginosa* (Kützing) Kützing 3

Microcystis wesenbergii (Komárek) Komárek ex Komárek in Joosen 3

Oscillatoria perornata Skuja 3 *Oscillatoria sancta* Kützing ex Gomont 3 *Oscillatoria simplicissima* Gomont 9 *Oscillatoria tenuis* Agardh ex Gomont 11 *Oscillatoria pseudocurviceps* Welsh 3

24

Pannus planus Hindák 3 *Pannus* sp. *(lAphanocapsa* sp.) 6

Phormidium irriguum (Kützing ex Gomont) Anagnostidis & Komárek 3

Phormidium cf. *papyraceum* Gomont ex Gomont 3 *Phormidium* spp. 3 16

Planktolyngbya cf. *brevicellularis* Cronberg et Komárek 82 24

Planktolyngbya contorta (Lemmermann) Anagnostidis et Komárek

Planktolyngbya limnetica

(Lemmermann) Komárková-Leg nerová et Cronberg 3 30 18

Planktolyngbya microspira Komárek et Cronberg 3 *Planktolyngbya minor* (Geitler) Komárek et Cronberg) 6 3 *Planktolyngbya regularis* Komárková-Legnerová et Tavera 3 *Planktolyngbya undulata* Komárek et Kling 3 *Planktothrix clathrata* (Skuja) Anagnostidis & Komárek 3 *Planktothrix isothrix* (Skuja) Komárek et Komárková 3

Planktothrix rubescens (De Candolle ex Gomont) Anagnos tidis & Komárek 3

Radiocystis geminata Skuja 3 3 *Rhabdogloea linearis* (Geitler) Komárek 3 *Snowella atomus* Komárek et Hindák 3

Sphaerocavum microcystiforme (Hindák) Azevedo & Sant'Anna (Syn. *Pannus microcystiformis* Hindák) 6 3

Spirulina corakiana Playfair 3 *Spirulina tenuissima* Kützing, nom. Inval. 3 *Synechocystis aquatilis* Sauvageau 3 *Tychonema tenue* (Skuja) Anagnostidis et Komárek 3 *Woronichinia delicatula* (Skuja) Komárek et Hindák 3 *Woronichinia fremyi* (Komárek) Komárek et Hindák 3 CRYPTOPHYTA

Chroomonas oblonga (Playfair) Pascher (Syn. *Crypto monas oblonga* Playfair) 3

EUGLENOPHYTA

Cryptoglena pigra Ehrenberg 3 25

Taxa/Frequency quotients FQ L W FQ H W *Euglena* spp. 18 3 *Dinema* sp. 3 *Lepocinclis teres* (F. Schmitz) Francé 6 3 *Strombomonas acuminata* (Schmarda) Deflandre 21 11 *Strombomonas* cf. *australica* (Playfair) Deflandre 3 *Strombomonasfluviatilis* (Lemmermann) Deflandre 6 8 *Strombomonas gibberosa* (Playfair) Deflandre 3 5 *Strombonas schauinslandii* (Lemmermann) Deflandre 9 3 *Strombomonas urceolata* (Stokes) Deflandre 6 3 *Strombomonas* sp. 3 *Trachelomonas caudata* (Ehrenberg) F. Stein 3 3 *Trachelomonas piscatoris* A. C. Stokes 6 *Trachelomonas planctonica* Swirenko 9 *Trachelomonas scabra* Playfair 3 *Trachelomonas volvocina* (Ehrenberg) Ehrenberg 3 *Trachelomonas* sp. 3

PYRRHOPHYTA

Ceratium - cysts 3 *Gymnodinium paradoxum* A. J. Schilling 3 *Gymnodinium*

spp. 9

Parvodinium africanum (Lemmermann) S. Carty (Syn. *Peridinium africanum* Lemmermann inG. S. West) 9

Parvodinium umbonatum (Stein) S. Carty (Syn. *Peridinium umbonatum* Stein) 6

Peridinium cinctum (0. F. Müller) Ehrenberg non *Peridin ium cinctum* Penard *Peridinium* spp. 9 8

Tovellia coronata (Woloszynska) Moestrup, Lindberg & Daugbjerg (Syn. *Woloszynskia coronata* (Woloszynska) R. H. Thompson) 6

CHLOROPHYTA

Actinastrum aciculare Playfair 3 *Actinastrum rhaphidioides* (Reinsch) Brunnthaler 67

26

Acutodesmus acutiformis (Schröder) Tsarenko & D. M. John (Syn. *Enallax acutiformis* (Schröder) Hindäk) 3

Ankistrodesmus arcuatus Korshikov (Syn. *Monoraphidium arcuatum* (Korshikov) Hindäk) 3

Ankistrodesmus falcatus (Corda) Ralfs 3 *Ankistrodesmus stipitatus* (Chodat) Komarkovä-Legnerovä 9

Binuclearia lauterbornii (Schmidle) Proschkina-Lavrenko (Syn. *Planctonema lauterbornii* Schmidle) 6

Carteria sp. 1 3 *Carteria* sp. 2 3 *Chlamydomonas* spp. 30

Chlorella elongata (Hindäk) C. Bock, Krienitz et Pröschold (Syn. *Dictyosphaerium elongatum* Hindäk) 3

Coelastrum astroideum De-Notaris 6 3 *Coelastrum microporum* Nägeli in A. Braun 6

Coelastrum microporum var. *octaedricum* (Skuja) Sodom 3

kovä

Coelastrum proboscideum Bohlin in Wittrock et Nordstedt 3 *Coelastrum pseudomicroporum* Korshikov 9 3 *Coelastrum pulchrum* Schmidle 9 *Coenochloris fottii* (Hindäk) Tsarenko 21 8 *Coenochloris pyrenoidosa* Korshikov (Syn. *Coenochloris hindakii* Komarek sensu Komarek et Fott) 27 3

Coenochloris sp. 3

Desmodesmus abundans (Kirchner) Hegewald (Syn. *Scenedesmus quadrispina* Chodat) 3

Desmodesmus brasiliensis (Bohlin) Hegewald 3 *Desmodesmus communis* (Hegewald) Hegewald (Syn. *Scenedesmus communis* (Turpin) Hegewald) S. S. An, T. Friedl et Hegewald 33 11 3

Desmodesmus denticulatus (Lagerheim)

Desmodesmus insignis (West & G. S. West) E. Hegewald 3 3 *Desmodesmus intermedius* (Chodat) Hegewald 3

Desmodesmus magnus (Meyen) Tsarenko (incl. Syn. *Scenedesmus oahuensis* (Lemmermann) G. M. Smith) 36 13

Desmodesmus opoliensis (Richter) Hegewald 3 27

Taxa/Frequency quotients FQ L W FQ H W

Desmodesmus opoliensis var. *carinatus* (Lemmermann) Hegewald *mononensis* (Chodat) He gewald 6 5 15 5

Desmodesmus opoliensis var.

Desmodesmus perforatus (Lemmermann) Hegewald 24 11 *Desmodesmus pleiomorphus* (Hindäk) Hegewald 3 *Desmodesmus protuberans* (Fritsch & Rieh) Hegewald 3 *Desmodesmus spinosus* (Chodat) Hegewald 3 3

Desmodesmus subspicatus (Chodat) Hegewald & A. Schmidt in Hegewald (Syn. *Scenedesmus subspicatus* Chodat) 3

Dictyosphaerium indicum Iyengar & Ramanathan 3 *Dictyosphaerium subsolitarium* Van Goor 3 *Eutetramorus fotti* (Hindäk) Komärek 9 *Eutetramorus polycoccus* (Korshikov) Komärek 6 *Franceia armata* (Lemmermann) Korshikov 3 *Hariotina reticulata* Dangeard 3

Hindakia fallax (Komärek) C. Bock, Proschold & Krienitz 21

(Syn. *Dictyosphaerium tetrachotomum* var. *fallax* Kom.)
Hindakia tetrachotoma (Printz) C. Bock, Pröschold & Krienitz (Syn. *Dictyosphaerium tetrachotomum* Printz) 6

Keriochlamys sp. ad *K. styriaca* Pascher 3 *Kirchneriella dianae* var. *major* (Korshikov) Comas Gonzales 3 *Kirchneriella lunaris* (Kirchner) Möbius 3 *Kirchneriella obesa* (West) Schmidle 9 3

Lacunastrum gracillimum (West et G. S. West) H. McManus in McManus et al. 9

Lagerheimia balatonica (Scherffel) Hindäk 3 *Lagerheimia chodatii* Bernard 3

Lemmermannia triangularis (Chodat) C. Bock & Krienitz in C. Bock et al. (Syn. *Tetrastrum triangulare* (Chodat) Komärek) 3

Lobocystis planctonica (Tiffany & Ahlstrom) Fott 3

Messastrum gracile (Reinsch) T. S. Garcia in T. S. Garcia et al. (Syn. *Selenastrum gracile* Reinsch) 15 3

28

Microspora sp. (fragments) 3 *Monactinus simplex* (Meyen) Corda 3

Monactinus simplex var. *echinulatum* (Wittrock) Pérez, Maidana et Comas 5

Monactinus simplex var. *sturmii* (Reinsch) Pérez Baliero et al. 3

Monoraphidium caribeum Hindák 3 *Monoraphidium griffithii* (Berkeley) Komarková-Legnerová 6 *Monoraphidium komarkovae* Nygaard 9

Monoraphidium saxatile Komárková-Legnerová 1969 (Syn. *Chlorolobion saxatile* (Komárkova-Legnerova) Komárek) 3

Mucidosphaerium pulchellum (Wood) C. Bock, Pröschold & Krienitz 12 3 3

Mychonastes botrytella (Komárek & Perman) Krienitz, C. Bock, Dadheech & Proschold (Syn. *Dictyosphaerium botrytella* Komárek & Perman)

STREPTOPHYTA

Actinotaenium globosum (Bulnheim) Teiling 9 *Actinotaenium* sp. 3 *Closterium angustatum* Kützing ex Ralfs 3 *Closterium gracile* Brébisson ex Ralfs 3 3 *Closterium limneticum* Lemmermann 21 3 *Closterium lineatum* Ehrenberg ex Ralfs 3 *Closterium moniliferum* (Bory) Ehrenberg ex Ralfs 3 *Closterium praelongum* Brébisson 3 *Closterium pronum* Brébisson 3 *Closterium strigosum* Brébisson 12 *Closterium* sp. 3 *Cosmarium abbreviatum* Raciborski 3 *Cosmarium contractum* Kirchner 6 *Cosmarium laeve* Rabenhorst 3 3 *Cosmarium obtusatum* (Schmidle) Schmidle 3 *Cosmarium phaseolus* Brébisson ex Ralfs 3 *Cosmarium tenue* W. Archer 3 cf. *Desmidium* (fragments) 9 8 *Gonatozygon* sp. 3

Taxa/Frequency quotients FQ L W FQ H W *Hyalotheca* cf. *mucosa* Ralfs 36 16 *Klebsormidium* sp. (fragments) 27 11

Mesotaenium cf. *macrococcum* (Kützing ex Kützing) Roy

3

et Bisset

Mougeotia spp. st. 3 8 *Penium* - zygotes 3 cf. *Pleurotaenium nodosum* (Bailey ex Ralfs) P. Lundell 3 *Spirogyra* spp. st. 8

3

Staurastrum brevispina Brébisson in Ralfs (Syn. *Stau rodesmus brevispina* (Brébisson) Croasdale)

Staurastrum chaetoceros (Schröder) Smith 3

Staurastrum pingue Teiling 3 3

Staurastrum pingue var. *planctonicum* (Teiling) Coesel & Meersters (Syn. *Staurastrum planctonicum* Teiling) 3 5

Staurastrum tetracerum Ralfs ex Ralfs 3 *Staurastrum volans* West etG .S . West 3 *Staurodesmus bulnheimii* (Raciborski) Round & A. J. Brook 3 *Staurodesmus cuspidatus* (Brébisson) Teiling 9 3

Staurodesmus dejectus (Brébisson) Teiling 3 *Staurodesmus glaber* (Ralfs) Teiling 3 *Xanthidium* sp. 3 OCHROPHYTA

Chrysophyceae

Bicosoeca cylindrica (Lackey) Bourrelly 3 3 *Bicosoeca* cf. *eurystoma* Hilliard 3 3 *Chrysamoeba scherfelii* (Pascher) Matvienko 6 *Chrysopyxis iwanoffii* Lauterborn 6 3 *Chrysopyxis paludosa* Fott 3 *Codosiga* cf. *botrytis* (Ehrenberg)

Kent 3 *Codosiga* sp. 3 *Codonosigopsis* sp. 3 *Dinobryon* sp. (?D. cf. *belingii* Svirenko) 3 *Dinobryon* sp. ad *D. dilatatum* Hilliard 3 *Diploeca elongata* (Fott) P. Bourrelly 6 21

30

Diploecaflava (Korshikov) Bourrelly 1957 8 *Diplosigopsis affinis* Lemmermann 21 5 *Epipyxis* cf. *epiplanctica* (Skuja) Hilliard et Asmund 3 *Epipyxis utriculus* (Ehrenberg) Ehrenberg 1838 3 *Lagynion infundibuliforme* Starmach 1966 3 *Lagynion oblongum* (Pascher) Bourrelly 3 *Salpingoeca* cf. *convolvulus* Skuja 3 *Salpingoeca eurystoma* Stokes 1886 34 *Salpingoeca* cf. *vaginicola* Stein 1878 3 *Salpingoeca* sp. ad *S. cylindrica* Fott 9 *Salpingoeca* sp. 9 26 *Stokesiella* sp. ad *Stokesiella epipyxis* Pascher 1930 12 3

3

Stokesiella sp. ad *Stokesiella longipes* (Stokes) Lemmer mann 1908

Synurophyceae

Mallomonas sp. 3 Tribophyceae

Bumilleriopsis brevis (Gerneck) Printz 1914 3

Centritractus africanus F. E. Fritsch & M. F. Rich in F. E.

18

Fritsch, M. F. Rich & M. L. Stephens 1930

Centritractus ellipsoideus Starmach 1966 3 Eustigmatophyceae

Tetraedriella regularis (Kützing) Fott 1967 3 *Tetraedriella spinigera* Skuja 1948 3 3 Bacillariophyceae

Achnanthes inflata (Kützing) Grunow 16 4 *Achnanthidium affine* (Grunow) Czarnecki 32 4 *Achnanthidium exiguum* (Grunow) Czarnecki 52 15

19

Achnanthidium exiguum var. *constrictum* (Grunow) An dresen, Stoermer et Kreis

Achnanthidium lineare W. Smith 26 12 *Achnanthidium minutissimum* (Kützing) Czarnecki 68 38 *Achnanthidium reimeri* (Camburn) Ponader et Potapova 10 *Achnanthidium subhudsonis* (Hustedt) Kobayasi 71 62 *Achnanthidium* sp. (connective view) 23 8

31

Taxa/Frequency quotients FQ L W FQ H W *Actinella punctata* Lewis 3 4

Actinocyclus normanii Gregory (Hustedt) 3

Adlafia bryophila (Petersen) Moser, Lange-Bertalot et Met

zeltin

Amphora copulata (Kützing) Schoeman et R. E. M.Archibald 6 8 *Anomoeoneis sphaerophora* Pfitzer 3 *Aulacoseira agassizii* (Ostenfeld) Simonsen 100 96 *Aulacoseira agassizii* var. *malayensis* (Hustedt) Simonsen 10 4 *Aulacoseira ambigua* (Grunow) Simonsen 100 100 *Aulacoseira granulata* (Ehrenberg) Simonsen 87 88

Aulacoseira granulata var. *angustissima* 100 92
(0. F. Müller) Simonsen

Aulacoseira herzogii (Lemmermann) Simonsen 52 46 *Aulacoseira minuscula* Tremarin, Torgan et Ludwig 23 23 *Aulacoseirapusilla* (Meister) Tuji et Houk 19 69 *Bacillaria paxillifera* (0. F. Müller) Marsson 6 8 *Brachysira brebissonii* Lange-Bertalot et Moser 16 8

Brachysira vitrea (Grunow) Ross 4 *Caloneis bacillum* (Grunow) Cleve 29 15

Capartogramma crucicula (Grunow) Ross 32 27

Cavinula cocconeiformis (Gregory ex Greville) Mann et
Stickle *Cavinula variostriata* (Krasske) Mann et Stickle

Cocconeis pediculus Ehrenberg 3 *Cocconeis placentula* Ehrenberg 55 27

Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow 3 4 *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck 4 *Cocconeis scutellum* Ehrenberg 58 23 *Craticula cuspidata* (Kützing) Mann 3 *Craticula molestiformis* (Hustedt) Mayama 19

Cyclostephanos invisitatus (Hohn et Hellermann) Theriot, Stoermer et Häkansson 90 58

Cyclotella atomus Hustedt 87 46 *Cyclotella* cf. *cyclopuncta* Häkansson et Carter 3 4 *Cyclotella meneghiniana* Kützing 100 62

32

Cymatopleura solea (Brébisson) W. Smith 16 8 *Cymbopleura frequens* Krammer 4

Cymbopleura naviculiformis (Auerswald ex Heiberg)
3
Krammer

Diadesmis confervacea Kützing 68 31 *Diadesmis gallica* W. Smith 13 42 *Diploneis elliptica* (Kütz.) Cleve 0 8 *Discostella pseudostelligera* (Hustedt) Houk et Klee 97 69 *Discostella stelligera* (Cleve et Grunow) Houk et Klee 16

4

Dorofeyukea kotschyi (Grunow) Kulikovskiy, Kociolek, Tusset et T. Ludwig *Encyonema caespitosum* Kützing 4 *Encyonema silesiacum* (Bleisch) Mann 13 19 *Encyonema minutum* (Hilse) Mann 16 4 *Encyonopsis cesatii* (Rabenhorst) Krammer 6 *Encyonopsis krammeri* Reichardt 8 *Eolimna minima* (Grunow) Lange-Bertalot et Schiller 23 12 *Eolimna subminuscula* (Manguin) Moser, Lange-Bertalot et Metzeltin 6 8

Epithemia adnata (Kützing) Brébisson 6 *Epithemia operculata* (C. Agardh) Ruck et Nakov 3 *Eunotia bilunaris* (Ehrenberg) Schaarschmidt 8 *Eunotia exigua* (Brébisson ex Kützing) Rabenhorst 6 *Eunotiaflexuosa* (Brébisson ex Kützing) Kützing 12 *Eunotia formica* Ehrenberg 3 4 *Eunotia incisa* W. Smith ex W. Gregory 6 15 *Eunotia perminuta* (Grunow) R. M. Patrick 23 *Eunotia minor* (Kützing) Grunow 52 23 *Eunotia* cf. *paludosa* Grunow 10 4 *Eunotia pectinalis* (Kützing) Rabenhorst 23 15 *Eunotia praerupta* Ehrenberg 6 8 *Eunotia praerupta* var. *excelsa* Krasske 6 *Eunotia rhomboidea* Hustedt 10 *Eunotia tenella* (Grunow) Hustedt 32 38 *Eunotia* cf. *tetraodon* Ehrenberg 3

33

Taxa/Frequency quotients FQ L W FQ H W *Eunotia zasuminensis* (Cabejszekowna) Körner 65 65 *Eunotia* spp. (connective view) 23 *Fallacia meridionalis* Metzeltin, Lange-Bertalot et García

16

Rodríguez *Fallacia subhamulata* (Grunow) D. G. Mann 3 *Fragilaria berolinensis* (Lemmermann) Lange-Bertalot 73 *Fragilaria capucina* Desmazieres 13 *Fragilaria rumpens* (Kützing) Carlson 65 31 *Fragilaria tenera* (W.Smith) Lange-Bertalot 35 4 *Fragilaria tenuissima* Lange-Bertalot et Ulrich 100 58 *Fragilaria vaucheriae* (Kützing) Petersen 13 19 *Frustulia rhomboides* (Ehrenberg) De Toni 26 19 *Frustulia saxonica* Rabenhorst 6 8 *Frustulia vulgaris* (Thwaites) De Toni 3 *Geissleria decussis* (0strup) Lange-Bertalot et Metzeltin 29 19 *Geissleria ignota* (Krasske) Lange-Bertalot et Metzeltin 3 4 *Gomphonema affine* Kützing 23 *Gomphonema affine* var. *insigne* (W.Gregory) G.W.Andrews 16 4 *Gomphonema* cf. *angustatum* (Kützing) Rabenhorst 3 27 *Gomphonema augur* Ehrenberg 4 *Gomphonema gracile* Ehrenberg 6

Gomphonema grande Karthick, Kociolek, Taylor et Cocquyt 3 *Gomphonema* cf. *lagenula* Kützing 16 15 *Gomphonema minutum* (Agardh) Agardh 13 *Gomphonema parvulum* (Kützing) Kützing 23 8 *Gomphoshenia grovei* (Schmidt) Lange-Bertalot 6 4

13

Gomphoshenia cf. *lingulatiformis* (Lange-Bertalot et Re
ichardt) Lange-Bertalot

Gyrosigma scalproides (Rabenhorst) Cleve 3 *Gyrosigma acuminatum* (Kützing) Rabenhorst 16 19 *Halamphora coffaeiformis* (Agardh) Levkov 12 *Halamphora montana* (Krasske) Levkov 13 8 *Hantzschia amphioxys* (Ehrenberg) Grunow 6 19

34

Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzel tin et Witkowski Kociolek, J. R. Jo hansen, Van de Vijver, Lange-Bertalot et Kopalova 6 4 6 4 87 50

Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin et Witkowski

Humidophila contenta (Grunow) Lowe,

Karayevia clevei (Grunow) Round et Bukhtiyarova 10 8 *Karayevia laterostrata* (Hustedt) Round et Bukhtiyarova 3 *Kobayasiella jaagii* (Meister) Lange-Bertalot 10 *Lemnicola hungarica* (Grunow) Round et Basson 6 4 *Luticola acidoclinata* Lange-Bertalot 10 8 *Luticola cohnii* (Hilse) D. G. Mann 35 19 *Luticola mutica* (Kützing) D. G. Mann 71 35 *Luticola saxophila* (Bock ex Hustedt) D. G. Mann 26 15 *Mayamaea atomus* (Kützing) Lange-Bertalot 3 8 *Melosira varians* Agardh 3 *Navicula* cf. *heimansii* van Dam et Kooyman 97 62 *Navicula cincta* (Ehrenberg) Ralfs 6 4 *Navicula cryptocephala* Kützing 27 *Navicula nielsfogedii* Taylor et Cocquyt 97 65 *Navicula schroeteri* F. Meister 0 4 *Navicula vandamii* Schoeman et Archibald 90 92 *Navicula viridula* (Kützing) Ehrenberg 6 *Navicula viridula* var. *rostellata* (Kützing) Cleve 10 27 *Navicula* spp. 13 4 *Neidium affine* (Ehrenberg) Pfizer 6 *Neidium* cf. *alpinum* Hustedt 6 *Neidium* cf. *hitchcockii* (Ehrenberg) Cleve 3 *Neidium productum* (W.Smith) Cleve 8 *Nitzschia* cf. *accomodata* Hustedt 90 85 *Nitzschia acicularis* (Kützing) W. Smith 10 12 *Nitzschia acidoclinata* Lange-Bertalot 10 *Nitzschia* cf. *archibaldii* Lange-Bertalot 3 *Nitzschia capitellata* Hustedt 13 38 *Nitzschia* cf. *congolensis* Hustedt 6 38

Taxa/Frequency quotients FQ L W FQ H W *Nitzschia* cf. *graciliformis* Lange-Bertalot et Simonsen 19 8 *Nitzschia frustulum* (Kützing) Grunow 13 12 *Nitzschia gracilis* Hantzsch 65 27 *Nitzschia heufleriana* Grunow 3 *Nitzschia inconspicua* Grunow 10 50 *Nitzschia intermedia* Hantzsch ex Cleve et Grunow 48 27 *Nitzschia irremissa* Chlonoky 4 *Nitzschia* cf. *lacuum* Lange-Bertalot 100 92 *Nitzschia lancettula* 0. F. Müller 100 100 *Nitzschia linearis* (Agardh) W. Smith 3 8 *Nitzschia linearis* var. *tenuis* (W. Smith) Grunow 13 4 *Nitzschia lorenziana* Grunow 13 4

Nitzschia lorenziana var. *incerta* Grunow in Cleve et Grunow (Syn. *N. reversa* W. Smith) 16 8

Nitzschia palea (Kützing) W. Smith 12 *Nitzschia paleacea* Grunow 61 38 *Nitzschia paleaeformis* Hustedt 6 4

Nitzschia peisonis Pantocsek 6 *Nitzschia pumila* Hustedt 19 27 *Nitzschia rostellata* Hustedt in Schmidt et al. 58 23 *Nitzschia sigma* (Kützing) W. Smith 32 15 *Nitzschia* cf. *soratensis* Morales et Vis 23 *Nitzschia spiculum* Hustedt 4 *Nitzschia subacicularis* Hustedt 4 *Nitzschia tropica* Hustedt 84 73 *Nupela wellneri* (Lange-Bertalot) Lange-Bertalot 39 12 *Nupela* cf. *neglecta* Ponader, Lowe et Potapova 6 31 *Orthoseira roseana* (Rabenhorst) O'Meara 32 23 *Pantocsekiella ocellata* (Pantocsek) K. T. Kiss et Ács 16 *Peroniafibula* (Brebisson ex Kützing) Ross 55 12 *Pinnularia acoricola* Hustedt 3 8 *Pinnularia acutobrebissonii* Kulikovskiy, Lange-Bertalot et Metzeltin 10

Pinnularia divergentissima (Grunow) Cleve 6 4 36

Pinnularia gibba Ehrenberg 6 8 *Pinnularia microstauron* (Ehrenberg) Cleve 10 *Pinnularia subcapitata* Gregory 16 35 *Pinnularia viridis* (Nitzsch) Ehrenberg 6 *Pinnularia* spp. 15 *Placoneis clementis* (Grunow) Cox 13 *Placoneis dicephala* (W. Smith) Mereschkovsky 4 *Placoneis exigua* (Gregory) Mereschkovsky 16 *Placoneis exiguiformis* (Hustedt) Lange-Bertalot 0 4 *Placoneis elginensis* (Gregory) Cox 13 15 *Placoneis gastrum* (Ehrenberg) Mereschkovsky 23 15 *Placoneis* cf. *pseudanglica* Cox 19 23 *Plagiotropis lepidoptera* var. *proboscidea* (Cleve) Reimer 3 *Planothidium daui* (Foged) Lange-Bertalot 19 12

Planothidiumfrequentissimum (Lange-Bertalot) Lange-Ber talot ex Kützing) Bukhti yarova 45 8 13 12

Planothidium lanceolatum (Brébisson

Planothidium rostratum (0strup) Lange-Bertalot 77 73 *Planothidium* sp. 3 8 *Platessa bahlsii* Potapova 26 4 *Platessa hustedtii* (Krasske) Lange-Bertalot 55

38 *Pleurosira laevis* (Ehrenberg) Compère 26 23 *Psammothidium* cf. *daonense* (Lange-Bertalot) Lange-Ber talot (Hustedt) Bukhtiyarova et Round 45 4 35 *Psammothidium subatomoides* *Pseudofallacia tenera* (Hustedt) Liu, Kociolek et Wang 61 23 *Pseudostaurosira brevistriata* (Grunow) Williams et Round 68 38 *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot 3 *Rhopalodia acuminata* var. *protracta* (Grunow) Krammer 3 *Rhopalodia gibba* (Ehrenberg) 0. Müller 4 *Rhopalodia gibberula* (Ehrenberg) 0. Müll. 8 *Rhopalodia* sp. 8 *Sellaphora bacillum* (Ehrenberg) Mann 13 8

Taxa/Frequency quotients FQ L W FQ H W *Sellaphora laevissima* (Kützing) Mann 3 4 *Sellaphora* cf. *meridionalis* Potapova et Ponader 3 4 *Sellaphora nyassensis* (0. Müller) Mann 13 8 *Sellaphora pupula* (Kützing) Mereschkovsky 55 27 *Sellaphora pseudoarvensis* (Hustedt) Wetzel et Ector 23 *Sellaphora pseudoventralis* (Hustedt) Chudaev et Gololobova 10 *Sellaphora pulchra* Enache et Potapova 6 *Sellaphora seminulum* (Grunow) D. G. Mann 3 46 *Sellaphora vitabunda* (Hustedt) Mann 10 8 *Sellaphora wallacei* (Reimer) Potapova et Ponader 6 4 *Sellaphora* sp. 6 *Simonsenia delognei* (Grunow) Lange-Bertalot 3 *Skeletonema potamos* (Weber) Hasle 8 *Stauroneis anceps* Ehrenberg 3 *Stauroneis kriegeri* Patrick 16 8 *Stauroneis livingstonii* Reimer 13 4 *Staurosira construens* Ehrenberg 10 58 *Staurosira construens* var. *venter* (Ehrenberg) Hamilton 45 8 *Staurosirella leptostauron* (Ehrenberg) Williams et Round 97 100 *Staurosirella pinnata* (Ehrenberg) Williams et Round 97 96 *Stenopterobia curvula* (W. Smith) Krammer 15 *Stenopterobia delicatissima* (Lewis) Brebisson ex van Heurck 10 8 *Stephanodiscus minutulus* (Kützing) Cleve et Möller 52 50 *Surirella birostrata* Hustedt 3 *Surirella* cf. *congolensis* Cocquyt et Taylor 13 8 *Surirella* cf. *linearis* W. Smith 6 *Surirella linearis* var. *constricta* Hustedt 10 8 *Surirella* cf. *minuta* Brebisson 3 *Surirella* cf. *splendida* (Ehrenberg) Kützing 3 *Surirella tenera* Gregory 26 15 *Surirella* sp. 4 *Thalassiosira faurii* (Gasse) Hasle 4 *Thalassiosira rudolfii* (Bachmann) Hasle 97 46

Thalassiosira weissflogii (Grunow) G. Fryxell et Hasle 81 46 *Tryblionella apiculata* Gregory 10 8 *Tryblionella calida* (Grunow) Mann 84 23 *Tryblionella coarctata* (Grunow) Mann 10 15 *Tryblionella hungarica* (Grunow) Frenguelli

23 15 *Tryblionella gracilis* W. Smith 3
Tryblionella levidensis W. Smith 68 46 *Ulnaria acus* (Kützing) Aboal 23 4
Ulnaria danica (Kützing) Compère et Bukhtiyarova 58 23 *Ulnaria delicatissima* (Grunow) Aboal et P. C. Silva 8 *Ulnaria ulna* (Nitzsch) Compère 58 31

taxonomic groups. They were followed by chlorophytes (108 taxa, or 21%) and cyanoprokaryotes (76 taxa, or 15%). - **Fig. 83.** Cyanoprokaryotes were represented only by coccal colonial (60%) and non-heterocytous filamentous species (40%). The lack of heterocytous cyanoprokaryotes capable of efficient nitrogen fixation, clearly indicates that there was no nitrogen limitation, or nitrogen shortage in riverine waters. This result is in accordance with the relatively high ammonium and nitrate values recorded during both studied periods (mean values of 2.3 (iM and 11.3 ^MinHW , and 1.3 and 36.7 in FW - D escy et a l . 2016). Among green algae coccal species prevailed (92% in Chlorophyta and 90% in Streptophyta) over filamentous algae (5% among chlorophytes and 10% in streptophytes) and flagellates (3% from chlorophytes). Although the number of identified species is high, considering the presence of taxa which could not be certainly identified in fixed samples (green flagellates, euglenophytes, pyrrhophytes, *etc.)* it is evident that our knowledge about the river algal biodiversity is far from complete and further studies are needed.

The number of taxa during the HW period was 314, compared with 431 in the FW period. This difference shows that 83% of the taxa occur during low water periods, and 60% of all taxa were recorded in high water periods. Logically, all taxonomic groups were more diverse during FW **(Fig. 84),** except the insignificantly higher numbers of species for chrysophyceans and eustigmatophyceans during HW period **(Table 1).** Algae from Cryptophyta, Tribophyceae and Synurophyceae were found only during low waters **(Fig. 84).** Although the general phytoplankton structure considered in terms of represented algal divisions is similar, we have to note that while cyanoprokaryotes comprised almost, the same part of this structure during both FW and HW periods (14% and 13%, respectively), the contribution of chlorophytes during the HW period was twice lower in comparison with LW (21% and 12%, respectively), and the participation of diatoms was 14% lower during HW

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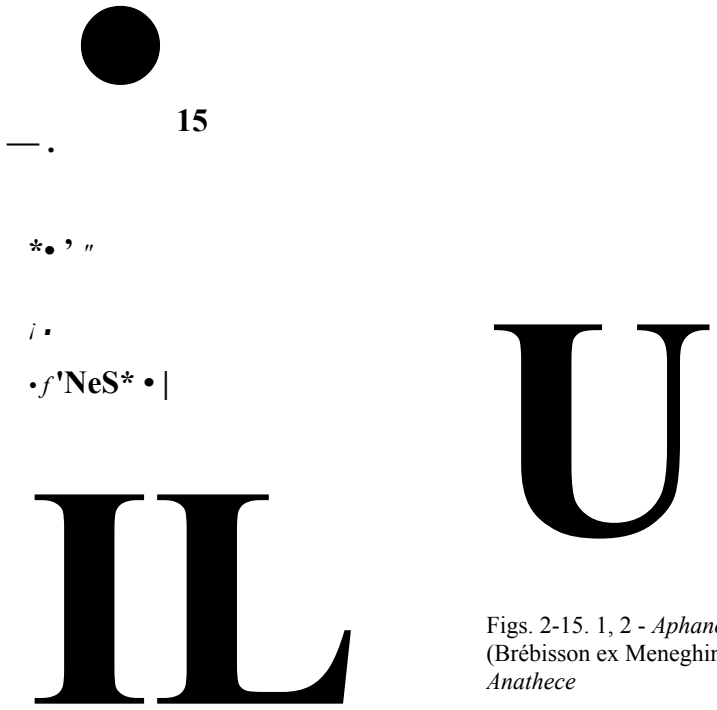

Figs. 2-15. 1, 2 - *Aphanothece elabens* (Brébisson ex Meneghini) Elenkin 1938; 3 - *Anathece*

smithii (Komárková-Legnerová & Cronberg) Komárek, Kastovsky & Jezberová; 4 - *Aphanocap sa holsatica* (Lemmermann) Cronberg et Komárek; 5 - *Aphanocapsa koordersii* K. M. Str0m; 6 - *Merismopedia punctata* Meyen; 7 - *Cyanodictyon* cf. *tubiforme* Cronberg; 8 - *Cyanodictyon* cf. *iac* Cronberg et Komárek - staining with Gentian violet; 9 - *Limnococcus limneticus* (Lemmer mann) Komárková, Jezberová, O. Komárek et Zapomélová; 10 - *Chroococcus vacuolatus* Skuja; 11 - *Chroococcus planctonicus* Bethge; 12 - *Microcystis wesenbergii* (Komárek) Komárek ex Komárek in Joosen; 13, 14 - *Planktolyngbya* cf. *brevicellularis* Cronberg et Komárek. Scale bar is 10 ^m.

Figs. 15-28. 15 - *Planktolyngbya undulata* Komárek et Kling; 16 - *Planktolyngbya micros pira* Komárek et Cronberg; 17 - *Limnolyngbya circumcreta* (G. S. West) X. Li & R. Li; 18 - *Planktolyngbya limnetica* (Lemmermann) Komárková-Legnerová et Cronberg; 19 - *Oscillatoria simplicissima* Gomont; 20 - *Oscillatoria sancta* Kützing ex Gomont; 21 - *Spirulina corakiana* Playfair; 22 - cf. *Hormoscilla* sp.; 23 - *Euglena* sp.; 24 - *Strombomonas acuminata* (Schmarda) Deflandre; 25 - *Strombomonas* sp.; 26-28 - *Strombomonas* cf. *gibberosa* (Playfair) Deflandre. Scale bar is 10 ^m.

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Figs. 29-42. 29 - *Trachelomonas* sp.; 30 - *Trachelomonas* cf. *piscicatoris* A. C. Stokes; 31 32 - *Actinastrum rhaphidioides* (Reinsch) Brunnthaler; 33 - *Ankistrodesmus falcatus* (Corda) Ralfs; 34 - *Coelastrum microporum* var. *octaedricum* (Skuja) Sodomkovä; 35 - *Coelastrum proboscideum* Bohlin in Wittrock et Nordstedt; 36 - *Coelastrum pseudomicroporum* Korshik ov; 37 - *Coenochloris fottii* (Hindäk) Tsarenko; 38, 39 - *Desmodesmus communis* (Hegewald) Hegewald; 40 - *Desmodesmus magnus* (Meyen) Tsarenko; 41, 42 - *Desmodesmus perforatus* (Lemmermann) Hegewald. Scale bar is 10 ^m.

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Figs. 43-56. 43 - *Desmodesmus protuberans* (Fritsch & Rich) Hegewald; *44 - Eutetramorus polycoccus* (Korshikov) Komárek; 45 - *Monactinus simplex* var. *echinulatum* (Wittrock) Pérez, Maidana et Comas; 46 - *Mucidosphaerium pulchellum* (Wood) C. Bock, Pröschold & Krienitz; 47 - *Parapediastrum biradiatum* var. *longecornutum* (Gutwinski) Tsarenko; 48 - *Lacunastrum gracillimum* (West et G. S. West) H. McManus in McManus et al.; 49 - *Messastrum gracile* (Re insch) T. S. Garcia in T. S. Garcia et al.; 50 - *Oocystis lacustris* Chodat; 51- *Oocystis* cf. *mars sonii* Lemmermann; 52 - *Phacotus* sp. *(ISestoma* sp.); 53 - *Scenedesmus praetervisus* Chodat; 54 - *Scenedesmus protuberans* var. *minor* Ley; 55 - *Selenastrum subtile* (Hindák) P. Marvan, Komárek & Comas; 56 - *Tetradesmus dimorphus* (Turpin) M. J. Wynne. Scale bar is 10 ^m.

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Figs. 57-82. 57 - *Treubaria triappendiculata* Bernard; 58 - *Willea apiculata* (Lemmermann) D. M. John, M. J. Wynne & P. M. Tsarenko; 59 - *Actinotaenium globosum* (Bulnheim) Teiling; 60 - *Cosmarium contractum* Kirchner; 61 - *Staurodesmus glaber* (Ralfs) Teiling; 62 - *Salpingoeca eurystoma* Stokes; 63 - *Centritractus africanus* F. E. Fritsch & M .F. Rich in F. E. Fritsch, M. F. Rich & M. L. Stephens; 64 - *Centritractus ellipsoideus* Starmach; 65 - *Aulacoseira agas sizii* (Ostenfeld) Simonsen; 66 - *Aulacoseira ambigua* (Grunow) Simonsen; 67 - *Aulacoseira granulata* (Ehrenberg) Simonsen; 68 - *Aulacoseira granulata* var. *angustissima* (O.F.Müller) Simonsen; 69 - *Aulacoseira herzogii* (Lemmermann) Simonsen; 70 - *Aulacoseira agassizii* (Os tenfeld) Simonsen; 71 - *Cyclostephanos invisitatus* (Hohn & Hellermann) Theriot, Stoermer & Hakansson; 72 - *Discostella pseudostelligera* (Hustedt) Houk & Klee; 73 - *Fragilaria tenuissi ma* Lange-Bertalot et Ulrich; 74 - *Eunotia zasuminensis* (Cabejszekowna) Körner; 75 - *Nitzschia* cf. *lacuum* Lange-Bertalot; 76-78 - *Nitzschia lancettula* O. F. Müller; 79 - *Nitzschia tropica* Hustedt; 80 - *Staurosirella leptostauron* (Ehrenberg) Williams et Round; 81 - *Staurosirella pin nata* (Ehrenberg) Williams et Round; 82 - *Thalassiosira rudolfii* (Bachmann) Hasle. Scale bar is 10 ^m.

period - **Fig. 84.** The general taxonomic structure of phytoplankton of LW period **(Fig. 84A)** is more similar to the taxonomic structure of the total phytoplankton of the river **(Fig. 83A)** in comparison with the HW phytoplankton **(Fig. 84B).**

The similarity in the river phytoplankton according to the SSI was only 57% calculated on the basis of 213 species common for both studied periods **(Table 1, Fig. 83B).** The distribution of the common taxa by taxonomic groups was similar to the general distribution of taxa in riverine phytoplankton, with diatoms as richest group (146 common taxa, which comprised 68% of all common species) followed by cyanoprokaryotes (21 taxa, or 9%) and chlorophytes (20 taxa, or 9%). However, some differences have to be noted: the percentage participation of Ochrophyta (and of diatoms especially) and Euglenophyta in the structure of the "common phytoplankton" was significantly higher in comparison with the role of cyanoprokaryotes and all green algae (Chloro- and Streptophyta), which had almost twice less participation in the common phytoplankton **(Fig. 83B).** These data show the significant core role of diatoms in the biodiversity of Congo phytoplankton.

Most of the recorded species (447) have been described from temperate re gions, but have been recorded in the tropics also. Less taxa (23) were described from tropics but have been found also in temperate regions: *Leptolyngbya circum creta, Merismopedia punctata, Planktolyngbya minor, P. regularis* and *P. undula ta; Achanthes inflata, Aulacoseira herzogii, Nitzschia accomodata, N. congolensis, N. lancettula*, *N. spiculum*, *N. tropica* and *Thalassiosira faurii*; *Centritractus afri*

Fig. 83. A - Taxonomic structure of the Congo River phytoplankton (2013-2014); B - Taxonom ic structure of the phytoplankton common for both studied periods of low (FW) and high (HW) waters, based on 213 common taxa.

canus; *Parvodinium africanum*; *Coelastrum proboscideum*, *C. pulchrum*, *Hinda kia fallax*, *Monoraphidium caribeum, Parapediastrum biradiatum* var. *longecor nutum, Scenedesmus protuberans* var. *minor, Schroederia indica* and *Treubaria triappendiculata.* In temperate waters they were recorded mainly in low amounts

(e.g. Komarek & Fott 1983, Anagnostidis & Komarek 1999, Komarek & Anag- nostidis 2005, Stoyneva 2016, Moestrup & Calado 2018), and only exceptionally were more abundant (Cellamareetal. 2010, 2013). Few species are known only from the tropics: *Aphanocapsa koordersii*, *Oscillatoria perornata*, *O. pseudocur viceps, Planktothrix clathrata; Trachelomonas piscatoris; Aulacoseira agassizii, A. minuscula*, *Gomphonema grande*, *Placoneis exiguiformis*, *Surirella congolensis* and *Thalassiosira rudolfii; Dictyosphaerium indicum* and *Staurastrum volans.* At the same time, during the study we identified 35 species and 2 varieties which,

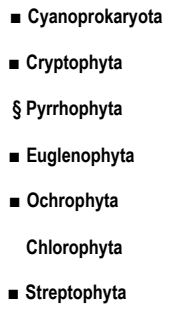

Fig. 84. Taxonomic structure of the phytoplankton of the Congo River (2013-2014) during pe riods of low waters (A) and high waters (B) with their percentage representation as additional labels.

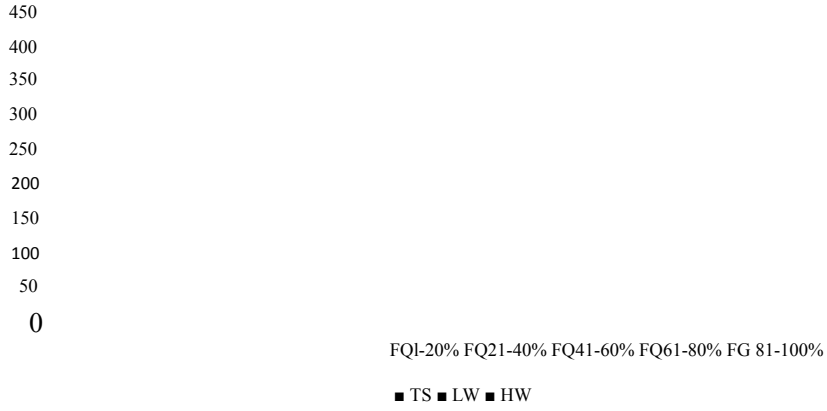

Fig. 85. Frequency of algal taxa in the Congo River phytoplankton represented by five classes of their frequency quotients (FQ) for all phytoplankton species found in the river (TS) and in the both studied periods of low waters (LW) and high waters (HW) (for details see text).

according to our knowledge, have not been recorded so far in the tropical regions: *Chroococcus planctonicus*, *C. vacuolatus*, *Pannus planus*, *Radiocystis geminata*, *Sphaerocavum microcystiforme, Tychonema tenue* and *Woronichinia delicatula; Chroomonas oblonga; Achnanthidium reimeri, Fragilaria tenuissima, Geissleria ignota*, *Fallacia subhamulata*, *Fragilaria berolinensis*, *Kobayasiella jaagii*, *Na vicula vandamii*, *Nitzschia linearis* var. *tenuis*, *Nitzschia peisonis*, *Platessa bahlsii*,

Sellaphora pulchra, S. wallacei and *Stauroneis livingstonii; Bicosoeca cylindri ca, Diploeca elongata; Tetraedriella spinigera; Tovellia coronata; Acantosphaera zacchariasii*, *Chlorella elongata*, *Desmodesmus pleiomorphus*, *Dictyosphaerium subsolitarium*, *Franceia armata*, *Neocystis ovalis*, *Nephrochlamys rotunda*, *Plano chloris pyrenoidifera, Scenedesmus praetervisus, Selenastrum subtile, Siderocelis granulata* and *Staurastrum pingue* var. *planctonicum.* Since they were found as rare algae in quite low amounts, it is possible to suppose that they have been trans ported to the river by migrating birds or other dispersal vectors (Kristiansen 1996; Padisak et al. 2016). However, at present state of art we have not to exclude com pletely the possibility that they have broader ecological amplitudes and their devel opment in tropics has been overlooked. Moreover, two species of marine diatoms were found, far from the ocean, each of them with a single specimen in FW: *Pla giotropis lepidoptera* var. *proboscidea* and *Rhopalodia acuminata* var. *protracta.*

According to the frequency, most of the algae can be considered as rare in the Congo River phytoplankton: FQ of 1st class (algae spread in 1-6 sites) had 84% of all phytoplankters, and 78% and 71% of the taxa during the LW and HW period, respectively **(Fig. 85).** Most of them were found in one site only: 40% of all taxa

in each ofboth studied periods. Widespread taxa, with FQ of Vth class, comprised only 3% of all species, and 5% and 3% of the species during LW and HW period, respectively **(Fig. 85).**

A pronounced difference in the frequency distribution of algae by taxonomic groups was observed: diatoms had the most diverse frequency in all five classes of FQ during both studied periods, cyanoprokaryotes and chlorophytes were spread in four and three FQ classes, respectively, while algae from all other taxonomic groups had FQ of one or two classes only **(Table 1).** In accordance with these results is the fact that most widespread algae in the river phytoplankton are representatives of these three groups, with a leading role for diatoms, which were the most widely spread along the main river bed. In all studied sites (FQ=100%) during both studied periods were found *Aulacoseira ambigua* and *Nitzschia lancettula.* They were followed (FQ=98-96%) by *Aulacoseira agassizii, Aulacoseira granulata* var. *angustissima, Nitzschia* cf. *lacuum, Staurosirella leptostauron* and *Staurosirella pinnata.* The most spread cyanoprokaryote in the river was *Planktolyngbya* cf. *brevicellularis* (FQ=53%).

When discussing the distribution of algae along the river, we have to note that some of the species, and especially of the rare ones, did not belong to the group of typical plankters. Some of them were passively transported as epiphytes over other planktic algae and such ones were most of the recorded chrysophycean algae (with the most spread *Salpingoeca eurystoma* in particular). The second group was represented by some filamentous algae, which could be considered tychoplanktic due to their more typical benthic mode of life *(e.g.* singular fragments of *Ulothrix* spp., *Microspora* sp., *Klebsormidium* sp.). However, generally, the number of typical plankters (euplankters) among non-diatoms prevailed (255 from 278) and they comprised 92% of the phytoplankton diversity. As for diatoms, the flora of the Congo River is mainly composed of taxa of benthic origin, represented by few specimens. A

significant part of diatoms are characteristic of acid, low conductivity rivers and streams, such as *Eunotia* spp. and *Pinnularia* spp., and are likely originating from tributaries, such as the Lobilo, Lobaye and Lomami rivers, located in the upstream part of the studied transect (Verheyen et al. 2017). Based on estimates of abundance and frequency of occurrence in the samples from the mainstem in the FW period, the number of euplanktonic diatom taxa may be fewer than 30, i.e. not more than 12 % of the total number of diatom species.

CONCLUSION

The unique floristic data set obtained during the study shows the rich algal biodiversity of the Middle Congo River phytoplankton. It comprised more than 520 taxa from 7 divisions, considering the presence of more taxa which could not be certainly identified in fixed samples and the fact that the results are based on two sampling series in such a large, still unregulated, river system. Moreover, the

understanding of the drivers of the phytoplankton diversity is still very limited, for instance as to the contribution of tributaries and lakes vs. the role of inputs from different habitats, including the river margins, side arms and large patches of aquatic plants, to the mainstem. Addressing these questions will certainly require more studies, based on both longitudinal surveys and on regular sampling at fixed sites, aiming at investigating the dynamics of phytoplankton diversity, which has been understudied in large tropical rivers.

ACKNOWLEDGEMENTS

The samples examined in this study were collected in projects funded by the European Research Council (ERC-StG 240002 AFRIVAL), the Fonds National de la Recherche Scientifique (FNRS, TransCongo, 14711103), the Belgian Federal Science Policy (BELSPO, COBAFISH, SD/AR/05A), the Research Foundation Flanders (FWOVlaanderen), the Research Council of the KU Leuven and the Fonds Leopold III pour l'Exploration et la Conservation de la Nature. Identification of some diatoms was checked by Priscila Tremarin (Universidade Federal do Parana, Curitiba, Brazil). JPD is grateful to Luc Ector and Carlos Wetzel for help in identification of some diatom taxa also present in Lake Edward.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS

Both authors contributed equally to the paper preparation. In the processing of

the samples J.-P. Descy worked with diatoms, and M. P. S toyneva-G ärtner - with the other algal groups.

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Received 25th March 2020
Accepted 7th May 2020