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[An Updated Checklist of the Phytoplankton of the Blue Nile at Khartoum]

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Open Access An Updated Checklist of the Phytoplankton of the Blue Nile at Khartoum

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Abstract

The phytoplankton of the Blue Nile at Khartoum was investigated during May 2000 to February 2002. Brook (1954) and Sinada (1972) presented similar data collected during 1949-1952 and during 1968-1970 respectively. A total of 225 species and varieties belonging to 75 genera was compiled as the algal flora of the Blue Nile at Khartoum. In terms of number of species Chlorophyta formed the most abundant group (118 species, 36 genera) followed by Bacillariophyta and Cyanobacteria. The contribution of Euglenophyta, Pyrrhophyta and Xanthophyta was negligible. Phytoplankton diversity, biomass and chemical analyses revealed no indication that the Blue Nile at Khartoum suffers from any degree of pollution. However, major changes occurred in the algal species composition when certain taxa which dominated the phytoplankton in the 1950s disappeared and new species appeared in appreciable numbers in early 1970s and during the present study. These changes may be influenced by changes in hydrological regime of the Blue Nile following the construction of the Roseires dam in 1966, and possibly incipient eutrophication resulting from agrochemicals and industrial wastewaters reaching the Blue Nile during the latter decades of the 20th century.

Keywords: Checklist; Phytoplankton; Blue Nile; Diatoms; Cyanobacteria.

Introduction

Historical background

For a long time limnological research was largely neglected in the Sudan; hydrobiological data on the Blue Nile were very scanty. The earliest limnological investigations carried out on the Nile within the Sudan can be traced back to the 19th and early 20th century before the construction of Sennar dam in 1925, when passing biologists compiled occasional notes on algae (see Gurney,1911; Hammerton, 1964). These and Beam (1906) indicated that the plankton of the Nile was then scanty and mixed with detritus and adventitious forms, a finding which is in conformity with our present understanding of dam influence.

In early 1950s more modern limnological work, which has contributed to our knowledge of the biology of the Nile within the Sudan, was launched by members and collaborators of the Hydrobiological Research Unit (HRU, 1953-1980 Annual Reports). The Research Unit was established in the Faculty of Science, University College of Khartoum in 1953 long after the construction of Sennar dam. For obvious reasons most of this limnological work was carried out within the vicinity of Khartoum.

Physical Background

The Blue Nile flows out of Lake Tana over a series of rapids and quickly descends into a deep gorge until it enters the Sudan plain south of Roseires at latitude 12ºN. Between Lake Tana and the Sudan plain the Blue Nile receives many torrential tributaries which supply most of the river water. The annual discharge from Lake Tana is only 7% of the corresponding water reaching Khartoum.

The flood occurring annually at Khartoum is mainly due to the torrential rains on the Ethiopian Plateau. The river is not navigable anywhere except for short stretches, until well within the Sudanese border. In the lower part of its course in the Sudan, the Blue Nile receives two tributaries: the Dinder and the Rahad Rivers, both flowing down the Ethiopian Plateau. The contribution of these two tributaries, only noticeable during the rainy season on the Ethiopian Plateau, is little; their combined annual discharge barely exceeds 8% of that of the main river. No other tributary drains into the river until it joins the White Nile at Khartoum. For comprehensive descriptions of the Nile system see Hurst (1957) and the monographs edited by Rzóska (1976) and Dumont (2009).

According to Sinada (1972) at the peak of its flood (August-September) the Blue Nile at Khartoum may rise to more than 5 m above its lowest level of May. Huge amounts of silt are carried annually by the Blue Nile, especially during the flood period, transporting a total of 100×10^6 - 130×10^6 tons of silt annually.

Two dams have been built across the Blue Nile namely, Sennar and Roseires dams. These two dams, with annual retention period, seasonally altered the natural flow of the river. Sennar dam, built in 1925, holds about 1×10^9 m^3 of water, producing a back water effect for 140 km. The reservoir has an area of 160 km^2, maximum depth of 17 m and mean retention time of 32 days. The dam provides water for irrigation, controls the flood and generates hydroelectric power. Roseires dam built 650 km south of Khartoum was completed in October 1966.

It holds about 3×10^9 m^3 of water, producing a backwater effect for 100 km. The reservoir has an area of 290 km^2 and a diminishing maximum depth of 45 m. Since the Blue Nile is abundantly rich in silt during the flood, a special system is used when its water is stored. The filling of the reservoirs behind the two dams is carried out in two stages in order to avoid adverse silt deposition. An initial filling is carried out during the flood period (July-September) when most of the water is allowed to pass through. When the flood subsides the final filling of both reservoirs is completed, usually by the end of November when the reservoirs reach their full capacities.
In general the water of the Blue Nile is determined by the amount of rainfall on the Ethiopian plateau and in Sudan. The maximum rainfall occurs at about the end of July. The amount of rainfall at Khartoum is much smaller with annual average of about 148 mm; most of the rainfall occurs within the period July-September.
Checklists of phytoplankton species in the Blue Nile have been documented by a few workers during the last century but not all were widely published (Brook, 1954; Sinada, 1972). The aims of this study were to up-date the phytoplankton checklist of the Blue Nile at Khartoum, compare systematic lists compiled in early 1950s and early 1970s with data collected during the present study, and to comment on changes in the phytoplankton of the Blue Nile at Khartoum which occurred during the last sixty years. The present data will serve as baseline information upon which future changes can be assessed, particularly the impact of heightening Roseires dam which will increase the storage capacity of the dam from 3×10^9 m^3 to 7.4×10^9 m^3.

Materials and Methods

Sampling was carried out at two-week intervals from May 2000 to February 2002. On each occasion phytoplankton was sampled with a 55 µm mesh size standard plankton net towed for 5 min at minimum cruising speed (<4 knots) from the Research Vessel *Malakal* belonging to the University of Khartoum or by a hand net from a fixed point near the bank 3 km upstream of the confluence with the White Nile. The net samples were transferred into plastic containers with screw caps. Each sample was preserved with 4% formalin and stored in the laboratory.
The algae were identified according to the standard works of West and West (1904, 1905, 1912), Geitler (1925), Hustedt (1930), Cleve-Euler (1951), Desikachary (1959), Prescott (1962), and Krammer (1991a,b). To enhance diatom identification, sub-samples of the original samples were acid-cleaned using a mixture of sulphuric and nitric and acids.

Results and Discussion

Brook (1954) in his systematic account of the phytoplankton of the Blue Nile from samples collected at Khartoum between 1949 and 1952 identified over 100 algal taxa. That detailed study was not repeated until after the completion of the Roseires dam when Sinada (1972), reporting over 150 taxa, presented a similar account. In the present study which was launched in 2000 over 100 taxa were identified.
Of the 100 algal taxa reported by Brook (1954) only a few contributed significantly to the total phytoplankton biomass. Rzóska *et al.* (1955) and Talling and Rzóska (1967) from records made during 1951-1953 and 1954-1956, respectively, have shown that the seasonally dominant species in the Blue Nile were *Aulacoseira granulata* and its variety *angustissima*, and *Anabaena flos-aquae* f. *spiroides*. According to the works of these pioneers the concentration of plankton was very low during the flood period (July-October) when adverse conditions of rapid flow and high turbidity were prevalent. As the current subsided in November, diatoms were the first to appear in appreciable numbers, particularly *Aulacoseira* (formerly *Melosira*) *granulata* which was favoured by the post-flood relatively high concentrations of nitrate-nitrogen, and phosphate-phosphorus, and adequate supply of silica. The reduction of the former nutrient to concentrations in the range of 10-20 µg l^{-1} was probably responsible for limiting further growth of *Aulacoseira*. The probably N-fixing *Anabaena* produced high population densities during January-February and was probably mainly responsible for the depletion of phosphorus. The phytoplankton concentration declined during March-April, but a second maximum developed during May/early June before the entire plankton was washed out in late June by early flood water. The components of the second maximum were: *Aulacoseira granulata*, *Anabaenopsis cunningtonii*, *A. tanganyikae*, *Anabaena scheremetievi*, *Raphidiopsis curvata* and *Ulnaria* (formerly *Synedra*) *acus* (Talling and Rzóska 1967). No further seasonal studies on the phytoplankton of the Blue Nile were carried out between 1956 and 1962 until the construction of the Roseires dam.

Impact of the Roseires dam

Man–made lakes have profound influence on the biological productivity and ecology of rivers. With this in mind the Hydrobiological Research Unit of the University of Khartoum launched in 1963, three years before the completion of the Roseires dam a long-term study of the whole 740 km stretch of the Blue Nile within the Sudan to document the impact of the Roseires dam on the biological conditions of the river. A survey was carried out on conditions before and after the dam was put into use. The previous valuable studies carried out by Brook (1954), Rzóska *et al.* (1955), Talling and Rzóska (1967), and then Hammerton (1970a,b; 1971a,b), have provided the necessary baseline data for comparison with conditions in the newly formed reservoir and in the river after the filling of the reservoir. Hammerton (1970a,b; 1971c,d), sampling the Blue Nile at Khartoum during 1963-1966, observed seasonal cycles and succession of phytoplankton which were remarkably predictable and similar to those recorded by previous workers without changes in the species composition of the phytoplankton.

Sinada (1972) studied the phytoplankton of the Blue Nile uninterruptedly for twenty nine consecutive months from August 1968 to December 1970. Sinada and Abdel Karim (1984), supported by the present findings thirty years later, confirmed that the annual flood of the Blue Nile is the most important factor limiting the growth of the phytoplankton. The scarcity of planktonic algae during the flood, despite ~~of~~ high nutrient concentrations, is attributable to the high silt content (>4 g L^{-1} suspended matter). The Secchi disc visibility during the flood season is in the very low range of <1-5 cm. In addition, the current velocity may be as high as 1.8 m sec^{-1} compared to 0.09 m sec^{-1} during May/early June when the second maximum of algal growth occurs. The increase in algal densities begins recognisably in late October/early November when the current subsides (velocity <0.35 m sec^{-1}) and most of the silt settles out (Secchi visibility around 20 cm). It is obvious that poor light penetration coupled with high current velocity is the sole factor checking the development of phytoplankton in the Blue Nile during the flood season. These conditions reported in the Blue Nile during the annual phase of the flood period by Sinada and Abdel Karim (1984) and by the present study were no different from those reported before the construction of the Roseires dam by Rzóska *et al.* (1955), Talling and Rzóska (1967), and Hammerton (1970a,b).

Systematic account of the phytoplankton of the Blue Nile

Table 1 shows the checklists compiled during the present study and by Brook (1954) and Sinada (1972). Sinada listed over 150 algal species belonging to 74 genera of the six algal classes Bacillariophyta, Cyanobacteria, Chlorophyta, Euglenophyta, Pyrrhophyta, and Xanthophyta. During the present study over 100 algal taxa belonging to 52 genera were encountered in the Blue Nile at Khartoum. Comparing these two lists with that of Brook (1954) compiled in 1949-1952, it is obvious that there was an increase in diversity of species recorded. Many rare algae appeared for the first time in 1970s and at the turn of the century though mostly in very small numbers; a few others disappeared (Table 1).

Table 1 Checklists of planktonic algae of the Blue Nile observed in net samples collected from the Blue Nile near Khartoum during the periods May 2000-February 2002 (present study), 1968-1970 (Sinada 1972) and 1949-1952 (Brook 1954)
(+) rare, (++) occasional-frequent and (+++) common-dominant.

Taxa	Present study	Sinada (1972)	Brook (1954)
1-CHLOROPHYTA			
Chlamydomonas sp.	+	+	+ +
C. attenuata Pascher	-	-	+ +
C. ehrenbergii Gorosch.	-	-	+ +
C. microscopica G. S. West	-	-	+ +
C. subasymetrica Pascher	-	-	+ +
C. subcaudata Wille	-	-	+ +
Eudorina elegans Ehrenberg	-	+	+ +
Pandorina morum (O. Müller) Bory	+	+	+ +
Gonium sociale (Dujardin) Warming	+	+	+
G. pectorale O. Müller	-	-	+
Phacotus sp.	-	+	-
P .lenticularis (Ehrenberg) Stein	-	+	-
Pteromonas aculeata Lemmermann	-	+	-
Volvox aureus Ehrenberg	-	+	+
V. globator (Lagerheim) Ehrenberg	-	-	+ +
Gloeocystis gigas (Kützing) Lagerheim	+	+	-
G. major Gerneck	+ +	-	-
Scenedesmus spp.	+++	-	-
S. quadricauda var. *parvus* G. M. Smith	+++	++	+ +
S. dimorphus (Turpin) Kützing	+++	+	-
S. bijuga (Turpin) Lagerheim	+	-	++
S. hustrix Lagerheim	+	+	-

Taxa	Present study	Sinada (1972)	Brook (1954)
S. acuminatus (Lagerheim) Chodat	+++	+	++
S. obliquus (Turpin) Kützing	-	-	++
S. opoliensis P. Richter	-	-	+
S. incrassatulus var.*mononae* G. M. Smith	-	+	-
S. quadricauda var. *maximus* West & West	+++	++	-
S. quadricauda var. *eualternans* Prescott	+	+	-
S. *denticulatus* Lagerheim	-	+	-
A. falcatus var. *mirabilis* (West & West) West	++	+	++
A. falcatus var. *acicularis* (A. Braun) G. S. West	+	-	+
A. falcatus var. *spiralis* (Turner) Lemmermann	-	-	++
Pediastrum simplex (Meyen) Lemmermann	+++	++	-
P. clathratum (Schröder) Lemmermann	+	+	+++
P. simplex var. *duodenarium* (Bailey) Rabenhorst	+++	++	++
P. duplex Meyen	+++	-	+
P. boryanum (Turpin) Meneghini	+ +	++	++
P. duplex var. *clathratum* (A. Braun) Lagerheim	-	++	+++
P. duplex var. *reticulatum* Lagerheim	-	++	++
P. obtusum Lucks	-	++	-
P. sturmii Reinsch	-	-	+
P. boryanum A. Braun	-	-	+ +
P. boryanum var. *granulatum* (Kützing) A. Braun	-	-	+
P. boryanum var. *longicorne* Raciborski	-	-	+
P. simplex var. *radians* Lemmermann.	-	-	+
P. tetras (Ehrenberg) Ralfs	-	-	+
Crucigenia quadrata Morren	+ +	+	+
C. rectangularis (A. Braun) Gay	+	-	+
C. tetrapedia (Kirchner) West & West	+ + +	-	-
Oocystis borgei Snow	+	+	-
O. *elliptica* W. West	-	-	+
Coelastrum microsporum Nägeli	+ +	-	+
C. reticulatum (P. A. Dangeard) Senn	+	+	+ +
C. sphaericum Nägeli	-	+	+ +
C. cambricum Archer	-	-	+
C. proboscideum Bohlin	-	-	+
Chlorella vulgaris Beyerinck	+ +	-	-
Kirchneriella sp.	+	+	-
Actinastrum schroeteri G. Huber	+	-	+ +
Actinastrum sp.	+	+ +	+
Tetraedron sp.	+	+	-
T. enorme (Ralfs) Hansgirg	-	-	+
T. limneticum Borge	-	-	+
T. minimum (A. Braun) Hansgirg	-	-	+ +
T. regulare Kützing	-	-	+
T. tetragonum (Nägeli) Hansgirg	-	-	+
T. victoria Woloszynska	-	-	+
T. trigonum (Nägeli) Hansgirg	-	+	-

Taxa	Present study	Sinada (1972)	Brook (1954)
T. trigonum var. *gracile* (Reinsch) DeToni	-	+	-
T. muticum (A. Braun) Hansgirg	-	+	-
T. muticum f.*puctulatum* (Reinsch) DeToni	-	+	-
T. gracile (Reinsch) Hansgirg	-	+	-
T. hastatum (Reinsch) Hansgrig	-	+	-
T. constrictum G. M. Smith	-	-	-
T. lunula (Reinsch) Wille	-	-	-
Westella botryoides (W. West) de Wildemann	+	-	+ +
Tetradesmus heterocanthum (Nordstedt) Chodat	+	+	+
Micractinium. pusillum Fresenius	+ +	+	+ +
M. radiatum (Chodat) Wille	-	-	+
Schröderia setigera (Schröder) Lemmermann	+ +	+	+ +
Errerella bornhemiensis Conrad	-	+	-
Golenkinia radiata (Chodat) Wille	-	+	-
G. paucispina West & West	-	+	-
Lagerheimia ciliata (Lagerheim) Chodat	-	+	-
L. wratislawiensis (Schröder) Ley	-	+	-
Treubaria triappendiculata Bernard	-	+	-
Echinosphaerella limnetica G. M. Smith	-	+	-
Selenastrum gracile Reinsch	-	-	+ +
S. westii G. M. Smith	+	+	-
Polyedriopsis spinulosa Schmidle	-	+	-
P. quadrispina G. M. Smith	-	-	+ +
Characium sp.	+	-	+
Staurastrum gracile Ralfs	+	+ +	+
S. bacillare var. *undulatum* West & West	+	+	-
S. leptocladum Nordstedt	+	+ +	-
S. oxycanthum var. *polycanthum* Nordstedt	+	+ +	-
S. limneticum Schmidle	-	-	+ +
Staurastrum sp.	-	+	-
Penium margaritaceum (Ehrenberg) Brébisson	-	+	-
Closterium sp.	-	+	-
C. lanceolatum Kützing	+	+	+ +
C. leibleinii Kützing	-	-	+ +
C. acutum var. *variabile* Krieger	-	-	+ +
C. acutum Brébisson	-	+	+
C. lineatum Ehrenberg	-	-	+ +
C. aciculare (Tuffen) West	-	+	-
C. strigosum Brébisson	+	+	-
C. peracerosum Gay	-	+	-
C. moniliferum Ehrenberg	+	+	-
C. parvulum Nägeli	-	+	-
Euastrum sp.	-	+	-
E. spinulosum Nordstedt	-	+	+
E. denticulatum (Kirchner) Gay	-	+	-
Cosmarium spp.	+ +	+	-

Taxa	Present study	Sinada (1972)	Brook (1954)
C. pseudogranatum Nordstedt	+	+	-
C. botrytis (Bory) Meneghini	-	-	+ +
C. moniliforme (Turpin) Ralfs	-	-	++
Gonatozygon monotaenium De Bary	-	+	+
2-XANTHOPHYTA			
Centritractus belonophorus (Schmidle) Lemmermann	-	+	-
Stipitococcus sp.	-	+	-
S. urceolatus West & West	-	++	-
Ophiocytium cochleare A. Braun	-	-	+
O. capitatum var. *longispinum* (Wolle) Lemmermann	-	+	+
O.capitatum var. *belanophorus* (Moeb) Lemmermann	-	+	-
3-BACILLARIOPHYTA			
Aulacoseira sp.	+++	++	-
A. distans (Ehrenberg) Simonsen	+++	+++	-
A. granulata var. *angustissima* (O. Müller) Simonsen	+++	+++	+++
A. granulata (Ehrenberg) Simonsen	+++	+++	+++
A. agassizii (Ostenfeld) Simonsen	+ +	-	+ +
Melosira varians C. A. Agardh	-	+	+
Cyclotella sp.	+ +	+ +	-
C. meneghiniana Kützing	-	+ +	+ +
C. comta (Ehrenberg) Kützing	-	+	-
C. kutzingiana Thwaites	+	+ +	-
Navicula sp.	+++	+	-
N. directa var. *subtilis* (Gregory) Cleve	+	+	-
N. galikii Pnat.	+ +	+	-
N. pupula var. *capitellata* Hustedt	+	+	-
N. bicapitellata Hustedt	+	+	-
Synedra sp.	+++	+++	-
Synedra ulna (Nitzsch.) Ehrenberg	+ +	+++	+ +
Ulnaria (formerly *Synedra*) *acus* (Kützing) M. Aboal	+ +	+++	-
U. acus var. *radians* (Kützing) Hustedt	+	+++	+ +
S. capitata Ehrenberg	+	+++	-
Gomphonema spp.	+ +	+ +	-
Gyrosigma sp.	+ +	+ +	-
G. acuminatum (Kützing) Rabenhorst	+ +	+	-
Rhopalodia spp.	+ +	+	-
R. gibba (Ehrenberg) O. Müller	+ +	+	-
R. gibberula var. *musculus* (Kützing) A. Cleve	+	+ +	-
Surirella sp.	+	+ +	-
S. capronii Brébisson	+ +	+ +	-
S. linearis W. Smith	+ +	+ +	+
S. robusts var. *splendida* (Ehrenberg) V. Heurck	+ +	+ +	-
S. linearis var. *constrica* (Ehrenberg) Grunow	-	+ +	-
S. tenera Gregory	-	+ +	-
Cymbella sp.	+	+	-
C. ventricosa Kützing	+	+	-
C. heteropleura Ehrenberg	+	+	-
Amphora sp.	+	+	-
Fragilaria sp.	+	+	-

Taxa	Present study	Sinada (1972)	Brook (1954)
F. crotonensis Kitton	-	+	-
Pinnularia gibba Ehrenberg	-	+	-
Diploneis finnica (Ehrenberg) Cleve	+	+	-
Hantzschia amphioxys (Ehrenberg) Grunow	+	+	-
Epithemia sp.	+	-	-
E. turgida (Ehrenberg) Kützing	-	+	-
Nitzschia sp.	+	+	-
N .acicularis G. W. Smith	-	+	+ + +
N. tryblionella var. *victoriae* Grunow	-	+	-
N. palea (Kützing) W. Smith	-	-	+ +
Attheya zachariasi J. Brun.	+	++	-
Caloneis amphisbaena (Bory) Cleve	-	+	-
C. patagonica Cleve	-	+	-
C. permagna (Bailey) Cleve	-	+	-
4 –EUGLENOPHYTA			
Euglena sp.	+	-	-
E. porxima Dangeard	+	+	-
E. granulata (Klebs) Lemmermann	-	-	+
E. acus Ehrenberg	+	+	-
Phacus sp.	+	-	+
Ph. pleuronectes (Mueller) Dujardin	-	+	+
Ph. longicauda (Ehrenberg) Dujardin	+	+	-
Trachelomonas sp.	+ +	+	-
T. superba (Swir.) Deflandre	+	+	-
T. volvocina Ehrenberg	+	+	-
T. lacustris Drezepolski	+	+	-
T. dybowski Drezepolski	+	+	-
T. pulchella Drezepolski	-	+	-
5-PYRROPHYTA			
Glenodinium sp.	+	+	-
*G. quadridens (*Stein) Schiller	-	+	-
Peridinium sp.	+	-	-
6-CYANOPHYTA (CYANOBACTERIA)			
Microcystis flos-aquae (Wittrock) Kirchner	+ +	+++	+ +
M. aeruginosa (Kützing) Elenkin	+++	-	+ +
M. incerta Lemmermann	-	+	-
Chroococcus dispersus (Keissl.) Lemmermann	++	-	+
C. limneticus var. *subsalsus* Lemmermann	-	-	+
C. turgidus (Kützing) Nägeli	+	-	+
Merismopedia tenuissima Lemmermann	-	+	+ +
M. minima Beck.	-	+	+
M. glauca (Ehrenberg) Nägeli	-	+	-
M. punctata Meyen	-	-	+
Anabaena flos-aquae (Lyngbye) Brébisson f. *spiroides* (Woron.) Elenkin	+++	+++	+++
Anabaena sp.	+ +	+	-
A. limnetica G. M. Smith	+ +	+ +	-
A. catenula Bornet & Flahault	-	-	++
A. constricta (Szafer) Geitler	-	-	++
A. inaequalis (Kützing) Bornet & Flahault	-	-	+ +
A. scheremetievi Elenkin	-	-	+
Anabaenopsis circularis (West) Woloszynska & Miller	-	+	+ +
A. tanganyikae (G.S.West) Woloszynska & Miller	++	+	++
Planktolyngby (formerly *Lyngbya) limnetica* Lemmermann	-	-	+

Taxa	Present study	Sinada (1972)	Brook (1954)
Oscillatoria sp.	-	+	-
O. agardhii Gomont	-	+	-
O. limnetica Lemmermann	-	+	-
O. princeps Vaucher	-	+	-
O. subbrevis Schmidle	-	+	-
O. tenuis C. A. Agardh	-	+	-
O. nigra Vaucher	+	+	-
Spirulina major Kützing	+	+	+
Phormidium mucicola Naumann & Huber-Pestalozzi	+	-	+
Nodularia spumigena Mertens	-	+	+
Raphidiopsis curvata Fritsch & Rich	-	+	+ +
R. mediterranea Skuja	-	+	+ +

Diatoms

According to Sinada and Abdel Karim (1984) *Aulacoseira granulata* and its variety *angustissima* in the Khartoum vicinity showed a definite and regular seasonal cycle. It appears at the end of the flood season in September/October and quickly establishes a peak in November-December before it decreases sharply to minimum numbers which are maintained until May. In late May/early June a sudden summer peak occurs before being washed out in late June by flood. This seasonal cycle of *Aulacoseira* reported during 1968-1970 is reminiscent of that reported by Rzóska *et al.* (1955) and Talling and Rzóska (1967) in the same area fourteen years earlier. Indeed the present study investigating the phytoplankton of the Blue Nile at Khartoum thirty years later during the period May 2001-February 2002 documented the same seasonal cycle of *Aulacoseira granulata* and its variety *angustissima* reported by previous workers.

Of the important species which appeared in the Blue Nile for the first time during the 1968-1970 study were *Aulacoseira distans* and *Attheya zachariasi*. These two diatoms contributed significantly to the total phytoplankton biomass of the Blue Nile at one time or another (Sinada and Abdel Karim, 1984). *Aulacoseira distans* continued to be an important component of the phytoplankton during the present study and to the present date (Sinada, unpublished). Intermittent sampling throughout the last four decades showed that the maximum development of *A. distans* at Khartoum occurred in November-December although it was likely that this period might extend until February (Sinada and Abdel Karim, 1984; present study; Sinada, unpublished). However, *Attheya zachariasi* was rarely encountered during the present study.

The present study confirmed the definite recurrent peaks showed by *Ulnaria* (formerly *Synedra*) *acus* during November-December and May-early June as reported by Brook (1954) and Sinada (1972).

Of the important species which were *first* reported during the present study and contributed significantly to the total phytoplankton biomass of the Blue Nile at one time or another was another *Aulacoseira* species (*A. ambigua*?). The present study confirmed the presence of *Aulacoseira agassizii* which was reported by Brook (1954) in his systematic account but was not observed by Sinada (1972) during his 29-month study.

Cyanobacteria

Anabaena flos-aquae f. *spiroides* was a major constituent of the phytoplankton in the 1950s, frequently dominating the phytoplankton during January-March (Brook, 1954; Rzóska *et al.*, 1955; Talling and Rzóska, 1967). Sinada and Abdel Karim (1984) reported that the cyanobacterium was prominent only during January-February 1969 but strikingly it maintained very low numbers during the rest of the period of their study from March 1969-December 1970, similar to conditions in Roseires reservoir as reported by Hammerton (1971c,d; 1972a). It is interesting to note that this cyanobacterium maintained very low numbers throughout the latter decades of last century until its unprecedented profuse growth which took place in May 2003 and January 2009 and which was a cause of public concern. In January 2010 and January 2011 a recurrent water bloom of *Anabaena flos-aquae* f. *spiroides* was observed at Khartoum (Sinada, unpublished).

Other cyanobacteria like *Anbaenopsis circularis*, *Raphidiopsis curvata* and *R. mediterranea* reported by Brook (1954) Rzóska *et al.* (1955) and Talling and Rzóska (1967) as important members of the plankton of the Blue Nile during 1950s were rarely encountered in 1968-1970 and never appeared during the present study. Interestingly *Anabaenopsis tanganyikae* has reappeared in unprecedented appreciable numbers in the surface waters of the Blue Nile at Khartoum only recently during December 2010-January 2011 (Sinada, unpublished).

Microcystis flos-aquae , which was reported by Brook (1954) during 1949-1952 as being an unimportant component of the phytoplankton of the Blue Nile, preponderated shortly after the filling of Roseires reservoir and spread downstream (Hammerton, 1972b) to constitute an important phase in the phytoplankton of the Blue Nile at Khartoum throughout 1968-1970 and during the present study from December-January and April-May. These results indicate that the cyanobacterium *Microcystis flos-aquae* as well as the diatom *Aulacoseira distans* have much increased shortly after the filling of Roseires dam reservoir with recurrent peaks during the same months of the year in different years although the magnitude of the peaks differed from year to year.

Conclusions

It is obvious that the algal flora of the Blue Nile has undergone a noticeable change within a short period of time between 1956 and 1968. This change in the algal flora of the Blue Nile may be attributed to the construction of Roseires dam which was built across the river and created lake-like conditions as of 1966. Likewise there was a change in algal flora accompanied by profuse growth of phytoplankton by the turn of the present century. Unprecedented peaks of the cyanobacterium *Anabaena flos-aquae* which took place in May 2003 and January 2009 had been a cause of public concern. These peaks may be attributed with caution to incipient eutrophication resulting from slight increase in phosphorus and nitrate nitrogen as found during the present study, possibly reaching the Nile from agricultural diffuse sources although other reasons like changes in river course cannot be ruled out.

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