The Zooplankton and the Zoobenthos of the White Nile and Adjoining Waters in the Republic of the Sudan

by

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(with 6 figs.)

There are many biological works about inland waters of Africa, but most of them only contain systematic and faunistic data. The Entomostracan fauna of the White Nile has been investigated by several biologists (EKMAN, 1903; GURNEY, 1911; DADAY, 1910; RZÓSKA, 1952, 1956), however, the first quantitative data on the zooplankton of this river appeared only recently (RZÓSKA, BROOK & PROWSE, 1955; BROOK & RZÓSKA, 1954; RZÓSKA, 1961; BISHAI, 1962; RZÓSKA, 1968). The bottom fauna of the White Niel in the Republic of the Sudan was not studied.

MATERIAL AND METHODS

In 1963—1964 a Soviet fisheries scientific expedition conducted a survey on the White Nile and adjoining waters. Complex hydrobiological, ichtiological, hydrochemical and hydrological studies were made from November 1963 to April 1964. The studies were made on definite areas of both the river, the lakes and the affluents. A series of samples were taken from Jebel Aulia dam to Bor, a distance of 1530 km (fig. 1).

Quantitative water samples were taken with a Dzjuban sampler of

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10 l capacity. At each station the samples from different levels (every two meters) were obtained. The samples from each station were passed through a plankton net and placed together in a single vial to represent an average sample for each station. In the places of the waters where the river was shallow or the current was very strong

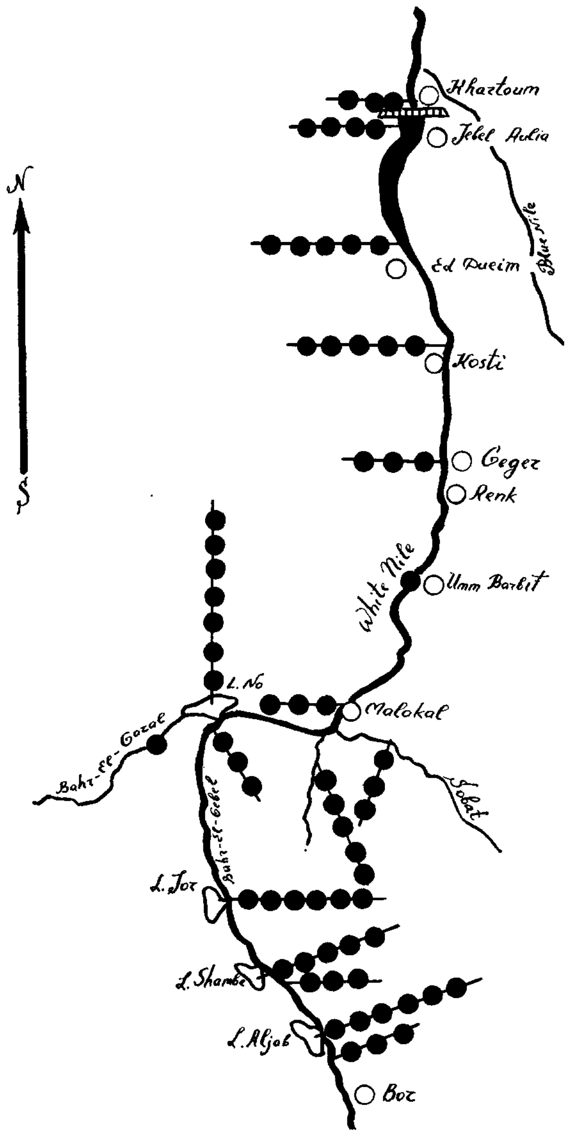

Fig. 1. Map of part of the White Nile showing sampling stations.

only surface samples were collected. In this case we usually used the plankton net and passed 100 l of water from the surface through it.

Plankton-net, hoog-net and trowels were employed for collection among water vegetation.

The Zooplankton collections were examined in the field laboratory on the expeditionary ship. The plankton samples were concentrated to a definite volume. Rotatoria and larvale stages of Entomostraca were identified and counted in 1/100 volume of the sample. The adults of Crustacea and other animals in the plankton samples were counted in 1/10 th volume of the sample in a Bogorov cell. The weight of plankton animals was determined from special tables of standard weight and the biomass was then calculated per 1 m^3.

Benthic organisms were collected with a Petersen bottom grab (1/40 m^2). Usually five samples were taken at each station and the material was separated immediately afterwards while still alive. The number of bottom grab collections was reduced if the bottom included many fragments of water vegetation. The material was preserved with 4% formalin or 80% alcohol. Then the water animals (Mollusca, Oligochaeta and Insect larvae) were dried on filterpaper and weighed with a torsion-balance. The biomass and number of bottom organisms were calculated per 1 m^2. On the whole about 300 samples of zooplankton and zoobenthos were studied.

In addition the stomachs of more than 300 representative Nile fishes were examined.

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The investigated region included the White Nile River with its tributaries, the flood-plain water bodies of the south and the Jebel Aulia reservoir.

The river part

The investigated part of the river included the segment of the White Nile between Bor and Renk. The greater part of the river winds its way here through wide papyrus swamps. The zooplankton of the Upper Nile is monotonous. The larvae of Cyclopoida are predominant. The Cladocera for the most part are represented by bottom or littoral species (*Macrothrix* sp., *Alona davidi*) and were not met uniformly but more by chance. The abundance of the zooplankton was very low, and the biomass did not exceed 0.015 g/m^3

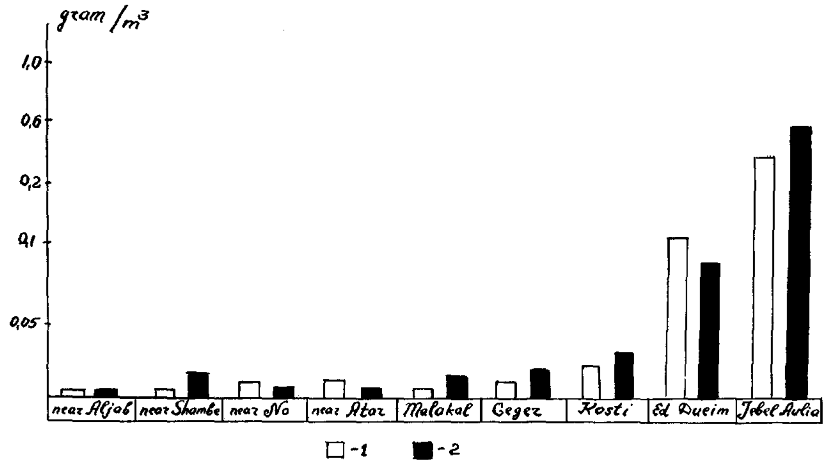

Fig. 2. Zooplankton biomass of the White Nile (in g/m³) 1 – in autunm; 2 – in spring.

both in summer and in winter (Table I, fig. 2). A low abundance of river zooplankton is very common. This part of the river it is supplementarily decreased by an abundance of detritus and by the very strong current (Table I). The same condition was noted by RZÓSKA (1961). According to his data the White Nile carries a rich plankton from Lake Victoria but after passing through the numerous waterfalls this plankton is destroyed and in the Sudan (between papyrus swamps) it is sparse and mixed.

An analogous picture was noted in the large tributary of the White Nile – the Sobat river. Series of samples were taken near khor Fel-lus. The zooplankton of the river also was very poor. The larvae of Cyclopoida predominated. *Moina dubia* and *Diaphanosoma excisum* were encountered rarely. The biomass of the zooplankton of the Sobat differed little from the biomass of the White Nile and fluctuated from 0 to 0.002 g/m³.

In contrast to the qualitatively and quantitatively poor zooplankton of the White Nile, the fauna of the water vegetation was rich and various. *Eucyclops serrulatus*, *E. angustus*, *Microcyclops varicans*, *Tropocyclops confinis*, *Ectocyclops phaleratus*, *Simocephalus latirostris*, *Euryalona occidentalis*, *Alona davidi*, *Chydorus kallipigos*, *Dunhevedia crassa*, *Estheria hislopi* and different species of Rotatoria were found abundantly in beds of reeds (*Phragmites*), *Papyrus* and between accumulations of floating *Eichhornia*. In addition, the water vegetation was densely populated with water insects and their larvae (Ephemeroptera, Trichoptera, Odonata, Chironomidae, Hemiptera), small littoral Mollusca, shrimps (*Athyaephura desmoresti*) and ticks.

TABLE I

Hydrological and hydrochemical characteristic (by W. P. KURDIN's data) and density of zooplankton at the river bed stations of the White Nile between Lebel-Aulia and Aljab

Place	Jebel-Aulia before the Dam		Umm-Shaba	Umm-Arda	Ed-Dueim		Kosti		Geger		Umm--Bar-bit	Malakal		Near khor Atar	Near lake No		Near lake Shambe		Near lake Aljab	
Date	XI-1963	IV-1964	V-1964	V-1964	XI-1963	IV-1964	XI-1963	IV-1964	XII-1963	IV-1964	XII-1963	XII-1963	IV-1964	IV-1964	II-1964	V-1964	II-1964	V-1964	I-1964	V-1964
Depth (m)	8.8	10.2	10.6	8.3	8.5	9.9	7.5	9.0	6.8	5.6	6.0	10.3	8.6	4.9	8.5	7.7	8.3	9.7	4.4	6.1
Temperature of water (°C)	24.1	26.4	26.4	27.9	25.0	28.6	24.0	27.2	22.3	27.1	22.8	26.0	28.2	29.5	23.4	29.6	26.7	28.8	26.3	29.8
Transparence of the Secchi disk (cm)	60	110	90	225	95	170	105	107	145	85	160	120	75	110	130	85	125	110	75	65
Speed of the current (m/sec)	0.18	0.16	—	0.20	0.17	0.18	0.4	0.31	0.51	0.40	0.70	0.96	0.59	0.63	0.53	0.64	0.80	0.80	0.94	1.02
Free CO_2 (mg CO_2/l)	—	4.1	2.6	2.4	—	1.6	4.7	2.4	7.3	2.7	9.4	12.0	7.9	9.8	9.6	9.9	9.8	12.4	6.0	7.1
Dissolved oxygen (mg O_2/l)	—	7.78	7.78	7.73	—	6.04	5.64	6.56	5.03	6.52	2.97	1.68	3.31	2.57	3.76	2.43	2.30	0.66	4.86	3.82
pH	8.0	8.4	8.3	8.3	7.8	7.7	7.2	7.8	7.2	7.7	7.2	7.1	7.4	7.3	7.2	7.1	7.1	7.0	7.3	7.2
Density of zooplankton (organisms per 1 m^3)	75200	32620	39400	22600	41600	36600	2950	2000	640	120	20	4160	6400	600	1200	2000	2920	7400	0	2040

As a rule the most diverse fauna was noted in the accumulation of *Eichhornia* especially near Malakal and the Sobat river. The biomass of Entomostraca in these places was 10 and sometimes 100 times greater than the biomass of the Entomostraca outside of the water vegetation (Fig. 3).

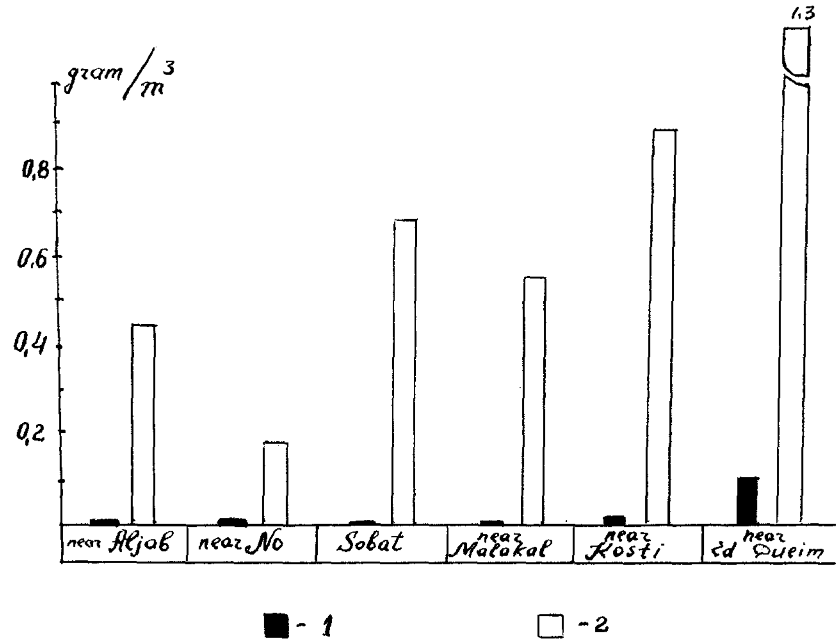

Fig. 3. Entomostraca biomass (in g/m³) in the river-bed of the W. Nile and its inshore thickets 1 – river bed; 2 – thickets.

As the zooplankton the bottom fauna of the White Nile between Bor and Renk was also monotonous. The sandy ground of the bed of the White Nile was sparsely populated by small larvae of Chironomidae (*Glyptotendipes* sp., *Cryptochironomus* sp.). The Oligochaeta (*Limnodrilus hoffmeisteri f. parva*) predominated at those stations with clay or sandy bottoms with small quantities of silt situated near river banks or at shallow depths.

In addition to them were found Hirudinea, Trichoptera larvae (*Oecetis* sp., *Chematopsyche* sp.,) and larvae of Ephemeroptera. Mollusca were absent. The general biomass of the benthos was low in this region. In the bed of the river it varied from 0 to 0.2 g/m² and near banks the biomass was greater (up to 4.9 g/m²). The maximum amount for this part of the river was found near Malakal (Figs. 4, 5). The larvae of Chironomidae (*Chironomus* sp., *Cryptochironomus*

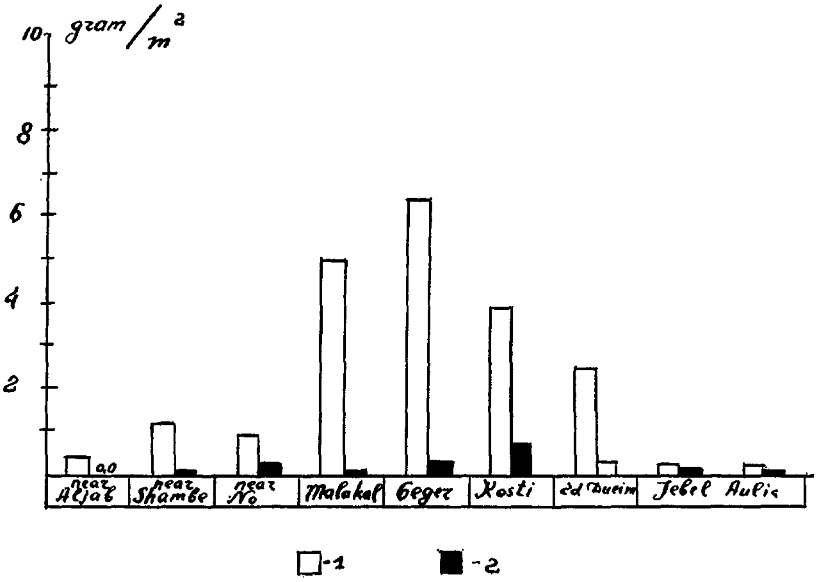

Fig. 4. Benthos biomass (in g/m²) of the W. Nile in autumn 1 – flood-plain station; 2 – river bed stations.

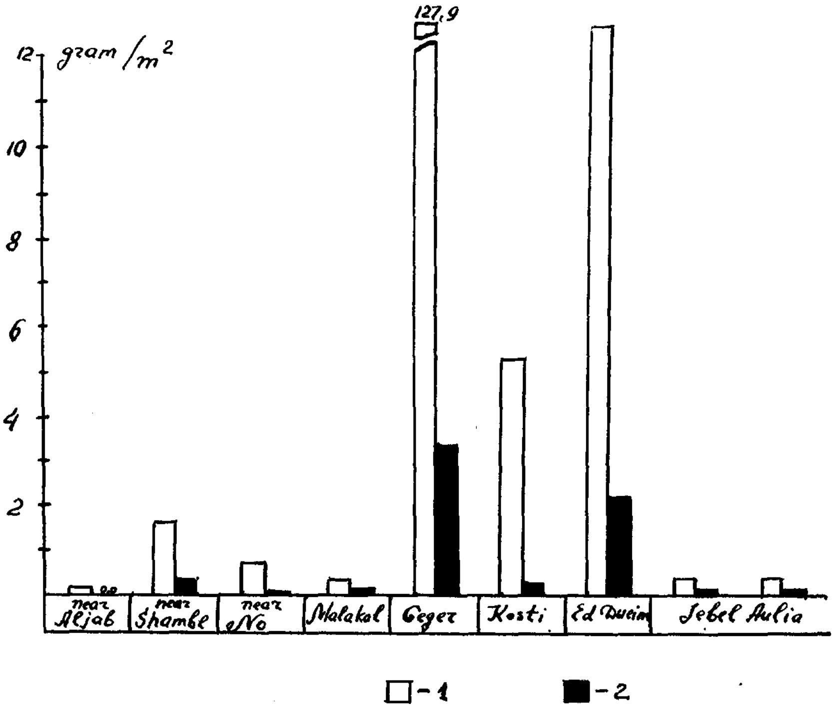

Fig. 5. Benthos biomass (in g/m²) of the W. Nile in spring 1 – flood-plian stations; 2 – river bed stations.

ex. gr. *conjugens* and *Glyptotendipes* sp.) and Oligochaeta were dominant here.

There was little difference in number of bottom animals between autumn and spring samples (Figs. 4, 5). Only near Malakal the biomass of the benthos decreased about tenfold evidently because of the emergence of Chironomidae.

The poverty of this region of the river may seemingly be explained by low concentrations of dissolved oxygen (0.6—4.8 mg/l, the average for this part of the river is 2.7 mg/l), and by the high content of dissolved CO_2 - up to 12 mg/l (Table I).

The benthos of the Sobat river differed very little from the bottom fauna of the White Nile. The clayey and gritty bottom of the bed of the Sobat was sparsely populated by larvae of Chironomidae (*Polypedilum* ex. gr. *scalaenum*, *Clinotanypus* sp., *Stictochironomus* sp., *Cryptochironomus* sp.) and Trichoptera. The total biomass of the benthos in the middle of the river was about 0.2 g/m^2. But near the mouth of the Sobat large parts of the bottom were found where large populations of the big Mollusca *Etheria elliptica* were noted. The colonies of molluscs were also populated by a rich fauna of Ephemeroptera and Trichoptera larvae. The genera *Amphipsyche*, *Cheumatopsyche*, *Aethaloptera* and *Ecnomis* predominated. In the same place *Eupera parasitica* (Mollusca) was found.

The flood-plain water bodies

Lakes Aljab, Shambe, Jor, No and khor Athar were also investigated by the expedition. With the exception of Athar which is situated on the right bank of the river, all the remaining lakes are located on the left bank between Bor and the mouth of the Sobat (Fig. 1).

The Aljab consists of a system of shallow lakes connected by numerous canals. The current is pronounced in spots (up to 0.3 m/sec.) and a drift of *Eichhornia* is carried to the major strait which connects the lakes with the river. The Aljab is exposed to strong mixing by winds because it is very shallow, (the average depth is only 3 m). The bottom sediments of the Aljab are quite varied. There are sandy, clayey and silty areas. The zooplankton of the Aljab is very poor and in composition and quantity differs little from that of the White Nile. The average biomass of the open parts of the Aljab does not exceed 0.002 g/m^3 (Table II), that is to say the zooplankton is almost absent. Only larval stages of Copepods are found in the samples.

The littoral vegetation of *Phragmites*, *Papyrus* was populated by a sparse but diverse fauna of Crustacea (*Athyaephura desmoresti*,

TABLE II

Hydrological and hydrochemical characteristic (by W. P. KURDIN'S data) and density of zooplankton of the flood-plain water bodies of the White Nile in 1964

Place	Aljab		Shambe		Jor		No		Atar
Month	I	V	II	V	II	V	II	V	IV
Temperature of water (°C)	24.8	28.8	26.2	28.8	23.9	29.8	23.9	29.9	28.2
Transparence of Secchi disk (cm)	130	120	110	85	185	135	100	95	45
Speed of the current (m/sec)	0.04	0.08	0.05	—	0.07	—	—	—	—
pH	7.1	7.05	6.95	7.05	7.4	7.25	7.65	8.0	8.0
Dissolved oxygen (mg O_2/l)	2.3	2.25	2.52	2.4	5.4	3.88	6.90	8.14	6.88
Free CO_2 (mg CO_2/l)	11.1	11.3	10.2	9.2	6.0	7.9	3.1	0.4	0.8
Average biomass of zooplankton (g per 1 m^3)	0.002	0.001	0.002	0.040	0.021	0.049	0.138	0.107	0.246
Density of zooplankton (organisms per 1 m^3)	180	3000	600	3000	2700	12400	8000	53000	59000

Microcyclops bicolor, *Microcyclops varicans*, *Ectocyclops phaleratus*, *Alona davidi*, *A. globulosa*, *Euryalona occidentalis*, *Kurzia longirostris*, *Dadaya macrops*, *Simocephalus latirostris* and other species). Hemiptera, the larvae of Trichoptera (*Oecetis* sp., *Cheumatopsyche* sp.) and others water animals were noted in addition.

The bottom fauna of Aljab is also very poor. In winter the chironomidae larvae and Oligochaeta composed the major part of the biomass (*Criptochironomus* ex. gr. *defectus*, *Glyptotendipes* sp., *Paratendipes* sp., *Limnodrilus hoffmeisteri*). In spring the number of Chironomidae decreased and at some stations Mollusca were found (*Mutela alluandi* and *Sphaerium abyssinicum*).

On an average the biomass of benthos was not high, about 1 g/m^2 (Table III).

Lake Shambe – is a large but comparatively shallow lake, situated among wide papyrus swamps. The zooplankton of Shambe, like Aljab, is very poor. Nauplii and copepodite stages of Cyclopoida (*Eucyclops*, *Thermocyclops*) predominate. But in contrast to lake Aljab, *Moina dubia* and *Diaphanosoma excisum* were also found. The number of these species remained very low. At some stations *Brachionus* sp. was noted. The biomass of the zooplankton (maximum 0.179 g/m^3) on an average was very low and fluctuated from 0.002 to 0.040 g/m^3 (Table II).

The exceptional poverty of the zooplankton of lakes Aljab and Shambe is explained by the fact that they are runningwater lakes, that the lakes have a similar hydrochemichal index as that of the White Nile in the same region.

A typical and relatively rich phytofauna develops in the Papyrus vegetation. As a rule, *Eucyclops serrulatus*, *E. laevimargo*, *Macrothrix spinosa* and *M. chevreuxi* predominate. But on the whole, the phytofauna of lake Shambe is practically not different from lake Aljab.

The poverty of the zooplankton of the Shambe is to a great extent compensated by the comparative richness of the bottomfauna. The greater part of the surface of the bottom is covered by a black or dark-grey silt. These areas are densely populated by Oligochaeta (*Limnodrilus hoffmeisteri*), while Chironomidae larvae (*Cryptochironomus* ex. gr. *defectus*, *Clinotanypus* sp., *Pelopia* sp.) are sparser. The biomass of Oligochaeta attains at some stations 10 g/m^2 and on an average fluctuated between 4.0 g/m^2 in the winter to 2.1 g/m^2 in the spring (Table III). The decrease of the average biomass in the spring is evidently connected with the emergence of Chironomidae. Their abundance clearly decreased in May.

Lake Jor – The zooplankton of the open parts of lake Jor is characterized by its diversity. The Cladocera are very common. *Moina dubia*

TABLE III

The biomass of the zoobenthos in the flood-plain water bodies of the White Nile in 1964 (Biomass is recorded in gramm per 1 m^2 of the bottom)

Place and month / Organisms	Aljab		Shambe		Jor		No		Atar
	I	V	II	V	II	V	II	V	IV
Oligochaeta	0.104	0.494	3.395	2.035	3.056	2.039	1.321	1.820	1.986
Chironomidae	0.881	0.002	0.635	0.096	1.435	0.062	0.248	0.129	0.029
Mollusca	0.000	0.625	0.000	0.000	0.180	0.000	0.000	0.040	0.760
Other	0.000	0.010	0.000	0.000	0.000	0.040	0.556	0.193	0.000
Total	0.985	1.131	4.030	2.131	4.671	2.141	2.125	2.182	2.775

and *Diaphanosoma excisum* usually predominate. A concentration of plankton Crustacea (of 0.400 g/m^3 for *Moina dubia*) was found in some parts of the lake. But such concentrations were rare, usually the average biomass of zooplankton fluctuated from 0.02 to 0.049 g/m^3 (Table II). The insignificant depth of the lake, the almost complete absence of current and its high transparency favor the development of submersed vegetation. Most areas of the bottom are occupied by *Najas* sp., where phytophil species of Crustaceae (*Pseudosida szalay*, *Latonopsis* sp. *fascicata group*, *Dadaya macrops*, *Simocephalus elizabethae*, *Camptocercus similis*) are found. These species were constantly found in the truly planktonic samples.

In the shore areas among the water vegetation many insect larvae, Hydracarina, Hemiptera and shrimps were found. *Ectocyclops compactus* (Copepoda, Cyclopoida) not found in other waters, was found here.

The composition and biomass of the bottom fauna of Lake Jor differed little from the benthos of Lake Shambe. The Oligochaeta also predominated and for the most part – *Limnodrilus hoffmeisteri*. The few Chironomidae larvae were represented here by *Cryptochironomus* ex. gr. *defectus*, *Chironomus* sp., *Clinotanypus* sp. and *Procladius* sp. As for Mollusca, *Cleopatra pirothi* was found in the open parts of the lake and *Lanistes carinatus* and *Pila wernei* were found in the shallow bays which were often isolated from the lake. The biomass of the Oligochaeta and the Chironomidae amounted to 8.2 g/m^2 at the some stations and on an average in the lake it averaged 4.6 g/m^2 in winter and 2.1 g/m^2 in May (Table III).

Lake No – is a widened mouth of a large tributary of the White Nile, Bahr El Gazal river. The composition and number of the zooplankton is clearly seen to differ from the zooplankton of lakes Aljab, Shambe and Jor. Here the following species formed the bulk of the Crustacean plankton: *Tropodiaptomus galebi*, *Moina dubia*, *Daphnia lumholtzi*, *Mesocyclops leuckarti* and *M.* (*Thermocyclops*) sp. In May the zooplankton of lake No was enriched due to the addition of Rotatoria: *Filinia* sp., *Kellicottia* sp., *Brachionus* sp., *Synchaeta* sp. and *Keratella* sp. The average biomass of the zooplankton in the pelagic zone of the lake was 4—6 times greater than the biomass in lakes Shambe and Jor; howewer, it remained very low (Table II).

A supplementary series of samples was taken in the Bahr El Gazal river above lake No (fig. 1). A slight current was noted here (about 0.1 m/sec), though the composition of the zooplankton was the same and its biomass was some times greater than the biomass of the lake. It is possible to say that the Bahr El Gazal influences the form of the lake plankton.

There was a rich and varied fauna among weeds of water vegetation. The phytophilic forms were found in quantitative and net samples. Of the Entomostraca *Microcyclops varicans*, *Microcyclops bicolor*, *Dunhevedia serrata*, *Oxyurella singalensis* predominated. In the small gulf on the west shore of the lake among weeds of *Nymphae* sp. the biomass of only the Cladocera and the Copepoda reached 20 g/m^3 (although this included shrimps).

A survey of the sediment performed in Lake No indicated that the greater part of the lake's bottom is covered by light-gray or dark-gray silts densely populated by Oligochaeta. And only small parts of the lake's bottom in the form of a narrow strip on the periphery of the lake were composed of ware swept brown soil with great numbers of fragments of vegetation (fig. 6).

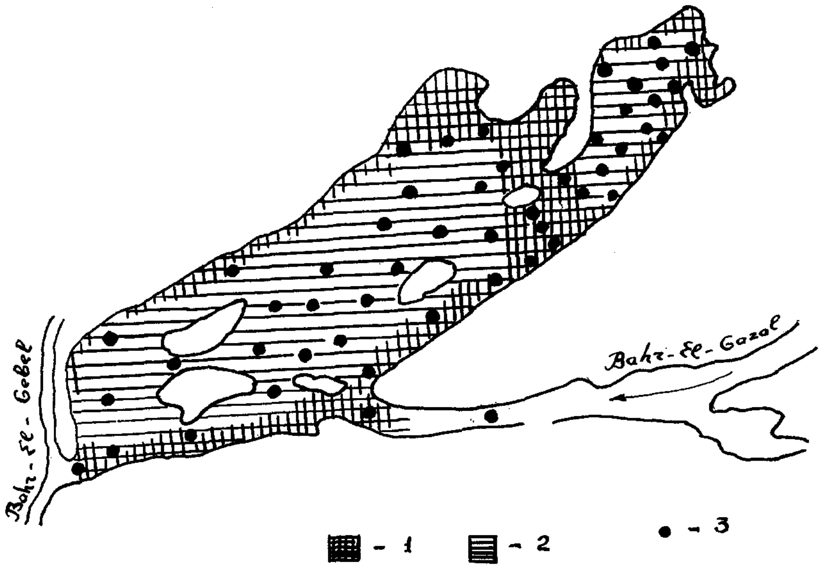

Fig. 6. Map of the lake No. 1 – brown silts; 2 – light – gray silts; 3 – hydrological stations.

The bottom fauna in such places was poor.

The Chironomidae larvae were distributed everywhere and consisted of the following species: *Cryptochironomus* ex. gr. *conjugens*, *Stictochironomus* sp., *Pelopia* sp. But it is necessary to say that their number and biomass was less than that of the Oligochaeta. The average biomass of the benthos of lake No was about the same in both winter and spring (respectively 2,12—2,18 g/m^2, Table III).

Khor Athar – is a shallow gulf with slanting banks lacking vegetation. Its monotonous zooplankton is represented almost completely by *Moina dubia* and Cyclopoida larvae. The biomass of zooplankton is high (to 0.6 g/m^3) and on an average for khor Athar it amounted to 0.2 g/m^3 (Table II).

The bottom of the khor Athar is composed of light-gray and gritty silts which are populated by Oligochaeta. The few Chironomidae larvae are represented by *Heleidae* gen. sp. In some places of water the small Mollusca (*Cleopatra bulimoides*) are found.

On an average for Ahtar the biomass of the benthos was 2.7 g/m^2 (Table III) and sometimes reached 5.0 g/m^2.

The Jebel Aulia reservoir

The Jebel Aulia reservoir stretches as a wide strip from Renk in the south to the Jebel Aulia dam in the north. The south part of the reservoir between Renk and Kosti is very similar to the river part of the Nile in its hydrological regime, although the speed of the current here is a little less than that of the river. In this connection the composition and biomass of the zooplankton of this part of the reservoir is little different from the zooplankton of the Nile (Fig. 2). But from Kosti, where the conditions of the reservoir change (the speed of current is lower, the oxygen regime is improved, Table I), the character of the zooplankton changes also. The plankton complex of the reservoir represents the typical lake forms. The following species occur: *Keratella* sp. , *Filinia* sp., *Moina dubia*, *Diaphanosoma excisum*, *Ceriodaphnia quadrangula*, *C. laticaudata*, *C. cornuta**, *Daphnia lumholtzi*, *D. longispina*, *Bosmina longirostris*, *Mesocyclops leuckarti*, *Mesocyclops* (*Thermocyclops*) sp. and *Tropodiaptomus galebi*. The number and biomass of plankton animals increases by degrees from the south to the north (Table I, fig. 2) and reaches its maximum of biomass near the dam. Here the highest possible biomass (1.1 g/m^3) was registered. The following species formed the bulk of the Crustacea plankton: *Ceriodaphnia cornuta*, *Diaphanosoma excisum* and *Tropodiaptomus galebi*. The biomass of the zooplankton averaged 0.15 g/m^3 in the autumn to 0.30 g/m^3 in April. BROOK & RZÓSKA (1954), who investigated this region in December of 1951, cited about equal ciphers for the number of zooplankton.

We have not uncovered any conformity in the distribution of the zooplankton on the transverse sections of reservoir; in some cases the flood-plain stations were more rich than the river bed stations, and in certain cases the zooplankton was evenly distributed (Table

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* RZÓSKA (1956) considers *Ceriodaphnia cornuta* and *Ceriodaphnia rigaudi* as synonym.

TABLE IV

The biomass of the zooplankton in the Jebel Aulia reservoir (Biomass is recorded in gramm per 1 m^3)

Place / Date	Kosti		Ed Dueim		Jebel Aulia (before the dam)	
	flood-plain st.	river bed st.	flood-plain	river bed	flood-plain	river bed
XI - 1963	0.027	0.003	0.113	0.161	0.320	0.388
IV - 1964	0.018	0.009	0.081	0.092	0.784	0.195

IV). At all stations the plankton animals usually were concentrated at the surface.

The general character of the distribution of the zooplankton along the reservoir, determinated by us in the winter, was similar to that of the spring (Fig. 2).

BROOK & RZÓSKA (1954) also noted a gradual increase of the number of zooplankton towards the dam.

The fauna of the water vegetation, particularly near Kosti and Ed Dueim, was various. Apart from different Insect larvae and Hydracarina there were many Crustacea: *Microcyclops varicans*, *M. davidi*, *Macrocyclops albidus*, *Simocephalus serrulatus*, *S. latirostris*, *Euryalona occidentalis*, *Macrothrix spinosa*, *M. laticornis*, *Alona davidi*, *A. globulosa*, *Dunhevedia crassa*, *Chydorus hybridus*, *Ch. eurynotus*, *Pseudosida szalayi*, *Dadaya macrops* and *Estheria hislopi*. Fig. 3 shows the comparison of the biomass of Cladocera and Copepoda (only) in the aquatic vegetation and the biomass of these animals in the pelagical parts of the reservoir.

The bottom fauna of the reservoir differs greatly from the benthos of the river and the flood-plain water bodies. The composition of the Mollusca increased*, the following species predominated: *Corbicula consobrina*, *Corbicula cunningtoni*, *Sphaerium abyssinicum* and *Cleopatra bulimoides*. The Chironomidae larvae were represented primarily by species of the genus *Cryptochironomus* and *Stictochironomus* but the total number of species of Chironomidae also increased (Table V). Of Oligochaeta, *Limnodrilus hoffmeisteri*, *L. udekemianus*, *Stylodrilus heringianus* – premidonated.

* The 19 species of Mollusca were found by expedition and 17 of them were noted in the reservoir.

Table V

The biomass of the zoobenthos in the Jebel Aulia reservoir (Biomass is recorded in gramm per 1 m² bottom)

Place / Date	Kosti		Ed Dueim		Jebel-Aulia (before the Dam)	
	flood-plain st.	river bed st.	flood-plain	river bed	flood-plain	river bed
XI - 1963	3.909	0.695	2.395	0.296	0.211	0.144
IV - 1964	5.420	0.276	12.766	2.312	0.351	0.080

The benthos of the reservoir was distributed unequally, the southern part of the reservoir is rich. This region (between Kosti and Renk, fig. 1) represents the zone of transition from river to lake-like condition. Here the speed of the current clearly seems to have decreased, the oxygen regime is improved (Table I). Here the solid sands, characteristic of the Upper Nile, changes to sandy-silts and clayey-sands. The gradual sedimentation of detritus improves conditions for the life of the benthic animals. At some stations near Geger the biomass of *Corbicula cunningtoni* and *C. consobrina* reaches 255 g/m^2. Colonies of *Etheria elliptica* were found at river bed stations near Jebelein. Such places usually are populated by *Eupera parasitica*, *Belamya unicilor* and by a rich fauna of Ephemeroptera and Trichoptera larvae.

The protected gulfs of the southern part of the reservoir have a rich fauna of Chironomidae larvae where the biomass of only *Chironomus* ex. gr. *plumosus* some times is as much as 18 g/m^2.

Towards the centre of the reservoir the composition of the bottom fauna changes little but the biomass of the benthos decreases (Fig. 4). However the biomass of the benthos at some stations may be high (24—36 g/m^2). In the north part of the reservoir near the dam the character of the benthos has changed. The Mollusca completely disappear. The gray and light-gray silts are populated here by a depauperate fauna of Chironomidae larvae and Oligochaeta. The biomass of the benthos above the dam varies from 0.1 to 0.3 g/m^2 (Figs. 4, 5). The poverty of this part is seemingly accounted for by the inconstancy of the hydrological regime of this section of the reservoir, which is exposed to the influence of a periodical release of water through the bottom outlets.

The variation in the distribution of bottom fauna is noted on the cross-section of the reservoir. Oligochaeta usually predominated on the river bed stations, Mollusca on flood-plain stations. As a rule the biomass of the benthos of the flood-plain stations was richer than that of the river bed (Table V). On an average for the reservoir the biomass of the bottom fauna amounted to 1.0 g/m^2 in the winter and increased to 20.0 g/m^2 in the spring when the young generation of Mollusca (Corbiculidae) predominated. (figs. 4, 5).

THE CONSUMPTION

A Survey of the food of fishes

The feeding of Nile fishes was not a special item in our studies the data described below are results of a systematical survey of stomachs of the Nile fishes. The following species were investigated:

1. *Alestes baremose* (JOANNIS, 1835) – 35 specimens
2. *A. dentex* L. 1737 – 5
3. *A. nurse* (RÜPPEL) – 10
4. *Labeo horie* HECKEL – 10
5. *Gnathonemus cyprinoides* L. – 10
6. *Hyperopisus bebe* (LACEPEDE) – 10
7. *Petrocephalus bane* (LACEPEDE) – 10
8. *Eutropius niloticus* RÜPPEL – 9
9. *Synodonthis shall* (BLOCH-SCHNEIDER) – 27
10. *S. membranaceus* GEOFFREY – 25
11. *S. batensoda* RÜPPEL – 10
12. *S. clarias* (L.) – 20
13. *S. frontosus* VAILLANT – 10
14. *Shilbe mystus* L. – 10
15. *S. uranoscopus* RÜPPEL – 20
16. *Mormyrus cashive* L. – 20
17. *Mormyrops anguilloides* L. – 10
18. *Citharinus citharus* GEOFFREY – 18
19. *Distichodus niloticus* L. – 17
20. *Heterotis niloticus* CUVIER – 18
21. *Tilapia galilea* ARTEDI – 4

In addition, the stomach contents of large carnivores (*Lates nilotica* L., *Hydrocyon brevis* GÜNTHER, *Bagrus* sp.) were studied.

Feeding characteristics of the Nile fishes permit us to divide all species into 5 groups: carnivores, detritophags, phytophags, plankophags and benthophags.

The first group includes the fishes which compose the major part of the fish fauna. It includes the large ichtiophags – *Lates nilotica*, *Mormyrops anguilloides*, *Hydrocyon brevis*, *Bagrus* sp. This group also includes two species of the genus *Shilbe* (*S. mystus* and *S. uranoscopus*) and *Eutropicus niloticus*. The food of these species consists of small fishes and adult or larval aquatic insects. The per cent of empty stomachs was usually large and sometimes as much as 50.

The group of detritus feeders also includes the fishes which form a major part of the fish fauna (*Heterotis niloticus*, *Citharinus citharus*, *Distichodus niloticus*). The contents of the stomachs of the first two species are a compact viscous mass of dark – gray colour lacking definite structure but consisting of small pieces of detritus. The stomachs of *Distichodus niloticus* contain coarse scraps of water vegetation (the fragments of roots and dying stems of *Papyrus*). The stomachs of some specimens of *Distichodus* contained the fragments of fresh leaves of *Potamogeton* sp.

As such *Distichodus niloticus* occupies an intermediate place between typical detritophags and phytophags.

The group of vegetation feeders. Two species (*Tilapia galilea* and *Labeo horie*) form this group. *Tilapia* feeds on periphyton. The stomach contents of *Labeo* is a gray-green mass with small plant fragments.

The group of plankton feeders. We can divide this group into two subgroups. The first subgroup is composed of specialized forms, which includes two species – *Synodonthis membranaceus* and *S. batensoda*. These fishes consume only plankton crustacea populating the open water or water vegetation. These species feed upside down and „suck" invertebrates from the roots of water hyacinths. The stomach content of these fishes is a red-brown mass containing many exoskeletal fragments of Crustacea of the genera *Moina*, *Ceriodaphnia*, *Diaphanosoma*, *Simocephalus* and *Microcyclops*.

Sometimes the young stages of Chironomidae larvae and some insecta were noted in the stomachs of these fishes.

The secoud subgroup includes representatives of the genera *Alestes* (*A. baremose*, *A. dentex*, *A. nurse*). In some periods of the year these species form an important part of the fisheries. These small active fishes were adapted to feed on water insects and it is possible to say that they are entomofauna feeders. The food of these species is represented by Ephemeroptera, Odonata and Diptera larvae and by several Hemiptera and Coleoptera. From time to time we noted in the stomachs of *Alestes* the fragments of littoral Crustacea and sometimes even pieces of water vegetation. The amount of food in the stomachs as a rule was not great, a large per cent of them were very often empty.

In this subgroup we can include another small fish – *Petrocephales bane*. The composition of food of this species was not different from the food of *Alestes* sp.

The group of benthos feeders. This group also can be divided into two subgroups. The first includes three species from the family Mormyridae – *Mormyrus cashive*, *Gnathonemus cyprinoides* and *Hyperopisus bebe*. They are typical benthic feeders. *Mormyrus cashive* and *Gnathonemus cyprinoides* consume only Chironomidae larvae. *Hyperopisus bebe* is adapted to feed on small Mollusca (Corbiculidae). They very low per cent of empty stomachs and the large number of filled stomachs indicates that these species feed intensively.

The second subgroup is represented by species of the genus *Synodonthis* (*S. shall*, *S. frontosus* and *S. clarias*). They are fishes with a wider spectrum of feeding. Both feed on true bottom fauna (Chironomidae larvae) and animals among aquatic vegetation (shrimps, mollusca, insecta larvae) and even the young fish fry generation are part of the food of these species.

The comparison of the results collected in different regions and during different seasons indicates that the feeding pattern of all of these fishes did not change. A slight distinction in the relation of the food components was noted for some species. It is possible to explain this by the unequal distribution of the fauna in several parts of the investigated waters.

Discussion

The analysis of the hydrobiological collections showed that the composition of the invertebrate fauna of the investigated region is rich and various*. The general list of the fauna (see the supplement) includes 156 forms. But only a small part of them are abundant. The mass forms of Crustacea are represented by *Mesocyclops leuckarti*, *Microcyclops varicans*, *Tropodiaptomus galebi*, *Diaphanosoma excisum*, *Moina dubia*, *Ceriodaphnia cornuta*, *Daphnia lumholtzi*, *Alona davidi*, *Dunhevedia crassa*, *D. serrata*, *Oxyurella singalensis*, *Alona globulosa*, *Chydorus globosus* and *Athyaephura desmoresti*. The Oligochaeta and Chronomidae larvae are represented by *Limnodrilus hoffmeisteri*, *L. udekemianus*, *Cryptochironomus ex.* gr. *defectus*, *Stictochiromus* sp. and *Chironomus* ex. gr. *plumosus;* the Mollusca – *Corbicula cunningtoni* and *Corbicula consobrina*.

* The Cyclopoida, Cladocera, Chironomidae larvae, Oligochaeta and Mollusca were identified as far as possible to species, the other animals– to genus or to family.

Several of the above mentioned species are widespread in the Palearctic and predominate over endemic species.

The poverty of the plankton fauna is of interest. Actually, the plankton population on the White Nile in spite of the great space is very poor. It is possible to explain this by the hydrological and hydrochemical regimes of the river, which winds its way through wide papyrus swamps, as described above. The same can be said about the flood-plain water bodies of the south where the number and biomass of the zooplankton is also very poor.

From Table II we can clearly see the influence of papyrus swamps on the abundance of the zooplankton: the first 3 lakes (where the biomass of the zooplankton is poor) are situated in the centre of the swamps, lake No – on the north frontier of them and khor Atar (which has the richest zooplankton) situated outside of the swamps.

Favorable conditions for plankton animals are found only in the northern part of the reservoir where a return of the river regime is noted. However the average biomass of the zooplankton for the whole reservoir is not high and is near in size to that of reservoirs of temperate latitudes.

The bottom fauna is better, although it is also poor. But it is necessary to say that a great part of the biomass of the benthos in the flood-plain, water bodies of the south consists of Oligochaeta and Chironomidae larvae – valuable as food for fishes. But their biomass, which usually is higher than the biomass of the same animals in the White Nile, is not rich (2—4 g/m^2). Only the section of the river between the mouth of the Sobat and Kosti can be considered to be rich. Here, many Mollusca were usually noted. Due to this region the average biomass of the benthos of the reservoir in spring is large, but at other times it did not exceed 1 g/m^2.

In such a manner, an impression is created by analogy with reservoirs of the northern latitudes that the state of the food base of fishes is not good. But two circumstances indicate that this is not so. The first of all is the presence of rich food resources in the form of populations among the water vegetation where the number and biomass of the invertebrates is much higher than in the open parts of the waters. On the other hand as was shown by the analyses of the stomachs of the fishes, a large part of the fishery fishes of the investigated region are species which specifically specialize on detritus, vegetation or which are predaters. Only two species of food-fished (*Mormyrus cashive* and *Synodonthis membranaceus*) are typical benthos and plankton feeders. But the absence of large numbers of fishes with empty stomachs and the great degree of filling of the stomachs suggest that these species have no deficiency of food.

Summary

1. The zooplankton and the zoobenthos of the White Nile in the Republic of the Sudan were studied from November 1963 to April 1964.

2. The investigated region included the White Nile river with its tributaries, the flood-plain water bodies of the south of the Sudan and Jebel-Aulia reservoir.

3. The zooplankton and the zoobenthos of the Upper Nile were monotonous. The abundance of the zooplankton was very low (did not exceed 0.015 g/m^3). In this region the general biomass of the benthos was also low and fluctuated from 0 to 5 g/m^2.

4. The zooplankton and the bottom fauna in the flood-plain water bodies were better although it is also poor. The influence of papyrus swamps on the abundance of the zooplankton was established.

5. Favorable conditions for plankton animals are found only in the northern part of the reservoir where a return of the river regime is noted. The benthos of the reservoir was distributed unequally. The southern part of the reservoir is rich; towards the centre of it the biomass of the benthos decreases and near the dam it is very poor.

Appendix

The general list of the plankton and benthos animals of the White Nile

Decapoda

1. *Athyaephura desmoresti* Millet

Copepoda

2. *Mesocyclops leuckarti* (Claus)
3. *Thermocyclops* sp.
4. *Microcyclops varicans* (Sars)
5. *M. bicolor* Sars
6. *M. davidi* (Chappuis)
7. *Microcyclops* sp.
8. *Macrocyclops albidus* (Jurine)
9. *Ectocyclops phaleratus* (Koch)
10. *Ectocyclops compactus* (Sars)
11. *Tropocyclops confinis* (Kiefer)
12. *Eucyclops serrulatus* (Fisher)

13. *E.* sp.
14. *E.* sp.
15. *Tropodiaptomus galebi* BARR.
16. *Diaptomus* sp.

Cladocera

17. *Daphnia longispina* O. F. MÜLLER
18. *D. lumholtzi* SARS
19. *Ceriodaphnia quadrangula* (O. F. MÜLLER)
20. *C. quadrangula hamata* SARS
21. *C. laticaudata* P. E. MÜLLER
22. *C. cornuta* SARS
23. *Bosmina longirostris* (O. F. MÜLLER)
24. *Moina dubia* GUERNEY & RICHARD
25. *Moina rectirostris* (LEYDIG)
26. *Diaphanosoma excisum* SARS
27. *D. sarsi* RICHARD
28. *Pseudosida szalayi* DADAY
29. *Latonopsis* sp. from group *fasciculata* SARS
30. *Simocephalus serrulatus* (KOCH)
31. *S. latirostris* (STINGELIN)
32. *S. elizabethae* (KING)
33. *Scapholeberis mucronata* (O. F. MÜLLER)
34. *Macrocthrix spinosa* KING
35. *M. chevreuxi* GUERNEY & RICHARD
36. *M. odiosa* GUERNEY
37. *M. laticornis* JURINE
38. *Ilyocryptus sordidus* LIEVIN
39. *I. spinifer* HERRICH
40. *Alona davidi davidi* RICHARD
41. *A. davidi iheringi* RICHARD
42. *A. davidi punctata* DADAY
43. *A. rectangula* SARS
44. *A. globulosa insulcata* STINGELIN
45. *A. globulosa* DADAY
46. *A. comboei* GUERNEY & RICHARD
47. *A. karua* KING
48. *A. pulchella* KING
49. *Alonella exigua* (LILLJEBORG)
50. *Euryalona occidentalis* SARS
51. *Chydorus kallipigos* BREHM
52. *Ch. eurynotus* SARS
53. *Ch. hybridus* DADAY

54. *Ch. globosus* BAIRD
55. *Ch. poppei* RICHARD
56. *Ch. parvus* DADAY
57. *Dadaya macrops* (DADAY)
58. *Dunhevedia crassa* KING
59. *D. serrata* DADAY
60. *Kurzia longirostris* (DADAY)
61. *Oxyurella singalensis* (DADAY)
62. *Pleuroxus laevis* SARS
63. *Pleuroxus denticulatus* BIRGE
64. *P. toumodensis* BREHM.
65. *Camptocercus similis* SARS

Conchostraca

66. *Estheria hislopi* BAIRD

Chironomidae larvae

67. *Cryptochironomus* ex. gr. *vulneratus* ZETT.
68. *C.* ex. gr. *conjugens* KIEFF.
69. *C.* ex. gr. *fuscimanus* KIEFF.
70. *C.* ex. gr. *defectus* KIEFF.
71. *Chironomus* ex. gr. *plumosus* L.
72. *Chironomus* sp.
73. *Stictochironomus* sp.
74. *Microtendipes* sp.
75. *Glyptotendipes* sp.
76. *Polypedilum* sp.
77. *P.* ex. gr. *scalaenum* SCHR.
78. *Limnochironomus* sp.
79. *Procladius* sp.
80. *Ablabesmyia* sp.
81. *Tanytarsus* sp.
82. *Pelopia* sp.
83. *Clinotanypus* sp.
84. *Paratendipes* sp.
85. *Psylotanypus* sp.
86. *Tendipedinae* gen. sp.
87. *Chironominae* gen. sp.

Trichoptera

88. *Oecetis* sp.

89. *Cheumatopsyche* sp.
90. *Aethaloptera* sp.
91. *Amphipsyche* sp.
92. *Ecnomis tenellus* RAMB.

Mollusca

93. *Belamya unicolor* (OLIV.)
94. *Cleopatra cyclostomoides* (KÜST.)
95. *C. bulimoides* (OLIV.)
96. *C. pirothi* JICK
97. *Eupera parasitica* (DESH.)
98. *Bulinus truncatus truncatus* (AUD.)
99. *Corbicula consobrina* (CAILL.)
100. *Corbicula cunningtoni* SMITH
101. *Melanoides tuberculatus* (MÜLL.)
102. *Mutela rostrata* RANG.
103. *Mutela alluandi* GERM.
104. *Gabbia humerosa* (MTS.)
105. *Sphaerium abyssinicum* POLON
106. *Pisidium (Afropisidium) pirothi* JICK
107. *Segmentorbis angustus* (JICK)
108. *Caelatura aegyptiaca* FÈR.
109. *Lanistes carinatus* (OLIV.)
110. *Pila wernei* PHIL.
111. *Etheria elliptica* f. *caillaudi* FÈR.

Oligochaeta

112. *Limnodrilus hoffmeisteri* f. *tipica* CLAP.
113. *L. hoffmeisteri* f. *parva* SOUTH.
114. *L. udekemianus* CLAP.
115. *Tubifex tubifex* LAM.
116. *Euilyodrilus hammoniensis* MICH.
117. *Stylodrilus heringianus* CLAP.
118. *Slavina appendiculata* UDEK.
119. *Branchiodrilus* sp.
120. *Pristina longiseta* EHREN.

Rotatoria

121. *Keratella tropica* (APSTEIN)
122. *K. lenzi* (HAUER)
123. *Filinia longiseta* (EHRB.)

124. *F. maior* (COLDITZ)
125. *F. terminalis* (PLATE)
126. *Anuraeopsis fissa* (GOSSE)
127. *Brachionus angularis* GOSSE
128. *B. calciflorus spinosa* (WIERZEJSKI)
129. *B. calyciflorus dorcas* (GOSSE)
130. *B. caudatus provectus* AHLSTROM
131. *B. caudatus vulgatus* AHLSTROM
132. *B. falcatus falcatus* ZACHARIAS
133. *B. falcatus lyratus* ZEMMERMAN
134. *B. quadridentatus brevispinus* (EHRB.)
135. *B. quadridentatus rhenanus* (LAUTERBORN)
136. *Conochiloides dossuarius* (HUDSON)
137. *Dicranophorus forcipatus* (MÜLL.)
138. *Euchlanis incisa* CARLIN
139. *E. dilatata* EHRB.
140. *Eudactylota eudactylota* (GOSSE)
141. *Hexarthra mira* (HUDSON)
142. *Lecane bulla* (GOSSE)
143. *L. curvicornis* (MURRAY)
144. *L. llontina* (TURNER)
145. *L. luna* (MÜLL.)
146. *L. ungulata* (GOSSE)
147. *Lepadella patella* (MÜLL.)
148. *Mytilina ventralis macracantha* (GOSSE)
149. *Platyias patulus* (MÜLL.)
150. *P. quadricornis* (EHRB.)
151. *Polyarthra vulgaris* CARLIN
152. *Testudinella patina* (HERMANN)
153. *T. patina trilobata* (ANDERSON & SHEPHARD)
154. *Tetramastix opolienzis* (ZACHARIAS)
155. *Trichocerca similis* (WIERZEJSKI)
156. *T. longiseta* (SCHRANK)

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