6.4 THE WESTERN RIFT

by Mary J. BURGIS

The Western Rift contains a series of large lakes, from Lake Mobutu Sese Seko (formerly L. Albert) in the North, through Lake Edward (for a period referred to as L. Amin) and L. Kivu, to Lake Tanganyika the second deepest lake in the world. Where the Ruwenzori Mountains rise from the floor of the Rift Valley, between Lakes Edward and Mobutu Sese Seko, they have formed a side-arm to the East of the main valley in which lies L.George, connected to L. Edward by the broad Kazinga Channel.

6.4.a LAKE GEORGE

L.George is a shallow, naturally eutrophic lake which has supported an important fishery for many years. During the International Biological Programme (1966-72) it was the subject of intensive investigation by a group of limnologists from Britain and Uganda plus many visitors from other countries. Summarising papers have been published by Viner and Smith (1973), Burgis et al (1973), Moriarty et al (1973), Ganf and Viner (1973), Greenwood (1976) and Burgis (1978): the latter gives a full list of publications from this project.

1. Geography and Morphology

Lake George is in Western Uganda, the northern half is in the District of Toro and the southern half in Ankole District.

Location: on the equator at 30°E

Altitude: 913m asl

Area: The drainage basin covers 9955km^2 including 250km^2 of the lake itself. The HYDROMET survey (1982) gives the area of the lake as 385km^2 which presumably includes that of the extensive swamp to the N.

Depth: Average depth of the lake is 2.4 +-0.1m and this shows little variation over most of the area. The maximum depth is only about 3m and occurs where the Nsonge River enters the lake from the northernlswamps.

Landscapes: (Fig.6.16) Lake George lies on the floor of the Rift Valley immediately S. of the Ruwenzori Mountains which rise steeply to nearly 5000m at their permanently snow-capped peaks. To the East the eastern escarpment of the Rift is close to the lake and rises to more than 1200m. To the West and SW lie savannah grasslands and the much larger and deeper L. Edward whose western shore is formed by the western escarpment of the Rift.

The L.George basin itself could be described as a roughly square or diamond-shaped saucer. Its width, c15km, is about the same as its length and there is little variation in its depth or substrate, which is a deep flocculent mud composed largely of dead algae. Two large

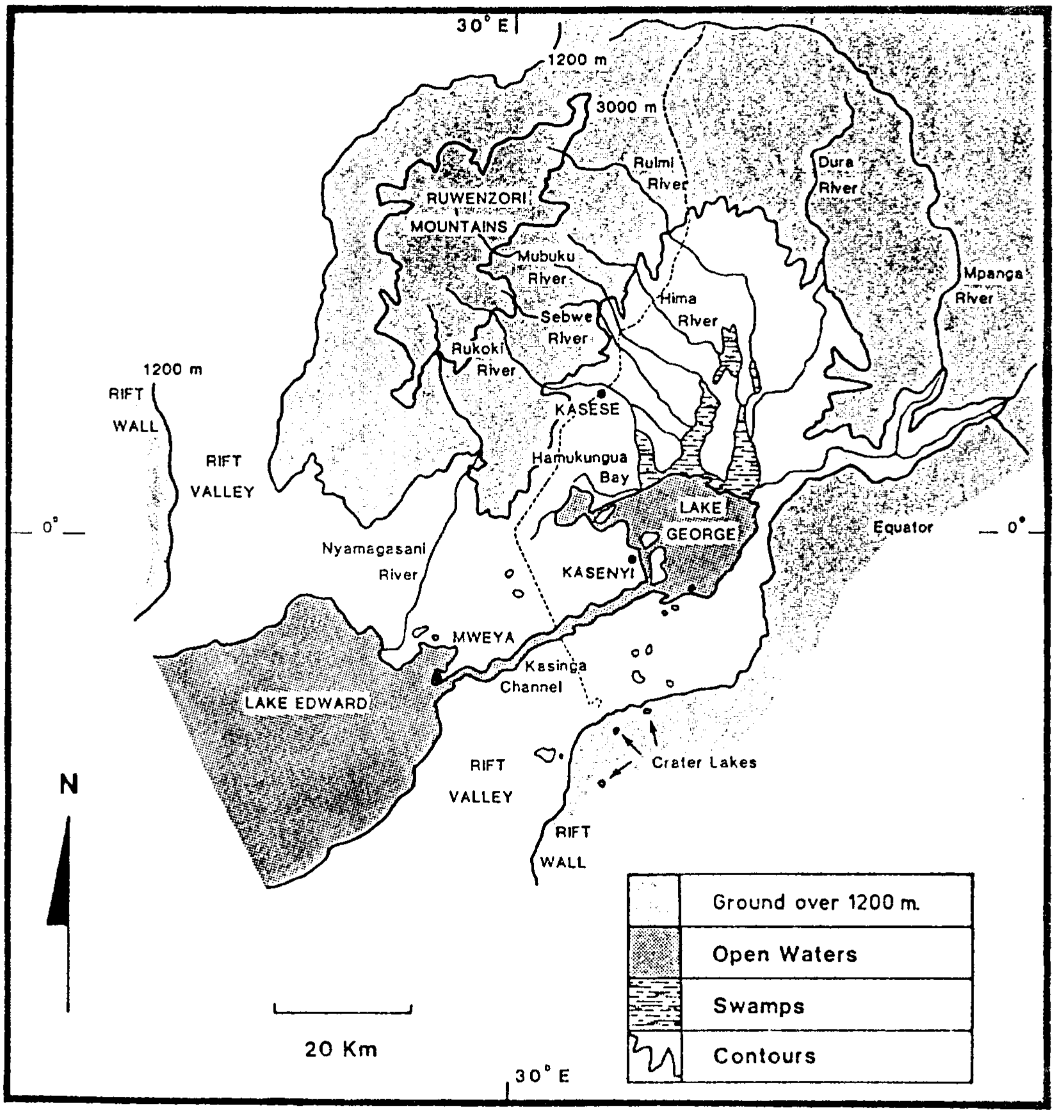


Fig 6.16 Map of Lake George and its catchment area.

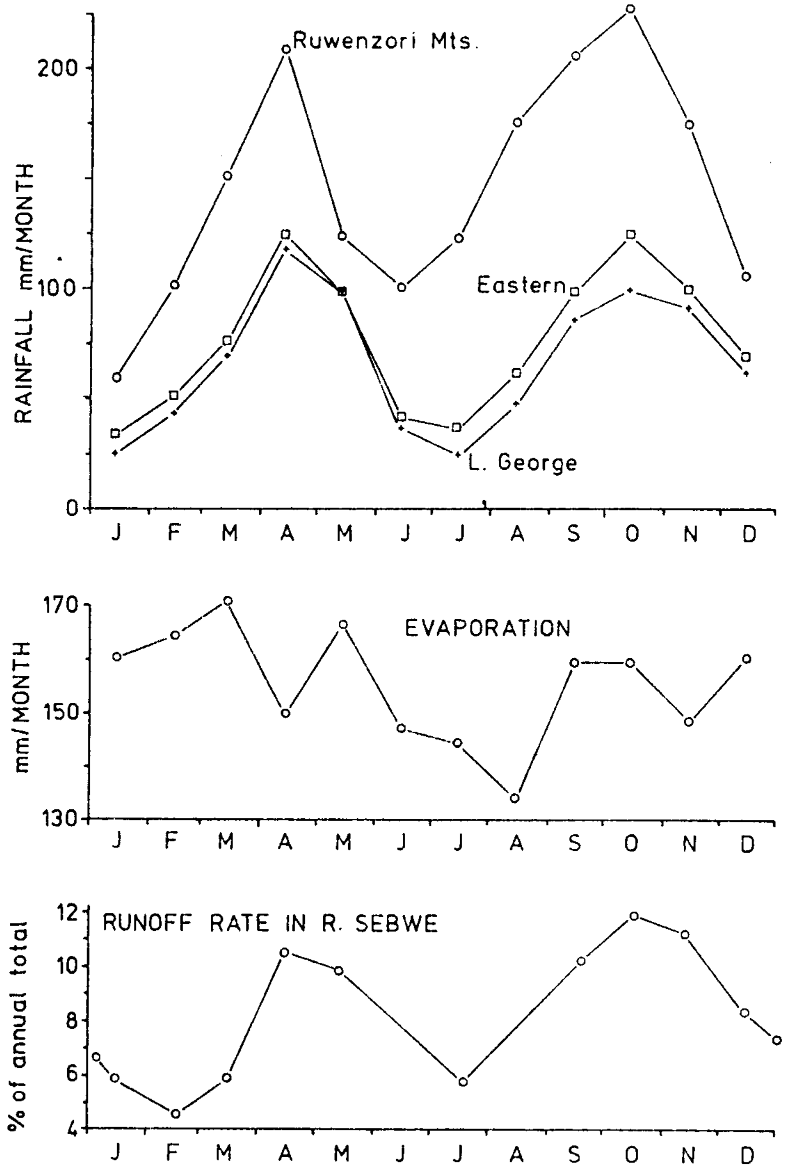


Fig. 6.17 Seasonal variation in rainfall on the Ruwenzori mountains, Lake George and the eastern sector of its catchment; evaporation from the lake and run-off in one of the main rivers flowing from the Ruwenzori into Lake George. Redrawn from Viner and Smith 1973.

islands lie close to the western shore and a third almost blocks the entrance to the very shallow Hamukungu Bay in the NW corner of the lake. Otherwise the open water is uninterrupted.

To the North lies an extensive swamp through which the inflows from the Ruwenzori and the Mpanga River from the Eastern Escarpment, enter the lake. A smaller swamp fills the most southerly extension of the lake. Just S. of where the Kazinga Channel leaves L. George a flooded crater is connected by a narrow channel to the main lake.

2. Geology

(from Lock 1973) The underlying strata are Pleistocene sands and clays of the Semliki Series, supplemented in the SW by volcanic tuffs derived from explosion craters in the Chambura Game Reserve. These are about 8000 years old (Bishop 1970). In the N. large quantities of material eroded from the SE flank of the Ruwenzori Massif have been deposited as a broad alluvial flat which borders the lake.

3. Climate

The climate is equatorial and illustrated by the climatic diagram for Kasese (Fig.6.8) which lies c16km NW of the lake at the foot of the Ruwenzori Mountains. Rainfall is somewhat higher there than over most of the lake area but it clearly shows the bimodal pattern of the seasonal cycle (Fig. 6.17).

Type: Afa Köppen

Insolation: Bright sunshine 1967 -70 averaged 2245 h/y

Total solar radiation: With a day length of 12.1h +-1 minute throughout the year, there is only small variation in solar radiation. Ten day means vary from 1720 - 2210 $J/cm^2/d$ but the range for individual days is wider and depends on such factors as cloud cover, but is still small in comparison with most other places. Mean 1970 +-13% $J/cm^2/d$; range on individual days 860 - 2760 $J/cm^2/d$; total approximately 7327×10^3 $J/m^2/y$.

Wind: Protected by the Ruwenzori to the N. and by the Rift escarpment to the E. and S., wind speeds are low, ranging from 0-3.5 m/s (monthly mean values 1966-68) with peaks in the wet seasons which are only obvious when meaned over the four years. Winds come predominantly from the E. throughout the year and are strongest in mid-afternoon (c1500h) and minimal during the night.

Rainfall: There are two ill-defined rainy seasons per year; April-May, which is more marked than Oct.-Nov. Annual total c820mm per year.

Evaporation: mean values of 5mm/d obtained by the Penman equation with a total of about 2000mm per year and little seasonal variation (Fig. 6.17).

4. Hydrography and Hydrology (see Smith and Viner 1973)

The catchment area is 9705km^2 from which Smith estimated a total inflow to the lake of 1948.3 x 10^6 m^3 per year. Of this more than 50% comes from gauged rivers of which the Mpanga (from the Rift escarpment) and the Mubuku (from the Ruwenzori) are the major contributors. Highest average flow rates were recorded on the Sebwe (1953 -68) in April- May, and September- November. Figure 6.17 shows the seasonal pattern of rainfall, evaporation and run-off in the Lake George catchment.

Inflows	Area of drainage km^2	% of inflow to L.George
from Ruwenzori (gauged)		
Rukoki/Kamulikwezi	183	6.7
Sebwe	83	3.3
Mubuku	256	20.2
Ruimi	266	9.7
Total from Ruwenzori	788	39.9
from Mpanga	4670	20.4
Ungauged	3247	39.7

The division of the ungauged catchments is such that in total 57% of their inflow comes from the Ruwenzori and 38% from the Central Plateau.

Outflow: is via the Kazinga Channel which is some 36km long, has an average width of 1.5km and depth of about 3m. There is only 1m difference in altitude between L.George and L. Edward and the channel therefore behaves more like a lake than a river and estimation of discharge from flow-rate measurements is fruitless. Smith therefore calculated the total annual discharge from L. George by difference as shown below:

Water balance for L. George	millions m^3 per year
Inflow	1948
Direct rainfall on the lake	240
Total income	2153
Evaporation from the lake	456
Hence discharge down the Kazinga Channel	1697

The average flushing rate is approximately 2.8 times per year.

5. Physico-chemical characteristics of the water

Temperature: The average water temperature of L. George is about 24.6°C but, whereas the temperature of the bottom water varied only between 25 -26°C, that of the surface water showed a daily range from about 25 to sometimes as high as 36°C. On most days the column of water (2 - 2.5m) was intensely stratified during several hours in the middle of the day. Stratification was broken down in the late afternoon and the water column remained isothermal during the night. Only on the coolest days did this cycle not occur and only under periods of unusual calm did the stratification persist overnight and perhaps for a few days.

Transparency: The dense concentrations of algae in the water column restrict light penetration and the depth of the euphotic zone. Secchi disc readings were from 26 - 46cm (Viner and Smith 1973) while the 1% level of total photosynthetically active radiation was 60 - 80cm.

pH: range from 8.5-9.5 with a maximum of 10.4. pH exhibited a diurnal pattern of stratification parallel to those of temperature and oxygen concentration.

Conductivity: The water of L. George is very dilute with a conductivity around 210×10^{-6}S/cm (in the wet season of October 1967) to 235×10^{-6}S/cm (in the dry season of July 1967).

Major ions: (from Viner 1969)

meq/l	Wet season July 1967	Dry season Oct. 1967
Na	0.89	0.85
K	0.114	0.097
Mg	0.6	0.64
Ca	0.722	1.0
HCO_3	1.25	2.0
SO_4	0.375	0.3
Cl	0.215	0.26
Mn 10^{-6}g/l	40.0	20.0
Fe (total) 10^{-6}g/l	520	332
SiO_2 mg/l	20.5	20.0
Nitrogen: (total) mg/l	2.4	2.7
NO_2'	0	0
NO_3'' 10^{-6}g/l	0	28.4
NH_4+ 10^{-6}g/l	51	0
Phosphorous:		
total PO4-P 10^{-6}g/l	200	240
soluble PO4-P 10^{-6}g/l	42.0	18.5

Oxygen: Although the oxygen concentration in the water column normally starts the day below saturation, intense photosynthesis in the shallow euphotic zone may raise the oxygen concentration of the surface waters as high as 250% saturation. Lower down, respiration is, however, keeping the oxygen concentration below 100%. This pattern of diurnal stratification is repeated on most days.

Mixing regime: The water column is subjected to a daily pattern of stratification and mixing which is illustrated by temperature, pH and oxygen. This series of diurnal changes is more marked than any seasonal variation in its details. If mixing does not occur during an unusually calm period the water column rapidly becomes deoxygenated and when mixing does occur this may result in a "fish-kill". Such events are unpredictable and have not therefore been monitored but their occurrence is well documented and the cause inferred from the observation that air-breathing fish are not among those dead. It is known that such events may decimate the whole population in a fish pond but in Lake George they seem to be localized and the recovery of the affected area is aided by horizontal mixing both of the water and of the fauna. Such events do however illustrate the fragility of the apparent stability of conditions in Lake George.

6. **Macrophytes** (see Lock 1973)

Submerged aquatic macrophytes are absent from the main body of the lake and are only found in the clear inflow of the Nsonge River. Floating vegetation, particularly Pistia stratiotes is abundant and to the North there are extensive swamps dominated by Cyperus papyrus at the edges but having a forest of Ficus sp apparently floating in the middle of the area. The southern boundary of this swamp seemed to be stable over the period 1945 -72. Papyrus also fringes most of the shoreline where it is usually floating and associated with such climbing species as Ipomoea rubens, Melanthera scandens and Cayratia ibuensis. In more exposed places Vossia cuspidata forms floating patches in front of the papyrus. Lock describes two other marginal communities besides those dominated by papyrus. Those of muddy shores often have P. stratiotes floating on the lakeward side which, near the papyrus, are bound into a mat by Hydrocotyle ranunculoides. Cyperus articulatus and C. latifolius are also often found at or above the water line along these shores accompanied by such species as Commelina diffusa and Spilanthes oleracea. Sandy beaches only occur on the exposed eastern shores of the two islands and here Paspalidium geminatum grows in very open stands. Hippos do not seem to graze the floating vegetation although they make paths through it on their way to and from the water. Elephants have been seen wading out into the lake to feed on the fringing and floating vegetation around the islands.

The terrestrial grasses all around the western and SW shore are heavily grazed by a variety of large mammals. For a description of this terrestrial vegetation and that of the rest of the Ruwenzori National Park see Lock (1977).

7. **Phytoplankton** (see Ganf 1974)

Ganf idientified 58 species of algae from the open water area of the lake. Of these 29 were blue-greens, 11 diatoms and 18 chlorophytes. Many more species (total >100) occur when those from the inshore and swamp areas are included.

The dominant genera were Anabaena, Anabaenopsis, Aphanizomenon, Lyngbya and Microcystis among the blue-greens, Melosira, Nitzschia and Synedra among the diatoms and Pediastrum and Scenedesmus among the chlorophytes. There is evidence that this composition was similar from the 1930s at least until the early 1970s. The blue-green algae comprised 70-80% of the biomass whose chlorophyll a concentration averaged about 400 -500 mg/m^2. This varied little throughout the year and maximum values were less than twice the minimum.

The phytoplankton biomass is not homogeneously distributed across the lake and tends to have a concentric pattern with the highest concentrations in the centre of the lake. This is thought (Viner and Smith 1973) to be due to complex seiche movements within the lake.

The vertical distribution of the phytoplankton shows marked diurnal changes which are thought to be dependant upon water turbulence and thermal stratification . This is discussed in detail by Ganf (1974).

High phytoplankton biomass and warm water temperatures lead not only to high levels of photosynthesis (ultimately limited by self-shading) but also to high levels of algal respiration. It therefore proved very difficult to make an estimate of net primary production. Using light and dark bottle methods for both O_2 and C^{14} analyses gave estimates for gross photosynthesis of 15.56 gO_2/m^2/12h and 4.5 gC/m^2/12h. Changes of total CO_2 concentration in situ within the euphotic zone gave a value of 2.25 gC/m^2/12h fixed during the day and in situ changes in the oxygen concentration gave estimates of gross photosynthesis of 12 gO2/m^2/12h. These last figures indicate zero net particulate production over 24 hours. It seems that photosynthetic fixation and respiratory breakdown are very finely balanced such that on some days net production is negative and on others positive. Overall there must be net production but it is a very small percentage of gross photosynthesis.

8. Invertebrates

Little is known about the invertebrates associated with the swamps, fringing vegetation and floating macrophytes but detailed studies have been carried out on the zooplankton (Burgis 1973, 1974) and on the benthos (McGowan 1974,1975 and Darlington 1977). The zooplankton is dominated by a small species of herbivorous cyclopoid copepod Thermocyclops hyalinus. There is one other cyclopoid and only three species of Cladocera, found in relatively small numbers, in the main lake. Rotifera are found in greater variety (up to 15 spp.) particularly when inflow from the swamps is high and species normally associated with the swamp fringes are swept into the lake.

The larvae of the phantom midges (Chaoborus) are found in both the benthos and the zooplankton. Two species have been recorded C.ceratopogones and C. anomalous; they form large swarms when the adults emerge from the lake. The species composition of the benthos is limited to those able to survive in the soft flocculent mud which is frequently stirred into the overlying water. Only oligochaetes are found below the disturbed layer. Besides the two species of Chaoborus mentioned above the surface mud contains several species of chironomid larvae the most abundant of which is Procladius brevipetiolatus. Most of the species found in the mid-lake mud also occur inshore but here there is greater variation in the substrate composition and diversity of species found. Darlington (1977) found no evidence of seasonal change in species composition or absolute levels of density and biomass during the period of her study. She also examined the horizontal distribution of the benthic fauna in some detail.

9. Fish

Thirty-two species of fish have been described from L. George. The majority (21 spp) are cichlids and 17 belong to the genus Haplochromis (Greenwood 1973). Only one of the Haplochromis species exceeds 12cm adult length and yet two of them H. nigripinnis and H. angustifrons make up nearly 60% of the biomass of the ten fish species that have a lake-wide distribution. Twenty percent of that biomass is made up of Oreochromis niloticus (=Tilapia nilotica = Sarotherodon niloticus), also a cichlid. This species was the most important component of the commercial fishery on L. George. It and H. nigripinnis are both herbivores and feed directly on the Microcystis and other blue-green algae that dominate the phytoplankton (see papers by Moriarty). H. angustifrons is a specialised benthic feeder adapted to sift the loose flocculent mud for chironomid larvae.

The ten species with lake-wide distribution also include the zooplankton feeders H. pappenheimi and Aplocheilichthys spp., the piscivorous H. squamipinnis and the larger carnivores Protopterus aethiopicus, Clarias lazera and Bagrus docmac.

Fish biomass and diversity is higher in the inshore areas of the lake. This may be correlated with the greater variety of feeding niches available inshore, plus the fact that many of those species that can feed in the open water areas of the lake have to come inshore to breed (eg the nest building cichlids such as O. niloticus) and the juveniles of the herbivores feed on micro-crustacea which are more abundant close to shore. The food preferences of the Haplochromis species have been discussed in some detail by Dunn (1975).

Estimates of the overall density and biomass of fish were made using a purse seine during 1971-72 by Gwahaba (1975): 45000 - 55000 fish/ha and 29 +-5 g/m^2. Biomass estimates ranged from 6.3 g/m^2 in the centre of the lake to 90.5 g/m^2 in the inshore region.

10. Other vertebrates

At the time of the IBP study there were thought to be about 3000 hippopotamus in the population that rested in the shallow inshore waters of the lake each day.

Large populations of fish-eating birds live on and around L. George; these include kingfishers, herons, cormorants, pelicans and the African fish eagle. Similarly large numbers of wading birds such as storks and ibises feed in shallow swampy finges of the lake.

Elephants were occasionally seen wading to the islands and feeding on the aquatic vegetation. Sitatunga were thought to occur in the swamps to the north of the lake and it is not impossible that shoe-billed storks did also. Reed buck, water buck and buffalo were very common on the west and SW shores of the lake which were included in the Ruwenzori (formerly Queen Elizabeth) National Park.

11. Human activities and management

The area in which L. George lies is sparsely populated but the catchment area does include the town of Kasese at the terminus of the railway from Kampala, and the mining community of Kilembe which mines copper on the flanks of the Ruwenzori.

When the National Park was gazetted (in 1952) a number of fishing villages such as Kasenyi (see Fig. 6.16) were allowed to remain on the shores of L. George and were excised from the Park area. During the 1960s the populations of these villages increased due to the arrival of refugees from Rwanda and Zaire. The present status of these communities is not known.

Outside the Park boundaries the main fishing villages on L. George are Kashka, Mayhoro and Kayinja. Powered launches ferry passengers across the lake from Kasenyi to Mayhoro from where ancient routes climb the escarpment and communicate with the rest of Uganda.

Modern communications are primarily maintained via the main N - S road from Mbarara to Fort Portal which runs across the Park about 16km from the west shore of L. George. A side road runs down to the lake at Kasenyi. The railway crosses the swamp north of the lake and its embankment has raised the level of the water on the north side. This has produced areas of open water with clumps of Cladium and some Nymphaea (Lock 1973). There is an airport at Kasese and an air-strip at Kasenyi.

At Kasenyi the Uganda Fish Marketing Corporation (TUFMAC) set up a buying and processing (filleting plus freezing and drying plus salting) plant which operated for at least twenty years (1952 - 72). Frozen fish were carried out by road to Kampala and to Kenya. Dried-salted fish was exported to Zaire as well as sold locally within Uganda. This operation ceased in 1973 but fishing continued and fish were sold directly to merchants with lorries who carried them to the cities. The current status of the fishery is not known but the history of its active period has been discussed by Dunn (1973) and its effect on the fish populations by Gwahaba (1973).

The proximity of the copper mine at Kilembe and the fact that rivers flowing through the mining area flow into the L. George swamps have prompted investigations of the copper concentration in the lake waters. Bugenyi (1979) measured the copper concentration of the waters of the Nyawamba River, Lake George, the Kazinga Channel and Lake Edward during the period from March 1976 - May/June 1977. Values ranged from 0.12 - 0.15 ppm in the river, 0.08 - 0.11 in Lake George, 0.05 -0.08 in the Kazinga Channel.

6.4.b. OTHER SHALLOW LAKES IN THE WESTERN RIFT

Crater lakes

Immediately south of the Ruwenzori Mountains there are a number of explosion craters many of which contain lakes. According to Melack (1978) this area contains a total of 89 crater lakes in four groups. Some of those on the eastern escarpment eg L. Nkugute (Beadle 1966) are rather deep but many of those on the floor of the Rift Valley between Lakes George and Edward are shallow and more or less saline. Melack (1978) surveyed sixteen and those less than 10m deep are listed below with his estimates of their depth, area and conductivity.

	depth m	Conductivity $x10^{-6}S/cm$	Area ha
L. Saka	8.5	c530	1.1
L.Kifuruka	c4.0	c280	15.0
L.Nyamusingire	4.9	c900	440
L.Kikorongo	8.5	c16,500	103
L.Mahega	4.1	c112,200	16
L.Bunyampaka	0.25	80,000	43
L.Katwe	0.33	116,000-166,000	245

In L.Katwe sodium chloride is dominant and the lake has long been the centre of trade in salt which is evaporated in pans along the shore. The salt has a distinctive pink colour. In the other lakes carbonates are predominant and some of them (eg L.Mahega which is often orange) are richly coloured by their bacterial flora.

Lake Mulehe

1. Geography and Morphology

South of Lake Edward the Rift Valley is blocked by the Virunga (or Mfumbiro) Volcanoes whose peaks rise to heights of more than 4000m and whose lava flows form steep sided valleys many of which are intensively cultivated using terraces. Papyrus swamps fill many of the valley bottoms which drain ultimately into either Lake Bunyoni or Lake Mutanda. These are both large deep lakes but the much smaller (area c5km^2) Lake Mulehe has a maximum depth of only c7.5m.

2. Physico-chemical conditions

Since it lies at an altitude of 1750m asl it is relatively cool (c20°C in the euphotic zone) but only spot measurements are available. Similarly sparse data on the water chemistry indicates a conductivity of about $260x10^{-6}S/cm$ and pH ranging from 7.4-8.0 (Talling and Talling 1965). The lake is cut off from Lake Mutanda by a lava flow from the South. It discharges to L.Mutanda via a papyrus swamp in the south-west and except here it is closely hemmed in by high hills.

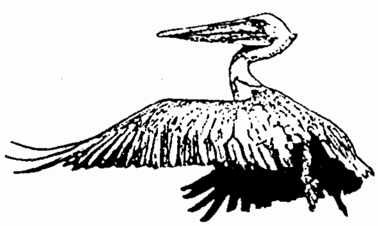
Major ions: (from three visits in 1960-61, Talling and Talling 1965)
Na 10.8; K 9.6; Ca 20.8-21.7; Mg 13-13.8; $mg.l^{-1}$
HCO_3+CO_3 2.10-2.18 meq. l^{-1};
Cl 12.0-14.2; SO_4 21-27; SiO_2 19.5-34; $mg.l^{-1}$
NO_3-N 22; PO_4-P 220-228; total P 240-272; $10^{-6}g/l$

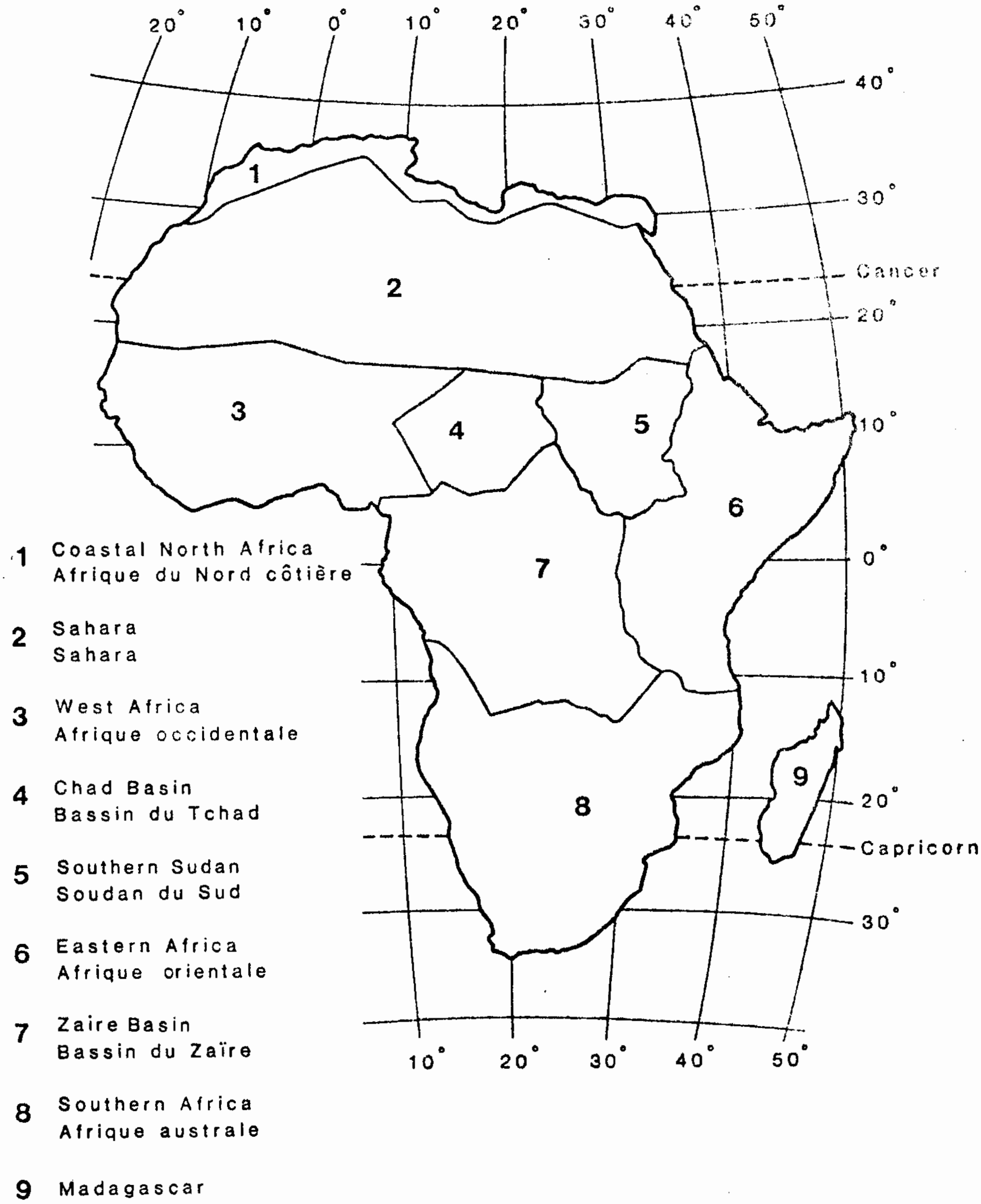
3. **Macrophytes and phytoplankton**

When Talling visited the lake in 1961 he reported that it contained large areas of water weed (probably Ceratophyllum sp) and that the water column was well mixed at 19.7°C. The phytoplankton consisted largely of Melosira granulata (about 170 cells/ml) with Synedra sp, Oscillatoria sp. Coelastrum reticulatum and an unidentified cryptomonad were also abundant. At 1355h the incoming radiation was 279 $kerg/cm^2/sec$ and maximum photosynthesis (121 $mgO_2/m^3.h$) occurred at 0.5m. The 1% level was at 3.5m and integral photosynthesis was estimated to be 240 $mg/m^2.h$ or 2.3 $gO_2/m^2.day$.

4. **Invertebrates**

Green (1976) sampled the zooplankton of the lake in October 1962 and found a total of 509-755 x $10^3/m^2$ animals at a density of 105 $x10^3$. Monia dubia, Ceriodaphnia reticulata, cyclopoids and nauplii were most abundant among the Crustacea while the six species of rotifer were dominated by Syncheata pectinata which comprised 72% of their population. Brachionus spp were also abundant. The phantom midge larva Chaoborus anomalus was also present in his samples.





Regions of Africa treated in this Directory
Régions d'Afrique traitées dans le présent répertoire

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African wetlands and shallow water bodies

Zones humides et lacs peu profonds d'Afrique

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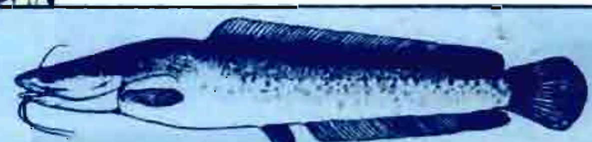

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