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A Report on the Fisheries of Uganda

Investigated by the Cambridge Expedition to the East African Lakes, 1930–31

WITH

3 Appendices,

5 Maps and 21 other Illustrations.

BY

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LIST OF ILLUSTRATIONS.

FIGURES.

SKETCH-MAPS.

LIST OF TABLES.

PART I.—LAKES EDWARD AND GEORGE AND THE KAZINGA CHANNEL.

(*Map* 2, *p.* 81.)

INTRODUCTION.

Previous Information.

There was very little previous information to use as a basis for work on Lakes Edward and George, but fortunately the region had been mapped in some detail by the Uganda-Congo Boundary Commission of 1906-08. This map served as a satisfactory foundation, but the western Congo shoreline of Lake Edward was inserted only by a dotted line, and a number of inaccuracies, particularly with regard to the islands and littoral of L. George, came to light during our survey. Furthermore, the shorelines of all the African lakes are undergoing rapid changes, particularly in those parts where the littorals are flat and sandy and where wind and wave action cause the growth of sand spits and bars. By these means considerable changes have taken place along the low-lying south-east shore of Lake Edward during the period from 1908-31. With regard to depths, practically nothing was known beyond the fact that a rough line of soundings down the Kazinga Channel, recently made by the Kenya and Uganda railway, had shown that there is sufficient water for steamer navigation along this route. It was generally supposed that both Lakes Edward and George were very shallow. The fauna and flora had not been studied in any detail, though some fishes, etc., had been collected by Professor Moore and other naturalists who passed these lakes en route for other parts, and shore shells had been collected by Capt. Pitman. The expedition, therefore, was left a practically open field for geographical and biological work.

Personnel.

The personnel consisted of :—

Dr. E. B. Worthington as Leader and Zoologist, whose work concerned the fish, plankton, the general ecology of the lakes and fisheries development.

Mrs. Stella Worthington as Geographer, who collaborated with the leader in his work and, in addition, was in charge of the maps and geographical data.

Mr. L. C. Beadle as Chemist and Zoologist, who was chiefly concerned with the study of water chemistry in relation to the fauna and flora.

Mr. V. E. Fuchs as Geologist, who made a particular study of the old lake faunas as represented by fossils in the Kazinga bone-beds.

The native staff comprised the following :—A Jaluo head fisherman, who came from the neighbourhood of Kisumu, but unfortunately developed spirillum fever soon after arriving at Katunguru, and was incapacitated for most of the work on Lakes Edward and George. Two local Banyankole fishermen were enlisted at Katunguru. The domestic staff consisted of a cook and two personal boys, and additional help for porterage, etc., was enlisted locally when required.

Equipment.

The equipment was mostly the same as used on Lakes Rudolf, Baringo, and Naivasha during the earlier work of the expedition. The greater part was brought from England, but, in addition, the residual stores left over from the Fishing Surveys of Lakes Victoria, Albert, and Kioga, 1927-8, were borrowed from the Game Offices in Kenya and Uganda, and some of the equipment was constructed locally. The most important items were the following :—

Ford box-body car (other over-land transport was provided by Government lorries and a staff car) ; 16 ft. wooden boat constructed near Kisumu of ½-in. pine with local cedar keel and ribs ; large dugout canoe borrowed at Katunguru ; 10 ft. canvas folding boat ; 12 h.p. Johnson sea-horse outboard motor ; a supply of gill nets of 1 in., 2 in., 3 in., 5 in., 7 in. and 9 in. mesh of flax twine of suitable thickness in each case ; long-lines fitted with cod and conger hooks ; 10 ft. beam trawl[1] ; oyster dredge[1] ; anchors, buoys, rope and twine, spring balance and fish measures ; two Friedinger sounding winches[1,2] ; sounding leads ; depth water bottle[2] ; grab[1] ; closing plankton nets of fine, medium, and coarse mesh ; Secchi's disc ; reversing thermometers ; ordinary thermometers ; monocular microscope[2] ; binocular microscope ; stop watch ; three zinc boxes fitted for chemical investigations to Miss P. M. Jenkin's design[3] ; copper still[3] ; 4 large zinc-lined collecting tanks and other boxes fitted with collecting jars and corked tubes[1] : surveying instruments such as prismatic compass, aneroids, plane table, etc.[4] ; box of tools ; reference books, maps and stationery ; pond nets, insect nets ; fishing rods, firearms, field glasses, and cameras ; the usual camp equipment comprising tents, etc.[5]

Itinerary.

The personnel and full equipment of the expedition arrived at Katunguru on the Kazinga Channel, midway between the two lakes, on May 23rd after motoring from Kampala. The Government rest camp on the south side of the channel at Katunguru served as a headquarters laboratory and dumping ground for collections and equipment throughout the work in this region. The interval between May 23rd and June 2nd was occupied with the study of the middle reaches of the Kazinga Channel. On the latter day the whole expedition moved to where the Channel opens into Lake Edward, and erected camp on the tip of the Mweya Peninsula, a convenient base for the study of Katwe Bay and the nearby parts of Lake Edward. This work lasted until June 15th, during which period Beadle and Fuchs also examined the eastern shoreline of Lake Edward as far south as Kanyamwongo spit, working from the land. On June 15th, Dr. and Mrs. Worthington proceeded on a three weeks' cruise, camped at Katwe, Kisenyi spit, Kanyamwongo spit, Katanda, crossed the lake from near Katanda to the precipitous Congo escarpment, and thence proceeded up the little-known western shore, camped at several stations en route, including the source of the Semliki River, and returned to Mweya on the 30th June. Meanwhile Beadle and Fuchs went by foot safari along the north shore to Katwe, and thence to Kisindi on the international boundary, and so into the Congo to visit the Semliki River in the region of the waterfalls, and also the western foothills of Mount Ruwenzori. On July 10th, Dr. and Mrs. Worthington returned to Katunguru while Beadle and Fuchs proceeded by boat to the source of the Semliki and the deep water under the Congo escarpment for further researches.

On July 14th the whole expedition moved to Lake George and erected a camp on the south shore where the Kazinga Channel opens into the lake. Work in this region continued until July 26th, when the expedition once more divided—Dr. and Mrs. Worthington proceeded on a week's cruise round Lake George, camped at Mayura, the north-east corner of the lake, Iragara Island, Mohokya, and crossed the lake in several directions. Meanwhile, Beadle and Fuchs visited a number of

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(1) Lent by the British Museum (Nat. Hist.) by permission of the Director.
(2) Lent by the Zoological Laboratory, Cambridge, by permission of Prof. J. Stanley Gardiner, F.R.S.
(3) Lent by the Trustees of the Percy Sladen Memorial Fund.
(4) Lent by the Royal Geographical Society.
(5) Mostly lent from the Land Office stores, Entebbe, by the Director of Surveys.

[Photo by E. B. W.

FIG. 1.—THE NORTH-WEST SHORE OF LAKE EDWARD.

crater lakes, particularly Kisenyi (or Bunyampaka) and Kikorongo in the region between the Kazinga Channel and Mt. Ruwenzori. On August 4th a return was made to Katunguru, where the expedition was met by motor transport on August 7th. Beadle started on the homeward journey to England, Fuchs to Naivasha, and Dr. and Mrs. Worthington to Lake Bunyoni.

During work on Lake Edward many of the native staff suffered seriously from spirillum fever, so that camp at Mweya was converted into a hospital for a week. Fortunately the European members of the expedition were unaffected, but Worthington, Beadle and Fuchs suffered occasional attacks of malaria, and Mrs. Worthington was laid up for ten days at Katunguru with dysentery.

Meteorological Conditions.

The part of the rift valley enclosing Lakes Edward and George, though at a comparatively low level, has a high rainfall, due to the proximity of Mt. Ruwenzori. The 1.400 mm. (annual total) area includes Lake George and the northern half of Lake Edward (Hurst, 1931, plate 23, p. 54). The period of the expedition's work in this area fell during the dry season, and on the whole quiet fine weather prevailed. Along the north shore of Lake Edward a regular daily lake breeze arose from the south-west at about 11 a.m. and continued till about 4 p.m. Heavy rain fell, however, from time to time, and storm winds sometimes caused seas sufficiently large to be dangerous to small boat navigation. On one occasion, in fact, when the boat was blown away from her moorings under the Congo escarpment the expedition nearly ended disastrously.

Regular daily observations show that the shade temperature at the mouth of the Kazinga Channel into Lake Edward ranged from an average maximum of 30·2° C. (86·4° F.) to an average minimum of 19·0° C. (66·2° F.) during 10 days in June. Similar figures obtained at the east end of the Kazinga Channel, during a week in July, were 29·5° C. maximum and 17·0° C. minimum.

Visibility in the Lake Edward region of the Uganda rift valley is extraordinarily poor during the dry season. This is patent owing to the rare occasions on which the snow peaks of Ruwenzori can be seen from well-known viewpoints, but it is even more strikingly brought home when working on the lakes themselves. During the four months near the foot of Ruwenzori the snow peaks were only visible on three or four occasions, and there was usually a thick haze over the water sufficient to obliterate the opposite shore. On the occasion when a crossing was made from east to west of Lake Edward, where the width is 17½ miles, the eastern shore was invisible after two miles of water had been traversed, and the high Congo escarpment did not loom into view until the boat was within a mile or two. Therefore, on this and on other open water cruises, navigation had to be directed entirely by compass.

Drainage.

Lake Edward, which is some 48 miles long by 25 miles wide, lies in the great rift valley a little south of Mt. Ruwenzori with its longer axis north-east to south-west. The south-east shore is flat and swampy, but on the west shore the Congo escarpment descends abruptly to the water from a height of more than 8,000 ft. to the level of the lake, which has now been fixed at 2,995 ft. above sea-level.

The main affluent rivers are the Ruchuru at the southern end, which drains the Mufumbiro volcanic range and parts of the Kigezi highlands, the Ishasha forming the Uganda Congo boundary to the south of the lake, and the Ntungwe. The last two, together with three smaller rivers, the Mchuera, Ruampuno and Niamweru, rise in the Kigezi and Ankole highlands and flow to the south-east shore. Entering along the north shore there are the Lubilia, forming the international boundary to the north of the lake, and the Nyamgasani, both of which find their origin among the foothills of Mt. Ruwenzori. In addition, a series of mountain torrents pour down the Congo escarpment from the west and sometimes enter the lake as beautiful waterfalls and cascades. Lake Edward is drained by the Semliki from its northern end down the rift valley to Lake Albert.

* Some of the matter of this section has already been published in brief (Worthington, 1932 a.).

Hurst (1927) has estimated the flow of the three most important affluents as follows :—

	Minimum.	Maximum.
Ruchuru	42 ...	130 cubic metres per sec.
Ishasha	8 ...	35–50 ,, ,, ,,
Ntungwe	5 ...	25–35 ,, ,, ,,

Further, he gives the following figures for the drainage of the lake basin as a whole :—

Run off	$= 4{,}500 \times 10^6$	cubic metres per annum.
Rain on lake	$= 2{,}400 \times 10^6$	,, ,, ,,
	$6{,}900 \times 10^6$	,, ,, ,,
*Evaporation	$= 2{,}600 \times 10^6$	,, ,, ,,
Outflow	$= 4{,}300 \times 10^6$	,, ,, ,,

Although Hurst points out that there is no detectable flow in the Kazinga Channel, he considers that the flow down the Channel to Lake Edward brings the total annual outflow at the Semliki source to $5{,}000 \times 10^6$ cubic metres.

My wife and I, while camped at the Semliki source, measured the flow of the river on 27th June, 1931, at a point some 50 yards down stream from the lake. The river's width was 71 metres, its depth was measured every three metres and the speed of the flow, which averaged 0·9 metres per second, was measured in several places. From these observations the flow of the river was calculated to be 103·3 cubic metres per second, which compares well with the previous estimation made by Sir William Garstin, who found the flow at the head and tail of the Semliki to be respectively 97 and 124 cubic metres per second in the dry season of 1903.

Shoreline.

The winds in the Lake Edward portion of the rift valley are not so regular or so powerful as those of the Lake Albert basin, and therefore conditions are not suitable for long sand spits to be built out into the lake, such as occur along the Lake Albert shores (Worthington, 1929). Instead of spits, a sand bar from 5–30 yards wide has been built up by regular wave action all along the low-lying south-eastern shore. In those parts where flat or swampy land intervenes between the lake and the rift escarpment this sand bar shuts off the swamps from the lake itself, so that it is possible to walk along the shore with the lake on one side and several miles of swamp on the other. In certain places the sand bar extends into the lake a little way, forming lagoons narrowly separated from the lake itself. Along the stretch of shore between the rivers Niamweru and Mchuera there is a pair of these lagoons ; the Kisenyi spit has grown out northward towards the Niamweru mouth, while the Kanyamwongo spit has grown southward. Both spits are narrow and have increased in length considerably since the 1906–8 survey. Their enclosed lagoons are very shallow and are being converted into swamps by silting.

Similar shore conditions hold along the northern stretch of shoreline between Katwe and the Semliki source. The sand bar at Kaianda is tending to shut off completely a shallow triangular lagoon, but a group of resident fishermen keep narrow channels open to allow the passage of fish. The western shore of Lake Edward is rocky and sometimes precipitous, shelving abruptly to very deep water. At intervals of about 10 miles there are little fans of flattish land extending into the lake associated with river gorges. There are only three islets in Lake Edward, which lie in Katwe Bay and are of volcanic origin.

* Assumed to be 1·2 metres per annum, as in the case of Lake Victoria.

in relation to the aquatic plants and animals has been dealt with by Beadle (1932*a*) among the general scientific results of the expedition, but a summary of the data concerning Lakes Edward and George is given below for accessibility in Uganda, and to serve as a basis for this report.

In spite of their direct connection by the Kazinga Channel the two lakes are of markedly different types. The water of Lake George is comparatively fresh, not quite twice as alkaline as Lake Victoria, but Lake Edward is five times as alkaline as Victoria, slightly more so even than Lake Albert, so that its water has an appreciable taste. The following table shows the differences between the two types of water. being the result of typical analyses of surface samples from the open water of each lake.

TABLE 1.

DATA CONCERNING THE SURFACE WATERS OF LAKES EDWARD AND GEORGE.

	Date.	Alkalinity expressed as normality.	pH (midday)	P_2O_5 mgms. per litre.	SiO_2 mgms. per litre.
Lake Edward... ...	9.7.31	0·0096	8·9	0·276	4·0
Lake George	22.7.31	0·0021	9·9	0·154	18·3

The alkalinity, expressed as normality, is determined by titrating a measured quantity of lake water against 0·01 N. sulphuric acid; the resulting figures are a useful index of the quantity of alkaline salts in solution. Although the alkalinity of Lake George is very much less than that of Edward, the pH at mid-day reaches a much higher figure. This is due to the greater amount of phytoplankton, especially of the blue-green alga, *Microcystis flos-aquæ*, in Lake George. In the process of photosynthesis these minute plants remove carbonic acid from the water during the day-time with the result that the pH rises. Conversely during the night-time the plant's respiration results in the addition of carbonic acid to the water so that the night-time pH of Lake George is considerably below that of Lake Edward.

The low phosphate content of Lake George is probably due to the great areas of papyrus swamp through which the affluent rivers flow before reaching the lake itself. The exuberant plant life of the swamps appears to reduce the phosphate supply as the water flows past.

The comparison between the two types of water has been put in another way by Hurst (1925) as follows :—

TABLE 2.

FIGURES GIVEN BY HURST (1925).

	Total dissolved Salts.	Carbonates and Bicarbonates.	Chlorides.
Lake George & Kazinga Channel	268	288	18
Lake Edward	360	437	17

This again shows the high proportion of dissolved salts in Lake Edward compared with Lake George, but it must be remembered that the composition of the waters has probably changed during the period from 1924, when these samples were collected, to 1931.

Results of analyses by the Government chemist, London, of three water samples from Lake Edward collected in 1921 and 1929, were published in the *Times* of April 30th, 1930, in a letter from Capt. Tracy Philipps. The analyses are reproduced below, by permission of the Editor, but considerable changes may have taken place during the transit of the samples from Uganda to London ; particularly the oxygen content must be accepted with reserve.

TABLE 3.

ANALYSES BY THE GOVERNMENT LABORATORY, LONDON, ON WATER SAMPLES COLLECTED BY CAPT. TRACEY PHILIPPS.

	No. 258, March 23, 1921, Lake Edward E.	No. 268, March 23, 1921, Lake Edward S.W.	Misc. No. 362, July 5, 1929, Lake Edward (Kigezi).
	Sample 600 *c.c.*	*Sample* 600 *c.c.*	*Sample* 1,000 *c.c.*
Total solids in solution	42·2	54·3	—
Calcium (Ca)	2·8	3·4	1·4
Magnesium (Mg)	3·0	3·7	4·7
Sodium (Na)	9·9	13·2	10·3
Carbonate (CO_3)	16·8	22·8	31·9
Chlorine (Cl)	1·1	1·0	—
Silica (SiO_2)	1·6	1·4	0·8
Sulphuretted hydrogen (H_2S)	0·49	0·68	0·82
Oxygen consumed in 4 hrs. at 80°F.... ...	1·01	1·23	1·07

Parts per 100,000.
Sp. gr. at 60°F.

Nitrate : trace. Pronounced odour of sulphuretted hydrogen. Black sediment of iron sulphide and silicates.—*J.E.T.P., March* 3, 1930.

The information given in Table 1 can be accepted as typical for the whole of Lake George, which is so shallow that depth has a negligible effect on the water chemistry, and for the shallow water of Lake Edward covering that area in Map 2 outside the 20 metre depth contour. In the deep parts of Lake Edward, however, there is an important factor which has a great effect on the chemistry and life of the waters. This is the thermocline or the definite division of the waters at a certain depth into the epilimnion (upper region) which has a good oxygen supply and supports abundant life, and the hypolimnion (lower region) in which oxygen is absent and, therefore, in which life is practically non-existent. Lakes in temperate latitudes typically develop thermoclines during the course of the warm summer months, during which the surface waters are continually heated and two distinct circulations are set up, one above and the other below the thermocline. In some temperate lakes the oxygen supply in the hypolimnion is exhausted during late summer, but every winter it is replenished by the cooling of the surface waters and

THE FISHES.—TABLE 4.

List of the Fishes recorded from Lakes Edward and George.

Scientific Name.	Lunyankole.	English.
Lepidosirenidæ.		
Protopterus aethiopicus Heck*	Mamba.	Lung-fish.
Mormyridæ.		
Mormyrus kannume Forsk	Ntanani.	Elephant snout fish.
Mormyrus caschive Linn.		
Cyprinidæ.		
Labeo forskalii Rüpp.	Omoruma.	
Barbus altianalis eduardianus (Blgr.)*... ...	Ndoche.	Barbel.
Barbus perince Rüpp*		
Barbus kerstenii Peters		
Clariidæ.		
Clarias lazera C. & V.*		Cat-fish or mud-fish.
Clarias moorii Blgr.*		
Clarias carsonii Blgr.	Minya.	
Bagridæ.		
Bagrus docmac Forsk	Omukora.	Cat-fish.
Cyprinodontidæ.		
Haplochilichthys pelagicus Worth.		
Haplochilichthys analis Worth.		
Haplochilichthys pumilus (Blgr.).		
Cichlidæ.		
Tilapia nilotica (Linn.)*	Ihere or Mahere	"Carp."
Tilapia eduardiana Blgr.*	Young Matole	
Haplochromis schubotzi Blgr.*	Nyamororo.	
Haplochromis angustifrons Blgr.*		
Haplochromis pappenheimi Blgr.*		
Haplochromis eduardii Regan*		
Haplochromis nigripinnis Regan*		
Haplochromis squamipinnis Regan*		
Haplochromis fuscus Regan*		
Haplochromis mentatus Regan*		
Haplochromis serridens Regan*		
Haplochromis guiarti (Pel.)*		
Haplochromis ishmaeli Blgr.		
Haplochromis melanopus Regan...		
Haplochromis multicolor Sch.		
Haplochromis nubilus (Blgr.) new subsp. ...		
Haplochromis macrops (Blgr.) new subsp. ...		
Haplochromis. 11 other new species		
Schubotzia eduardiana Blgr.*		
Astatoreochromis alluaudi Pellegr.		

Previous work on the fishes of Lakes Edward and George has been restricted to the examination of small collections brought home by certain scientific expeditions which have visited the lakes, particularly the second Tanganyika Expedition of 1899 under Prof. J. E. S. Moore. The extent of knowledge of the Edward fauna up to 1920 has been summarised together with that of the other

* Previously recorded from these lakes ; all species not so marked were newly recorded during the expedition.

great African lakes by W. A. Cunnington (1920) who recorded 14 fishes from the lake basin. It will be seen from Table 4 that as a result of the recent expedition there are now recorded 44 species included in 11 genera. This fish fauna is essentially similar to that of Lakes Victoria and Kioga rather than to that of Lake Albert and the Lower Nile, in that the important Lower Nile genera such as *Lates*, *Hydrocyon*, *Distichodus*, *Citharinus*, etc., are entirely absent. Compared with the Victoria fauna, Lakes Edward and George are remarkable in the complete absence of Characinidæ, Schilbeidæ, Mochochidæ and Mastacembelidæ, so that the Edward fauna comprised very few kinds of fish, but those few kinds are present in astonishing numbers. Of the 44 fishes, seven are typical Lake Victoria species, five are Lower Nile species, four are common to both Lake Victoria and the Lower Nile and 26 are endemic to Lakes Edward and George.

The identification of the fishes has involved a considerable amount of systematic work at the British Museum (Natural History), where all the specimens have been deposited. A number of species were found to be new to science, and certain alterations in the previous classification became necessary. The new species belonging to the family Cichlidæ are being described by Miss Trewavas (1933), and the other families have been dealt with from the systematic point of view in a paper—Worthington (1932 *c*).

Another remarkable fact about the Edward fauna is the complete absence of crocodiles. This is of great importance for the fisheries, since crocodiles in Lake Victoria and elsewhere do inestimable damage to fishing nets and other gear. The significance of the paucity of the Edward fauna and the absence of crocodiles is discussed in relation to geological history of the region in Appendix II.

Knowledge of the mode of life, breeding and feeding habits, and data concerning the size attained by the different kinds of fish is essential if a fishery is to be started and maintained to advantage, and therefore such information as was obtained during the expedition is recorded in the following pages. The species included in Table 4 are considered in turn and information concerning each is given in accordance with the following scheme :—

Scientific Name. (For native and English names, *see* Table 4.)

Distribution in other African waters.

Habitat in Lakes Edward and George.

Economic Value.

Food, based upon the contents of stomachs examined during the expedition.

Size.—For convenience much of the data is bulked in Table 9 (p. 33). The size of each fish was recorded in the log books as the length in centimetres from the tip of the snout to the extremity of the caudal fin, to the nearest cm. below the actual length. Therefore, in giving the average of a number of recorded lengths, 0·5 cms. has been added to give a true average, and in giving the range of lengths, 1·0 cms. has been added to the upper limit. Weight observations are given also for most species, but in general the recording of weights of fish is not an easy matter in the field. The relation of length to weight of a fish is expressed by the equation :—

$$100\ W = kL^3, \text{ in which—}$$

W = Weight in gms.
L = Length in cms.
k = A constant known as the *condition factor.*

Barbus is common in the Kazinga Channel, Lake George and the shallow parts of Lake Edward. It abounds particularly in the fast-running water at the source of the River Semliki, where it may be caught easily on a spoon-bait in the same way as *B.a.radcliffii* may be caught below the Ripon Falls. It is sometimes taken in considerable numbers by gill-nets set for *Tilapia*. In common with other members of the genus, the flesh, though palatable, suffers from an abundance of lancet-shaped bones, so that it is not a fish of economic value for the European trade, and it fetches a low price in the native market.

Stomach examinations showed that the species is omniverous. Of 61 stomachs 15 were empty, 17 contained aquatic vegetation, 14 mud, 7 fish remains, 6 Mollusca, 1 Hippopotamus dung and 1 Chironomid larvæ.

Data concerning size are given in Table 9. The greatest length attained among the 317 examples studied was 74 cms. The condition factor of different sized fish has been calculated with the following results :—

TABLE 5.

SIZE AND CONDITION FACTOR OF *Barbus*.

Length in cms.	No. of specimens.	Av. wt. in kgms.	Av. k.
35—40	1	0·60	1·1
40—45	3	0·83	1·1
45—50	9	1·12	1·0
50—55	8	1·40	1·0
55—60	11	2·18	1·1
60—65	3	2·80	1·1
65—70	4	3·18	1·0

Breeding fish were taken at many stations in all these waters; males were found to be considerably smaller than females on the average.

Barbus perince.

Known from the Lower Nile to the Blue Nile and Bahr-el-Jebel.

This little fish, which grows only to about 11 cms. length, was previously doubtfully recorded from Lake Edward. One or two specimens obtained during the expedition from the shores of the Kazinga Channel confirm the record.

Barbus kerstenii Peters.

Known from Kilimanjaro, Masai district and the Tsavo River.

A single specimen was collected from the Kazinga Channel.

Family : CLARIIDÆ.

Clarias lazera.

Known from the whole Nile system below the Murchison Falls, the rivers of west Africa from the Senegal to the Congo, and in East Africa from the Eusso Nyiro and the River Molo.

This species is abundant in the Kazinga Channel and Lake George. Like the lung-fish, it is adapted to breathing air, and so can live in unoxygenated waters and in the foulest of swamps. Like the lung-fish also, it is capable of living dried up in mud, and so can withstand long periods of drought in temporary water basins.

The flesh is red in colour, like raw beef, but is much in favour with the native population, and is sometimes eaten by Europeans. Since this fish is so common and can be caught easily with long-lines, it offers a considerable opportunity for economic development (p. 44).

It is primarily a predacious fish, feeding on *Tilapia* and *Haplochromis*, but also obtains subsistence from vegetation and débris, and can filter minute animals and plants from the water by means of its long and closely-set gill-rakers. The results of 97 stomach examinations were as follows: 29 were empty, 33 contained fish remains, among which full-grown *Tilapia* were recognisable in five, large *Barbus* in two, *Haplochromis* in five, *Haplochilichthys* in one; one contained fish remains and dragonfly nymphs, two fish and locusts, four fish and mud, two fish and water weeds, three locusts, three mud, 12 water weeds, seven *Microcystis* and other planktonic organisms, one Hippopotamus dung.

Clarias may often be seen swimming slowly along the water surface, with their long barbels projecting into the air, skimming dead insects off the surface. On one occasion large numbers were observed doing this right out in the open water after a cloud of lake flies had passed, and when the surface of the lake was littered with the bodies and pupa cases of these flies.

The species grows to more than $1\frac{1}{4}$ ms. in length in Lake Edward (*see* Table 9). The condition factor of different sized fish has been calculated with the following results :—

TABLE 6.

SIZE AND CONDITION FACTOR OF *Clarias*.

Length in cms.	No. of specimens.	Av. wt. in kgms.	Av. k.
60— 70	1	1·6	0·6
70— 80	2	2·8	0·7
80— 90	4	3·8	0·6
90—100	2	6·1	0·7
100—110	3	8·1	0·7
110—120	9	12·8	0·8
120—130	4	12·8	0·7

Breeding fish were taken in small numbers all over these water.

Clarias carsonii.

This small species, which I have identified to be the same as the Nsonzi of Lake Bunyoni (introduced), was taken in small numbers from the papyrus areas of the Kazinga Channel and Lake George.

Family : BAGRIDÆ.

Bagrus docmac.

Previously known from the whole Nile system from Lake Victoria to the delta, also from the Omo River and Lake Stephanie.

This cat-fish is very abundant in the shallow water of Lake Edward, where it grows to a large size, measuring in some cases more than a metre in length. It lives according to the prevailing species of animals and plants in the plankton; in fact, the mass of organisms from *Tilapia* stomachs resembles very closely the catches of fine silk mesh plankton nets fished in the same waters. Thus, in the part of Lake George bordering the northern papyrus swamp the Algæ*—*Microcystis flos-aquæ* and *Athanocapsa grevillii,* and the Rotifers*—*Brachionus angularis* and *B. pala* were predominant, with the Crustacea—*Diaptomus* sp. and *Cyclops* sp. In other parts of Lake George and the Kazinga Channel, in addition to the above there were the Algæ—*Pediastrum simplex, Melosira* sp., *Synedra* sp., *Navicula* sp., the Rotifers—*Anurea aculeata. Asplanchna brightwelli, Triarthra longiseta. Polyarthra platyptera,* and certain water mites or Hydrachnida.

Across the water junction at the mouth of the Kazinga Channel there was found a marked change in *Tilapia* food corresponding to the change in phyto and zooplankton which is associated with the change in chemical constitution of the water (*see* page 20). Such forms as *Microcystis flos-aquæ,* the Rotifers, and *Diaptomus* became less obvious, until in the clear water parts of Lake Edward the following forms were found both in the *Tilapia* stomachs and in plankton nettings:—Algæ—*Microcystis flos-aquæ* and *Athanocapsa grevillii* only in small numbers, *Surirella biseriata, Nitzschia* sp., *Cyclotella* sp.; Rotifers—*Brachionus angularis* and *B. pala, Notops mollis*; and the Crustaceans—*Moina* sp., *Ceriodaphnia* sp. and *Cyclops* sp.

In the clear water of Lake Edward there is far less plankton than in the thick green water of George and the Kazinga Channel, and consequently the *Tilapia* sometimes eat other food than plankton. At certain stations, for instance, chewed water weeds were found intermixed with minute organisms, and sometimes lake flies constituted an important part of the diet, a fact which was shown in a somewhat striking manner. Periodic hatchings and swarmings of lake flies (*Chronomidæ* and *Corethridæ*) which appear in the distance like columns of smoke on the horizon, are a feature of Lake Edward as they are of Lake Victoria. On one occasion, when making a voyage across the north of Lake Edward on a still day, when there had recently been a swarm over the water, the corpses of lake flies were thickly scattered over the surface. In patches, each of about half an acre, the surface was broken by schools of fish with their backs just projecting above the surface, swimming along the surface evidently skimming off the lake flies with their mouths. There was no possibility at the time of employing a net, and so, intent on finding out what these fishes were, we had recourse to a shotgun and succeeded in bagging a specimen. Subsequent examination showed that it was a *Tilapia nilotica* and that its stomach was stuffed with lake flies. This observation was interesting in another way, since it showed that schools of *Tilapia* sometimes wander into deep open water at the surface, for a sounding made at the position, which was a good five miles from shore, gave 23 metres. The swarming of *Tilapia nilotica* has been observed in other waters; for instance, near the eastern shore of Lake Rudolf in 1931 we observed circular swarms of about 10 yards diameter, a little below the surface, all of the fish swimming round in one direction, leaving a vacant space at the centre of the circle. This type of swarming cannot be associated with feeding habits but probably has some connection with the breeding of the fish. Other species have been observed to swarm in somewhat similar manner (Norman, 1930, p. 431).

The size data in Table 9 show that this species in Lake Edward and Lake George grows to a length of 46 cms. In Lake Albert the same species reaches 50 cms. and in Rudolf it grows very much larger still, up to 64 cms. A number of fish of different

* **For these identifications I am indebted to Miss F. Rich for the Algæ and Prof. P. de Beauchamp for the Rotifera.**

sizes were weighed and the condition factor has been calculated with the following results :—

TABLE 8.

SIZE AND CONDITION FACTOR OF *Tilapia.*

Length in cms.	No. of specimens.	Av. wt. in kgms.	Av. k.
30·5	7	0·60	2·1
31·5	21	0·64	2·1
32·5	18	0·71	2·1
33·5	22	0·80	2·1
34·5	12	0·90	2·2
35·5	20	0·93	2·1
36·5	11	1·03	2·1
37·5	9	1·13	2·1
38·5	5	1·15	2·0
39·5	0	—	—
40·5	5	1·50	2·3
41·5	3	1·53	2·1
42·5	3	1·70	2·2

These figures show a slight tendency for the condition factor to increase with the size of the fish, but for practical purposes the value 2·1 can be taken for converting length records into weights.

Concerning breeding habits there is no very detailed knowledge about the African species of *Tilapia*. The figures of Table 9 show that on the whole females outnumber males by 1·6 to 1, and breeding females were in the great majority of 4 to 1 over breeding males. This suggests that a single male fertilises the eggs of more than one female. From the fact that populations close to the shore contained much higher proportions of breeding fish than those at a distance from it (*see* p. 42). There is no doubt that breeding takes place in the inshore waters, particularly in the neighbourhood of swamps.

All the African Cichlidæ hollow out nests in the sand or mud of the lake floor by producing powerful currents with their tail fins.* It is supposed that the female lays eggs in a nest and the male sheds his sperm upon them, and soon afterwards the female takes them into her mouth and there shelters them during their development, until the young fish have entirely absorbed their yoke sacs and can swim about for themselves. Even afterwards she shows remarkable maternal care, keeping her swarm of babies, which may number several hundred, close together, and taking them back into her mouth on the approach of danger. Correlated with this habit of carrying eggs and young, the mouth of the female undergoes certain changes in structure during breeding, involving an enlargement of the mouth cavity, which is shown in Figure 6.

* C. A. Boulenger (1908) has shown that in the case of *Tilapia nilotica* it is the male which hollows out the nest.

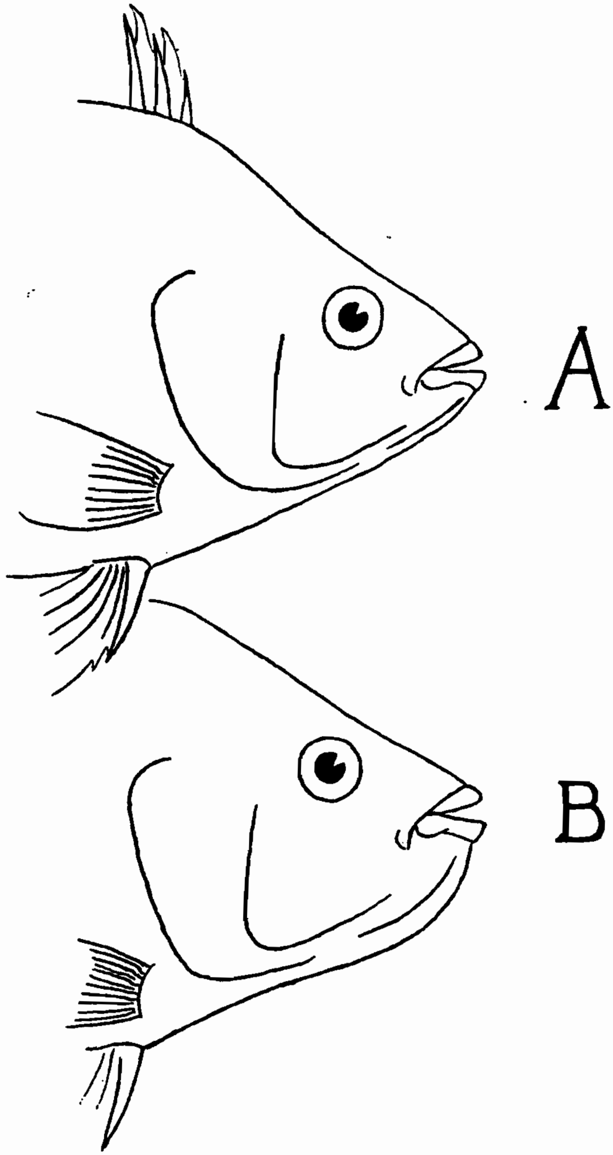


FIG. 6.—TILAPIA NILOTICA.

A.—Head of normal female.
B.—Head of breeding female to show modification for carrying eggs and young fry in the mouth.

There is no precise information how often each female breeds, but from the fact that females which were carrying young have often been found, from the state of the genital organs, to be already making up to breed again, we can conclude that the space of time between one spawning and the next is quite short—usually not more than a month or so.

South American members of the Cichlid family provide an interesting comparison with the African, since in South America it is the male who undertakes parental care, having precisely the same modifications for carrying eggs and young in his mouth as the female has in Africa.

TABLE 9.

Data concerning the Common Fishes of Lakes Edward and George.

	Total Number of Specimens Caught.	No. of Lengths Recorded.	Range of Lengths in cms.	No. of Weights Recorded (adults).	Average length of Weighed Specimens in cms.	Average Weight per Fish, in kgs.	No. of Gonads Examined.	Total Number of Males.	Range of Length of Males, in cms.	No. of Breeding Males.	Average Length of Breeding Males, in cms.	Total number of Females.	Range of Length of Females, in cms.	Number of Breeding Females.	Average Length of Breeding Females, in cms.	No. of Specimens with undeveloped Gonads.
Protopterus aethiopicus ...	34	17	45–118	5	94·0	4·7	17	6	70–118	0	—	6	75– 86	3	85·5	5
Mormyrus, both spp. ...	23	23	43–101	—	—	—	14	5	58–101	1	69·5	9	47– 66	8	56·0	0
Barbus a. eduardianus ...	317	297	18– 74	39	52·0 (Table 5)	1·8	228	56	21– 57	26	36·0	140	28– 69	27	54·0	32
Clarias lazera	143	118	29–131	29	103·5 (Table 6)	8·95	104	61	37–131	12	100·5	40	58–123	20	100·0	3
Bagrus docmac	249	234	27–104	84	52·0 (Table 7)	1·88	150	63	30–104	5	76·5	84	33–104	30	58·5	3
Tilapia nilotica	1,444	1,226	10– 46	138	34·5 (Table 8)	0·91	751	285	22– 43	51	37·5	459	22– 46	204	35·0	7

PRESENT STATE OF THE FISHERY.

In former days there was a considerable native population along the Kazinga Channel and round the shores of Lakes Edward and George, but, owing to outbreaks of sleeping sickness some years ago, almost the entire native population was removed from the Uganda littoral, and quite recently the Belgian Congo authorities have taken the same course with the native settlements along the western escarpment shore of Lake Edward. As a result, most of the fishing villages marked on the Uganda-Congo boundary commission map of 1908, such as Kazinga, Kisenyi and Kanyamwongo along the east shore of Lake Edward, are now entirely devoid of inhabitants. Native settlements where fishing is carried on are few and far between, and are restricted to those places on trade routes, where strips of the littoral are kept clear of vegetation to prevent the breeding of tsetse flies. These fishing stations are dealt with separately below.

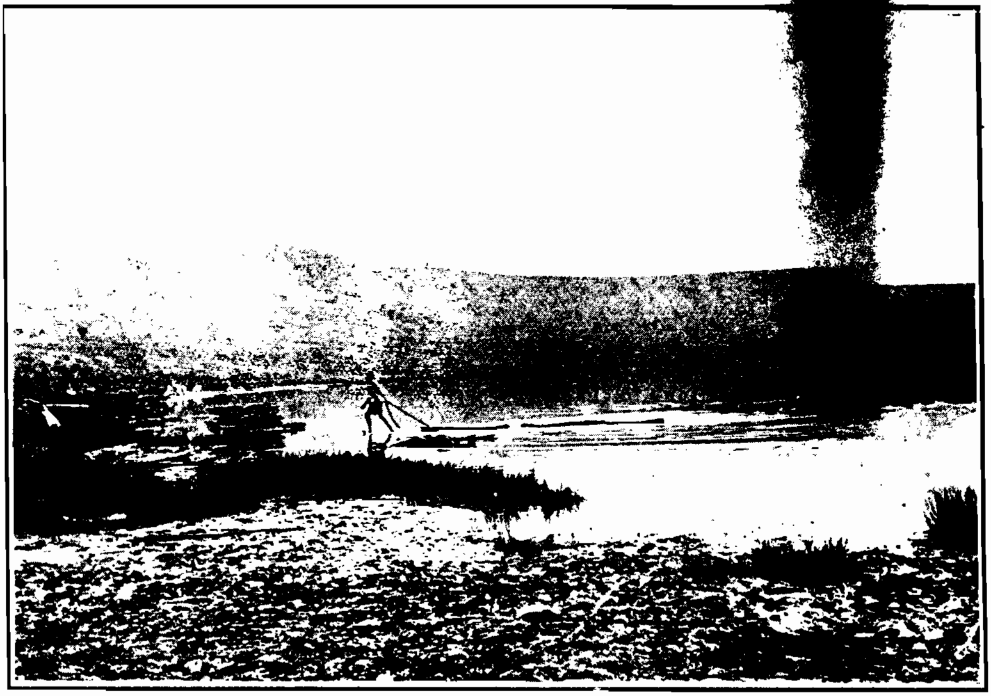
Of the native tribes concerned, the whole southern shore from the Ishasha River, which is the Uganda-Congo boundary, eastward along Lake Edward and the Kazinga Channel to the River Hoindagi, which enters Lake George a little west of Mayura, is inhabited by the Banyankole tribe. The northern Uganda shore of Lake Edward from the River Lubilia right round Lake George to Mayura is in the Watoro Territory. Owing to the trade route across the Kazinga Channel at Katunguru to Katwe, which is the main outlet for the Katwe salt industry, the Banyankole and Watoro peoples seem to have intermixed considerably in this region, as they have also on another salt route from the Kisenyi salt lake across Lake George to Mayura. The whole of the Congo littoral of Lake Edward is sparsely inhabited by various Congo tribes.

Kazinga Channel.

The settled area at Katunguru is restricted to a narrow strip about half-a-mile wide along both shores of the Kazinga Channel. Across the Channel there is continual traffic of motor lorries and porters, taking salt from Katwe to Mbarara, and food in the reverse direction. There is a ferry for motor cars and several large dugout canoes for the porters. In all there are some ten canoes, most of which are used intermittently for fishing operations, which are entirely restricted to the section of the Channel opposite the sleeping sickness clearings. In this small area of water several fishermen obtain a good living by catching *Clarias* and *Protopterus* on long-lines baited with dead fish or offal, and *Tilapia* and *Barbus* in gill-nets of 5 in. mesh. These gill-nets are of the same type as those used on Lake Victoria for the Ngege fishery, from which lake the nets have undoubtedly been imported.

Lake Edward.

There is a large native population at Katwe with several Indian shops, concerned almost solely with the important salt industry of the crater lake which lies about half-a-mile to the north of Katwe Bay. (Figure 7). Though a certain amount of agriculture takes place, the food produced is in no way sufficient to feed the large population, and therefore there is a continual stream of porters from the highland fertile regions of Ankole, carrying bananas and other food to Katwe and returning laden with salt. The local market here provides a great opportunity for the development of a fishing industry by supplementing the diet of the moving population, but at present fishing is only followed as a casual employment. One Goanese man employs several natives with a canoe and two or three gill-nets and catches



[*Photo by S. W.*

FIG. 7.—KATWE SALT LAKE.

[*Photo by F. B. W.*

FIG 8.—HAND BASKET FISHING ON LAKE GEORGE.

information concerning the Kamande fishery I am indebted to Lady Broughton who visited the region from Rutchuru at the beginning of 1932.

Kamande is on the lake shore at the foot of the escarpment. A road leads down to it from the new Rutchuru-Lubero road. Kamande being in the Parc National Albert, no one is allowed to use this road except those engaged in the fishing industry or holders of special permits from the Conservateur of the Parc National. The fishery is in the charge of a Belgian, M. Larbalestrier, who has an iron boat and a contingent of natives with several large dugout canoes. At the beginning of 1932 he had just acquired an outboard motor which could be fitted to the iron boat or to the dugouts. Gill-netting is the regular method of fishing employed, and *Tilapia* is the most important fish, though other species are also used. A great quantity of fish is caught; practically all are split open and dried in the sun, and are then transported inland by motor lorries. Most are taken to the Butembo mines which are north-east of Lubero, on the Beni road, but some go to the Mohanga mine which is south of Lubero, near the main Rutchuru-Lubero road.

Lake George.

At present the most productive part of Lake George from the fisheries point of view is the long bay extending to the west under the foothills of Ruwenzori, its mouth into the main lake nearly blocked by Iragara Island. At the village of Mohokya some 16 fishermen are in the employ of a European from Fort Portal. They work gill-nets from two dugout canoes and a large roughly-made boat, adopting the unusual practice of fishing by day, sitting over their nets, and removing the fish as they are caught. I understand that this fishery has been in progress for a year or two and that in August, 1931, about 100 fish were caught per day. Formerly it seems that some of the fish were smoked and converted into kippers for the European trade, but in 1931 all were dried and smoked over open fires and transported to Toro for the native market, where each fish was sold for about 20 cents.

In addition a number of natives with headquarters at Kaiandero, a village situated a little to the west of Mohokya, employ several primitive fishing methods. The most productive seems to be the catching of *Tilapia* with conical hand-hole baskets (figure 8). The fishermen, who have canoes, paddle considerable distances to favoured places on Iragara Island and the nearby mainland. Three or four men, each with a basket, drive shallow creeks along the shore, thereby impelling the fish into back-waters where they can easily be captured. On one occasion three men, employing this method, caught 45 fish in the course of an hour, every one of which was a female either ready to breed or just finished breeding.

At Kaiandero another interesting method is employed which resembles very closely the " Ngogo " or papyrus seine of the Jaluo natives at the north-east corner of Lake Victoria. The apparatus consists of a long rope with innumerable banana stalks and leaves attached to it. The whole is taken into water about 4 feet deep and then dragged round into a large circle until the two ends meet. Subsequently one end is slipped over the other in such a way that the circle is gradually reduced in area until its diameter is no more than 15 feet. The effect of this is to concentrate most of the fish of a large water area into a small pond, from which they can easily be removed with the conical hand-hole baskets. This fishing apparatus occupies about half-a-dozen men, and a single haul takes about half-an-hour. It does not seem to be nearly so productive as the simpler method of driving creeks, described above.

At Kisenyi, near the salt crater lake opposite Akika Island, there are about half-a-dozen fishermen who employ another ingenious method. They make short fences near the reeds of the lake shore by sticking papyrus stems into the bottom mud at intervals of about 3 inches. Each fence is about 10 yards long and constructed in the shape of a V with a basket-trap, with re-entrant mouth, placed at the apex. These baskets are large and coarse-meshed, very similar to those employed by the Banyoro on Lake Kioga. Apparently they catch *Tilapia*, which tend to move up and down the shores, and also occasional *Protopterus* and *Bagrus*. Canoes are continually passing from Kisenyi to Mayura on the opposite shore of Lake George, taking salt for transport to the highland regions of Toro and Ankole, but these canoes are seldom used for fishing. The native population of Mayura apparently exists by its position on the salt trade route. Quantities of sweet potatoes and bananas are grown, while one or two men use 5 inch gill-nets for catching *Tilapia*.

RECOMMENDATIONS FOR DEVELOPMENT.

There are various reasons which go to foretell a good future for the Edward and George fisheries—(1) There is a large untouched supply of fish available. (2) Crocodiles are absent from these waters, which makes it possible for nets to be fished close to the shore with little danger of damage or loss ; (crocodiles in Lakes Victoria, Kioga and Albert create much havoc by entering the nets to feed on fish caught in them). (3) There has recently been a considerable development in road communications to these lakes. (4) An abundant supply of salt is available, part of which might well be used in a salt fish industry.

Recommendations concerning lakes such as these, where the fishery is still in its infancy, must consist of advice as to the best fishing methods to be employed, information concerning the return to be expected from the use of these methods, and provisions for control of the fishery, should such become necessary in the future. These subjects are dealt with in the following pages.

Tilapia and the 5-inch gill-net.

In order to find out how much fish is available at the present time, regular fishings were made with gill-nets in as many different positions as possible. The regulation 5-inch gill-net, as employed in the Lake Victoria fishery, consists of a sheet of netting measuring about 60 yards long by 8 feet deep when mounted. It is 26 meshes deep, each mesh being 5 inches*. The whole net is made of fine flax twine whose thickness is described as 35/3 ply. Each net is mounted on a headline, with corks or floats fitted at intervals, and a foot line fitted with leads or stones, so that the whole hangs vertically in the water. In fishing, a fleet of several nets, attached together, is fixed to vertical ropes at either end. These ropes are anchored to the bottom of the lake by heavy stones, and marked at the surface by buoys. The fleet is usually put out in the evening, allowed to remain in the water over-night, and hauled early in the morning. Since the nets are never hauled through the water they can only catch fish which happen to swim into them. These nets, which are manufactured in Great Britain, retail at Kampala for 20s. each or a little less.

Size of fish caught by nets of different mesh.

The 5-inch net can only catch fish between certain limits of size, since the fish are caught behind the gills where the meshes tighten on their thick shoulders. Therefore, in order to catch a complete range of sizes, gill-nets of 3-inch mesh and 7-inch mesh were always fished together with the 5-inch. These caught fish of respectively smaller and larger sizes. In practice the 3-inch net caught very few fish and can be

* The mesh is measured as the diagonal distance equalling two bars, when the mesh is stretched from head to foot. That is, the knots are 2½ inches apart.

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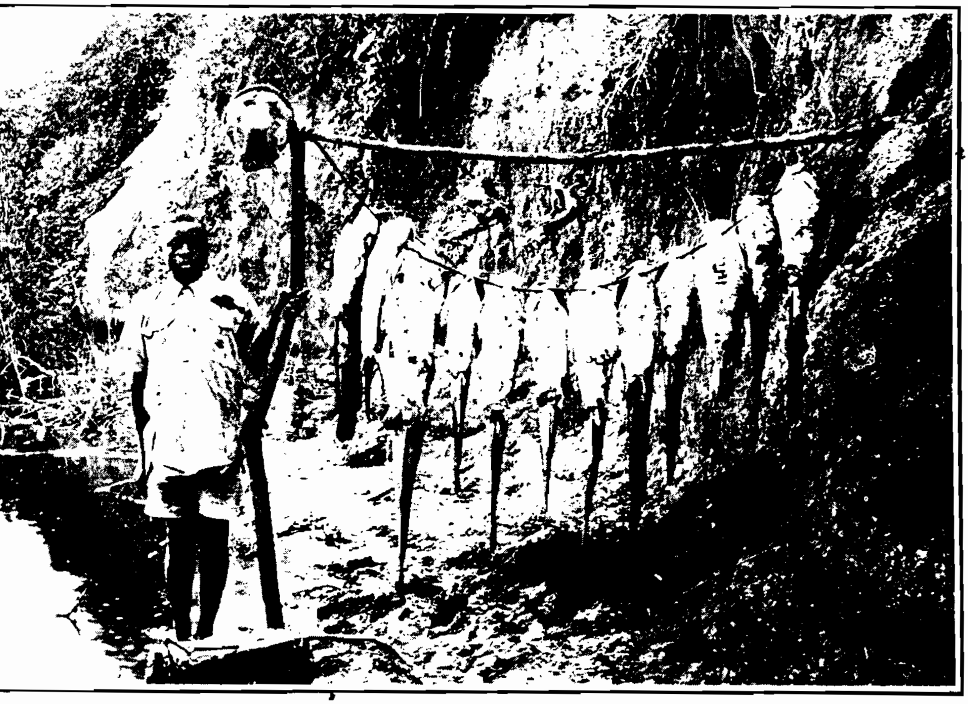
* The mesh is measured as the diagonal distance equalling two bars, when the mesh is stretched from head to foot. That is, the knots are 2½ inches apart.

[Photo by E. B. W.

FIG. 9.—CATCH OF 5-INCH GILL-NET, MOSTLY *Tilapia*.



[Photo by E. B. W.

FIG. 10.—CATCH OF LONG-LINE, MOSTLY *Clarias*.

TABLE 10.

CATCH OF *Tilapia* PER NET FISHING.

Position.	Depth in ms.	5 inch gill-nets.		7 inch gill-nets.	
		No. of net fishings.	Catch per net.	No. of net fishings.	Catch per net.
Kazinga Channel, nr. Katunguru (fished waters)	2·5	2	20	3	13
Kazinga Channel, nr. Katunguru (unfished waters)	2·5	2	92	2	23
Kazinga Channel, nr. L. George ...	3·0—3·5	4	23	2	2
Lake George, south end	3·0	1	4	1	1
Lake George, nr. Mayura	2·0—2·5	2	15	2	3
Lake George, north-east corner ...	2·0	1	about 100 (eaten by lung-fish)	—	—
Lake Edward, nr. mth. of Kz. Chl. ...	2·2	2	120	2	2
Lake Edward, 2½ mls. from Kz. Chl. ...	8·3	1	26	—	—
Lake Edward, Katwe Bay (unfished waters)	4.0	2	42	1	6
Lake Edward, Katwe Bay (fished waters)	3·0	2	18	—	—
Lake Edward, nr. Kisenyi spit ...	8·5	1	29	1	1
Lake Edward, nr. Kanyamwongo spit...	4·6—8·6	2	2	—	—
Lake Edward, nr. Katanda	6	1	14	—	—
Lake Edward, west shore	15	1	2	—	—
Lake Edward, north shore	7	1	2	—	—

The first significant conclusion drawn from table 10 is the comparative abundance of *Tilapia* in the Kazinga Channel and Lake George, and their comparative scarcity in Lake Edward, with the exception of Katwe Bay and the shallow water near the Channel's mouth. This is explicable by the feeding habits of *Tilapia* (page 28). The food consists entirely of minute organisms particularly of the phytoplankton, and, as mentioned on page 16, the water of the Kazinga Channel and Lake George is dark green in colour owing to the extreme abundance of phytoplankton whereas the water of Lake Edward is clear. The conclusion reached is that fishing for *Tilapia* can only be carried on to advantage in those waters marked red on Map 2.

A further point of importance is that the catches in those waters which are habitually fished by natives, were poorer than in waters which are at present untouched. Thus in the Kazinga Channel the catch per net was 20 at Katunguru compared with 92 at a station 2 miles west of the Katunguru clearing. Similarly in Lake Edward, the fished waters of Katwe Bay gave only 18 fish per net, whereas the unfished parts of Katwe Bay near the mouth of the Kazinga Channel averaged 120 per net.

A series of fishing stations on a line from the mouth of the Kazinga Channel towards the middle of Lake Edward gave 120 fish per net in 2·2 metres near the shore, 26 per net in 8·3 metres about 2½ miles from the shore, and only 2 or 3 per net in 15 metres about 8 miles from shore. This shows well the falling off in numbers of *Tilapia* towards the deep open water.

By comparison with the Lake Victoria Ngege fishery, for which Graham concludes that a return of 10 fish per net is sufficient for economic fishing, it is obvious that there is a source of considerable wealth in Lakes Edward and George. When the Victoria fishery was started at the beginning of this century very large numbers of Ngege were caught, sometimes more than 100 per net. The supply has been steadily reduced, until now many fishermen have been compelled to give up their pursuit. Since Lake Edward is still in its original highly productive state, such a disaster can easily be prevented by the supervision and control of fishing methods.

Preservation of breeding grounds.

In all, some 300 fish were examined from near Katunguru, of which only 100 were males, showing that females were predominant by 2 to 1. 38 per cent. of the males and 36 per cent. of the females, or in other words more than ⅓ of the total population, were in a state ready to breed or having just bred. Compared with this, fishings in Lake Edward near the mouth of the Kazinga Channel produced 73 males of which none were breeding, and 53 females of which only 13 per cent. were breeding.

Again, 36 fish caught near the swampy shore of Katwe Bay were all breeding females, with the exception of one breeding male. Compared with this, among 29 fish caught in 8·5 ms. of water several miles from the shore, only 5 (16 per cent.) showed any signs of readiness to breed. In Lake George also it was found that breeding fish were rare in the open water and abundant near the shore ; 45 fish caught by natives in baskets along the shore of Iragara Island were all breeding females.

All these facts point to the conclusion that breeding of *Tilapia* takes place close to the shore, especially in the neighbourhood of papyrus swamps, and that the fish undergo definite movements towards the shore to breed.

The methods of catching *Tilapia* employed to-day, particularly basket fishing, tend to catch the inshore breeding fish. At present this does no harm, since the waters are so well stocked—if anything it does good in that it helps to avoid dwarfing of the fish by over-population, a phenomenon which has been observed for *Tilapia* in Lake Kioga. If, however, a large gill-net fishery is developed, and in the course of time the catches are observed to fall off seriously in numbers, there is a ready means of control. Certain areas, such as the Kazinga Channel, the inshore parts of Katwe Bay and Lake George, should be completely closed to fishing, so that the *Tilapia* may breed in peace.

Gill-nets for Barbus.

Barbus is of minor importance compared with *Tilapia*, owing to the poor, bony quality of its flesh and consequent low market price. Nevertheless gill-nets set for *Tilapia* often catch *Barbus* in numbers not to be disregarded. In the Kazinga Channel and Katwe Bay, the catch of *Barbus* per net fishing ranged from 10 to 20 ; in Lake George the numbers were rather smaller, from about 5 to 10. These *Barbus* caught by 5-inch gill-nets averaged 50 cms. in length and 1·2 kgs. in weight.

Predacious Fishes.

In a lake which is in a natural state, that is, in which a fishery has not been developed, there is a natural balance between the microphagous fish, such as *Tilapia*, and the predacious fish, which are represented in Lakes Edward and George by *Bagrus*, *Clarias* and *Protopterus*. If a fishery is started for the microphagous forms and the predacious forms are left to themselves, a reduction in stock of the former will in time result in a serious reduction of food supply for the latter. This tends to an increased onslaught on the microphagous forms by the predacious, which may lead to disaster. Something of this sort has probably occurred in Lake Victoria and has led to the recent serious decrease in the supply of *Tilapia*.

In the case of Edward and George, which are still in their virgin state of production, it should be possible to prevent such an occurrence from the outset by proper control. One method already mentioned is to make reserves of the breeding areas, by the prevention of fishing; but another method, which has the advantage of increasing, rather than reducing, the total product of the fishery, is to fish the predacious forms at the same time as the *Tilapia*.

It so happens that the predacious fishes of these lakes are readily eaten by natives, if not actually preferred to *Tilapia*, so there should be no difficulty in establishing a fishery for them. Moreover, the 5-inch gill-nets recommended for *Tilapia* also catch predacious fishes to some extent, particularly the *Bagrus*.

Gill-nets for Bagrus.

Bagrus is not a shallow water fish, and therefore may be disregarded in Lake George, the Kazinga Channel and the shallower parts of Edward, although one or two per net fishing were usually recorded. It is on the edge of the water marked red on Map 2 that *Bagrus* occurs in fishable numbers and therefore deserves attention. The following Table gives the analysis of catches with the 5-inch net.

TABLE 11.

CATCH OF *Bagrus* PER 5-INCH NET FISHING.

Position.	Depth in ms.	No. of net fishings.	Catch per net.
Lake Edward, $2\frac{1}{2}$ miles from Kz. Chl.	8·3	1	14
Lake Edward, nr. Kisenyi spit ...	8·5	1	5
Lake Edward, nr. Kanyamwongo spit	8·8	1	29
Lake Edward, nr. Kanyamwongo spit	4·6	1	14
Lake Edward, west shore	15·0	1	4
Lake Edward, nr. Semliki source ...	3·5	1	6

The numbers of the last column are small compared with the numbers of *Tilapia* caught in the 5-inch net, but the average size of these *Bagrus* was about 54 cms. length and 1·3 kgs. weight compared with 34 cms. and 0·9 kgs. for *Tilapia*. Many of the *Bagrus* caught with gill-nets are immature fishes, so that continued netting of them may reduce the stock, but *Bagrus* is of small importance compared with *Tilapia*, and, in view of its predacious habits, a reduction in the stock would react beneficially on the *Tilapia* fishery.

The return may be expressed in a different way as a total of 85 fish caught for 181 hooks set, or one fish caught for about every two hooks set. For this experimental fishing short long-lines were used, each fitted with about 12 hooks ; on one occasion every hook caught a fish. In an economic fishery much longer lines would be employed, each about 400 yards in length with about 100 hooks, so that large quantities of *Clarias* and *Protopterus* may be obtained. After a year or so's fishing, it may be expected that the stock will become considerably reduced and catches correspondingly lower, but, as already mentioned, this will probably lead to an increase in the productivity of the *Tilapia* gill-net fishery.

Consumption and curing of Fish.

Owing to the high air temperature which prevails in the Lake Edward basin (80-90°F. during the time of the expedition) fish tends to go bad within very few hours of capture. A certain amount of the catch is eaten fresh by natives near the fishing stations, but the greater part is dried in the sun or partially smoked, and then stored until required or transported away from the lakes for sale.

There is obviously room for improvement in modifying the present native-dried fish into a more hygienic article. With the rapidly advancing state of native education in Uganda a salt-fish trade may well be introduced in the near future, and Lakes Edward and George offer unique opportunities for this, owing to the abundant supply of salt at Katwe on Lake Edward and Kisenyi on Lake George. The simple immersion of the freshly caught fish in a solution of brine for an hour or two should be quite sufficient to prevent rapid decay, after which the fish can be sun-dried or smoked by the methods employed at present.

For the European market, however, a more complicated process is necessary. At present there is always a sufficient supply of fresh *Tilapia* for any Europeans who may happen to visit Katunguru, but, since the road journey from Katunguru to Mbarara occupies several hours, fresh fish is very rarely obtainable by the white population at Mbarara. A supply can only be arranged by special rapid transport immediately after the fish are caught. Graham (1929, page 28) gave instructions for the preparation of "kippers" from the Lake Victoria Ngege as a result of exhaustive experiment in salting and smoking. I can only recommend that the same procedure be adopted with the Lake Edward *Tilapia*, when a constant supply of fish, for European consumption at Mbarara and Masaka, becomes desirable.

Transport Facilities.

During the field work the only road to these waters was from Mbarara to Katunguru, but by the time of publication the new road should be completed from the north side of the Katunguru ferry, past Mohokya at the west end of Lake George, and to Fort Portal. In addition there is a road, regularly used by motor transport, from the Katunguru ferry to Katwe, and Kisenyi on Lake George can easily be approached by motor. A well-used track westward from Katwe connects to Kisindi on the Uganda-Congo boundary, and a regular trade route for salt exists on the east shore of Lake George, into the highlands to the east. Therefore, even if a large scale fishery is developed in the Uganda waters of these lakes, and a very large supply of fish becomes available, there should be no difficulty in transporting the fish from their sources of origin to the large native markets of Fort Portal, Mbarara, Masaka, and even as far as Kampala.

With regard to the respective sites of the fishery, the existing villages of Katwe, Katunguru, Kisenyi, Mohokya and Mayura could not be better, since they are centred on the chief areas of the *Tilapia* fish supply, and also lie on the trade routes.

The existing fisheries at these places may well be increased by the gradual importation of supplies of fishing nets and hooks for long-lines.

Collection of Statistics.

It is of the utmost importance that statistics relating to the fishery should be collected from the start, since only thereby can knowledge be obtained when the stock is becoming reduced by overfishing. The quantity of fish consumed locally is likely to be small for some time to come, and may therefore be disregarded for the present, but if the policy of developing the fisheries to supply markets far afield is adopted, it may be expected that dried fish will be transported from these waters in lorry loads in the near future.

I am aware that government has experienced difficulty in putting into practice the recommendations made by Graham (1929, page 15) and Worthington (1929, page 32) to collect statistics from the native markets, but in the case of Lakes Edward and George, it should be much more simple.

Already there are native clerks at Katwe, Mayura and Katunguru, whose duty it is to keep a record of the salt sales and transports. I suggest that the duties of these clerks be extended to cover the transports of dried fish away from their source along the trade routes. A complete record should be kept ot numbers of dried fish, divided into the following categories, all of which can be distinguished at a glance in the dried state :—*Tilapia*, *Barbus*, *Clarias*, *Bagrus*, *Protopterus*.

At the same time a record of the number of 5-inch gill-nets on these waters should be kept, and for this purpose I suggest, as Graham (1929, page 18) has done, that the sale and distribution of gill-nets should be taken over as a Government monopoly.

SUMMARY OF RECOMMENDATIONS FOR LAKES EDWARD AND GEORGE.

It is recommended that the present use of 5-inch mesh gill-nets for the capture of *Tilapia* and other fishes be extended at Katungura, Katwe, Kisenyi, Mohokya and Mayura as far as is compatible with sleeping-sickness regulations. In particular at Katunguru netting by boat might be allowed for a considerable distance up and down the Kazinga Channel outside the waters opposite the sleeping-sickness clearings. Finally, when the native population is allowed to return to the parts of the shoreline which are at present S.S. Reserves, the gill-net fishery should extend over all the waters marked red on Map 2. Fishermen should be encouraged to employ their nets in other areas near the shores of Lake Edward for the purpose of catching *Bagrus*.

It is recommended that a long-line fishery for *Clarias* and *Protopterus* be developed at the same time as the gill-net fishery, since a natural balance in the lakes can only be maintained if the predacious fishes are caught at the same time as the *Tilapia*.

If at any time the catches of *Tilapia* by gill-nets fall off seriously, certain areas of the Kazinga Channel and the inshore parts of Lakes Edward and George near papyrus swamps should be made *Tilapia* reserves and net fishing should be prevented in them. The reserves need not be applied to the predacious fishes, but, on the other hand, long-line fishing should be encouraged in these areas.

These waters offer an excellent opportunity for the development of a salt fish industry.

It is strongly recommended that statistics be collected relating to all fish which are transported for sale at markets away from these lakes.

PART II.—LAKE BUNYONI.

(*Map 3*)

INTRODUCTION.

At the conclusion of work on Lakes Edward and George I was asked to extend the expedition's investigations in Uganda, in order to carry out a study of some smaller lakes, and in particular to report on the present fisheries and the possibilities of improving them by the introduction of more useful species, either for sporting or commercial purposes. On the 26th September. 1931, before my return to England a preliminary Report containing recommendations for these smaller lakes was submitted to the Government, the matter of which is published as Parts II, III and IV of this final report. I understand that by the time of publication certain of the recommendations have already been put into effect.

It is evident to people on the spot that the productivity of some lakes might be greatly increased by introductions of fish from other waters. This has been proved in the case of Lake Naivasha in Kenya by the recent introduction of *Tilapia nigra* and the Black Bass (see page 57). I would mention. however, that during the last year or two the action of certain Colonial Government Departments in introducing fish into waters which they do not naturally inhabit has been strongly criticised by certain scientific authorities in England. The chief reasons for this criticism are the probable disturbance of the native fauna and the loss to zoological science of certain small unique forms of life which may be exterminated as a result of the introductions. Though in general agreement with these authorities in that I consider that the fauna and flora of the world should be left in its untouched natural state in so far as is compatible with the progress of civilization, I conclude. after detailed examination of the conditions prevailing, that certain areas of water should be improved by fish introductions. These introductions should only be made, however, under strict supervision by competent authorities. after thorough collections have been made of the indigenous fauna and flora, and after the ecology of the waters has been studied in detail. It is satisfactory that biological surveys of most of the Uganda waters have now been carried out before the introduction of fishes has proceeded very far.

The benefits to accrue from the proposed introductions are, firstly, the improvement of native fishing industries by increasing the supply of palatable fish, and secondly, in the case of certain waters situated in healthy regions, the provision of sport and recreation for Europeans, particularly for Government officers and others on local leave from the unhealthy parts of Uganda. Indirectly, the proposed introductions may be expected to benefit the uphill work of saving the fauna of the Empire in the same way that the introduction of Trout and Black Bass to Kenya is doing, since the great game animals will be saved much unnecessary persecution by attracting sportsmen to the waters.

Beadle and Fuchs had to leave the expedition at the conclusion of work on Lake George, and therefore my wife and I studied the smaller lakes of Uganda alone. The same equipment (page 9) was transported to Bunyoni, and a fortnight was spent on that lake from the 10th to the 25th of August. The rest camp at Bufundi made a comfortable headquarters from which the whole lake could be worked by boat.

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Lake Bunyoni, lying at a height of 6,474 feet, occupies one of the steep-sided valleys and tributary valleys of the Kigezi highlands. Its approximate centre lies on longitude 29° 55′E. and latitude 1° 17′S. The lake has a length of 16 miles, a breadth of from ½ to 3 miles, and comprises an area of 22 square miles. There are some 20 small islands concentrated about the middle of its length. It is fed by several small rivers from the south, and is drained intermittently through a series of papyrus swamps to the north by the river Ruezaminda, a tributary of the Ruchuru, which flows into the south end of Lake Edward.

The lake was caused in quite recent times by volcanic activity at the east end, near Mukko. A lava flow of basalt formed a dam across the original valley, which was consequently flooded.

Depth.

Previous soundings were rough. The three major arms have now been sounded in detail and the results (Map 3) show that the deepest water (39 metres) is off Bufundi, about the middle of the lake's length. From this area rather shallower water was found in passing up the three major arms, but the whole lake, except very close to the shores, is more than 20 metres deep. The cross section (Figure 14) shows that the floor of the drowned valley is practically level as are the floors of most of the other Kigezi valleys. Furthermore, the steep slopes of the valley walls are carried on below the present water level, which proves that the lake is of recent origin, since the water has not yet cut any platform on the valley walls. The bottom deposit consists of a soft black mud mixed near the shore with stones and sand.

Temperature.

In August, 1931, the air shade temperature at Bufundi ranged from a minimum of 12·8°C. (55°F.) to a maximum of 24°C. (75°F.). The water temperature was ascertained in some detail, since on this must depend to a large extent the success of fish introductions. The open water at the surface ranged from 19·7° to 20·2°C. Surface heating during the daytime took place to a depth of about 5 metres, below which there was an even temperature gradient from 19·1°C. at 5 metres to 18·8°C. at 38 metres, at midday and midnight. Among the weeds close to the shore, where day heating and night cooling takes place more readily than in the open water, there is a rather wide range from 17·8° before dawn to 25·0°C. during the afternoon.

Chemistry.

The water is slightly alkaline, a little more so than Lake Victoria, considerably less than Lake Edward or Lake Albert. The alkaline reserve, determined by titration against centinormal sulphuric acid was determined at each end of the lake, in the centre of the lake at surface and bottom, and among the shore weeds. It ranged from normality 0·00215 to 0·00237. The hydrogen-ion concentration (pH) of the open water ranged at the surface from 8·1 (day) to 7·9 (night); from 10 metres depth to the bottom it was practically constant at 7·65. In the dense water-weeds near shore the pH rose higher; in the *Potamogeton* zone (Figure 14) it was found to reach values as high as 9·6 during the afternoon, and to drop to 7·9 at night. Unlike Lakes Victoria, Albert, Edward and other tropical lakes yet examined, vertical mixing of the waters during the night took place only to a very small degree.

The water of Lake Bunyoni is fairly clear; Secchi's disc (see page 16) was found to disappear at 2·9 metres below the surface.

The lake is unique in the absence of indigenous fish life, the only indigenous vertebrates being frogs and otters. There is however a very abundant invertebrate fauna consisting of crabs, prawns (*Caridina nilotica*), many kinds of insect larvæ, in particular of the families Aeschnidæ and Agrionidæ belonging to the Odonata or Dragon-flies, and the families Bætidæ and Palingeniidæ belonging to the Ephemeroptera or May-flies, and a great number of minute crustacea belonging to the genera—*Daphnia*, *Ceriodaphnia*, *Moina*, *Bosmina*, *Diaptomus* and *Cyclops*. Also Major M. Connolly has identified the following molluscs: *Segmentina kempi* Preston, *Bulinus syngenes* (Preston), *Burnupia kempi* (Preston) but possibly a new species, and *Sphaerium* sp. Of these invertebrates, the crabs and most of the insect larvæ are restricted to the shore waters where bottom weeds grow. In the open water there is a very abundant plankton consisting of minute crustacea and also larvæ and pupæ of the lake-fly, *Chaoborus*.

Concerning the frogs, a small species is a particularly noticeable and important member of the fauna. It abounds both among the shore weeds, where insect larvæ form its staple diet, and in the open water, where it feeds on prawns, minute crustacea and *Chaoborus* larvæ and papæ. This frog has been identified by Mr. H. W. Parker (1932) as *Xenopus lævis* (Daudin), but Parker notes that it differs from the normal *X. lævis* from other African waters in the much smaller size, the exceedingly dark colour, and the eyes, which are very large and prominent. The small size can, however, be attributed to over-population and malnutrition, and the eyes are definitely pathological since "the tissues of the lower eyelids are literally packed with encysted metacercariæ of an Echinostomid fluke." The adult stage of this fluke undoubtedly lives in one of the predacious forms (otters or birds) which habitually feed on the frogs, but unfortunately it was not detected during the field work.

Concerning the otters, there are two species. The African spotted-necked otter, *Lutra* (*Hydrictis*) *maculicollis*, inhabits the water-lily areas and the open water, and a larger clawless otter (*Paraonyx phillipsi* Hinton) is found in the adjoining swamps. Seven specimens of the spotted-necked otter were obtained and examined for food remains: one had been eating the introduced cat-fish Nsonzi, the other six had eaten *Xenopus*. Many other individuals were observed feeding in the open water of the lake, where there was nothing but frogs for them to catch.

There is a small trade in otter skins, which fetch prices from 3 to 10 shillings per skin (spotted-necked otter) and 2 to 5 shillings (clawless otter) from European visitors. The native otter hunters have no traps, but sit motionless in their canoes stationed among the weeds in likely spots, for hours at a time in the evening and early morning, their spears ready poised to strike. It seems that many of the skins are carried far into the Belgian Congo where they fetch higher prices than prevail locally.

Water birds are very abundant on Lake Bunyoni. Cormorants of both species are present and probably feed entirely on the little black frogs. The only one shot, a large cormorant, had certainly been doing so. Another frog-eating bird is the African little grebe, *Poliocephalus ruficollis capensis*. Seven of these were caught by mistake in a fishing net; three had been eating frogs, but the other four had been feeding on water insects—beetles, bugs and dragon fly nymphs.

Ducks of many species, which, before the closure of the duck shooting on the lake, had been reported as seriously reduced in numbers, were extremely abundant at the time of the expedition, especially around Bufundi and along the southern arms of the lake. They are for the most part vegetarians and find abundant subsistence in the fringe of waterlilies and weeds near the shores. According to accounts by residents near the lake, the ducks fluctuate in numbers and it seems probable that they become reduced by migration rather than by intensive shooting.

The Situtunga antelope abounds in many of the swamps which adjoin Lake Bunyoni. According to native accounts large numbers used to be killed previous to the imposition of game laws. The swamps were driven towards the lake, and the Situtunga were speared from canoes as they swam across the lake in attempts at escape.

FLORA.

The flora of a lake is of the greatest importance in the ecology, since all animal life must finally depend for food on plants which obtain their nutriment directly from the inorganic salts and CO^2 in solution. Furthermore, many forms of animals of great value as fish food depend on the bottom growing plants for support and protection. Lake Bunyoni is peculiarly rich in these bottom plants wherever the water is shallow enough. Owing to the steep shelve of the lake floor the plants are, as a rule, restricted to a narrow belt not more than 15 yards wide along the shore line, but owing to the extreme indentation of the shore, the lake as a whole contains a great quantity of plants.

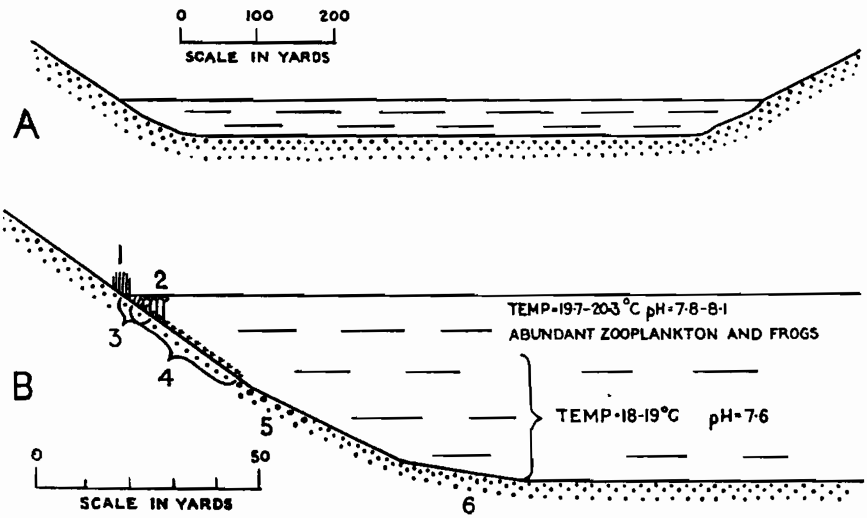

Fig. 14.—Diagrammatic cross-section of Lake Bunyoni.
A.—Across the lake near Bufundi.
B.—Enlargement of part of A.
1. Reeds at water's edge.
2. Water lilies.
3. Water weeds (*Potamogeton lucens*, *P. pectinatus* and *Hydrilla verticillata*).
4. *Chara fragilis.*
5. Black mud and stones.
6. Black mud.

The distribution of the bottom plants is indicated in figure 14*. *Chara fragilis* Desv., a member of the algal family Characeæ, is the most abundant. It grows from quite shallow water down to a depth of about 16 metres, below which there is no bottom plant growth. It is characterised by filamentous leaves and forms a dense mat on the bottom from six inches to a foot thick. *Potamogeton lucens* L. and *P. sp.* probably *pectinatus* L. (Zannichelliaceæ) are characterised by a stout leafy foliage.

* I am indebted to Mr. J. Ramsbottom of the British Museum (Nat. Hist.) for the identification of these plants.

proportions, as is shown by the following excerpt from Mr. Trewin's District Commissioner's Quarterly Report on Kigezi District for the quarter ended 31st March, 1928 :

"16. The reopening of the fish industry from Lake Bunyoni was attended with remarkable result. The profits accruing to native fish traders who purchase the Nsonzi here, transport it by motor to Kampala, and retail it there, are exorbitant and are as much as 400 per cent. on their outlay.

"17. Fish is purchased here at 5 to 10 cents per stick and retailed in Kampala at 50 cents. Freight is approximately 25s. per load of 520 sticks, or 200 lbs.

"18. I have endeavoured to keep a record of the amount exported and the following figures show how popular the industry is and the amount of cash distributed amongst the fisher folk :—

	Minimum amount exported in lbs.	Representing minimum number of Shs. paid for purchase at 7 cts. per stick.	
January	15,840 (7 tons)	2,930/-	(£146)
February	62,280 (28 tons)	11,521/-	(£576)
March	31,320 (14 tons)	5,760/-	(£288)

"The above amounts are *known* and can therefore be regarded as *minimum* figures."

This appears to have been the most productive year of the fishery. When Capt. Philipps again took over the district in 1928 a regular 6 months' closed season was imposed, from July to December each year. The open season from January to June was calculated to correspond with the time when small *Clarias*, which are prized as a luxury by many natives, are difficult to obtain in the Kampala, Jinja, Kisumu and Bukoba markets. During the open season several tons of fish were exported every week by lorry to the markets far afield : and in spite of the closed season which has been carried on more or less without interruption to the present, complaints are still made that the fish have become reduced in size and numbers.

Present State of the Fishery.

The Nsonzi is restricted to the weed belt close to the shore, where it lies concealed during the day and so is not noticeable to the casual observer.

The size of fish caught by natives ranges in length from about 8 to 25 cms., and in weight average 22 gms. or about $1\frac{1}{2}$ ounces.

Females are in the minority ; they afforded only 28 per cent. in a lot of 324 fish examined in August, 1931. The size of breeding females was found to be considerably smaller than that of breeding males, 12 to 16 cms. in length as opposed to 14 to 25 cms. Breeding females are of course all important to the proper reproduction of the race : thus the conclusion is reached that, to ensure proper reproduction, all the smaller fish, including the majority of breeding females, should not be killed. This has led to my recommendation (p. 55) that a size limit should be imposed below which all fish caught should be returned to the water. The females can be saved by a size limit in the case of Nsonzi, unlike most fish, owing to the fact that they are considerably smaller than the males. The size distribution of fish is shown in the accompanying histogram, figure 15.

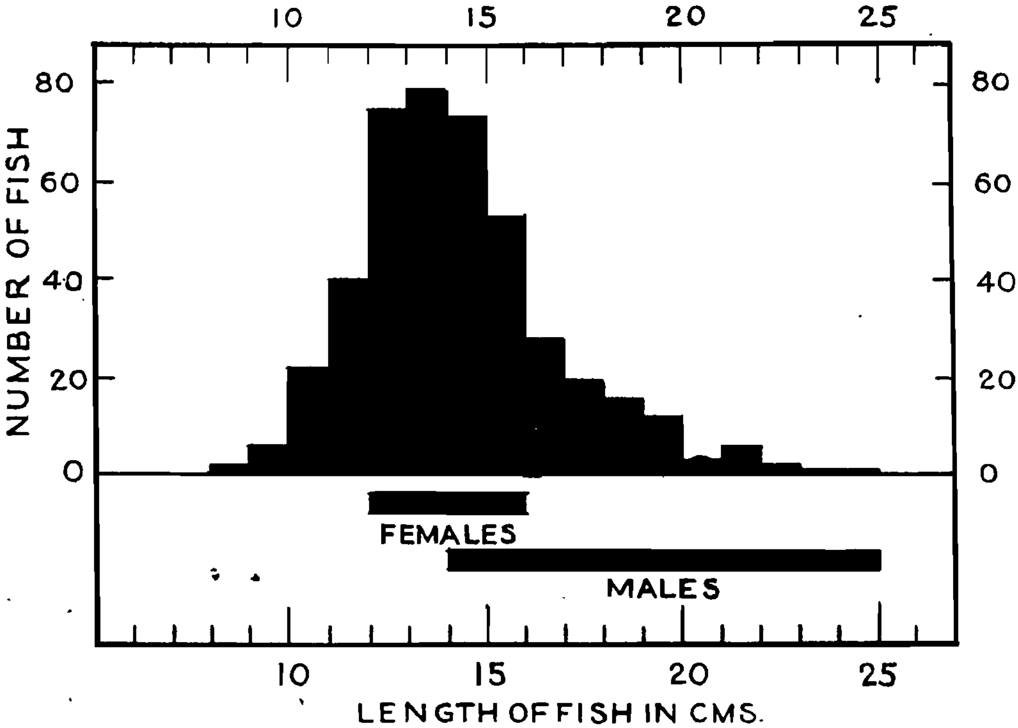

FIG. 15.—HISTOGRAM OF NSONZI CATCH TO SHOW THE SIZE DISTRIBUTION IN A LOT OF 438 FISH EXAMINED.

The range of length of breeding males and females is indicated below the histogram.

The food of the Nsonzi consists of the abundant small animals associated with the bottom weeds, and to a less extent portions of the weeds themselves. Thirty-five stomachs were examined in detail, and showed food materials in order of abundance as follows :—

Ephemerid nymphs	in 14 stomachs.
Prawns	.. 12 ..
Ostracods	.. 11 ..
White ants (bait in traps)	.. 9 ..
Dragon fly nymphs	.. 7 ..
Waterbeetle and other larvæ	.. 7 ..
Gastropod shells	.. 6 ..
Cladocera and Copepoda	.. 6 ..
Water weeds	.. 4 ..
Water bugs	.. 3 ..
Lake fly adults	.. 3 ,,
Frogs	,. 2 ..
Ants	.. 2 ..
Crabs	.. 1 ..
Caddis larvæ	.. 1 ..
Worm	.. 1 ,,

The method of fishing is to place small basket traps, about 2 feet long, built on the principle of lobster pots, close to the shore among the weeds. Portions of white ants' nests with the ants inside are generally placed in the baskets ; the ants serve as bait for the Nsonzi, which enter the baskets and are trapped. When the fishery is in progress several hundred baskets are set nightly in the neighbourhood of Bufundi alone. One basket catches anything up to 25 fish in each night's fishing.

The fish are dried before being eaten. They are impaled on sticks about 2 feet long, about 15 to the stick, each fish impaled through the head and through the tail, so that it assumes the form of a semicircle. The sticks of fish are sun dried or partially smoked. The fish are not cut or cleaned, so there is no waste. Only a small quantity is eaten locally; most are transported, some to the Kabale and Mbarara markets, but by far the greatest quantity direct by lorry to Kampala.

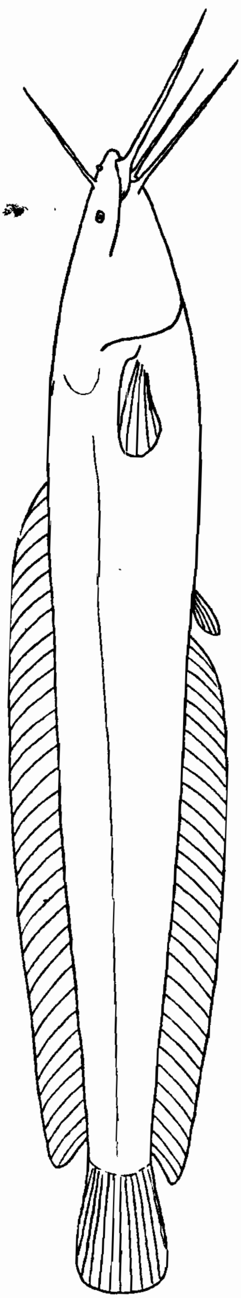

FIG. 16.—The NSONZI (*Clarias carsonii*); 15 CMS. LONG; THE CRITICAL SIZE BELOW WHICH ALL FISH SHOULD BE RETURNED TO THE WATER.

Proposed control.

From our observations on the size of breeding fish, I suggest that a method of control better than imposing a closed season would be to impose an all the year round size limit of 15 cms., below which all fish must be returned to the water. This would mean that about half of the fish caught would be returned.

The advantages to be gained by this method of control are, firstly, the fishery would benefit from it considerably more than from a closed season for 6 months and young and old fish being caught indiscriminately during the other 6; secondly, there would be a more regular supply of fish to the markets; and thirdly, the fishermen would be employed regularly throughout the year. The disadvantage is, as the District Commissioner, Kigezi, has pointed out to me, that it would be a much more difficult restriction to impose*. I think, however, that this difficulty could be surmounted as follows:—The export fish could be easily controlled by an occasional inspection of the fish as they are bought from natives at Chabahinga, but the undersized fish might be retained and consumed locally. To avoid this I suggest that the control be put into the hands of the local chiefs; that pieces of wood, the same length as the fish of figure 16 (the size being that of the largest breeding females), be given to the chiefs for distribution to all the fishermen.†

Tilapia nilotica (Ngege).

The Nsonzi is of little use for European consumption, and it seems to have been the dream of each successive D.C. at Kabale to make good the want of table fish, and at the same time to increase the productivity of the lake for natives, by introducing a *Tilapia* similar to the excellent eating Ngege so well-known in Lake Victoria.

In 1927 Mr. Trewin had fish ponds made at Bufundi and Chabahinga (small areas some 6 yards square close to the shore, barred off by stakes from the rest of the lake), and gave instructions for fry of *Tilapia nilotica* of Lake Edward to be caught at the mouth of the Ishasha river, and to be

* Owing to the shape of the Nsonzi it is impossible to control the size of fish caught by restricting the mesh of the basket traps, as the size of Ngege caught in L. Victoria can be controlled by restricting the mesh of gill-nets.

† A size limit is already imposed by the Gombolola Chief at Bufundi; all fish under about 12 cms. are supposed to be returned to the water.

must be the result of either Trewin's or Philipps' introduction, but it is impossible to say whether it is one of the original specimens which has now grown to adult size, or whether the progeny of the original fish.

PROPOSED INTRODUCTIONS.

Tilapia nigra from Lake Naivasha.

There is no doubt that a good edible *Tilapia* would improve Lake Bunyoni, both from the native and European points of view, but I do not consider that the Lake Edward *Tilapia nilotica* is the most suitable species for the purpose. In the first place the change in environment is considerable, involving a change in altitude from 3,000 feet to 6,000, and in water temperature from 26° to less than 20°C. In the second place the feeding habits of the Lake Edward fish are against the introduction. This species feeds mostly on the minute algae or phytoplankton, which it sucks off the bottom or filters from the water. Lake Bunyoni is not rich in this type of food, but other food materials, such as small crustacea, prawns, insect larvæ, etc., abound. *T. nilotica* of Lake Edward can probably not accustom itself to this larger type of food; certainly the single specimen caught in Lake Bunyoni was conservative in its diet, since its stomach was full of minute plants in spite of the abundance of other food.

The introduction of *Tilapia esculenta* from Lake Victoria or Lake Nabugabo is not to be recommended either, since that species is also phytophagous, and a similar big temperature change would be involved. We are therefore compelled to look to the Kenya lakes for a suitable species of *Tilapia*, and I suggest that the best species is *T. nigra* of Lake Naivasha.

Lake Naivasha is very similar in general conditions to Lake Bunyoni as shown in the following table :—

	Height.	Temperature.	Alkaline reserve.
Lake Naivasha...	6,230	about 19°C.	0·0020
Lake Bunyoni	6,474	,, 20°C.	0·0023

Water-lilies and other shore weeds, with their associated small animals, are likewise abundant in the two lakes.

Now Lake Naivasha has been the seat of an experiment on fish introduction during recent years, with a view to improving its productivity and sporting facilities. In 1925 Mr. R. E. Dent, Assist. Game Warden in charge of fish in Kenya, introduced *Tilapia nigra* from the Athi river system. This fish is very adaptable in its diet, and eats whatever food is available at different times of the year, whether mud with an admixture of plant material, or small animals. About two years after the introduction the fish could be netted in considerable numbers, and now, after six years, the lake is grossly overstocked and a considerable fish industry could be opened.

There is little doubt that *Tilapia nigra*, if introduced from Lake Naivasha, would find an admirable home in Lake Bunyoni; it would doubtless accustom itself to the animal diet, and in two or three years after introduction should have obtained sufficient foothold for a fishery to be started.

Tilapia nigra is a hardy fish and has been transported from Lake Naivasha by road and introduced into many other waters in Kenya, so that the introduction to Lake Bunyoni by rail to Kampala, and thence by road, should not be very difficult. The whole journey could be accomplished easily in three days or less.

The Black Bass, *Micropterus salmonoides.*

As mentioned on page 50 there is in Lake Bunyoni an enormous number of little black frogs, which are not restricted to the weed areas, but are astonishingly abundant in the open water as well. They are occasionally caught and eaten by natives, but there is no industry in frogs, and therefore the frogs afford a large food supply which is at present wasted. I suggest introducing a predacious fish in addition to the *Tilapia*, in order to avoid this waste.

There is no suitable predacious fish indigenous to East African waters. The temperature of Lake Bunyoni is unfortunately too warm for Trout, whose critical breeding temperature is 15°C., but the Black Bass, a native of America, but naturalised in parts of Europe, South Africa, etc., would be highly suitable. The Black Bass was introduced to Lake Naivasha at the beginning of 1929 by Mr. R. E. Dent. Two years later the original 50 young specimens had attained maturity and had bred, and by October, 1931, their numbers had increased so much that the lake was opened up to anglers. Fry should be obtainable from Lake Naivasha in a year or so's time.

The Black Bass, which grows to about 12 lbs. weight, was introduced to Naivasha for sporting purposes, but is in addition an excellent table fish. Its food consists of the large aquatic insects, prawns, fish, etc., and the Lake Bunyoni frogs would certainly be eaten readily. The introduction might prove dangerous if made immediately, however. It is unlikely that the Bass would kill out the Nsonzi, but, finding the frogs and other small animals easy prey, it might reduce its own food supply to a serious extent. For this reason I recommend introducing the *Tilapia* first, and postponing the Bass until it is ascertained that the *Tilapia* are breeding in the lake. If this is done, the *Tilapia* will afford additional food for the Bass, as they do in Lake Naivasha.

If *Tilapia nigra* and the Black Bass are introduced, I see no reason why Lake Bunyoni should not become very productive in fish, and so be of greater value to the native inhabitants at the same time as a sporting lake for the recreation of Europeans in Uganda. In addition to the Black Bass, one of the best game fish in the world, the *Tilapia* has proved exceedingly good sport on a fly rod in Lake Naivasha.

Since November, 1927, Lake Bunyoni has been a sanctuary for ducks. If the Black Bass is introduced successfully, I would suggest that the duck shooting be opened for a short season each year, say from Christmas till the end of April, as is now the case with the duck shooting on Lake Naivasha. This would afford an added attraction to the sporting facilities of Lake Bunyoni.

SUMMARY OF RECOMMENDATIONS FOR LAKE BUNYONI.

Nsonzi Fishery.

It is recommended that the present system of 6 months closed season during the year be abolished, and in its place a size limit of 15 cms., below which all fish caught must be returned to the waters, be imposed. This would allow breeding to take place satisfactorily and would produce a regular, though at first smaller, supply of fish to the markets, instead of a large supply for 6 months and nothing at all for the rest of the year, as at present.

Introduction of Fish.

(*a*) *Tilapia nigra.* It is recommended that young of this species be obtained from Lake Naivasha in Kenya*, and transported by rail to Kampala, thence by road to Bunyoni. In 2 or 3 years after introduction, the *Tilapia* should have reproduced sufficiently to start a fishery.

(*b*) *Black Bass.* Fry may probably be obtained from Lake Naivasha in a year or so's time. They would flourish in Lake Bunyoni, but should not be introduced until the *Tilapia* are known to have obtained a foothold, and to have bred in the lake.

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* These could be obtained by arrangement with Mr. R. E. Dent, Fish Warden in Kenya, who frequently supplies *Tilapia* fry to settlers in Kenya for introduction to ponds and lakes on their estates.

the lake regains its outlet. On this account the figure for alkaline reserve given in Table 13 cannot be taken as permanent. The salts in solution are unlikely ever to reach so high a figure as to become toxic to fish.

Information with regard to these lakes is bulked in the following table. The heights and areas are taken from Land Office figures ; the other figures are from our own observations :—

TABLE 13.

Data concerning Lakes Nakavali, Kachira and Kijanebalola.

	Lake Nakavali.	Lake Mburo.	Lake Kachira.	Lake Chanagwora.	Lake Kijanebalola.
Altitude : ft. above M.S.L....	—	—	4,040	—	4,025
Area in square miles ...	10	4	14	27	
Max. depth in metres ...	3·5	—	4·1	—	4·8
Water Temp. °C.	24·8—25·9	—	25·0—26·0	—	23·3—24·8
Alkaline reserve (normality)	0·0027	—	0·0020	—	0·0029
pH.	7·7—8·5	—	8·0—8·4	—	8·3
Disappearance of Secchi's disc (metres)	0·5	—	0·5	—	0·4

[*Photo by S. W.*

Fig. 18.—View across Lake Nakavali, from the South.

THE FISHES.

These lakes are not rich in variety of fish life. The three investigated have practically the same fauna, which shows affinity with that of Lake Victoria. There is no *Tilapia* (Ngege), nor any other fish which is palatable to Europeans.

Clarias mossambicus Peters. Amfu.

This cat-fish, which is the well-known Mali or Mumi of Lake Victoria, is the largest and most important fish. It does not grow to so large a size in these waters as it does in Lake Victoria, those caught by natives ranged from 31 to 69 cms. in length, or about ½ to 2 kgms. in weight. The food of this species was found to consist of small fishes, water insects, shell fish, worms and mud. Fish of about 40 cms. long and upwards were found to be breeding in each of the lakes. Most specimens were badly infected with nematode worms, both in the abdominal cavity and in the flesh.

Clarias werneri Blgr. Nsonzi.

The little cat-fish of these lakes is very similar to, though not the same species as, the nsonzi of Lake Bunyoni. It grows to a length of 26 cms. The remarks with regard to food and breeding of the Lake Bunyoni Nsonzi will apply also to this species.

Haplochromis spp. Nsuli, Kiamba, or Weamba.

There are at least two species of this genus in the lakes.* They measure up to about 10 cms. in length. In general appearance they resemble small *Tilapia*.

Haplochilichthys pumilus (Blgr.) Suri.

This little fish, which measures only 3 or 4 cms. in length, was found in Lake Nakavali, but in neither of the other two lakes. It is of no economic value.

THE FISHERY.

As far as we could ascertain the approximate numbers of Banyankole natives actually engaged in fishing operations, are as follows :—

Lake Nakavali	25	fishermen.
,, Mburo	30 ?	,,
,, Kachira	20	,,
,, Chanagwora	25 ?	,,
,, Kijanebalola	25	,,
Total	125	,,

These fishermen have small dugout canoes, and for the most part catch Amfu (*Clarias*) on long-lines. Each long-line is fitted with about fifty small barbed hooks bought from traders at Mbarara or Masaka. The hooks are baited with locusts or with long worms obtained from the swamps. Fishing is usually carried out during the daytime, and the average catch per line of fifty hooks is only six fish. Practically all the fish is sun-dried and smoked and carried to the Mbarara or Masaka markets, where a single fish sells at 10 to 30 cents, according to size.

In addition to long-line fishing, small basket traps are set in the papyrus swamps for the little *Clarias* or Nsonzi, but this is said to be a productive method only during the rainy season. A few *Haplochromis* are usually caught in the baskets with the Nsonzi.

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* These have been identified by Miss Trewavas as *H. nubilus* (Blgr.) and *H. multicolor* Sch. *Astatoreochromis alluaudi* Pellegr. was also represented in the collection.

RECOMMENDATIONS.

In all of these lakes a natural balance between fish and fishermen has been struck, and therefore no restrictions need be imposed. Moreover, the methods of fishing now employed, long-lines and basket traps, are quite satisfactory.

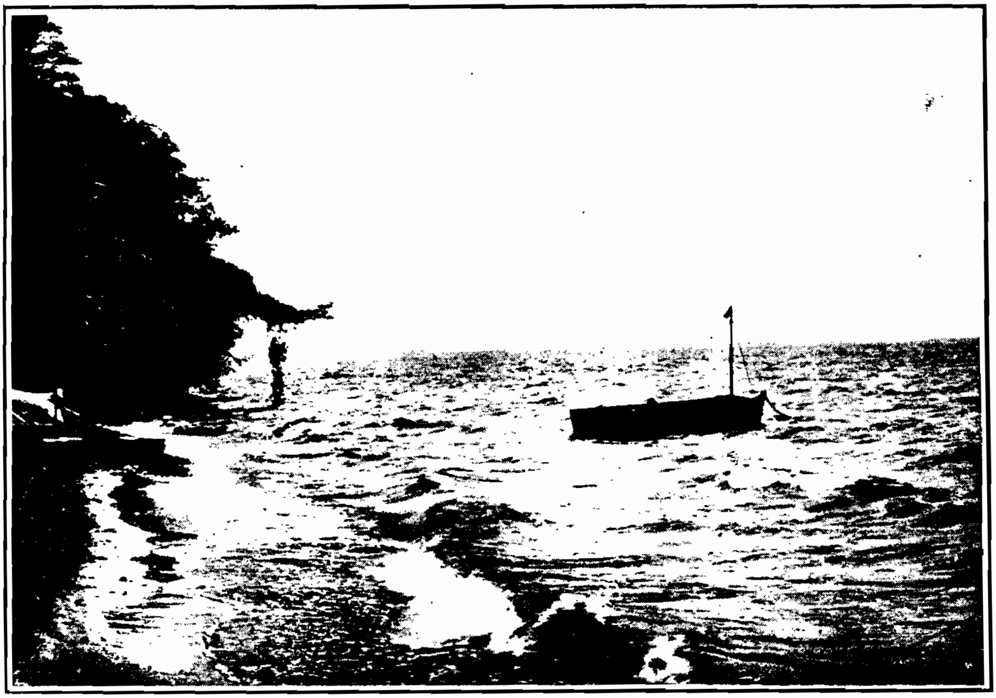
The lake resources might be improved, however, by the introduction of another species of fish, and for this purpose I suggest the well-known Ngege of Lake Victoria. The conditions of life in these swampy lakes approximate to the conditions in the swampy arms of Lake Victoria, so the fish would have to suffer no drastic change during introduction.

There are two species of Ngege in Lake Victoria: *Tilapia esculenta*, the one usually eaten, and *Tilapia variabilis*, also an excellent fish, which is restricted to the inshore waters. Either of these species would be suitable for Lakes Nakavali, etc. *Tilapia* fry are obtainable along most of the Lake Victoria shores; I suggest that they be collected at Bukakata, placed in empty petrol tins of lake water, and run through to the lakes in question by road. During transit the water should be aerated from time to time by agitating the surface. I do not think it would be necessary to construct special enclosures in the lakes for the young ngege to be reared.

Note.—In Lake Victoria there are a number of small fishes, *Haplochromis* spp. which bear a superficial resemblance to *Tilapia*, especially in the young stages (*see* Graham, 1929, p. 33). Experienced native fishermen can usually distinguish between the two. The accidental introduction of *Haplochromis* with the *Tilapia* should be avoided if possible.

uniform pH from bottom to surface. Near the east shore the pH was as low as 6·0 owing to the acid nature of the adjoining swamp, and in the swamp itself the pH was doubtless lower still.

The water of Nabugabo is rendered opaque by fine detritus in suspension and also by the abundant phytoplankton, consisting mostly of the filamentous diatom, *Melosira* sp.



[*Photo by S. W.*

FIG. 19.—LAKE NABUGABO, VIEW FROM MASAKA SPORTS CLUB CAMP.

THE FISHES.

Since Lake Nabugabo represents a cut-off portion of Lake Victoria, it contains a sample of the Victoria fauna, as might be expected, but all the Victoria fishes are not represented. The following species were recorded :—

Protopterus aethiopicus (Heck.). The lung-fish or Mamba. Found near the swampy shores, where it feeds on molluscs, small fishes and weeds.

Gnathonemus longibarbis (Hilg.). A small species restricted to the swamps.

Alestes nurse (Rüpp.). A little silvery fish found close to the shores.

Clarias mossambicus Peters. The Mali. Found all over the lake, but especially near the shores. It feeds on small fishes, Crustacea, etc.

Clarias werneri Blgr. The Nsonzi. Restricted to the swamps.

Bagrus docmac (Forsk.). The Semutundu. Found all over the lake. It feeds on other fishes.

Schilbe mystus (L.). The Butter-fish or Nsere. Another predacious cat-fish which feeds on small *Haplochromis*, but is much smaller in size than *Bagrus*.

Synodontis afro-fischeri Hilg. Only one specimen caught.

Tilapia esculenta Graham. The Ngege. Present, but not in large numbers. It has probably become reduced in numbers recently by intensive net fishing.

Haplochromis or Nkaeje. There are about ten species in the lake; they afford the chief food of *Schilbe* and *Bagrus*.

THE FISHERY.

There are some 30 fishermen with about 15 canoes on Lake Nabugabo. They live for the most part on the dry land to the north-east of the lake, but build fishing huts on the drier parts of the swamp round the other shores.

Fishing is carried out with gill-nets of 5-inch mesh for Ngege and Semutundu, and of 3-inch mesh for Nsere. Gill-net catches are very small, averaging only from two to five fish per net. Some fishermen have long-lines with which they catch Mamba and Mali, and others set basket traps along the shore for Nsonzi and Nkaeje.

RECOMMENDATIONS.

The resources of Lake Nabugabo are small and are scarcely sufficient to support the present fishing population of about 30 men. Although the 3-inch mesh nets now in use do a certain amount of damage in catching young Ngege, I do not consider it worth while to impose restrictions, since very little improvement would result therefrom. The lake, however, is an admirable site for an experiment on the introduction of another sort of fish.

The Nile Perch (Lates).

The possible introduction of the Nile Perch (*Lates*) to Lake Victoria has been often discussed, but the risk involved is too great to warrant an experiment on such a large scale (*see* Graham, 1929, p. 22, and Worthington, 1929, pp. 33-34). In Lake Nabugabo there is virtually a part of Lake Victoria cut off from the main lake. If the Nile Perch were to be naturalised in these waters we should find out (1) whether the Nile Perch would live in water so cool as Lake Victoria; (2) whether the Lake Victoria fish would be suitable food for it; (3) whether the introduction would ruin the Ngege fishery. In fact, the intensive research which is necessary before the Nile Perch is introduced to Lake Victoria, could be carried out with the minimum of trouble and expense.

For these reasons I suggest that an attempt be made to introduce the Nile (or Albert) Perch, *Lates albertianus* Worth. from Lake Albert to Lake Nabugabo.

Method of Introduction.

A small area of Lake Albert, say 10 yards square, should be enclosed with wire gauze or closely set stakes; a suitable place would be along the sandy shore of Butiaba bay. Young *Lates*, from 2 to 6 in. long, should be caught and placed in the enclosure. When sufficient have been accumulated, say 100 or 200, they should be placed in vessels of lake water as large as are obtainable, and motored straight to Nabugabo with as little delay as possible. An enclosure should be made on the shore of Lake Nabugabo for the reception of the young fish. A supply of very small fish fry, insects, etc., should be provided for them in their new home until it is observed that they have accustomed themselves to the new conditions of water, temperature, etc., after which they may be released into the open lake.

During transit from one lake to the other the young fish should not be concentrated more than two fish to a gallon of water. Means should be taken to keep the water warm, it must never drop below 24°C. (75°F.), and from time to time the water should be aerated by violent agitation of the surface.

If this outline of instruction be carried out, there is no reason why the introduction may not be successfully accomplished. The only difficulty likely to be experienced is in obtaining a sufficient supply of young *Lates* at Butiaba. It is possible that local fishermen could obtain them with basket traps or a small mesh seine near the shore, but more likely a method employed by the natives of Buhuka, Tonya and Kaiso, will have to be employed. This method is described in my report on Lake Albert (Worthington, 1929, p. 14 and Fig. 3). Young *Lates* and *Haplochromis* are caught in bundles of brushwood or grass, sunk at the bottom of the lake in six to ten metres of water. So far as I know, this method is never employed at Butiaba, but there is no reason why it should not be applied. In order to obtain an ample supply of young *Lates* at about the same time, I suggest that about 100 bundles of brushwood be sunk at different places in Butiaba bay and left down for a week before being examined. There is no difficulty in distinguishing the young *Lates* from other small fish which will be caught by the same method.

It is, of course, possible that the proposed introduction will be unsuccessful owing to the *Lates* being unable to accustom themselves to different conditions. It is also possible that the *Lates* will grow and breed rapidly, and, finding the fish of Nabugabo easy prey, will exhaust their food supply and then die out. If the latter should prove the case, the Nabugabo fishermen would be put out of work, but could easily transfer their activities to the nearby shores of Lake Victoria. After introduction, the *Lates* must not be fished until they have passed through at least one generation in their new environment. All fish caught by mistake in nets or otherwise should be returned to the water.

If the introduction is effected and a natural balance is struck between the Nile Perch and the Lake Nabugabo fishes, the introduction of Nile Perch to Victoria may be reconsidered. If it is decided to make this drastic change in the Lake Victoria fishery, Nabugabo will become an admirable store-house from which to supply the great lake.

Nabugabo as a Sporting Lake.

Lake Nabugabo, being easily accessible, is much frequented as a holiday resort for bathing. A good sporting fish such as the Nile Perch would increase its attraction enormously. If the Nile Perch introduction proves to be impossible, the Black Bass might be tried as I have recommended for Lake Bunyoni, but it would be a great mistake to introduce the Black Bass first, since such an action would ruin the experiment to find out the effect of Nile Perch on the Lake Victoria fishery.

SUMMARY OF RECOMMENDATIONS FOR LAKE NABUGABO.

It is not considered worth while to impose restrictions on the present fishery, which is very small.

The introduction of *Lates albertianus*, the Nile (or Albert) Perch, from Lake Albert to Lake Nabugabo is recommended. This introduction, without itself doing any considerable damage and with every chance of success, will afford an admirable experiment on the possible effect on the fisheries of the introduction of Nile Perch to Lake Victoria.

APPENDIX I.

LISTS OF FAUNA.

The ecology of the Uganda lakes will be discussed in detail in a subsequent publication among the scientific results of the expedition, but in order to make this Report as comprehensive as possible with regard to the lake faunas, lists of the animals so far recorded are given below, with notes where they are considered relevant. In the case of groups which are being dealt with in detail elsewhere, the list is omitted, but reference is given to the publication where it may be found.

Lakes Edward and George and the Kazinga Channel.

MAMMALIA.

Hippopotamus amphibius is astonishingly abundant all round the shores. In the sleeping sickness areas, where hippos are untroubled by man, they may often be seen running about on dry land even at mid-day.

Lutra (Hydrictis) maculicollis, the Spotted-necked Otter, was observed at the north end of Lake George.

BIRDS.

Only the fish-eating birds, which are of importance in the lake ecology, are given in the list :—

Anhinga rufa or Darter. Particularly common along the Kazinga Channel and round Lake George. Feeds on large *Haplochromis* and small *Tilapia.*

Phalocrocorax carbo lugubris or Large African Cormorant. Frequents the same environment as the Darter, and feeds on similar food.

Phalocrocorax africanus or Small African Cormorant. Very abundant all over these lakes. Feeds on smaller fish than the two previous species. Large flocks often stray far from shore in order to feed on *Haplochilichthys pelagicus* in the open water.

Halioetus vocifer or White-breasted Fish Eagle. Common round the shores. Feeds mostly on adult *Tilapia.*

Pelecanus onocrotalus roseus or Rosy Pelican. Very common on Lakes Edward and George, both near the shore, where it was found to feed on adult *Tilapia*, and in the open water of Lake Edward. where it consumes astonishing numbers of *Haplochilichthys pelagicus.*

Ceryle rudis rudis or Pied King-fisher, which is so common in the gulfs of Lake Victoria, was not observed in many places round Edward and George.

In addition to this list, several of the Herons, which eat fish, and Terns were observed from time to time.

REPTILIA.

The only truly aquatic reptiles in these lakes are water tortoises, of which a small species was observed on several occasions near the shores of Lake Edward, but unfortunately was not collected.

The Nile Monitor (*Varanus niloticus*) occurs in places and often enters the water. Several snakes lead a semi-aquatic existence near the shores ; those actually collected from the water have been identified as *Chlorophis heterolepidotus* (Günther), *Chlorophis irregularis* (Leach), and *Naja melanoleuca* (Hallowell), a big black Cobra.

BATRACHIA.

The only definite records of frogs from these lakes are :—

Hyperolius picturatus (Peters).
Hyperolius stuhlmanni (Ahl.).

PISCES.

For list, *see* Table 4, page 21.

MOLLUSCA.

Lake George.

Succinea lauzannei (Germain).
Segmentina kempi (Preston).
Bulinus trigonus (Mts.).

Kazinga Channel.

Planorbis sudanicus (Mts.).
Planorbis gibbonsi (Mts.).
Segmentina kempi (Preston).
Bulinus trigonus (Mts.).
Melanoides tuberculata (Müll).
Pila sp.

Lake Edward, West Shore :—

Planorbis apertus (Mts.).
Planorbis smithi (Preston).
Melanoides tuberculata (Müll).
Bulinus trigonus (Mts.).
Bulinus strigosus (Mts.).
Planorbis stanleyi (Smith).
Bithynia alberti (Smith).
Sphærium nyanzæ (Smith).
Mutela sp.

Lake Edward, East Shore :—

Planorbis gibbonsi (Mts.).
Planorbis pfeifferi (Krs.).
Planorbis sudanicus (Mts.).
Succinea sp.
Melanoides tuberculata (Müll).
Bithynia alberti (Smith).
Unio stuhlmanni (Mts.).
Unio sp.
Mutela sp.
Corbicula africana edwardi (P. and B.).
Sphærium stuhlmanni (Mts.).

CRUSTACEA.

Potamon emini (Crab).
Caridina nilotica (Prawn).

Various species of Entomostraca, not yet identified, belong to the genera—*Daphnia*, *Ceriodaphnia*, *Moina*, *Bosmina*, *Alona*, *Diaphanosoma*, among the Cladocera; *Diaptomus*, *Cyclops*, among the Copepoda, etc. Cunnington (1920) has previously recorded nine species from these lakes.

HYDRACHNIDA.

Hydrachna signata (Koen. var *fissa* Lundblad).
Arrhenurus sp.
Neumania sp.

OLIGOCHÆTA.

Alma emini.
Others not yet identified.

HYRUDINEA.

Glossiphonia tricarinata (Blanchard).
Placobdella jægerskioldi (Johansson).
Salifa perspicax (Blanchard).

ROTIFERA.

Numerous species. For list *see* Beauchamp (1932).

POLYZOA.

Plumatella repens.
Plumatella emarginata (Allman).

PORIFERA.

Spongilla moorei (Evans).

Lake Bunyoni.

MAMMALIA.

The Hippopotamus is absent. As mentioned on page 50, the Otter, *Lutra* (*Hydrictis*) *maculicollis* is very abundant, and *Paraonyx phillipsi* occurs in the swamps.

BIRDS.

The lake is famous for its water birds. The cormorants and grebes, which are of importance in the ecology, have been mentioned on page 50.

REPTILIA.

The snake, *Hyperolius cinctiventris* (Cope) was taken close to the shore.

BATRACHIA.

Xenopus levis (Daudin) has been discussed on p. 50.
Rana fuscigula (Dum. and Bibs).

PISCES.

See page 52.

MOLLUSCA.

Lymnæa elmeteitensis (Smith).
Planorbis pfeifferi (Krs.).
Planorbis gibbonsi (Nels).
Segmentina kempi (Preston).
Bulinus syngenes (Preston).
Burnupia c.f. *kempi* (Preston), but possibly a new species.
Sphærium sp.

CRUSTACEA.

Potamon emini (Crab).
Caridina nilotica (Prawn).
Various species of Entomostraca, not yet identified.

APPENDIX II.

ON THE DISTRIBUTION OF CROCODILES.

The distribution of crocodiles in the numerous Uganda waters presents many problems of great interest and has called forth much comment in the past. Taking the fresh waters of East Africa as a whole, crocodiles abound in the Bahr-el-Jebel, Lake Albert, the Victoria Nile, Lake Kioga, Lake Victoria, Lake Rudolf, Lake Baringo and Lake Tanganyika. They are absent from Lake Edward, Lake George, Lake Kivu, and the small lakes of the Kenya rift valley such as Nakuru, Elmenteita and Naivasha. In the Uganda lakes, with which this report is particularly concerned, crocodiles exist in Lakes Nakavali and Kachira, but according to native account they are absent from Kijanebalola and Chanagwora, which are connected by papyrus swamp with the last two. Lake Bunyoni and the other highland Kigezi lakes are free from crocodiles, and so also is Lake Nabugabo, in spite of its proximity to the Victoria Nyanza.

The absence of crocodiles from Edward and George, as opposed to their abundance in nearly all the rest of the Nile system, is particularly remarkable, and various hypotheses have been put forward as explanations. The subject has been discussed recently in the correspondence columns of *The Times*. Some people have maintained that the absence is fictitious, and that crocodiles really exist but in such small numbers as generally to be overlooked; there are, in fact, a few references to young crocodiles in Lake Edward. Opposed to this, however, natives of several tribes round the lake shores are convinced of the crocodiles' absence, and no trace of them has been seen by competent observers who have visited the region. The probability is that large specimens of the Nile Monitor (*Varanus niloticus*) which is also a semi-aquatic reptile inhabiting a similar environment, have been mistaken for young crocodiles. The crocodile's presence in large numbers in the River Semliki from Lake Albert as far upstream as the Semliki Falls has been established by several competent observers.

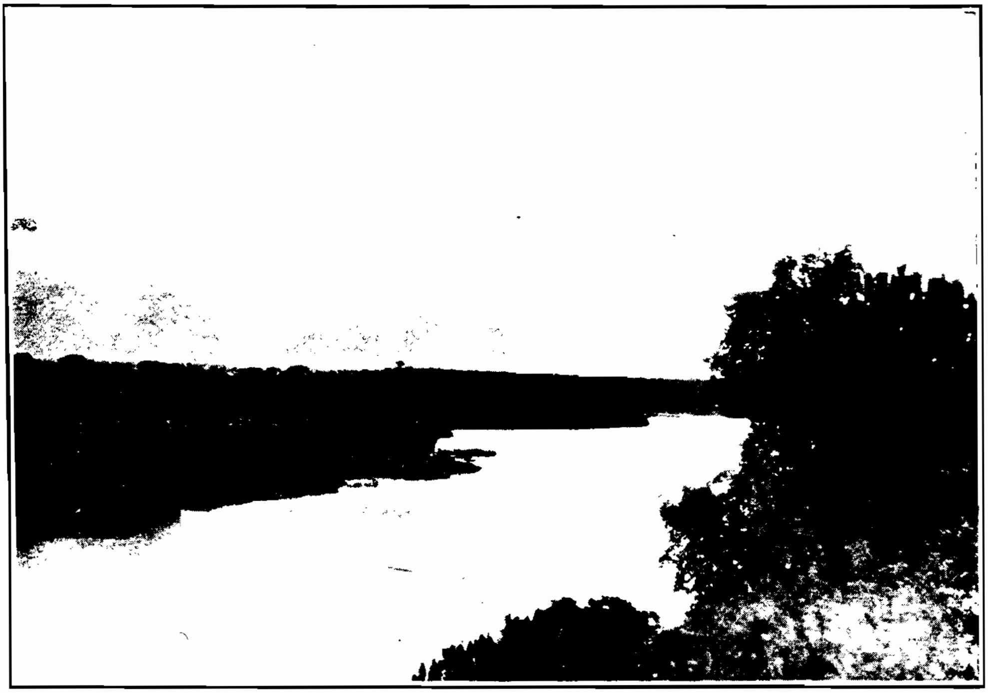
I believe H. E. Sir William Gowers was the first to suggest that the Semliki Falls have proved a barrier to the upward movement of crocodiles, but this hypothesis has been challenged by various people, particularly by Captain Tracy Philipps (1930) who points out that in other parts neither waterfalls nor rapids present physical obstacles to movements of an amphibian like the crocodile, and who suggests as an alternative hypothesis that there is some substance in the water of Lake Edward which is toxic to crocodiles. Philipps points out that the presence of sulphuretted hydrogen was detected in the samples of Lake Edward water analysed in the Government Laboratory, London, and suggests that this quantity of H_2S " while not in sufficient quantity to be detrimental to fish or hippo life, may act unfavourably to crocodiles." During the expedition numerous water samples from different parts of the lake were analysed in the field, and, though H_2S was found to be present in considerable quantity in the deep water below the thermocline, it was undetectable in the surface waters. Furthermore, it may be pointed out that H_2S or any other noxious chemical in the water would have a far greater effect in killing fishes and invertebrate aquatic organisms than in killing crocodiles, since fishes live in much closer contact with the aquatic environment.

The temperature of the water has also been summoned to explain this remarkable distribution. Though Lakes Edward and George themselves have a temperature fully as high as that of Lake Victoria, quite warm enough for crocodiles, it has been pointed out that a number of cool streams flow off the slopes of Mount Ruwenzori to join the Semliki River between its source in Lake Edward and the Semliki Falls. It has been suggested that these streams draw down the river's temperature to such an extent that the crocodiles which abound in the lower reaches are dissuaded from ascending towards the lakes. This hypothesis is also quite untenable since it is impossible that the river's temperature suddenly increases as the water passes down the waterfall, which, as has already been mentioned, affords the line of demarkation between no crocodiles and abundant crocodiles. Moreover, in June, 1930, Beadle took a series of temperatures in several streams flowing from Ruwenzori to the upper reaches of the Semliki. He found that these streams become warmed up to a remarkable degree after descending the mountain, before ever they enter the Semliki River.

During the expedition certain discoveries were made which throw a considerable light on this problem, and the absence of crocodiles from Lakes Edward and George may now be explained on geological grounds, concerning the rise and fall of lake level during the pluvial and interpluvial periods of recent geological times. This subject has already been summarised by Worthington (1932*a*), but for convenience the argument is given again here.

In addition to the absence of crocodiles, the absence of the important Lake Albert fishes, such as the Tiger-fish (*Hydrocyon*) and Nile Perch (*Lates*), may be explained on the same grounds. The evidence comes from the neighbourhood of the west end of the Kazinga Channel, where there is a bone-bed exposure similar to the well-known Kaiso bone-beds of Lake Albert. These deposits were laid down during a period of desiccation (Middle Pleistocene times), during the important interpluvial period between the first and second major pluviations. The Kazinga exposure was worked in detail by Fuchs, and rendered numerous teeth and scales of crocodiles, the vertebræ of *Lates*, and other fish remains, together with a mammalian fauna consisting of a pigmy *Hippopotamus*, *Stegodon*, etc. This shows conclusively that, in former times, the crocodiles and Nile perch inhabited the Edward basin in common with Lake Albert. Some drastic change must have occurred in the Edward basin which exterminated crocodiles and the other original fauna. As the most reasonable explanation I have suggested that desiccation, which is known to have taken place after the first of the pluvial periods, as evidenced by phosphatic bone-beds and gypsum deposits in the Albert, Victoria, and Kenya rift valley basins, must have dried up Lake Edward completely. Subsequently the Edward basin again became a lake with the oncoming of another wet period, and the existing fauna found its way in, mostly from the east, from Lake Victoria. From that time to the present day the original fauna of crocodiles, Nile perch, etc., were prevented from ascending the Semliki River from Lake Albert by the Semliki Falls.

In order to investigate this matter further Beadle and Fuchs made a special trip into the Belgian Congo to the Semliki River in the neighbourhood of the falls. Though there is no vertical drop of water, they described the river as running through a deep, rocky gorge for several miles, and the surrounding country as dense impenetrable forest (Fig. 21). It seems that the rapids themselves are sufficient to prevent the upward movement of fish from Lake Albert, and they must involve a detour of several miles through dense forest for the crocodiles. We can only suppose that crocodiles, which are essentially sun-loving creatures when out of the water, have not yet attempted to make the passage. If they do so at any time in the future, there is nothing to prevent their rapid spread in the upper reaches of the Semliki and all round Lakes Edward and George, for the conditions of these lakes are



[Photo by L. C. B.

Fig. 20.—The source of the Semliki River, looking north-west.

[Photo by L. C. B.

Fig. 21.—The Semliki Falls.

APPENDIX III.

ON CERTAIN CRATER LAKES.

The innumerable small lakes of Uganda which occupy craters of extinct volcanoes offer a unique opportunity for geographical and biological investigations. There is a group of a score or more of these lakes in the Ankole district near the escarpment which descends to the plain bordering Lake Edward and the Kazinga Channel. They vary in size from a few yards across to Lake Niamsigeri, the largest, which has a length of two miles. Several are formed by two or more craters joined together, so that they do not have a typical circular shape. Another group of crater lakes, close to the south end of Lake George, comprises Lakes Kanera, Bagusa, Maseche, and Kararo, and also includes a bay of Lake George with an opening into the lake 200 yards wide, which represents the broken-down side of the crater. To the north of the Kazinga Channel there are a number of others, many having almost perfectly circular shapes with steep sides. Among these lakes, Katwe and Kisenyi (Bunyampaka) are the sites of important salt industries. Another large group in the Toro district, near Fort Portal, is well-known to visitors to that region.

The water of these crater lakes ranges from almost fresh good drinking water to a saturated solution of salt, such as in Katwe and Kisenyi. Most are in their own closed drainage systems, so that the water level rises and falls according to the seasons; some are fed by salt or fresh water springs, and some undoubtedly have subterranean outlets. Practically nothing is known about the depth or the fauna and flora of any. Time during the expedition was too much occupied with the large lakes for any detailed study of these craters, but the opportunity was taken to put a canvas boat and sounding winch on to two of those which lie close to the Mbarara-Katunguru road.

The **small crater lake** lying in a deep hollow just to the east of the road, about two miles south of Kichwamba rest camp, was sounded with the following results :—

The lake is some 300 yards across and soundings were made at equal intervals of 50 yards.

8·3	metres, 20 yards from east shore.	
14·0	,,	Intermediate positions.
16·2	,,	
15·8	,,	
12·6	,,	
6·3	,, , 20 yards from west shore.	

The water is good to drink but contains a large quantity of green phytoplankton. The lake contains small *Tilapia* and *Clarias*, which are eaten by pelicans and a few native fishermen.

Lake Lutoto, which lies some four miles further south alongside the road, was also sounded by means of the canvas boat. It consists of a large steep-sided crater about two-thirds of a mile across, with a bay to the south which probably represents the remains of a subsidiary crater. This bay was found to be shallow, with about four metres of water, but the main crater was decidedly deep with steeply shelving sides, as shown by the following soundings :—

52·6 metres, one-quarter across the lake on a line due W—E.
57·3 metres, centre of lake.
52·4 metres, three-quarters of the way across.

Lakes Bagusa and **Maseche** at the south end of Lake George, which have their names wrongly transposed in the 1906-8 map, were visited by Beadle during July, 1931. Beadle has discussed his observations in a paper (1932*b*) among the scientific results of the expedition. Lake Bagusa has the high alkalinity of 0·235 Normal; the water is coloured, and has rather a high sulphide content. The only living organisms found in the water were the larvæ of a mosquito and of *Eristalis*, but the lake is inhabited by innumerable ducks and geese. Lake Masecha has a still higher alkalinity of 0·71 Normal. Its water is clear and the sulphide content is one-half that of Bagusa. Culicine, Ephydrid and *Eristalis* larvæ were found in abundance near the shore, and the water contained great quantities of the blue-green alga, *Arthrospira*, in numbers estimated by Beadle to be 500 million per litre. It was not possible to sound either of these lakes.

Lake Kikorongo, which lies within two miles of the western bay of Lake George, was examined by Beadle on 28th July, 1931. He noted a foul smell arising from it due to a floating carpet of decaying matter which had been blown by winds to one shore, but the water itself was odourless and quite clear. The alkalinity of the water was very high (0·408 Normal). and along the northern shore there were about 15 small springs welling up from the bottom in the shallow water at the edge. The water of these had a lower alkalinity (0·386 Normal). Much of the north and east shores was formed of calcareous tufa, presumably deposited by springs. The water contained large numbers of *Arthrospira*.

Nettings for fish were quite unsuccessful in 1931, but Mr. R. E. Dent, who visited the lake in 1905, recorded large numbers of *Tilapia*, most of which were blind and many of which were being washed up on the shore in a dead or dying condition. In 1931, moreover, Beadle found large numbers of skeletons of recently dead *Clarias* and *Tilapia* along the western shore. The water of Lake Kikorongo changes in alkalinity from time to time as shown by analyses made in January, 1920, and April, 1930; and the presence or absence of fish is probably dependent on the changing alkalinity. This conclusion was confirmed by an old native of the district, according to whose evidence the water of Lake George rises and flows over into Lake Kikorongo during the wet season, and as a result some fish find their way into Kikorongo, the water of which would then be less alkaline owing to dilution with the flood water. Subsequently the water level falls, the lakes are again separated, and the water of Kikorongo undergoes an increase of alkalinity until the fish are killed off.

The innumerable crater lakes of Uganda do not only provide a fascinating opportunity for scientific research, but their detailed examination, when that takes place, may be expected to offer many opportunities for fishery developments. At present most of those which contain fresh water contain fish of some sort, either *Tilapia* or small species of *Clarias*, or both. But many of the lakes, particularly those which lie in populated districts, would repay the trouble of introducing other fishes. Several of those in the highland region near Fort Portal would probably be suitable for the introduction of a sporting fish, which would greatly add to the amenities of that region for Europeans. The Black Bass would perhaps be the most suitable fish to introduce, but it is strongly urged that no attempt should be made with regard to such possible introductions until the lakes in question have been submitted to an exhaustive examination by a competent authority. In any case, introductions should be restricted to those lakes which lie in closed drainage basins, since the escape of the introduced fishes to other waters might do serious harm.

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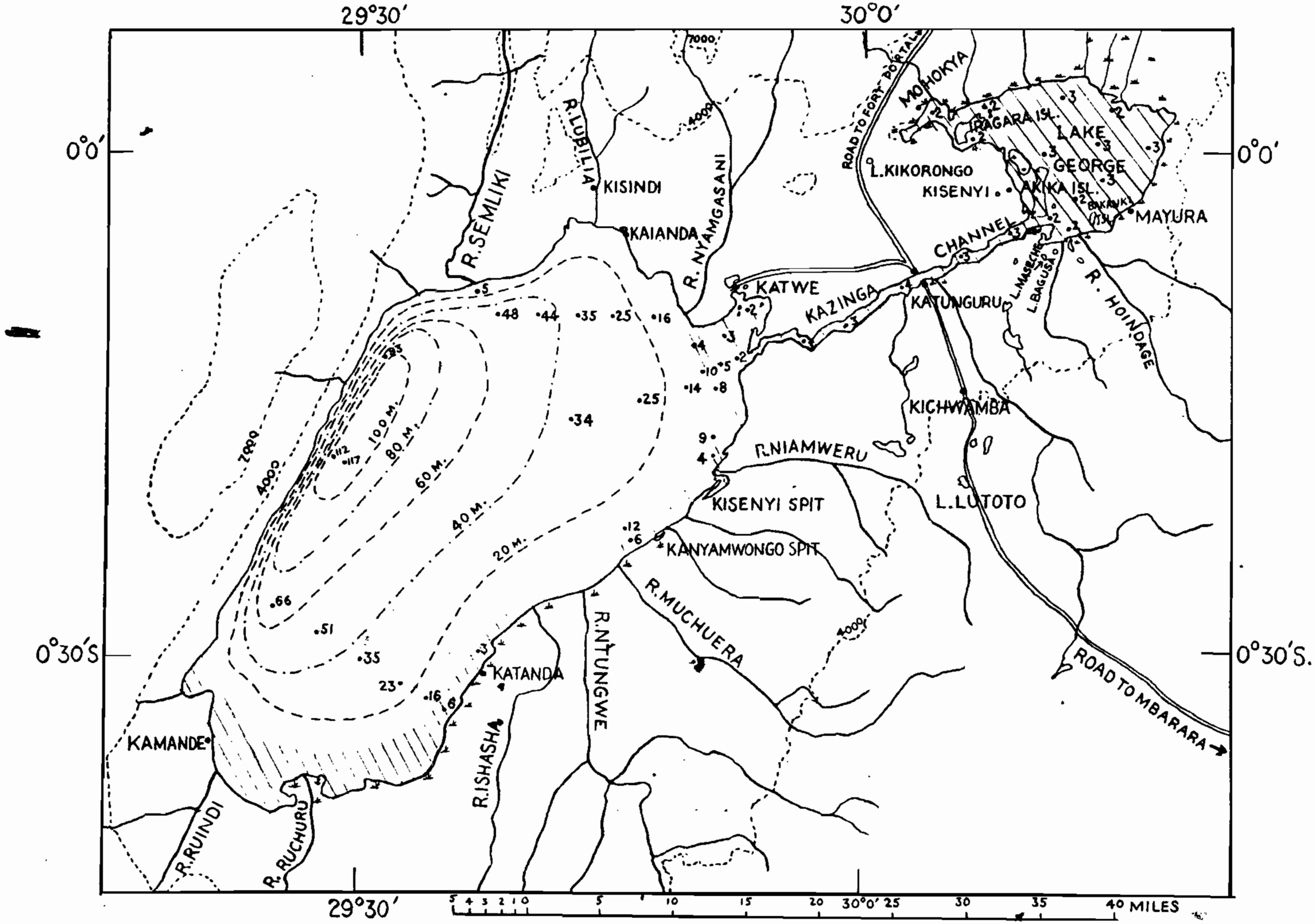
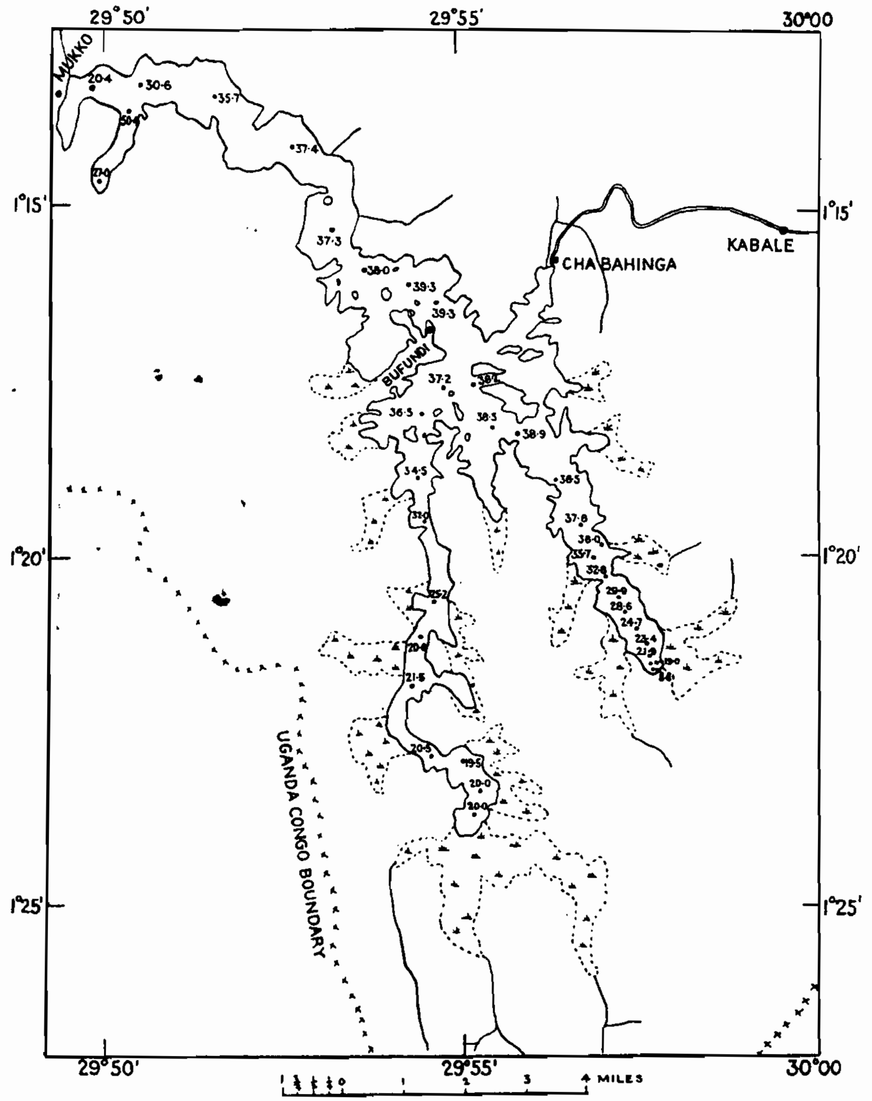
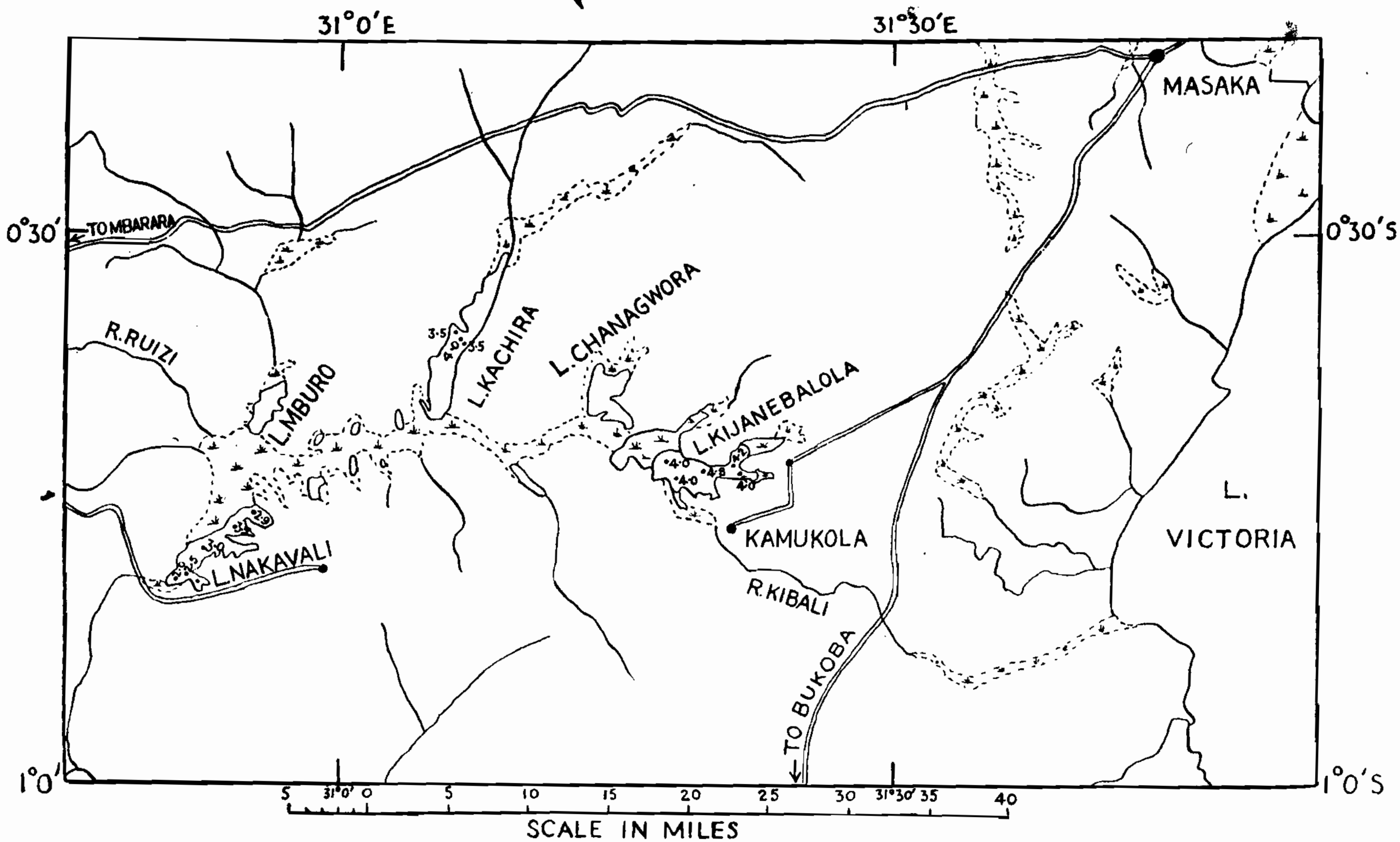


Map 2.—Lakes Edward and George.

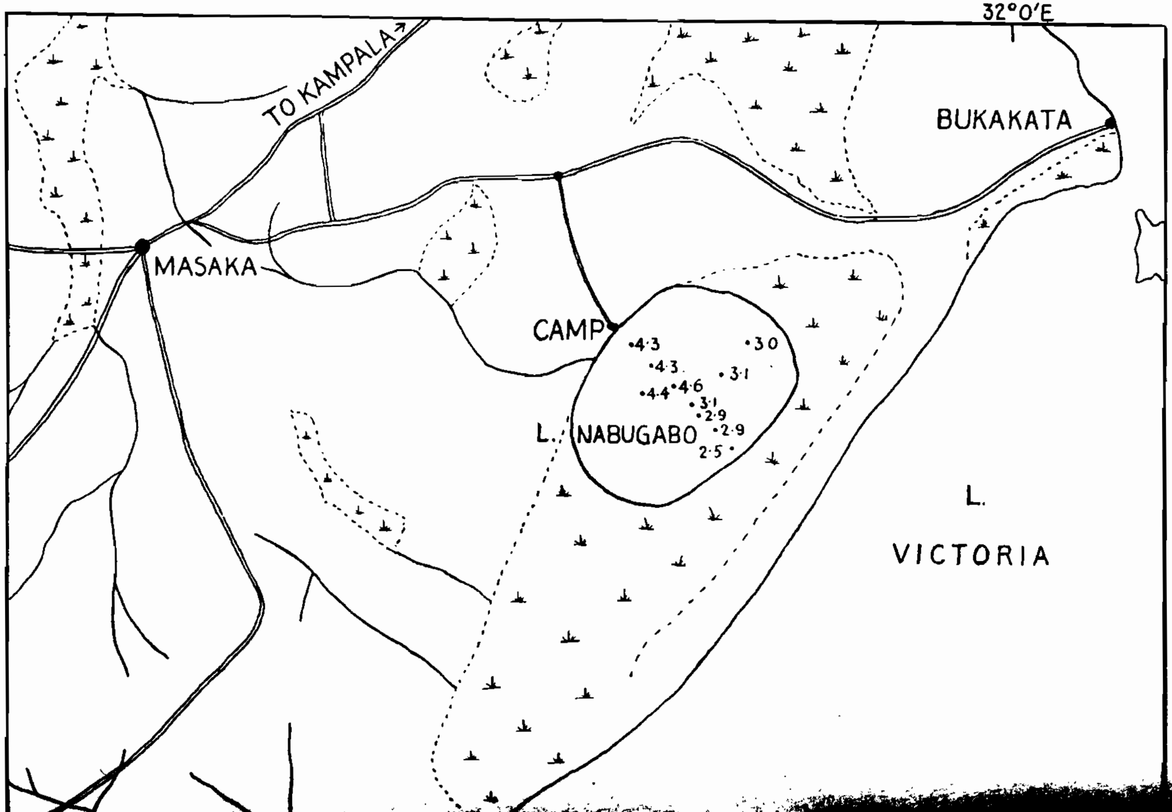
A few of the soundings are indicated in metres. The depth contours at 20 metre intervals have been inserted for Lake Edward as a result of data obtained by the expedition. The area marked red is shallow water suitable for a *Tilapia* gill-net fishery.



MAP 3.—LAKE BUNYONI, SHOWING POSITIONS OF SOUNDINGS (IN METRES) MADE DURING THE EXPEDITION.



Map 4.—Lakes Nakavali, Kachira and Kijanebalola, showing Soundings (in metres) made during the Expedition.


32°0′E
TO KAMPALA
MASAKA
BUKAKATA
CAMP
L. NABUGABO
4·3
4·3
4·4
4·6
3·1
2·9
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2·5
3·1
3·0
L.
VICTORIA

INDEX.

Note.—Heavy type has been used for some of the more important references.

CONTENTS.

PREFACE.

The investigations of the Uganda lakes, on which this report is based, was carried out by the Cambridge Expedition to the East African lakes during the period from May to September, 1931, by arrangement with the Uganda Government. This work followed immediately after six months' investigation on Lakes Rudolf, Baringo, Naivasha, etc., in Kenya Colony, so that no time was lost in the preparation of apparatus or perfecting the technique of limnological research in the tropics, and the best use was made of the four months in Uganda.

Parts II to IV of this report reproduce in all essential particulars the draft submitted from Entebbe on 26th September, 1931. Part I and the appendices have been prepared after some months in England spent in studying the collections and analysing the field records. The whole is intended to make a companion volume to Mr. M. Graham's report on the Lake Victoria fisheries and my own on the fisheries of Lakes Albert and Kioga. The three works together contain a quantity of data and information which should prove of value in the future development and control of the Uganda fisheries.

With regard to the illustrations, the photographs were taken by various members of the expedition, indicated by initials in each case. The sketch-maps and line drawings have been prepared by my wife or myself.

At the conclusion of the expedition the collections were sorted and submitted to the following authorities for examination and identification :—

Mammals to Miss St. Leger ; Reptiles and Amphibians to Mr. H. W. Parker ; Cichlid fishes to Dr. C. Tate-Regan, F.R.S. and Miss E. Trewavas ; Fishes other than Cichlidæ to Dr. E. B. Worthington ; Mollusca to Major M. Connolly ; Oligochaeta to Lt.-Col. J. Stephenson, F.R.S. ; Parasitic Worms to Mr. H. A. Baylis ; Leeches to Dr. J. Percy Moore ; Sponges to Mr. M. Burton ; Polyzoa to Dr. A. Hastings ; Rotifera to Prof. P. de Beauchamp ; Large Crustacea to Dr. I. Gordon ; Argulidae to Dr. W. A. Cunnington ; Parasitic Copepoda to Mr. Leigh-Sharpe ; Planktonic Crustacea to Mr. A. G. Lowndes ; Myriapoda and Arachnida to Dr. S. Finnegan ; Hydrachnida to Dr. O. Lundblad ; Adult Insects to members of the British Museum Entomological Department ; Insect Larvæ to Dr. A. D. Imms ; Dried Plants and Water Weeds to Mr. J. Ramsbottom ; and Phytoplankton to Miss F. Rich.

In the course of work by these authorities, which in some cases is not yet complete, many organisms previously unknown to science have been discovered. These are being described, together with other matters of scientific importance, as a series of papers—the " Scientific results of the Cambridge Expedition to the East African lakes, 1930–31," in the Journal of the Linnean Society of London. Papers by Worthington (1932 *b* and 1932 *c*), Beadle (1932 *a* and 1932 *b*), Parker (1932) and de Beauchamp (1932) are now in the press. Others by Trewavas, Lowndes, Gordon, Lundblad, and Rich are in process of preparation. In those cases where the authorities are not actually writing papers on the collections submitted to them, lists are being furnished to me of the species identified. Some of these lists have been used for the purposes of Appendix I.

I take this opportunity of recording my thanks in the first place to the other members of the expedition: Mrs. Stella Worthington, Mr. L. C. Beadle, Mr. V. E. Fuchs, and the native staff, for their unvarying helpfulness throughout the field work; to His Excellency Sir William Gowers for his valued advice, hospitality, and assistance through the several Government Departments; to the various Government officers and others with whom the expedition came in contact, particularly Messrs. G. Maitland Warne, Temple Perkins, Lukyn Williams and Rogers, of the administrative staff; Messrs. E. J. Wayland and W. C. Simmons of the Geological Department. Messrs. B. T. Watts and W. O. Matthews of the Land Office, Drs. Schofield and Sharpe of the C.M.S. My thanks are also due to those people in England who have assisted in making arrangements for the expedition and in working out the results, particularly to Prof. J. Stanley Gardiner. F.R.S., of Cambridge University.

of Lakes Victoria, Albert, and Kioga, 1927-8, were borrowed from the Game Offices in Kenya and Uganda, and some of the equipment was constructed locally. The most important items were the following :—

Ford box-body car (other over-land transport was provided by Government lorries and a staff car); 16 ft. wooden boat constructed near Kisumu of ½-in. pine with local cedar keel and ribs; large dugout canoe borrowed at Katunguru; 10 ft. canvas folding boat; 12 h.p. Johnson sea-horse outboard motor; a supply of gill nets of 1 in., 2 in., 3 in., 5 in., 7 in. and 9 in. mesh of flax twine of suitable thickness in each case; long-lines fitted with cod and conger hooks; 10 ft. beam trawl[1]; oyster dredge[1]; anchors, buoys, rope and twine, spring balance and fish measures; two Friedinger sounding winches[1,2]; sounding leads; depth water bottle[2]; grab[1]; closing plankton nets of fine, medium, and coarse mesh; Secchi's disc; reversing thermometers; ordinary thermometers; monocular microscope[2]; binocular microscope; stop watch; three zinc boxes fitted for chemical investigations to Miss P. M. Jenkin's design[3]; copper still[3]; 4 large zinc-lined collecting tanks and other boxes fitted with collecting jars and corked tubes[1]: surveying instruments such as prismatic compass, aneroids, plane table, etc.[4]; box of tools; reference books, maps and stationery; pond nets, insect nets; fishing rods, firearms, field glasses, and cameras; the usual camp equipment comprising tents, etc.[5]

Itinerary.

The personnel and full equipment of the expedition arrived at Katunguru on the Kazinga Channel, midway between the two lakes, on May 23rd after motoring from Kampala. The Government rest camp on the south side of the channel at Katunguru served as a headquarters laboratory and dumping ground for collections and equipment throughout the work in this region. The interval between May 23rd and June 2nd was occupied with the study of the middle reaches of the Kazinga Channel. On the latter day the whole expedition moved to where the Channel opens into Lake Edward, and erected camp on the tip of the Mweya Peninsula, a convenient base for the study of Katwe Bay and the nearby parts of Lake Edward. This work lasted until June 15th, during which period Beadle and Fuchs also examined the eastern shoreline of Lake Edward as far south as Kanyamwongo spit, working from the land. On June 15th, Dr. and Mrs. Worthington proceeded on a three weeks' cruise, camped at Katwe, Kisenyi spit, Kanyamwongo spit, Katanda, crossed the lake from near Katanda to the precipitous Congo escarpment, and thence proceeded up the little-known western shore, camped at several stations en route, including the source of the Semliki River, and returned to Mweya on the 30th June. Meanwhile Beadle and Fuchs went by foot safari along the north shore to Katwe, and thence to Kisindi on the international boundary, and so into the Congo to visit the Semliki River in the region of the waterfalls, and also the western foothills of Mount Ruwenzori. On July 10th, Dr. and Mrs. Worthington returned to Katunguru while Beadle and Fuchs proceeded by boat to the source of the Semliki and the deep water under the Congo escarpment for further researches.

On July 14th the whole expedition moved to Lake George and erected a camp on the south shore where the Kazinga Channel opens into the lake. Work in this region continued until July 26th, when the expedition once more divided—Dr. and Mrs. Worthington proceeded on a week's cruise round Lake George, camped at Mayura, the north-east corner of the lake, Iragara Island, Mohokya, and crossed the lake in several directions. Meanwhile, Beadle and Fuchs visited a number of

(1) Lent by the British Museum (Nat. Hist.) by permission of the Director.
(2) Lent by the Zoological Laboratory, Cambridge, by permission of Prof. J. Stanley Gardiner, F.R.S.
(3) Lent by the Trustees of the Percy Sladen Memorial Fund.
(4) Lent by the Royal Geographical Society.
(5) Mostly lent from the Land Office stores, Entebbe, by the Director of Surveys.

PHYSIOGRAPHY.*

Meteorological Conditions.

The part of the rift valley enclosing Lakes Edward and George, though at a comparatively low level, has a high rainfall, due to the proximity of Mt. Ruwenzori. The 1.400 mm. (annual total) area includes Lake George and the northern half of Lake Edward (Hurst, 1931, plate 23, p. 54). The period of the expedition's work in this area fell during the dry season, and on the whole quiet fine weather prevailed. Along the north shore of Lake Edward a regular daily lake breeze arose from the south-west at about 11 a.m. and continued till about 4 p.m. Heavy rain fell, however, from time to time, and storm winds sometimes caused seas sufficiently large to be dangerous to small boat navigation. On one occasion, in fact, when the boat was blown away from her moorings under the Congo escarpment the expedition nearly ended disastrously.

Regular daily observations show that the shade temperature at the mouth of the Kazinga Channel into Lake Edward ranged from an average maximum of 30·2° C. (86·4° F.) to an average minimum of 19·0° C. (66·2° F.) during 10 days in June. Similar figures obtained at the east end of the Kazinga Channel, during a week in July, were 29·5° C. maximum and 17·0° C. minimum.

Visibility in the Lake Edward region of the Uganda rift valley is extraordinarily poor during the dry season. This is patent owing to the rare occasions on which the snow peaks of Ruwenzori can be seen from well-known viewpoints, but it is even more strikingly brought home when working on the lakes themselves. During the four months near the foot of Ruwenzori the snow peaks were only visible on three or four occasions, and there was usually a thick haze over the water sufficient to obliterate the opposite shore. On the occasion when a crossing was made from east to west of Lake Edward, where the width is 17½ miles, the eastern shore was invisible after two miles of water had been traversed, and the high Congo escarpment did not loom into view until the boat was within a mile or two. Therefore, on this and on other open water cruises, navigation had to be directed entirely by compass.

Drainage.

Lake Edward, which is some 48 miles long by 25 miles wide, lies in the great rift valley a little south of Mt. Ruwenzori with its longer axis north-east to south-west. The south-east shore is flat and swampy, but on the west shore the Congo escarpment descends abruptly to the water from a height of more than 8,000 ft. to the level of the lake, which has now been fixed at 2.995 ft. above sea-level.

The main affluent rivers are the Ruchuru at the southern end, which drains the Mufumbiro volcanic range and parts of the Kigezi highlands, the Ishasha forming the Uganda Congo boundary to the south of the lake, and the Ntungwe. The last two, together with three smaller rivers, the Mchuera, Ruampuno and Niamweru, rise in the Kigezi and Ankole highlands and flow to the south-east shore. Entering along the north shore there are the Lubilia, forming the international boundary to the north of the lake, and the Nyamgasani, both of which find their origin among the foothills of Mt. Ruwenzori. In addition, a series of mountain torrents pour down the Congo escarpment from the west and sometimes enter the lake as beautiful waterfalls and cascades. Lake Edward is drained by the Semliki from its northern end down the rift valley to Lake Albert.

* Some of the matter of this section has already been published in brief (Worthington, 1932 a.).

3–4½ metres in depth. About a quarter of a mile off the mouth of the Channel into Lake Edward there is a shallow shoal of two metres. The shallow water extends over Katwe Bay (1-4 metres) but was found to deepen steadily towards the centre of Lake Edward.

Soundings in the body of Lake Edward were surprising, since they showed the lake to be deeper than any other in Kenya or Uganda. There is a trough close to the steep Congo escarpment where the maximum depth recorded was 117 metres within two miles of the shore. From this trough the floor of the lake slopes gradually upward to the south-eastern shore. The extreme south end of the lake was not sounded, but there can be little doubt that there are considerable areas of shallow water near the mouth of the Ruchuru River.

During work at the source of the Semliki the interesting fact was discovered that there is a shallow shoal, with water of less than three metres depth, about half-a-mile out into the lake opposite the river's origin. This shoal may represent the remains of a river delta which was deposited a long time ago when, according to Wayland, the southern part of the Semliki flowed in the reverse direction from at present, that is, into instead of out of Lake Edward.

The bottom deposit is mud nearly all over, but in places near the east shore of Lake Edward the grab brought up a mixture of shell and gravel coated with lime, which seemed to represent an oolite in process of formation. The steep rocky shore of the Congo escarpment extends some distance below the water level and then gives place to soft black mud.

Turbidity.

The turbidity of the water was measured with the instrument known as Secchi's disc. This consists of a white enamel plate of 20 cms. diameter, which is lowered into the water at mid-day until it becomes invisible. The depth of disappearance is useful in comparing the turbidity of different waters. In the thick green water of Lake George and the Kazinga Channel, the disc disappeared at 0.4 metres. In Lake Edward near the mouth of the Channel it disappeared at 1·8 metres, and the higher figures of 2·2 metres and 2·8 metres were recorded in the open water of Lake Edward. Compared with these figures, the open water of Lake Albert ranged from 2·7–3·5 in 1928 (Worthington, 1929, p. 58) and figures from 1·3 (Kavirondo Gulf) to 8·2 (open water) were obtained in Lake Victoria (Graham, 1929, p. 173). The degree of turbidity of lake water is controlled by the numbers of minute animals and plants in the water, but debris washed up from the bottom has some effect in very shallow water.

Water Temperature.

The water temperature of Lake George was found to range at the surface from a maximum of 26·6°C. at about 2 p.m. each day, to a minimum of 24·0°C. shortly before dawn. The Kazinga Channel at Katunguru was found to heat up during the day rather more, to about 28°C. The open water of Lake Edward, at the surface, showed a maximum of 26·5°C. during the afternoon. The water below the thermocline was constant at 24·8°C. (*see* p. 19.)

Water Chemistry.

All the East African lakes are to some extent alkaline with a considerable quantity of dissolved salts, particularly sodium carbonate. Since the planktonic organisms depend on the degree of alkalinity, and the plankton is of importance as fish food, it follows that the alkalinity of the lake waters is a factor influencing the quantity of fish the waters can support. The whole question of water chemistry

This again shows the high proportion of dissolved salts in Lake Edward compared with Lake George, but it must be remembered that the composition of the waters has probably changed during the period from 1924, when these samples were collected, to 1931.

Results of analyses by the Government chemist, London, of three water samples from Lake Edward collected in 1921 and 1929, were published in the *Times* of April 30th, 1930, in a letter from Capt. Tracy Philipps. The analyses are reproduced below, by permission of the Editor, but considerable changes may have taken place during the transit of the samples from Uganda to London ; particularly the oxygen content must be accepted with reserve.

TABLE 3.

ANALYSES BY THE GOVERNMENT LABORATORY, LONDON, ON WATER SAMPLES COLLECTED BY CAPT. TRACEY PHILIPPS.

	No. 258, March 23, 1921, Lake Edward E.	No. 268, March 23, 1921, Lake Edward S.W.	Misc. No. 362, July 5, 1929, Lake Edward (Kigezi).
	Sample 600 *c.c.*	*Sample* 600 *c.c.*	*Sample* 1,000 *c.c.*
Total solids in solution	42·2	54·3	—
Calcium (Ca)	2·8	3·4	1·4
Magnesium (Mg)	3·0	3·7	4·7
Sodium (Na)	9·9	13·2	10·3
Carbonate (CO_3)	16·8	22·8	31·9
Chlorine (Cl)	1·1	1·0	—
Silica (SiO_2)	1·6	1·4	0·8
Sulphuretted hydrogen (H_2S)	0·49	0·68	0·82
Oxygen consumed in 4 hrs. at 80°F.... ...	1·01	1·23	1·07

Parts per 100,000.
Sp. gr. at 60°F.

Nitrate : trace. Pronounced odour of sulphuretted hydrogen. Black sediment of iron sulphide and silicates.—*J.E.T.P., March* 3, 1930.

The information given in Table 1 can be accepted as typical for the whole of Lake George, which is so shallow that depth has a negligible effect on the water chemistry, and for the shallow water of Lake Edward covering that area in Map 2 outside the 20 metre depth contour. In the deep parts of Lake Edward, however, there is an important factor which has a great effect on the chemistry and life of the waters. This is the thermocline or the definite division of the waters at a certain depth into the epilimnion (upper region) which has a good oxygen supply and supports abundant life, and the hypolimnion (lower region) in which oxygen is absent and, therefore, in which life is practically non-existent. Lakes in temperate latitudes typically develop thermoclines during the course of the warm summer months, during which the surface waters are continually heated and two distinct circulations are set up, one above and the other below the thermocline. In some temperate lakes the oxygen supply in the hypolimnion is exhausted during late summer, but every winter it is replenished by the cooling of the surface waters and the resultant overturn, or complete mixing, throughout the lake. In tropical lakes, on the other hand, where there is practically no seasonal change in climate, a thermocline, if developed at all, should be permanent.* So far as is known, the Lake Edward thermocline, which we discovered in 1930 and is described by Worthington and Beadle (1932), is the only known case in the African equatorial waters. Such a state has not been observed in any other of the Kenya and Uganda lakes. In Lake Edward we found on the 26th June and 9th July, 1931, that down to a depth of 40 metres the temperature is comparatively uniform at about 25·8°C. These upper layers of the water behave like an ordinary shallow lake with temporary surface heating during the day up to 26·6°. From 40-60 metres, however, there is a definite break in the temperature graph (Fig. 4), and below 60 metres the temperature is constant at about 24·8°C.

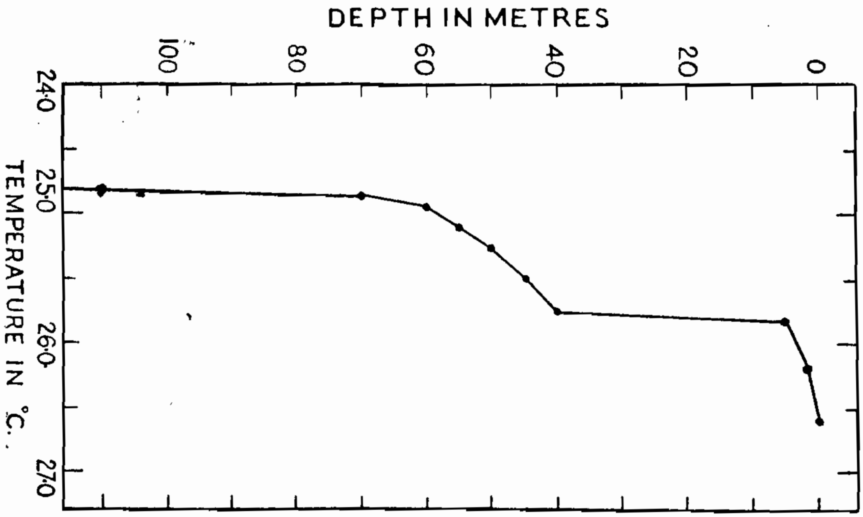

Fig. 4.—The Thermocline of Lake Edward.
Observations made at 2 p.m. on 26th June, 1931, in the deepest part of the lake.

With regard to the chemistry of these deep waters, the alkalinity was found to increase uniformly from the surface to about 60 metres, below which it was constant. The pH below the thermocline was uniform at 8·7 whereas it was 8·9 above. The phosphate content was higher below than above the thermocline. The surface waters were odourless, but samples taken from the hypolimnion (below 50 ms.) smelt strongly of H_2S, and correspondingly the sulphide content was higher below the thermocline. The hypolimnion also was practically devoid of oxygen. The effect of the thermocline on plant and animal life was admirably shown by plankton collections; above the thermocline there was an abundant phyto- and zooplankton, whereas below practically the only living organisms found were the fly larvae, *Chaoborus*, which undergo a diurnal migration to and from the upper layers, and probably take down a supply of oxygen in their air-sacks. Correspondingly the only fish obtained from the hypolimnion was *Clarias*, which has an air-breathing adaptation; the specimens caught must have taken down their own supply of oxygen.

* Except in the case of certain temporary thermoclines which are broken by agitation of the surface waters during periods of winds, such as those recorded from the lakes of Java by Rüttner (1931).

The way in which minute animals and plants of the plankton depend on the chemical constitution of the water was strikingly illustrated by the junction between the two types of water at the south-west end of the Kazinga Channel. The channel itself contains nearly fresh water of the same constitution as that of Lake George with a very abundant phytoplankton, which renders the water turbid (page 16) and gives it a muddy flavour. On the other hand, Lake Edward itself contains clear water. A series of water analyses and plankton collections made every half mile or so down the Channel and out into Lake Edward showed that there is an abrupt change in chemistry and fauna and flora in passing across the junction of the two waters. Within a distance of two-thirds of a mile there was a rise in alkalinity from 0·0033 to 0·0096 N. and a decrease in silicate content from 17·7 to 5·4 mgms. per litre. The phosphate content showed a considerable rise in passing from the Channel into Lake Edward. With regard to flora and fauna, the *Microcystis*, which is exceedingly abundant in the Channel and Lake George, is almost absent from Lake Edward, whereas the unicellular diatoms are more abundant in Edward than in the Channel. The numbers of kinds of minute animals in the plankton showed similar changes. (*See* also section on food of *Tilapia*, p. 29).

Errors in Uganda-Congo Boundary Commission Map, 1906–08.

Lake George.

There is a large island near the shore, north-west of Akika Island, some three by one miles (*see* p. 15). The rough outline is inserted on Map 2.

The entrance to the crater bay at the south end of the lake by Kitoma is only about 200 yards wide, instead of about half a mile as marked on the map.

Bakanki Island is very much larger than marked on the 1908 map, being about one mile long by a quarter of a mile broad, its long axis north and south.

The shores of the eastern part of the Kazinga Channel are in error, since Lake George is visible from the Channel at the point on the southern shore one mile west of Lake Chinona.

The names of Lakes Bagusa and Maseche are interchanged on the 1908 map, according to several natives who know the district well.

Lake Edward.

Kisenyi spit, marked on the map as an island, is now joined to the mainland to the south.

The tip of Kanyamwongo spit is now almost joined to the mainland to the south-west, partly by further growth of the spit itself, partly by growth of the sand bar along the main shoreline.

Along the western shore of the lake, which is dotted on the 1906–08 map, under the Congo escarpment there are five rivers entering the lake. These have built out fans of flattish land at the foot of the escarpment, which project as promontories from the more or less straight shore of the escarpment wall.

On the north shore of the lake the point of swampy land just south of the Niamgasani river mouth now projects much further into the lake.

Thus, if the condition factor is known, a ready means is provided for converting the lengths recorded into weights. During the expedition, fish of various sizes for each species were weighed; this information is included where it may be of use and is expressed as a value for k, the condition factor.

Information regarding Sexual Development and Breeding.—Most of the data is also bulked in Table 9. For the purpose of field records the development of the gonad or genital organs was divided into five stages: quiet, starting, ripening, ripe and spent. In condensing the records for inclusion here, the last three of these stages have been amalgamated as "breeding."

To assist in the field identification, outline drawings of the most important fishes are given in Figure 5.

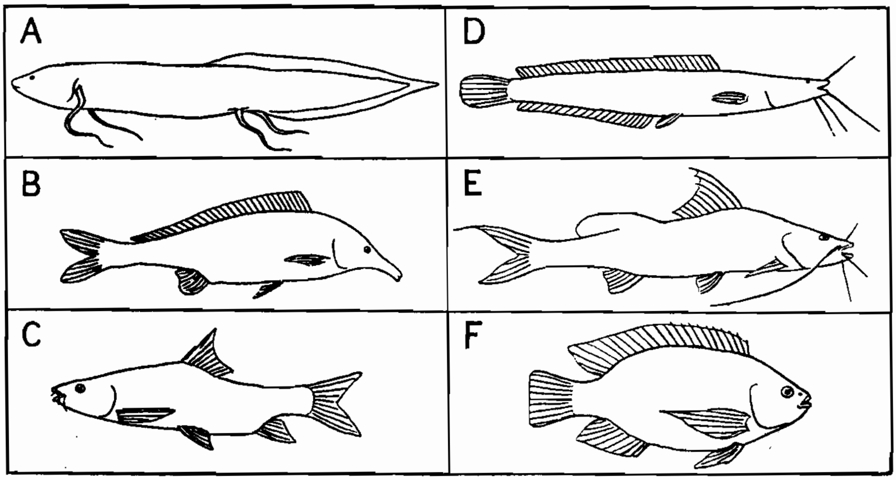

FIG. 5.—OUTLINES OF THE IMPORTANT FISHES OF LAKES EDWARD AND GEORGE.

A.—*Protopterus aethiopicus.*
B.—*Mormyrus caschive.*
C.—*Barbus altianalis eduardianus.*
D.—*Clarias lazera.*
E.—*Bagrus docmac.*
F.—*Tilapia nilotica.*

A to E—about $\frac{1}{20}$ nat. size. F—about [illegible] nat. size.

Family: LEPIDOSIRENIDÆ.

Protopterus aethiopicus.

Widely distributed in the Upper Nile from the eastern Sudan to Lake Victoria, and also present in Lake Tanganyika.

It frequents quiet water, especially in the neighbourhood of swamps, and therefore abounds in Lake George and the Kazinga Channel. In Lake Edward it exists in great numbers round the shallow shores, particularly in Katwe Bay and at the south end of the lake. It is absent from the steeply-shelving western shore and from the deep open water.

This fish breathes air by means of lungs, except in the very young stages; hence the English name of Lung-fish. It is a favourite native food, though seldom eaten by Europeans, and can be caught in considerable numbers by the use of long-lines.

Both jaws are provided with heavy plate-like cutting teeth which are effective for catching smaller fish, but as stomach examinations have shown, the lung-fish is omniverous. Eighteen stomachs were examined, of which nine were empty and the remainder contained fish remains (6), Mollusca (1), Chironomid larvæ (1) and plant remains (1). The Lung-fish is addicted to feeding on fishes previously caught in nets, and therefore does considerable damage to the *Tilapia* gill-net fishery.

Data concerning size are given in Table 9, but the fish grow very much larger than there shown. A specimen from Lake Victoria in the Coryndon Memorial Museum, Nairobi, measures more than 6 ft. in length, and a specimen at least as large as this was observed in Katwe Bay, Lake Edward.

Breeding fish were taken in the neighbourhood of swamps, where the male fish makes a nest or hollow in the swamp at some distance from the lake shore. The female lays her eggs in the nest and the young fish are subsequently guarded by the male, who exhibits remarkable paternal care.

Family : MORMYRIDÆ.

Mormyrus kannume.*

Common to the whole Nile system from Lakes Victoria and Edward to the delta.

Mormyrus caschive.*

Previously known from the Lower Nile to Lake Albert.

These two closely related species may be considered together. In the Edward basin *Mormyrus* were only found in the Kazinga Channel and Lake George, the only station where they were found in any numbers being close to the papyrus area at the north of Lake George. They are essentially bottom-living fish, with long snouts adapted to burrowing in the bottom mud. All the stomachs examined contained Chironomid larvæ mixed with mud and vegetable debris.

Size data are given in Table 9. Very little is known about the breeding habits of *Mormyrus*, but most of the specimens examined had gonads ready to breed.

Family : CYPRINIDÆ.

Labeo forskalii.

This species was formerly recorded only from the Lower Nile. Its presence in Lake Edward was unexpected. Only four specimens were taken, all in the deep clear water close to the steep west shore of the lake. Being so rare a fish, it is of no economic value.

In common with most other members of this genus it obtains its subsistence from the organisms in the bottom deposit. The four specimens ranged in length from 38-48 cms. One male and one female were breeding, the other two smaller specimens were immature males.

Barbus altianalis eduardianus.

A large number of specimens preserved from Lake Edward have shown this *Barbus* to be the same species as *B.a.altianalis* from Lake Kivu, and ***B.a.radcliffii*** from Lakes Victoria and Kioga, so that the one species *Barbus altianalis* is common to Kivu, Edward, George, Victoria and Kioga, with a subspecies in Kivu, another in Edward and George, and a third in Victoria and Kioga.

* The specimens collected from the Kazinga Channel and Lake George differed in certain characters from typical specimens from other African waters.

This species forms a most interesting comparison with the pelagic *Engraulicypris argenteus* of Lake Victoria, which was found to have pelagic eggs and fry during the Lake Victoria Fishing Survey (Graham, 1929, p. 154). In 1930 another species of *Engraulicypris*, *E. stellae* (Worthington, 1932 *c*), was found in Lake Rudolf, and another species exists in Lake Tanganyika, both of which also lead a pelagic existence. In Lake Edward there is no *Engraulicypris*, but *H. pelagicus* has taken on its role in the ecology in contrast to all other species of *Haplochilichthys*, which inhabit rivers or the inshore waters of lakes.

Haplochilichthys analis.

This is another new species from the Lake Edward basin described by Worthington (1932 *c*); it was not obtained from the lakes themselves, but from the rivers Niamweru and Ruampuno, which flow into Lake Edward from the east, and from a river near Malabunde in the Belgian Congo, which flows into the upper reaches of the River Semliki.

Its size is still smaller than the last, not exceeding 33 mms. It is of no economic importance.

Haplochilichthys pumilus.

Specimens of this little fish, which grows to a size of about 55 mms., were obtained from the swamp bordering the northern shore of Lake George. The species was previously known only from Lakes Tanganyika and Victoria. It is of no economic value.

Family : CICHLIDÆ.

Tilapia nilotica.*

Common in the Nile system from the Murchison Falls and from Lakes Edward and George to the delta; also from West Africa—the Senegal, Niger and Chad basin, Lake Tanganyika and the Upper Congo, certain of the East African rivers, and the fresh waters of Syria.

This is the same species as the Ngege of Lake Albert which was dealt with by Worthington (1929, p. 90), but its habitat in Lakes Edward and George is different from that in Lake Albert. In Lake Albert it is restricted to the inshore waters, due to the predacious fishes, particularly *Lates albertianus*, which prevent it straying far from shore. *Lates* is absent from Lake Edward and so *Tilapia* is free to wander into the open water. The typical habitat, however, is the comparatively shallow inshore waters where there is abundant food and to which the fish resort for breeding purposes. The numbers of *Tilapia* become conspicuously less towards the open water areas, and the species does not occur in the deep water of Lake Edward except occasionally at the surface.

From the fisheries viewpoint this is the most important fish in Lakes Edward and George. The supply available and methods of capture are discussed in later sections (pp. 34–42).

In common with the other members of the genus in Lakes Victoria, Kioga, Baringo, etc., the food consists for the most part of minute animals and plants, but *Tilapia nilotica* favours larger food on the whole than *T. esculenta* of Lake Victoria, which feeds almost solely on the phytoplankton. Many stomachs were studied in the field, and detailed microscopic examinations of 13 were made in the laboratory. These were chosen from different localities and showed plainly how the food varies

* On writing this section I was under the impression that there was only one species of *Tilapia* in Lakes Edward and George. Miss Trewavas has now (October, 1932), found a second closely related species among the specimens collected from Lake George.

Owing to the absence of large predacious fishes referred to above, damaged or deformed fishes are frequently enabled to live in Lake Edward, whereas in Albert or Rudolf, where there are Tiger-fish and Nile Perch, conditions of life are much harder and such forms are killed off immediately. Thus in Lake Edward deformed examples of *Tilapia* were frequently observed. One fish, for instance, was completely blind in both eyes, the eyes being healed over with skin. Mouth deformities are common also, and one example, whose head had been broken and torn in youth, could not open its mouth, but obtained nutriment through a hole which had been torn below the lower jaw. Such curiosities were probably the result of attack by *Clarias* or *Protopterus* during youth. Oddly enough the deformed fish were usually in just as good condition as undamaged examples.

Tilapia is remarkably free from parasitism. None was caught with worm cysts in the flesh and very few worm parasites were found in the body cavity or gut. Occasionally fatty tumours were found in the tail region, and a few specimens were carrying fish lice (*Dolops ranarum* and *Argulus africanus*).

Tilapia eduardiana.

The inclusion of this species in the Lake Edward list rests on specimens collected from the foothills of Mt. Ruwenzori (not from the lake itself) by Mr. R. B. Woosnam's expedition of 1904. These were described as a species distinct from *T. nilotica* by Boulenger.

Haplochromis, Schubotzia and Astatoreochromis.

The collection of Cichlidæ other than *Tilapia* brought home by the expedition has been studied by Miss E. Trewavas, who has found, as Table 4 shows, 11 new species and 2 new subspecies from Lakes Edward and George. The new forms will be described in a forthcoming paper among the scientific results of the expedition in the Journal of the Linnean Society of London.*

Twenty-eight species are now recorded from Lakes Edward and George, of which 21 are endemic and the other seven are known elsewhere only from Lake Victoria (two of these are represented in Edward and George by endemic subspecies).† All of these fishes are quite small, the different species ranging in length from about 10 to 25 cms. in length. None of them is ever likely to be the subject of a fishery, but many of them are of indirect economic value in providing food for the predacious fishes—*Clarias*, *Bagrus* and *Protopterus*.

These small Cichlids live in the shallow inshore waters; none were discovered in the deeper parts of Lake Edward, though, by analogy with Lakes Victoria and Albert, some forms of *Haplochromis* might be expected to live at the bottom in fairly deep water, though not below the thermocline.

The food of the different species is very diverse. Those with small mouths and pointed pharyngeal teeth are microphagous like *Tilapia*, feeding on minute plants and animals floating in the water or adhering to the shore weeds and bottom deposits. Some species have flat-headed pharyngeal teeth for the purpose of crushing little molluscs which they eat. Others again, particularly the larger species, have large prognathous jaws resembling those of perch, and are predacious, feeding on the smaller *Haplochromis* and the fry of *Tilapia*.

Many of these fishes are prettily coloured, and most exhibit considerable sexual dimorphism; the males can usually be distinguished by their brighter colouring, black pelvic fins and bright spots or ocelli on the anal fins. So far as is known all of them breed in the same manner as *Tilapia*: a nest is hollowed out in the bottom deposit near the shore, and the female carries the eggs and young fry in her mouth.

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* I am indebted to Miss Trewavas for sending me certain preliminary notes on the collection; these have been incorporated in Table 4 and in this section of the report.

† One species, *H. multicolor*, has been recorded also from the lower parts of the Nile system.

about 100 fish per day, mostly *Tilapia*. Almost all of these are now sold at Katwe for 5-20 cents per fish according to size, but I understand that in previous years lorry loads of dried fish were occasionally taken from Katwe to the Uganda markets as far afield as Kampala. In addition a few natives with two or three canoes carry on intermittent fishing operations with gill-nets.

Kaianda is the only other fishing station on the Uganda part of the north Lake Edward shore. Mr. Beadle visited the village and the following is taken from his notes. There is a shallow lagoon at Kaianda 1-1½ metres in depth, about half a mile across, shut off from the main lake by a narrow sand bar 30 yards wide and 4 ft. high. On this sand bar the natives have constructed a village of some seven huts. They wade about in the lagoon and catch *Tilapia* and *Haplochromis* by means of conical baskets fitted with hand-holes at the top. Realising that the fish supply in the lagoon would quickly become exhausted, the natives take much trouble in keeping a number of channels across the sand bar open to the lake. This enables fish from the main lake to enter the lagoon, which they undoubtedly do for purposes of feeding, since the lagoon water contains a very abundant phytoplankton.

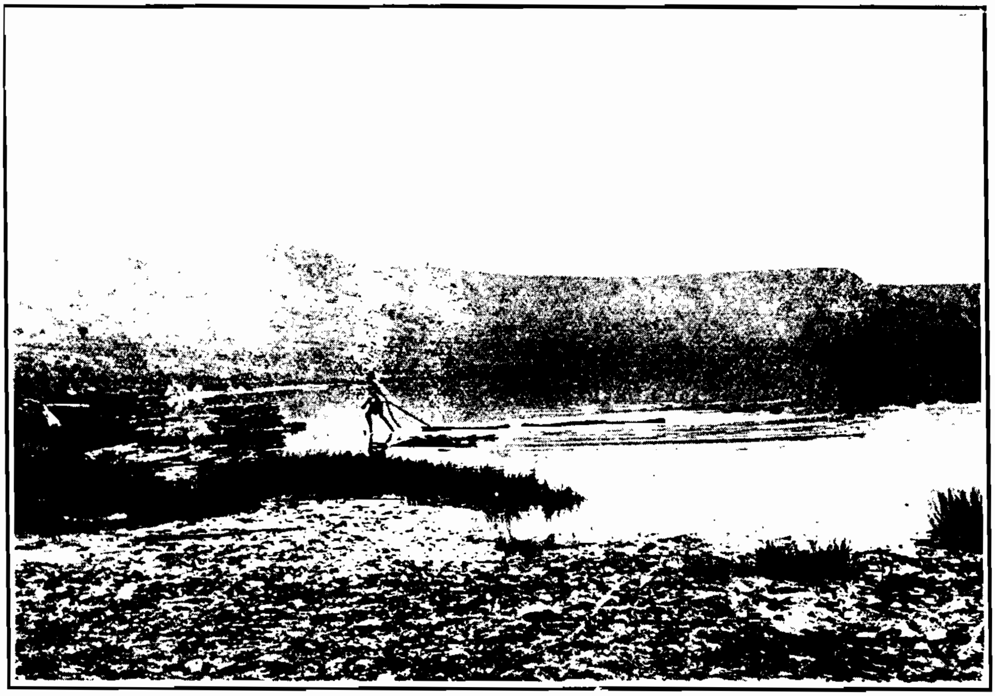
At the mouth of the Ishasha River on the Uganda (north-east) bank there is a native settlement of people who call themselves Wakingwe, a section of the Banyankole. These people live mainly by agriculture, but there are a few fishermen who construct rough oblong-shaped rafts of ambatch trunks, and spear *Clarias* and *Protopterus* in the shallow water. They have no canoes.

The adjoining Congo tribesmen of the south-west bank of the Ishasha construct fences fitted with basket traps across the river near its mouth. These fences, which are very similar to the " keks " of the Lake Victoria rivers, catch *Barbus* ascending and descending the river, and during the rainy seasons catch large numbers of *Tilapia*, according to native accounts.

Another Congo settlement, a little south of Katanda, fishes the shoreline with large basket-traps set among the reeds. These traps capture considerable numbers of *Tilapia*. Owing to recent outbreaks of sleeping sickness the population of the western Congo shore has recently been removed. The remains of villages with large banana plantations, which were being ravaged by elephants, were located at some four or five sites underneath the Congo escarpment where small fans of flattish land have been built out into the lake by river torrents.

Another group of Congo people fish the upper reaches of the Semliki River, a few miles north of its exit from Lake Edward. These people live up in the hills to the west and only visit the river for a few weeks at a time. They construct long V-shaped fences of brushwood in the shallow parts of the river, the apex of the V pointing down stream. The fences are not fitted with basket traps, but the fishermen wade into the water at night-time with lights, drive the fish to the apex of the V, and then catch them with hand-hole baskets. *Barbus* is the fish most often caught by this method.

At the south end of Lake Edward, at the village of Kamande, a few miles north of the mouth of the Ruindi River, there is a large organized fishery in progress, which is run by the Congo authorities for the purpose of supplying food for the workers at the Butembo and Mohanga gold mines. This is comparable to the large fishery at Kasenyi on Lake Albert, similarly organised by the Belgians to provide food for the gold mine workers at Kilomoto. Unfortunately there was no opportunity during the expedition to visit the extreme south end of Lake Edward, but for



[Photo by S. W.

Fig. 7.—Katwe salt lake.

[Photo by F. B. W.

Fig 8.—Hand basket fishing on Lake George.

disregarded, but the range of sizes caught by the 5-inch and 7-inch is important, and is shown in the histograms of Figure 11, which have been prepared from statistics obtained from these lakes. For comparison a group of adult fish caught by a method which is not selective with regard to size (*i.e.*, native basket traps) has been plotted in the same way. The histograms show that the 5-inch net catches fish which are on the whole somewhat smaller than full-grown, and the 7-inch catches fish which are on the whole larger than the normal. It would therefore seem that the most satisfactory net for these lakes would be an intermediate between the 5-inch and 7-inch, but the introduction of such a net would involve considerable difficulties in administration and control, and therefore I consider the 5-inch net, of which there is always a large supply available for the Victoria fishery, to be the most suitable. Fish caught by it range in length from 27-45 cms., the average being about 34 ; these are not immature fish since breeding *Tilapia* were found to range in length from 24-46 cms. for the females, and 31-43 for the males.

Quantity of Tilapia available.

The abundance of *Tilapia* in different areas is shown by the number per net fishing, *i.e.*, the number of fish caught in one net fished for one night.

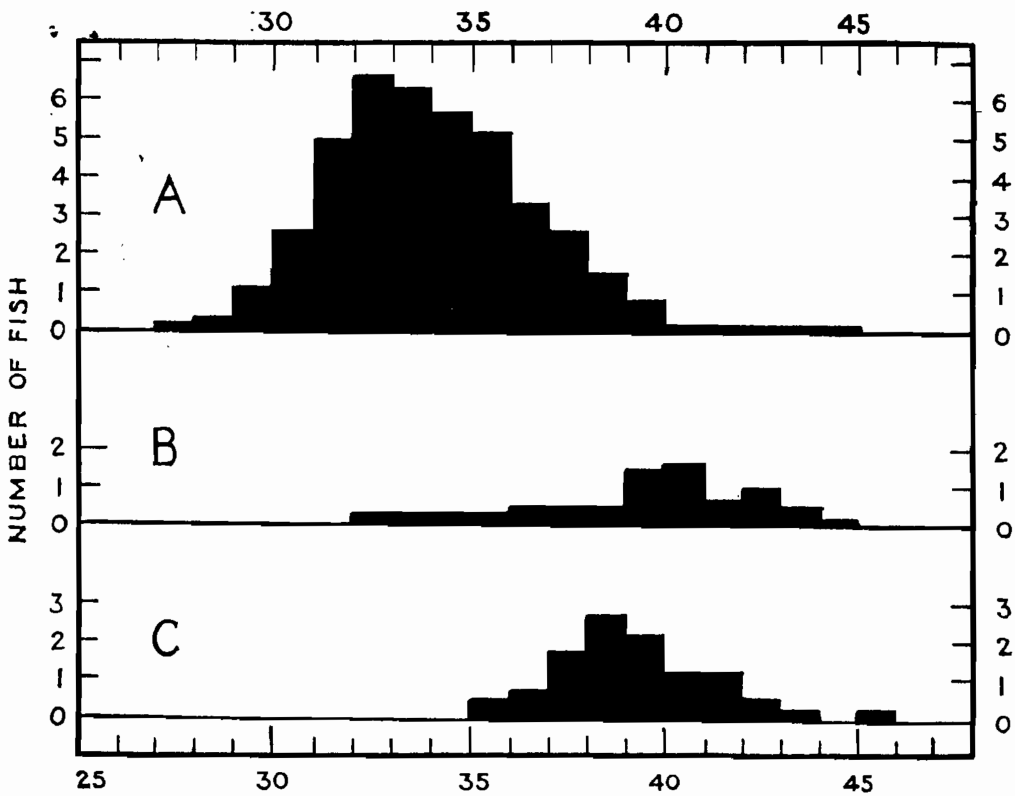


FIG. 11.

A.—SIZE OF *Tilapia* CAUGHT BY THE 5-IN. GILL-NET.
The graph represents the average catch (41½ fish) of 18 net fishings.

B.—SIZE OF *Tilapia* CAUGHT BY THE 7-IN. GILL-NET.
The graph represents the average catch (8¾ fish) of 13 net fishings.

C.—SIZE OF A GROUP OF ADULT FEMALE *Tilapia* CAUGHT BY A METHOD WHICH IS NOT SELECTIVE WITH REGARD TO SIZE (*i.e.*, BASKET TRAPS).

Predacious Fishes.

In a lake which is in a natural state, that is, in which a fishery has not been developed, there is a natural balance between the microphagous fish, such as *Tilapia*, and the predacious fish, which are represented in Lakes Edward and George by *Bagrus*, *Clarias* and *Protopterus*. If a fishery is started for the microphagous forms and the predacious forms are left to themselves, a reduction in stock of the former will in time result in a serious reduction of food supply for the latter. This tends to an increased onslaught on the microphagous forms by the predacious, which may lead to disaster. Something of this sort has probably occurred in Lake Victoria and has led to the recent serious decrease in the supply of *Tilapia*.

In the case of Edward and George, which are still in their virgin state of production, it should be possible to prevent such an occurrence from the outset by proper control. One method already mentioned is to make reserves of the breeding areas, by the prevention of fishing: but another method, which has the advantage of increasing, rather than reducing, the total product of the fishery, is to fish the predacious forms at the same time as the *Tilapia*.

It so happens that the predacious fishes of these lakes are readily eaten by natives, if not actually preferred to *Tilapia*, so there should be no difficulty in establishing a fishery for them. Moreover, the 5-inch gill-nets recommended for *Tilapia* also catch predacious fishes to some extent, particularly the *Bagrus*.

Gill-nets for Bagrus.

Bagrus is not a shallow water fish, and therefore may be disregarded in Lake George, the Kazinga Channel and the shallower parts of Edward, although one or two per net fishing were usually recorded. It is on the edge of the water marked red on Map 2 that *Bagrus* occurs in fishable numbers and therefore deserves attention. The following Table gives the analysis of catches with the 5-inch net.

TABLE 11.

CATCH OF *Bagrus* PER 5-INCH NET FISHING.

Position.	Depth in ms.	No. of net fishings.	Catch per net.
Lake Edward, 2½ miles from Kz. Chl.	8·3	1	14
Lake Edward, nr. Kisenyi spit ...	8·5	1	5
Lake Edward, nr. Kanyamwongo spit	8·8	1	29
Lake Edward, nr. Kanyamwongo spit	4·6	1	14
Lake Edward, west shore	15·0	1	4
Lake Edward, nr. Semliki source ...	3·5	1	6

The numbers of the last column are small compared with the numbers of *Tilapia* caught in the 5-inch net, but the average size of these *Bagrus* was about 54 cms. length and 1·3 kgs. weight compared with 34 cms. and 0·9 kgs. for *Tilapia*. Many of the *Bagrus* caught with gill-nets are immature fishes, so that continued netting of them may reduce the stock, but *Bagrus* is of small importance compared with *Tilapia*, and, in view of its predacious habits, a reduction in the stock would react beneficially on the *Tilapia* fishery.

The conclusion reached is that it will be well worth the while of fishermen to extend their activities with 5-inch gill-nets into the open water of 5-20 ms. depth in Lake Edward, for the capture of *Bagrus*, and, indeed, this should be encouraged since it may improve the *Tilapia* fishery.

Long-lines for Clarias and Protopterus.

The other predacious fishes, *Clarias* and *Protopterus*, are of such a shape, being long and thin, as not to be entangled easily in gill-nets. Nevertheless they were caught occasionally as a result of entering the nets to feed on *Tilapia* previously entangled. Moreover, a number of very large *Clarias* were caught by gill-nets in a remarkable way. *Clarias*, like most other fishes, swallow their prey head-first, since the numerous sharp backward projecting spines on the *Tilapia*'s dorsal fin prevent the reverse method. Accordingly, in attacking a *Tilapia* caught in the net, the *Clarias* takes it by the head which is projecting through the meshes, and in swallowing draws part of the net into its mouth. Then in an attempt at regurgitating the net the dorsal spines of the *Tilapia* pierce the gullet or sides of the mouth, and the *Clarias*, caught as though by a barbed hook, is choked. *Protopterus* is never captured in this way since it can shear through fish and net alike with its large cutting teeth.

Far more effective than gill-nets for the capture of these two species are long-lines or night-lines. The typical long-line consists of a stout cord stretched at the surface, usually between two buoys which are securely anchored. At intervals of about two fathoms along the cord, short lines or snoods are attached, fitted with baited hooks. The long-line is left in the water over night or throughout the day and examined at intervals to remove the fish caught and to rebait the hooks.

This method is already practised by the fishermen at Katunguru, but it might be improved by the introduction of better hooks than those available at present. Large-sized Conger hooks fitted with swivels, which can be bought cheaply from wholesale firms, are the most suitable. The best and most convenient method of fishing is to attach one end of the long-line to the shore and to lay it out on the surface to an anchored buoy. The type of bait does not matter materially; portions of meat are perhaps the most alluring, but cut up fish or whole small fish were found to be nearly as effective. Long-lines have considerable advantages over gill-nets in that they are much cheaper in the first place, have a longer life, and involve less labour in use.

By applying this method a surprisingly good return of fish was obtained, as shown in the last column of the following table.

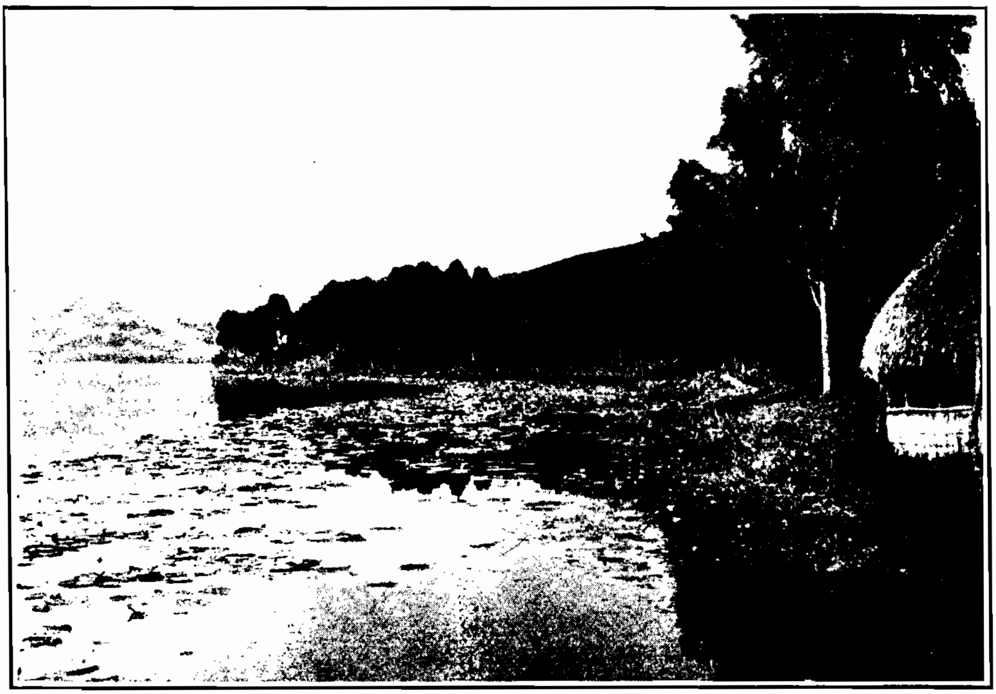
TABLE 12.

ANALYSIS OF LONG-LINE FISHING FOR *Clarias* AND *Protopterus*.

Position.	No. of fishings.	No. of hooks set.	No. of *Clarias* caught.	No. of *Protopterus* caught.	Wt. of fish per hook set. in kgs.
Kazinga Chl.	4	60	22	3	2·9
Lake George	5	97	39	8	1·8
Lake Edward, Katwe Bay and near Kisenyi ...	2	24	13	0	3·8
TOTAL	11	181	74	11	2·4

[Photo by S. W.

FIG. 12.—LAKE BUNYONI, VIEW FROM BUFUNDI CAMP.



[Photo by E. B. W.

FIG. 13.—LAKE BUNYONI, SHORE LINE NEAR BUFUNDI.

residents near the lake, the ducks fluctuate in numbers and it seems probable that they become reduced by migration rather than by intensive shooting.

The Situtunga antelope abounds in many of the swamps which adjoin Lake Bunyoni. According to native accounts large numbers used to be killed previous to the imposition of game laws. The swamps were driven towards the lake, and the Situtunga were speared from canoes as they swam across the lake in attempts at escape.

FLORA.

The flora of a lake is of the greatest importance in the ecology, since all animal life must finally depend for food on plants which obtain their nutriment directly from the inorganic salts and CO^2 in solution. Furthermore, many forms of animals of great value as fish food depend on the bottom growing plants for support and protection. Lake Bunyoni is peculiarly rich in these bottom plants wherever the water is shallow enough. Owing to the steep shelve of the lake floor the plants are, as a rule, restricted to a narrow belt not more than 15 yards wide along the shore line, but owing to the extreme indentation of the shore, the lake as a whole contains a great quantity of plants.

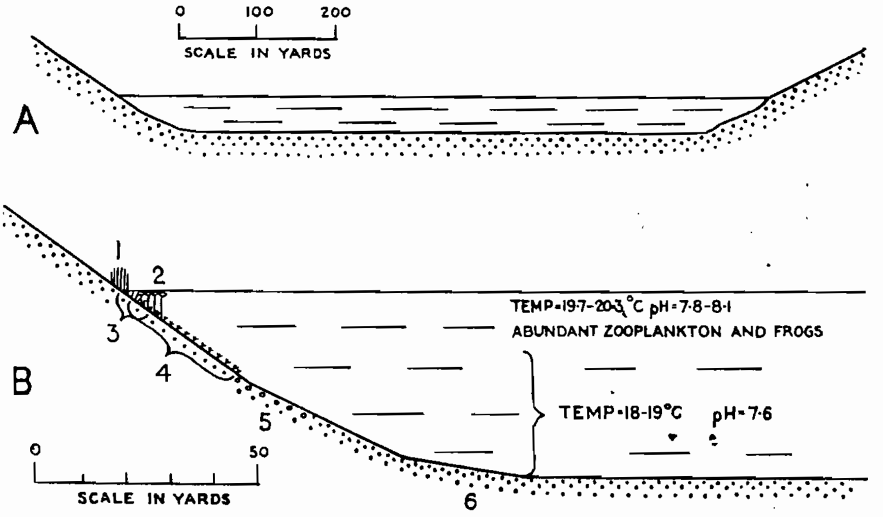


FIG. 14.—DIAGRAMMATIC CROSS-SECTION OF LAKE BUNYONI.
A.—Across the lake near Bufundi.
B.—Enlargement of part of A.
1. Reeds at water's edge.
2. Water lilies.
3. Water weeds (*Potamogeton lucens*, *P. pectinatus* and *Hydrilla verticillata*).
4. *Chara fragilis.*
5. Black mud and stones.
6. Black mud.

The distribution of the bottom plants is indicated in figure 14*. *Chara fragilis* Desv., a member of the algal family Characeæ, is the most abundant. It grows from quite shallow water down to a depth of about 16 metres, below which there is no bottom plant growth. It is characterised by filamentous leaves and forms a dense mat on the bottom from six inches to a foot thick. *Potamogeton lucens* L. and *P. sp.* probably *pectinatus* L. (Zannichelliaceæ) are characterised by a stout leafy foliage.

* I am indebted to Mr. J. Ramsbottom of the British Museum (Nat. Hist.) for the identification of these plants.

and grow only in very shallow water, and *Hydrilla verticillata* (Vallisneriaceæ), whose leaves are divided up into filaments, grows in water from about ½ to 2 metres. Water-lilies, which were found to grow in water as deep as 5½ metres, border almost the whole shore-line, and among the water-lilies float growths of *Utricularia*, the bladderwort.

In addition to these larger plants, bunches of filamentous green algæ grow in many places as epiphytes, and the larger plants are covered in the shallow water by a film of minute Desmids and Diatoms*. In the swamps masses of blue-green algæ flourish.

The edge of the swamps is formed by reeds and papyrus floating in water from 2–3 metres deep. From time to time small portions of the swamp are blown away and travel across the lake as floating islands, but floating islands are not characteristic of Lake Bunyoni, as they are of many other Uganda lakes.

In the open water there was not much phytoplankton at the time of the expedition, but species of the diatom *Synedra* were present. There must be a quantity of exceedingly minute organisms and detritus which serve as food for the zooplankton which is eaten by frogs, and these in turn by otters.

INTRODUCED FISH.

There is a considerable native population around Lake Bunyoni, notably near Bufundi, and along the south-eastern arm. This is composed of watermen, who have fast dugout canoes, and use the lake as the highway for communications. Without fish the lake was, to a large extent, a wasted area of water. Therefore from about 1917 onward various District Commissioners stationed at Kabale have made or attempted to make fish introductions. My information with regard to the history of these introductions has been provided by Capt. Tracey Philipps who was District Commissioner, Kigezi in 1919–20 and again in 1928–29, Mr. A. B. Trewin who has also been D.C. Kigezi on several occasions ; Dr. Sharpe of the C.M.S. Mission in Kigezi, and the native staff of the Kabale district office.

The Nsonzi or little Cat-fish (*Clarias carsonii Blgr.*) History of the Fishery.

Tracey Philipps (1923) has summarised the early days of fish introduction to Lake Bunyoni. In 1919 he obtained the Nsonzi from the Kivu district of the Belgian Congo and from Ruanda. These were deliberately introduced with a view to starting an economic fishery, but at first they were regarded by native lakeside dwellers with portentous mistrust. The Nsonzi seems to have multiplied very rapidly, and the natives soon became accustomed to the new food supply and the new occupation of fishing. In the following years an export fishery assumed large proportions and a comprehensive system of marketing (the taxes being expended on rest houses and sanitation for the numerous buyers) and of examination of exports by native inspectors, was operated. After a time it appeared evident that the increased activities of traders were in danger of exhausting the supply of fish, so in 1923 Mr. Elliott, when acting D.C., imposed a 3 months' closed season from June to September each year. This did not seem to afford adequate protection, so in 1927 Mr. Trewin imposed a whole year's closed season to ensure covering a complete breeding season of the fish. On re-opening at the beginning of 1928 the fishery assumed very large

* These have been identified by Miss F. Rich as belonging to the genera—*Synedra, Cocconeis Cymbella, Gomphonema, Rhopalodia, Surirella, Epithemia* and *Navicula*.

carried up to Lake Bunyoni to the fish ponds. The introduction was successfully accomplished towards the end of 1927 as is shown by the following extract:—

Copy of letter No. 459/100 of 22nd October, 1927, from the District Commissioner, Kigezi, to the Provincial Commissioner, Western Province.

> "With reference to my para. 7, September Quarterly Report, and para. 15a June Quarterly Report, I am glad to state that I at last have been successful in introducing 270 young Ngege fish into Lake Bunyoni. They have now been there for a fortnight and no casualties to date have been observed."

For three months these fish were observed alive in the fish ponds; then they vanished, and nothing was heard of them later, so it was presumed that they had escaped into the lake.

Subsequent to Trewin's introduction, Tracey Philipps, who returned to Kigezi district in 1928, had other fish ponds constructed at Mukko at the western end of the lake; and the only exit to the lake, the stream which flows intermittently over the lava flow near Mukko, was similarly fenced. Then in 1929 more young *Tilapia nilotica* were caught in the Ishasha and Ntungwe rivers, and, by a system of native runners in relays, were placed alive in the fish ponds. In 1930 a number of these fish were loosed into the open lake.

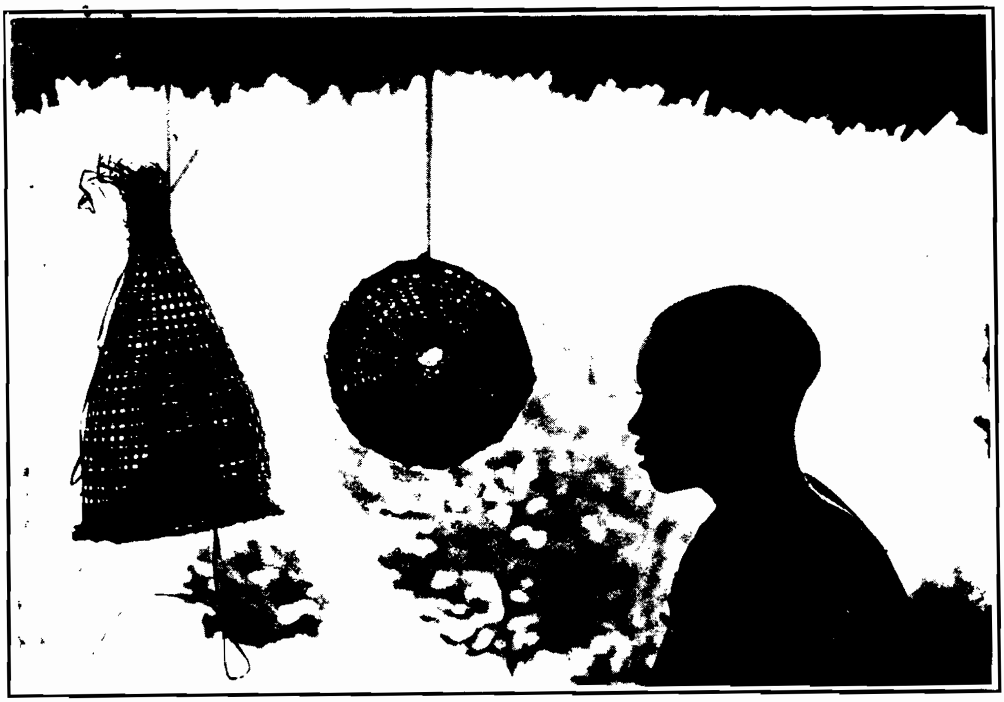


FIG. 17.—BASKET TRAPS USED IN THE NSONZI FISHERY. [*Photo by E. B. W.*

According to the available evidence, no trace of the *Tilapia* has been seen since 1930, but a few large "mali" (*Clarias lazera*) have been observed in the lake, and it has been presumed that these were introduced with the *Tilapia* from Lake Edward by mistake, and have flourished.

During our fortnight's work on the lake, fishing with gill-nets of various meshes was carried out on most nights. All but one of these fishings were negative in so far as fish are concerned, but in one fishing a single adult *Tilapia*, a breeding female, was captured, close to the weeds by the shore of an island near Bufundi. This fish

PART III.—LAKES NAKAVALI, KACHIRA AND KIJANEBALOLA.

(*Map* 4, *p.* 83.)

A fortnight was devoted to these lakes, from 26th August to 9th September. The time was apportioned as follows:—

Lake Nakavali.—26th August to 2nd September, camping at the south end of the lake.

Lake Kachira.—3rd to 4th September, camping near Kateti hill.

Lake Kijanebalola.—5th to 9th September, camping at Kamukalo near the south shore.

The 16-foot motor boat was transported to the first and last lakes, although it involved several miles head porterage to the latter.

PHYSIOGRAPHY.

The three lakes, together with Lake Mburo north of Nakavali, and Lake Chanagwora* near Lake Kijanebalola, form a system of open water areas in a huge papyrus swamp. The chief affluent is the River Ruizi from the west, which itself connects at its headwaters (the Ruakatengi swamp) with the River Ntungwe flowing into Lake Edward. The system is drained, at any rate on occasions, by the River Kibali to the east, which flows into Sango Bay, Lake Victoria. Thus there is virtually a water and swamp connection between Lake Edward and Lake Victoria.

Mr. Wayland has pointed out that there has been a reversal of drainage at the eastern end of this water connection, and that the same valley, at one time in the past, contained one of the series of east to west rivers, which found their origin in high land to the east of the present Lake Victoria, and flowed to the Congo system and so to the Atlantic Ocean.

Floating islands, consisting of portions of sudd broken away from the shore, are features of all the swampy lakes under consideration; and according to the distribution of the sudd along the shores, the lakes vary in size and shape from year to year. Thus, at the time of the land office survey of Koki District in August, 1929, there was very little open water in Lake Kijanebalola, whereas in September, 1931, the area of open water was much greater, approximating to that shown on Map 4.

We found that Kijanebalola was about the same depth, 4 to 4·8 metres all over, even very close to the shore, so that it is unlikely that the lake ever dries up completely. Nevertheless there is some evidence that the actual water level varies from year to year. Mr. W. C. Simmons, of the Uganda Geological Survey, considers that there is a more or less definite cycle, as in the case of other Uganda lakes, and that about every 12 years the level reaches its maximum and overflows into the Kibali River. If this be so, for periods of ten years the lake is without an outlet, which would lead to a concentration of salts in solution, to be diluted again when

* Lake Chanagwora was, in September, 1931, separated from Kijanebalola by a mile or two of swamp; the two lakes are together named Kijanebalola on the published maps, but the individual name Chanagwora was obtained from several natives on the spot.

PART IV.—LAKE NABUGABO.

(*Map 5, p. 85.*)

A week, from September the 9th to 16th, was spent on this lake. The admirable rest camp, built on the lake shore by the Masaka sport club, afforded a very convenient base for the work. The lake presents several problems for which I am unable to offer explanations; of these, the complete absence of crocodiles and the extraordinary freshness of the water (*i.e.* the absence of salts from solution) are the most striking.

PHYSIOGRAPHY.

The lake comprises an area of eleven square miles, is oval in shape, with a length of about five miles and width of about three miles. Along the north-west shore there is a stretch of forest with clean sandy beaches running down to the water, on one of which the camp is situated. All the rest of the shore is composed of swamp, which is unlike any other swamp I know of in East Africa, being remarkably acid in constitution and characterised by *Sphagnum* moss, reeds and an associated flora, instead of by the usual *Papyrus*. The only area of papyrus around the lake shore is close to the mouth of the Juma River at the north-east corner.

There can be little doubt that Lake Nabugabo was once part of Lake Victoria, and that it was cut off by the growth of a sandspit from the south, caused by the northerly current and by wave action along the Budu coast. The strip of land so formed, which is about $\frac{3}{4}$ of a mile wide in the narrowest part, is marked as swamp, called the Lwamunda swamp, on the published maps, but the part along the Lake Victoria shore is forest covered, and there is no water connection between Nabugabo and the great lake.

Lake Nabugabo is shallow. The deepest sounding made was 4·6 metres, exactly in the middle of the lake. On the whole the water along the north-east shore tends to be a little deeper than that on the other side of the lake (Map 5).

The water as a whole has a temperature of about 23°C., about the same as Lake Victoria. During the heat of the day the surface warms up to 25°C., and doubtless higher temperatures might be recorded from the water close to the shore on quiet days. Nabugabo is affected by the regular daily winds which blow off Lake Victoria. At the time of our work these winds, blowing from the south-east, started each day at about 10 a.m. and continued till sunset, causing a choppy sea and surf along the north-east shore.

The alkaline reserve, determined in various parts of the lake, was found to vary between 0·00027 and 0·00029 normal. This, compared with an average figure for Lake Victoria—0·0012—shows that Lake Nabugabo contains remarkably fresh water. pH in the open water ranged from 8·2 at the surface to 7·3 at the bottom during the day. This is a wide range, caused by intense photosynthesis in the upper layers. During the night, complete vertical mixing of the water caused a

CONCLUSION.

In conclusion to this Report, I would mention that if the various proposed introductions are carried out, their effects on the lakes in question should be diligently watched. From time to time it may be necessary to impose special regulations referring to the fisheries, or, if the introduced predacious fish are found to be increasing too rapidly, special measures may become necessary to reduce their numbers.

With experimental work of this nature in progress it is all the more important that there should be a scientific officer on the spot capable of taking the necessary steps in control, and therefore, I would further support the remarks on the establishment of a lake fishery authority made by Graham (1929, pp. 33-36), and in my own report on Lakes Albert and Kioga (p. 33). Such an officer could not only take over the development and control of the fisheries of Lakes Victoria, Kioga, Albert, Edward and George, and the supervision of the proposed introductions, but could also carry out further investigations on the smaller lakes and the rivers and streams of Uganda, with a view to further development for economic or sporting purposes.

HYDRACHNIDA.

Limnesia aspera (Koen).

HYRUDINEA.

Glossiphonia conifera (Moore).
Glossiphonia weberi (Blanchard).
Limnatis oligodonta (Johansson).

PORIFERA.

Stratospongilla bombayensis (Carter).
Ephydatia fluviatilis var. *capensis* (Kirkpatrick).

Lakes Nakavali, Kachira and Kijanebalola.

MAMMALIA.

The Hippopotamus occur sparingly in these lakes. Otters were not observed but doubtless occur.

REPTILIA.

Crocodiles occur in some of these lakes, *see* Appendix 2.

BATRACHIA.

Many frogs occur, but the only definite records are :—

Rana galamensis (Durn. and Bibs).
Hyperolius stridatus (Peters).

PISCES.

See page 76.

MOLLUSCA.

Lymnæa elmeteitensis (Smith).
Planorbis gibbonsi (Nels.).
Bulinus trigonus (Mts.).
Pila ovata (Oliv.) var. *emini* (Mts.).

CRUSTACEA.

Various species of Entomostraca, not yet identified.

HYDRACHNIDA.

Georgella incerta (Koen).
Bargena merifica (Koen).
Hydrachna signata (Koen var. *fissa* Lundblad).
Hydrachna inæquiscutata Lundblad.
Diplodontus despiciens (Müll).

OLIGOCHÆTA.

Alma emini.
Others not yet identified.

HYRUDINEA.

Limnatis oligodonta (Johansson).

ROTIFERA.

Numerous species. For list *see* Beauchamp (1932).

admirably suited to them, and there is an abundant supply of fish food. This barrier to the upward movement of crocodiles is indeed slender. The rapids are now in a closed area for sleeping-sickness, but if at any time a forest clearing along the river bank is made to rid the country of tsetse fly and to allow its rehabitation by natives, irreparable harm would be done at the same time by making a path for crocodiles.

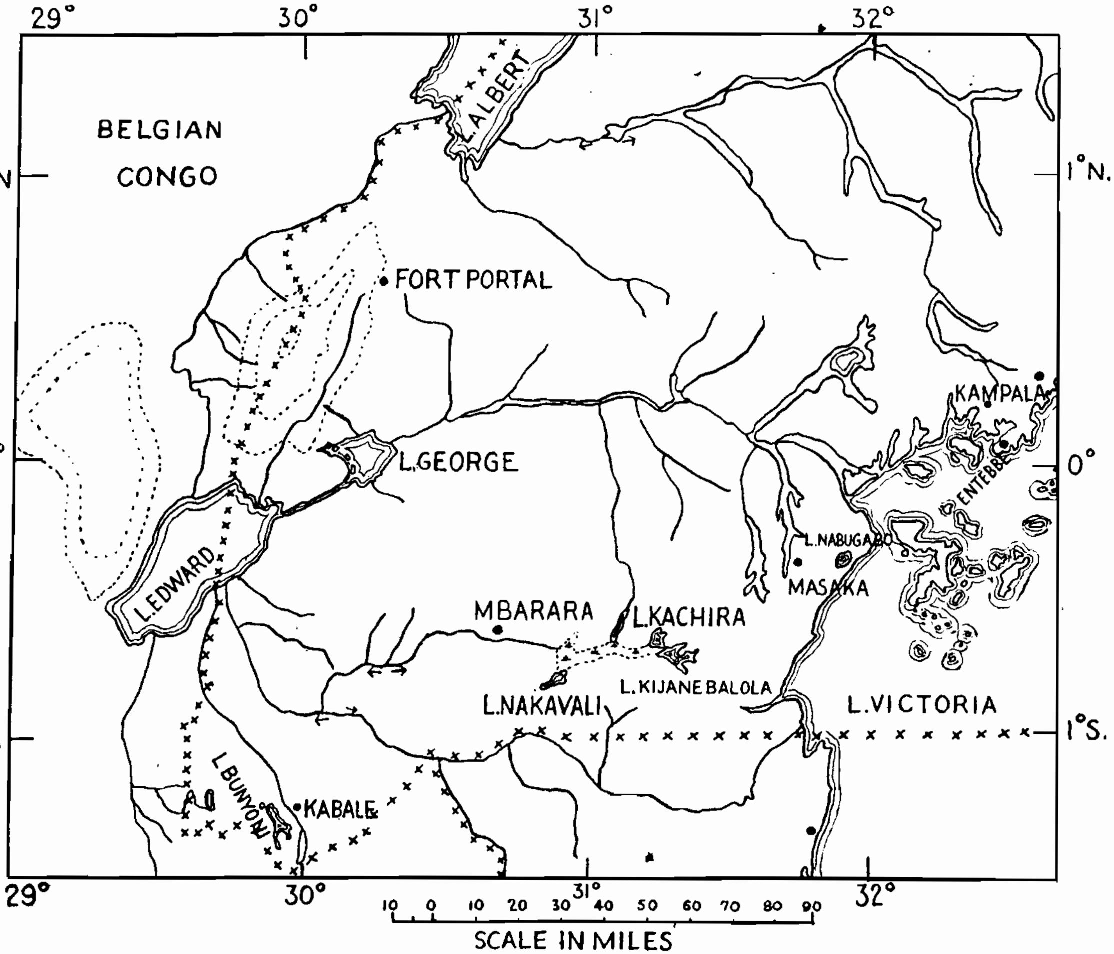
With regard to my conclusion that Lakes Edward and George dried up during the interpluvial arid period, it might be urged that Lake Edward—being deeper than Victoria or any other lake in Kenya or Uganda—would be the least likely to dry up. In this connection the cross-section of the Edward Basin (Worthington, 1932*a*, Maps) is significant, since it shows that the general slope of the rift valley floor from the Ankole escarpment to the Congo escarpment is continued uniformly under the lake. The rifting movements are now known to have continued until quite recent times, and indeed are still in progress, as evidenced by the frequent earthquakes centred about the main faults. It therefore seems quite possible that the floor of the Edward rift valley has tilted in recent times, since the pluvial periods, and that, at the time before desiccation, the lake was not so deep as at present. Nevertheless, there is faunistic evidence that the interpluvial desiccation was much more intense than has previously been imagined, causing the disappearance of nearly all the East African lakes, including Lake Victoria, or at least reducing them to a few mud pools. The detailed evidence for this will be published elsewhere.

The absence of crocodiles from Lakes Kijanebalola and Chanagwora is very remarkable, more particularly in view of their presence in Lakes Nakavali and Kachira, which are further removed from Lake Victoria. All these four lakes lie at practically the same level and are connected by papyrus swamps. There is no doubt that they were desiccated during the interpluvial times like Edward and George, and that the crocodiles found their way into them from Lake Victoria since those times. It must be concluded, therefore, that crocodiles have died out in Kijanebalola and Chanagwora quite recently. According to native accounts the water level of Kijanebalola and Chanagwora is subject to a considerable rise and fall according to the extent of the rainy seasons. Therefore it is quite possible that these lakes have suffered a secondary desiccation during a series of dry years in quite recent times. This may have been sufficient to cause the crocodiles to migrate to a more favourable environment.

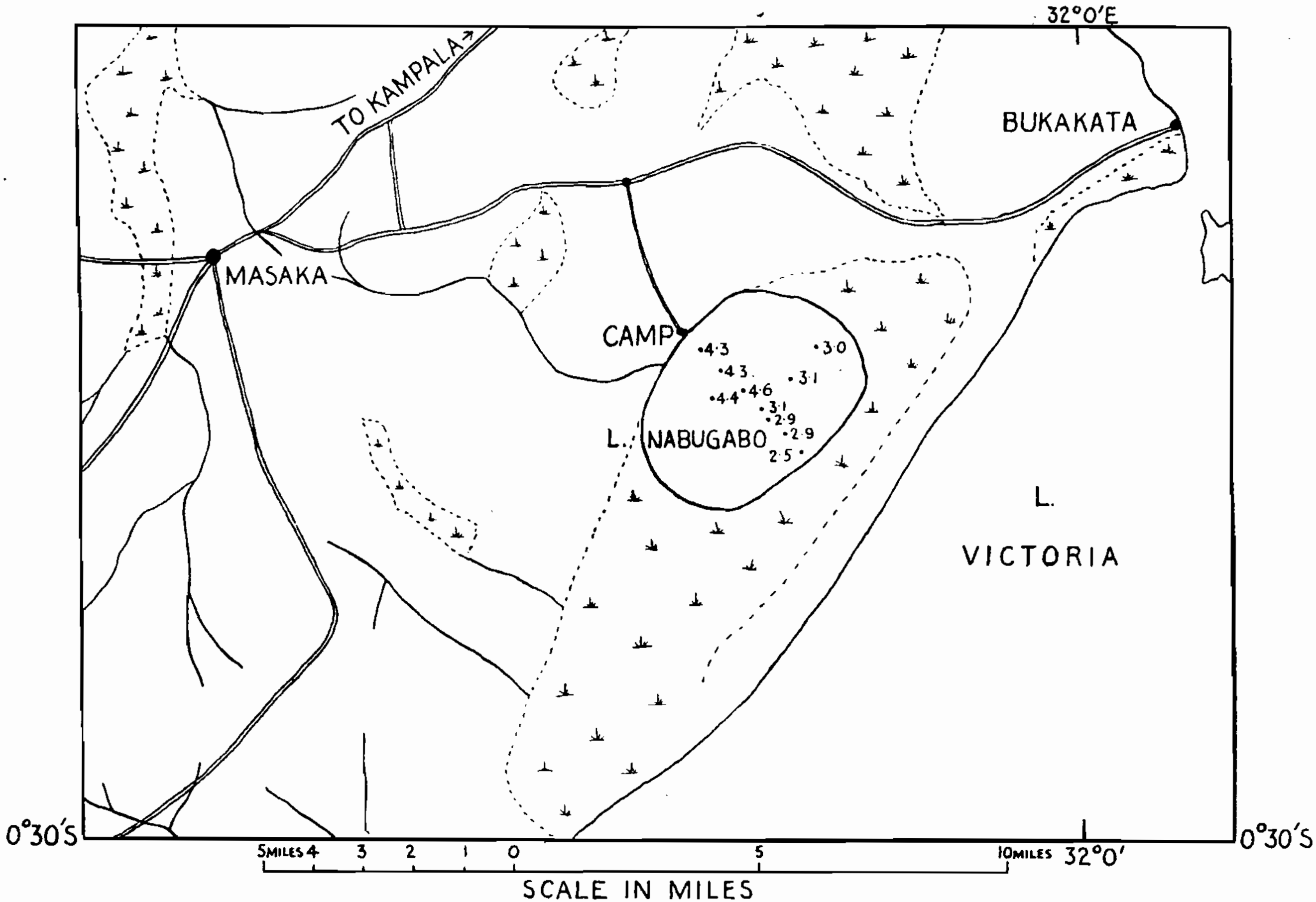
With regard to Lake Bunyoni there is no reason to suppose that crocodiles have ever been present. As mentioned on page 49, this lake is of very recent origin and contains no indigenous fishes. Neither crocodiles nor fishes have yet found their own way into it from other waters.

The absence of crocodiles from Lake Nabugabo is at present a complete mystery. There can be no doubt of its truth, since no native or European has ever seen a crocodile in the lake. Since Nabugabo was originally part of Lake Victoria, which became shut off by the growth of a sand spit, it should contain these reptiles like all the Victoria shores and bays. The crocodiles must therefore have died out for a reason as yet unexplained.

NOTE.—Since writing the above there has been further reference to the absence of crocodiles from Lakes Edward and George in *The Times* (June, 1932). Capt. Salmon's Uganda Game Report for 1932 was quoted as disagreeing with some of my views. This was followed up by a letter from Sir William Gowers stressing the failure of any chemical hypothesis to explain the sudden change in the Semliki River from crocodiles to no crocodiles; a letter from myself defended the views expressed above; and a letter from Capt. Philipps reverted to the question of water temperature as a possible controlling factor.



Map 1.—Uganda Protectorate to show the Positions of the Lakes Investigated.



Map 5.—Lake Nabugabo, showing Soundings (in metres) made during the Expedition.