REPORT ON THE SURVEY OF NORTHERN LAKE NYASA

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OF NORTHERN LAKE NYASA
1954-55

by the

Joint Fisheries Research Organization

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CONTENTS

CHAPTER FIVE

THE FISHERIES OF THE NORTHERN LAKE

LIST OF ILLUSTRATIONS

Plate V

A. The gorge at Chiwandama, Luweya river, where Sanjika (*Barilius microcephalus*) are caught on their upstream breeding migration.

B. Breeding Sanjika being lifted from slack water in crevice of the rock, where they rest before attempting to move further up the rapids. Note the construction of the " Khombe " net.

C. " Mono " basket set in deep water to catch *Synodontis njassae*. Usually baited with dough as fish bait attracts crabs. Near Nkata Bay.

D. Arrangement of canoe for Usipa fishing. The torch-bearer is forward with the netsman close to him, while the paddler sits astern.

Plate VI

A, B, C. A seasonal fishery for breeding *Rhamphochromis* (probably *R. longiceps*) at Bana near the entrance to the lagoon (obstructed by weir, C). Small seines are hauled by the two men.

D. A large beach seine being hauled in the south-west arm.

E, F. Fishing in Kambwe lagoon near Karonga with scoop nets, and baskets are stabbed vertically downwards, trapped fish being removed through an aperture halfway up.

G. A " Mono " basket trap filled with crabs, the result of baiting with fish bait, Nkata Bay.

LIST OF FIGURES

Chapter Two

Chapter Three

Chapter Four

Section 2

Section 3

Chapter Five

Section 1

Section 2

Maps and Charts

FOREWORD

The survey of northern Lake Nyasa, of which this is the report, came to an end in November, 1955, and the matter which now appears was written in 1956 and early 1957. Delays of one kind and another have prevented the earlier publication of the report, but work on Lake Nyasa has gone on. The four authors, however, have not altered the words which they wrote then nor sought to modify in any way the nature of the statements made. This work remains almost entirely as it was originally written in 1956, and the main exception is that published papers of the several authors' own, which were either in press or in preparation in 1956, are here referred to in full. No references to literature later than 1956, with these exceptions, are made.

A lapse of five or six years, in which research on Lake Nyasa has continued has made parts of this work a little out of date to those who are familiar with the hydrobiology of the lake, but none of the information contained herein has been published before, and much of the data is basic to the work which has since been done. This applies especially to the work concerning the mathematical theory of the operation of gill-nets and its use as a fisheries research tool, a subject which was in its infancy in 1956 but in which increasing interest is nowadays being taken. Also, it applies to the check list of fishes, a revised and expanded version of which is being published separately by the National Museums of Southern Rhodesia and is at present in press.

Summaries of the work done on Lake Nyasa since the survey by the Joint Fisheries Research Organization, and references to its later literature, are to be found in the J.F.R.O. Annual Reports No. 8 for 1958 *et seq.*, which are printed by the Government Printer, Lusaka, Northern Rhodesia.

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CHAPTER ONE

1. Introduction

The authors would like to express their thanks to all the many people who assisted the Organization during its two years' work on the northern half of Lake Nyasa, most of whom it is not possible to mention here by name. Their thanks go to all members of the Nyasaland Government for their help and advice, in particular to Mr. H. J. H. Borley, Mr. K. T. Howard, Fish Ranger, and Mr. A. D. Sanson, *sometime* Fisheries Officer, of the Game, Fish and Tsetse Control Department, and to Mr. C. D. P. T. Haskard, Provincial Commissioner, Mr. M. M. V. Leonard, District Commissioner, and all other members of the Provincial Administration in the Northern Province for valuable help and advice willingly given whenever it was asked for. They are also indebted to Mr. Jollyman and Mr. R. C. Wood for help and the benefit of advice made the more valuable by their many years of experience of the lake. Their thanks go also to all members of the Nyasaland Railways Lake Service for much valuable assistance in regard to the Organization's boats. And finally thanks are due to Mr. J. G. Pike, Senior Hydrological Assistant, who assisted on several hydrographic cruises and drew out charts (Maps 2 to 5) of soundings taken in the northern lake area.

It is also not possible to mention all the research workers who assisted the authors, each in his own sphere, but the authors wish to record their gratitude to all of them and in particular to Dr. Ethelwynn Trewavas and Dr. J. P. Harding, both of the British Museum, for advice on the systematics of fishes and Crustacea, to Dr. C. H. Mortimer, F.R.S., of Millport for advice on the hydrological work, and to Mr. R. S. A. Beauchamp of the East African Fisheries Research Organization, Jinja, for much help, and advice on limnological matters. Mrs. R. H. Lowe-McConnell, out of whose single-handed study of the southern lake the present work was born, was most helpful at all times, and made available to the senior author the notebooks of her survey.

The authors would like also to express their thanks to all other members of the survey team, in particular to Mr. M. P. Gilbert, Technical Officer, without whose skill and devotion to his task of keeping boats, engines and equipment repaired and maintained under the most difficult conditions, the survey would not have been possible, to Mr. A. J. P. Mzumara, the keen and efficient Laboratory Assisant at Nkata Bay, to Miss J. D. Ohms, the Organization's Secretary at Samfya, who re-drew practically all of the graphs and other figures, to the fishermen and Fish Guards, in particular Mr. Langley Phiri, Mr. Blackston Siska, Mr. Kajawa Mwenda and Mr. Akusayinda Banda, for their keenness and hard work, and to Mr. Amos Kabwesha, Clerk to the Organization at Samfya, who typed and retyped the manuscript not once but many times. Outside of the Organization the authors are grateful to the Department of Game and Tsetse Control, Northern Rhodesia, for continued help, especially with regard to the financial accounting, which was done in Northern Rhodesia, and in particular to Mr. T. G. C. Vaughan-Jones and Mr. F. I. Parnell, then Director and Assistant Director of the Department. Finally the authors' thanks are due to Dr. C. F. Hickling, Fisheries Adviser to the Colonial Office, for his helpful interest at all times during the survey.

The survey took place from October, 1953, to November, 1955, a period of two years which in practice proved all too short a period for thorough research to be done on all aspects of limnology and fisheries biology of the northern lake, and it was, indeed, not until well on in 1954 before even some housing and laboratory facilities were available on the lake-shore at Nkata Bay where the team was based. Due to the lack of housing facilities all members of the team had to live on the Limpasa Dambo, ten miles away from the lake on a bad road, and indeed one of them (G. Fryer lived there for the whole of the two-year period. There was a considerable delay, also, in the delivery of the steel survey launch, the *Gigipat*, which eventually arrived at Limbe cut into two pieces, which were skilfully joined together by our Technical Officer. The slow start and short duration of the research survey is, however, offset by the establishment of a substation of the Organization at Nkata Bay, which was visualized when the Joint Fisheries Research Organization was first formed and which is now happily a reality.

The Joint Fisheries Research Organization was formed in 1951 to undertake research into all aspects of fisheries research on the lakes, rivers and other waters, jointly, of Northern Rhodesia and Nyasaland. It was to have its headquarters at Samfya, on Lake Bangweulu, with a substation on Lake Nyasa, and all members of the Organization were to undertake a two-year survey of the fisheries potentialities of the northern part of Lake Nyasa, the southern part having already been surveyed since the war by Miss R. H. Lowe. This report embodies the results of the survey; although presented jointly by all four scientists, each concentrated on a particular aspect while being helped by the others. Thus the leader has edited the work generally and also wrote Chapters 1. 4.1 and 5.4, Mr. Harding wrote Chapter 2, Dr. Fryer Chapters 3 and 5.3, and Mr. Iles the remainders of Chapters 4 and 5. As mentioned above the Organization's work on Lake Nyasa did not come to an end with the end of the survey, and work on certain aspects, in particular the biology and fisheries for Usipa (*Engraulicypris sardella*) and the *Barilius* species (Mpasa and Sanjika) is still continuing as are observations into physical conditions in the lake and work on the *Rhamphochromis* (Batala) fish and fisheries, so that some data on these aspects of the work, while collected in 1953–55, are not included in this work except where mentioned in the Summary of Recommendations and Conclusions (Chapter 1, 2) but will be presented as part of longer term research findings at later date.

The Organization's terms of reference include also fresh-water biological research of a more academic kind, so essential from the long-term point of view, and the scientists were able also to do some work of this nature, which space does not allow of more than brief mention in this report, but which have appeared in appropriate scientific journals, to which references may be found in the reference lists at the end of each chapter. Dr. Fryer in particular concentrated on this type of work, and has contributed greatly to our knowledge of the freshwater crustacea, and made a study of shoreline conditions at Nkata Bay valuable in adding to our knowledge of the ecology of the northern lake littoral. In addition Mr. Iles has revised the *Utaka* group of the lake *Haplochromis* and Mr. Jackson the clariids of Nyasaland, which places our knowledge of these fishes on a sounder footing. It is hoped to continue this more academic research, essential in the long run to a proper understanding and therefore more efficient management of the fisheries, at the Nkata Bay substation, which continues to co-operate successfully with the J.F.R.O. headquarters at Samfya to the advantage of all concerned.

Nkata Bay and the northern half of Lake Nyasa, where most of the survey's work was done, is, with its rugged rocky coastline, great stretches of deep open waters, currents, storms and pounding waves, in many ways more reminiscent of the sea than an inland lake, yet it is these physical attributes that make its potential fisheries less great than the more calm, sandy shallow waters of the south. The difference is only relative, however, and the northern fisheries are capable of great development and form a valuable asset to its peoples. From a scientific viewpoint, too, the northern lake is most valuable and interesting; in its multiplicity of fish species alone Lake Nyasa is at once a challenge and a stimulus to zoological thought. The authors' experience has been greatly enlarged by working there; they are grateful for the opportunity they have had to contribute their small share to the knowledge of Lake Nyasa.

2. Summary of Recommendations and Conclusions

(NOTE. For convenience, the conclusions arrived at with regard to the fisheries of northern Lake Nyasa, and the recommendations which the J.F.R.O. have been able to make to the Nyasaland Government in this regard, are summarized below. In order to implement development of the fisheries as much as possible, and as the Organization worked at all times in the closest co-operation with the Government, recommendations were made from time to time during and after the survey.)

(i) Because of the steep-to and rocky nature of the coast of most of the northern half of Lake Nyasa, the great depth of water, most of which lies below a virtually permanent thermocline and is devoid of oxygen, and the paucity of pelagic species of fish, it is not thought the northern lake has the potential productivity of fish found in the southern half of the lake. Nevertheless a valuable potential does exist and is not fully exploited.

(ii) A deepwater gill-netting fishery of a type not exploited at the present time exists. The main species to be exploited in this fishery are *Bagrus meridionalis*, *Bathyclarias* species, *Mormyrus longirostris* and *Haplochromis heterotaenia*. *B. meridionalis* is the staple species, forming 50–60 per cent. of the overall year's catch in the larger size gill-nets.

(iii) Exploitable depths range down to the thermocline (an average of 60–80 metres) with the substrate mainly rocky. Because of the steepness of the coast this means that in most places nets must be set within a few hundred yards of the shoreline.

(iv) Nets smaller than 4 inches stretched do not give economical catches in this fishery and the optimum size is around 5 inches.

(v) Nylon nets are recommended in preference to flax or terylene.

(vi) The recommended method of mounting is 100/70 yards or slightly more, rather than the more usual 100/50–60. For this deep-set fishery the optimum mesh size is 26–30 meshes.

(vii) As this type of fishery was not known in the northern lake there appear to be distinct possibilities of its development. Techniques of mounting and laying are described in the text, and a total potential of the order of two tons of fish per mile of coastline per year is estimated.

(viii) There is a considerable variation in catch throughout the year, the best times being during the rainy season.

(ix) Because of crab and rock damage, as well as normal deterioration and wear and tear, particular attention must be paid to care and maintenance of nets.

(x) At certain places not fishable by these methods, particularly at Bana and Karonga, there exists a potentially important gill-net fishery for sand-frequenting species, particularly *Labeo mesops*, which are not at present extensively exploited by this method.

(xi) The lake crab (*Potamon lirragensis*) has proved to be a major pest in the gill-net fishery, destroying fish and nets. These are easily caught in wicker basket traps, are edible and provide a source of calcium carbonate. If possible a fishery for them should be instituted, possibly for crushing up with maize or rice hullings to form a chicken food. Used in this way they are likely to provide a valuable source of protein and calcium grit.

(xii) Researches on Utaka showed that these are not primarily an open-water group and their association with the lake margins is much closer than was previously suspected, due to their need to lay their demersal eggs on a solid substrate. Yet the resources of the open lake are used by them to a very great extent, mainly indirectly in that currents caused by physical conditions in the lake sweep past the rocks where most species live and bring them a continual supply of plankton. However one important species (*Haplochromis quadrimaculatus*), is believed to spend part of its life-history in more open waters, though even these come inshore to breed and are exploited at the margins.

(xiii) The close association of Utaka with underwater rock formations, particularly when a current is flowing, is used by local fishermen in the most efficient method of catching Utaka, e.g. by use of the chirimila, a form of open-water seine. This is shot upstream of an underwater rock (called chirundu) when a current is flowing, and is swept down towards the chirundu by the current, the paddling effort of the canoes serving only to form the net into its fishing shape. Utaka congregate near the rock positioning themselves in the current to catch the plankton drifting with it; they are thus concentrated in a definite area relative to the current and when the net is tucked many are captured.

(xiv) The best possibility for further development lies in the modification and improvement of the chirimila, at present heavy and cumbersome. The design and use of an improved net is described in the text; this proved consistently more efficient than nets of local manufacture.

(xv) It follows that good fishing grounds tend to be localized but possibilities of extending the present grounds and discovery of new ones seem to be good, as this form of fishery is of comparatively recent origin.

(xvi) The northern lake fisheries potential for Utaka appears to be of the order of 1,000 short tons per annum.

(xvii) The only species in Lake Nyasa which appears to be truly pelagic in that it has floating planktonic eggs and larvae is the Usipa (*Engraulicypris sardella*). All other open-water species are tied to the shore-line for at least part of their life history, mainly for breeding purposes but also for feeding.

(xviii) No economical method of fishing the open water of the northern lake was found although several methods were tried which were within the resources of the Organization. It is moreover not recommended that expensive ring-netting vessels or gear or any other fishing method involving heavy capital expenditure be used experimentally in the northern lake, as indications seem clear that fisheries involving pelagic waters only in the northern lake are unlikely to be economic.

(xix) It is possible that when the biology of the Usipa and Batala (*Rhamphochromis* species) are better known, these fishes, which already contribute substantially to the northern lake fisheries, may be further exploited. Further studies on these fishes are, however, required before their life history is known, and work on them is being undertaken.

(xx) Those cyprinid fishes which ascend rivers to spawn, such as *Barilius microcephalus*, *B. microlepis*, *Barbus eurystomus* and *Labeo mesops*, form a most valuable source of protein to inland areas, where they are heavily fished during their spawning migration. These also warrant further study, and while exploitation of a breeding migration of fishes is permissible within limits, it always has its dangers, particularly in the case of African cyprinid fishes. The fishery at present appears haphazard and it is recommended that, in view especially of its importance to inland areas, steps should be taken to manage it from river mouths upwards. Management should be undertaken by Native Authorities themselves, preferably in the form of a River Management Board, as in England, which could control fisheries and all other aspects of river use.

(xxi) In general, fisheries in the northern lake and rivers lend themselves to exploitation by small local units of one or more people; they are not sufficiently concentrated to make large concerns likely to be economically successful.

(xxii) Export of fish from Likoma Island and the lake-shore should be encouraged, to provide incentive to fishermen. Compared, for example, with Northern Rhodesia, very little fish is transported from the lake to inland areas by Africans themselves. This means that there is a large unfilled demand from inland areas.

(xxiii) The use of fish in the economy of the Northern Province should be studied. At present it seems that lake-shore prices for fish, and especially from Likoma Island, are disproportionately low in comparison with the prices that have to be paid for other commodities.

(xxiv) As prices are at present, many African fisheries appear to be on a distinctly marginal basis, and purchase of gear forms a high proportion of the costs of a fishing unit. This militates against the use of efficient imported gear, and thus against the efficiency of African fisheries as a whole.

(xxv) Ways and means should therefore be sought firstly to raise the price of fish, having due regard to its place in the general economy, and secondly to reduce the price of fishing gear, by encouraging competition in its sale or by the formation of co-operative societies.

CHAPTER TWO

STUDIES ON THE HYDROLOGY OF LAKE NYASA AND ASSOCIATED RIVERS

FIGURES

16. Usisya Deep Station (over 385 fathoms). Profiles of temperature, oxygen, silicate and phosphate down to 600 metres. 21/vii/55.

17. Bridge diagram and calibration curve of a thermistor set used at Nkata Bay. Lettering. T=Stantel Type Thermistor (2311/300)=S Helical Potentiometer of 1000 ohms resistence, Resistences . . . . R 1600 ohms, R 2500 ohms, G galvonometer 3000 ohms resistence with maximum sensitivity at the centre zero. The battery used in the circuit was a 1.34 v. Ruben Mallory Battery RMB-3.

TABLES

1. Description of the Lake

Lake Nyasa is a tectonic lake, being formed by movement of the earth's crust as part of the Rift Valley System. Accordingly it is long, narrow and very deep and is the southernmost of the series of lakes situated in the western rift valley, which extends from Ethiopia to beneath the Indian Ocean near Madagascar.

It occurs between longitudes 33° to 35° East and latitudes 9°30′ and 14°25′ South, its long axis lying almost due north and south. At latitude 14° South it divides into two arms, of which the larger, generally known as the south-east arm, lies along the main axis while the smaller, known as the south-west arm, branches away to the west. Dimensions of the lake are given in Table I. At the end of the south-east arm the single outflow from the lake, the Shire River, begins its journey to the Zambesi. Twelve miles from the bar or commencement of the river is Lake Malombe, a shallow rectangular area of water approximately ten miles wide by twelve miles long.

The age of Lake Nyasa is still *sub judice* but originally it was much smaller than at the present time. The original small lake was situated in the northern part of the present lake and probably reached only as far south as the narrows between Deep Bay in Nyasaland and Manda in Tanganyika (Lat. 10°25′ South). It was a good deal higher than the present level of the lake, and was during the passage of time lowered in stages to near its present level. At the same time the lake was elongated southwards and subsequently with the development of further faulting in the Rift area and associated down-warping, it reached its present southern limits by flooding the former head of the Shire Valley (Dixey, 1941). Dixey (*op. cit.*) estimates the original small lake to have been formed during the mid-Pleistocene, though more recent opinion based on a comparative study of the fossil fauna of the adjacent fossiliferous beds indicates that the lake is rather older and may date back at least to the early Pleistocene. It seems possible, therefore, that life has existed in the waters of Lake Nyasa for a continuous period of not less than a million years (Fryer, 1957).

Lake Nyasa was first surveyed by Commander Rhoades, R.N., in the late nineteenth century. His soundings showed the bottom of the lake to have its greatest general depths near its eastern shores, in the north above Manda and in the south below Likoma and Chisimulu Islands. Between these localities the opposite is true, the greatest depth being to the west, about seven miles off Usisya (Lat. 11°12′ South) where (as recorded by Rhoades in 1897) a " hole " occurs with a maximum depth of 386 fathoms. The soundings made by Commander Rhoades with line and winch were recently shown, with the aid of an echo sounder from the J.F.R.O. launch *Gigipat*, to be substantially accurate, and reflect the greatest credit on that naval officer with his restricted equipment in a remote and primitive area. Furthermore, the work of J.F.R.O. has confirmed the warping, as mentioned above, of the lake bottom and has given a more accurate picture of the lake bed north of Nkata Bay (Lat. 11°35′ South). Our findings show that a distinct ridge occurs between the eastern and western shores in latitude 10°25′ South. A chart, which includes the results of recent J.F.R.O. soundings and those of Commander Rhoades, is given in the Appendix.

A very good description of the shore line of Lake Nyasa has been reported by Borley *et al.* (1942), pp. 13–14. Although this work is now out of print the description reappears in van Meel (1954), p. 186, and this author also enlarges upon it by giving more details of the mountain ranges, climate, geology and depth contours (fig. 1). As a comprehensive list of references is given in this extensive and readily available publication, it is necessary here only to provide a brief general description of the coastal terrain, and to enlarge on features important to the climate and hydrology of the lake.

In general, the foundation of the whole region consists of Eozoic rocks, mainly gneisses and schists, some of which are igneous in origin. The gneisses appear to be

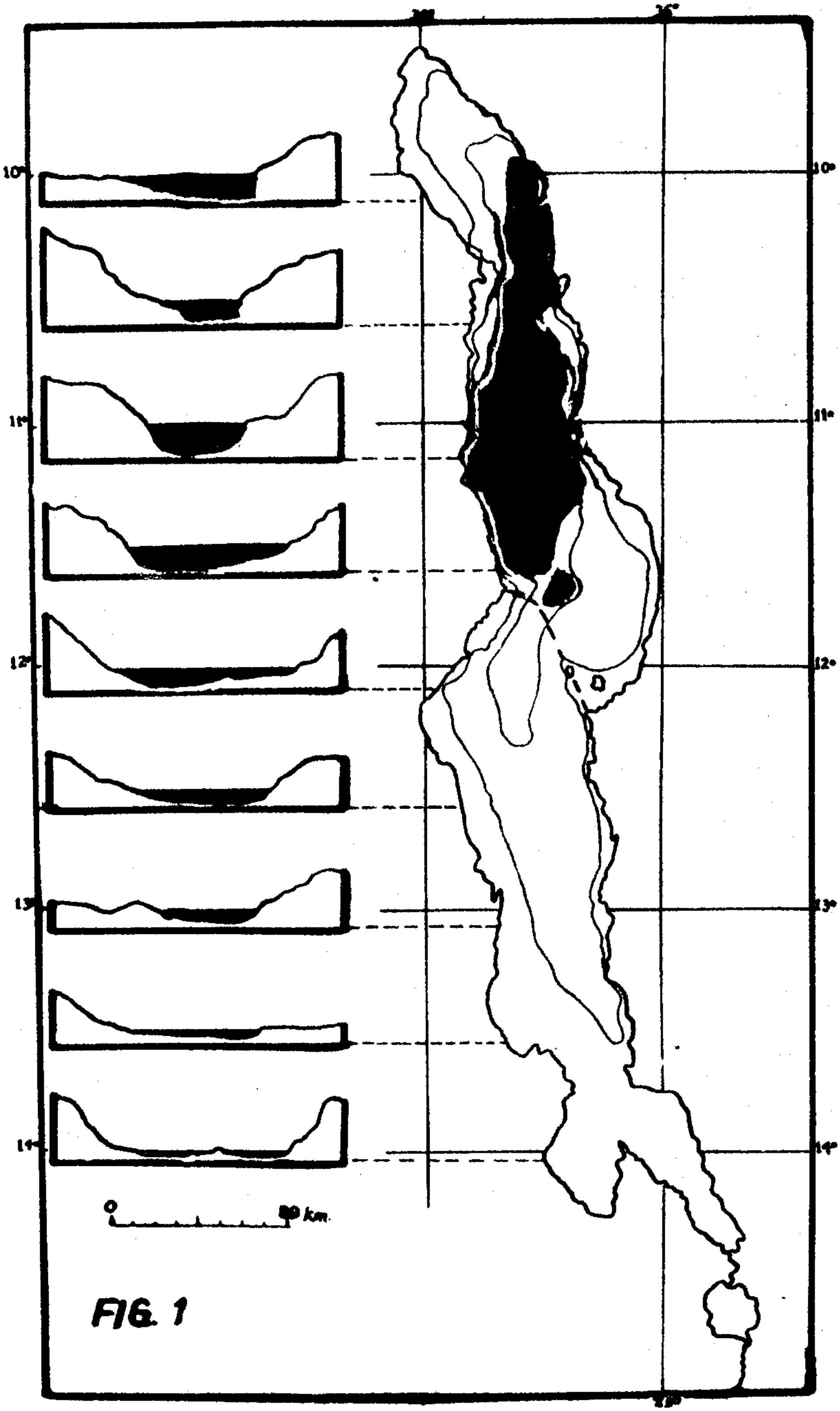

Fig. 1. Lake Nyasa after E. L. Rhoades and W. B. Phillips 1901 (from van Meel 1954). The shaded area on the chart indicates the part of the lake which lies below sea level.

mainly altered sediments, with intrusions of granite and syenite (Gregory, 1921). A map showing the geological structure as depicted by Dixey (1924), is given in the Appendix. These rocks form high mountains which surround the lake and are especially prominent to the north. In the extreme north-west is the mountain block of the Nyika Plateau, from which rivers drain to a wide fertile plain bounding the north-western extremity of the lake from the Mwaya region down to Karonga. The lake shore along this plain consists of flat, shallow-shelving, sandy beaches, with only a few outcrops of rock occurring. The rivers entering the lake in this region are the Mbase, the Luviria, the Songwe and the North Rukuru.

The valley of the South Rukuru River forms the southern boundary of the Nyika Plateau to the south of which rises the equally extensive but lower Vipya Plateau. The scarps of these plateaux are steep, running down to a rugged, steeply shelving, rocky coastline below Deep Bay and extending as far south as Cape Chirombo. Sandy beaches occur only at isolated intervals along this coastline.

South of Cape Chirombo the scarp of the Vipya Plateau inclines away from the lake to the south-west; the only river of consequence draining this area is the Luweya. From Cape Chirombo to the extreme south of the south-west arm, the mountains have in the main receded from the lake, leaving a flat coastal plain with only occasional hilly intrusions such as Sani Hill and those near Salima. The coastline here consists of extensive stretches of sandy beach. Across the wide plain flow several important rivers, which differ hydrologically from those of the north; firstly their flow in the dry season is negligible compared to the northern rivers and secondly they drain from the central plateau country which contains considerable limestone deposits. These rivers include the Dwangwa, the Bua, the Lilongwe and the Lintippe.

Between the south-west arm and the south-east arm is a promontory, ending in Cape Maclear, which consists of a rocky granite intrusion with a number of small rocky islands. The coastline here is reminiscent of that found to the north, for example, at Nkata Bay. To the south-east of this peninsula extends the narrow, shallow body of water known as the south-east arm which consists mainly of long, gently shelving, sandy beaches on its western shore, and ends to the south in the single outflow of the lake, the Shire River. On the eastern side of the south-east arm the mountains of the Kirk Range bound the shoreline in places, so that the coast presents a variable picture of rock and sandy beaches.

This type of coastline continues northwards on the eastern side for about 150 miles, as far as Malo Point, off which the islands of Likoma and Chisimulu are situated. Roughly similar but progressively more rocky shore conditions continue from this point northwards as far as the delta of the Ruhuhu River, which drains the huge Livingstone range of mountains. The Ruhuhu is the only river of consequence which flows into the lake from the eastern side. All the other important rivers from these eastern mountains flow into the Indian Ocean through Portuguese East Africa.

Northwards from Manda the coastline is dominated by the 7,000 and 8,000 foot peaks of the Livingstonia range, which continues beyond the northernmost boundary of the lake. In this region the coastline is again rugged and precipitous with rocky shore and very few areas of sandy beach, these occurring only where a cape juts into the lake or where there is a small indentation in the coastline.

2. Meteorological Data Affecting the Lake

As is typical of Central Africa, meteorological conditions which affect the lake occur in more or less well-defined phases. Thus, the year may be divided into a wet season and a dry season, and also into a hot season and a cold season. These two climatic phases overlap, so that the hot season which commences in October, almost coincides with the wet season, which begins a little later, in December. The rains generally cease towards the end of March, when temperatures drop and the cold, dry period begins. During these months the prevailing winds on the lake are northerly or north-westerly, the latter bringing moisture-laden air to the area. These humid winds are warm, often strong and gusty heralding thunderstorms, and frequently blow for several days at a time. In April, however, the climate begins to change, and, with the onset of the " winter ", the colder trade winds, known locally as the *Mwera*, blow consistently from the south-east. Air temperatures decrease rapidly, pressures rise, and there is considerable drying of the land atmosphere. The constant, strong winds of the *Mwera* season blow more or less directly up the lake, being funnelled along the length by the mountains on either side. By mid-August conditions once more begin to change, air temperatures rise, winds become more variable in direction, and thunderstorms indicate the approaching wet season, thus completing the annual cycle. A chart (fig. 2) shows the rainfall at Nkata Bay between November, 1953, and August, 1955.

These meteorological conditions have a profound effect on the lake at all times of the year. Their influence on the general hydrology of the lake have already been described during the hot and wet season by Beauchamp (1953); in the present investigation the period of study has been extended through two winters and the picture is now more complete.

3. Analyses of Inflows into the Lake

Analyses of water of the main inflow to the northern part of Lake Nyasa were first made late in the rainy season of 1954, when the rivers were in spate. The sampling stations were all situated high on the Vipya and Nyika Plateaux between 4,000 and 8,000 ft. above sea level, that is, more than 2,500 ft. above the surface of Lake Nyasa. At this height above the lake the river waters are rich in silicates but poor in all other ions. Readings of pH taken in the field show two different types of water. Those of streams, such as the Nchena stream, which flows directly off the plateau land of the Nyika Mountains, and which has a steeply sloping bed of rock and gravel, often with waterfalls of a hundred feet or more in height, and with crystal-clear water, were generally on the acid side of neutral. The head waters of these rivers lie in eroded peat bogs and grass land of the plateau country and, at this time of year, are more or less surface run-off water as a result of the constant heavy rains. These are the trout streams of the Northern Province of Nyasaland.

The large rivers and those streams which flow through agricultural land below the Nyika Plateau have hydrogen ion concentrations in the region of 7.0 or higher. In addition, they have higher conductivities than the mountain streams and they carry considerable material in suspension, the water being often brown in colour and slightly opalescent. These large rivers such as the Kasitu and South Rukuru have travelled considerable distances over the Vipya Plateau before they pass the stations where samples were taken. *En route* they collect waters from many minor streams draining the Vipya Mountains, the Kandoli Hills and the western side of the Nyika Mountains. Chemically they were quite distinct from the clear mountain streams in that they had more ions in solution; as indicated by the concentrations of silicate and calcium ions (Table III). The high values for calcium and magnesium in the Kasitu River were probably due to drainage from the tung estates on the Vipya Plateau, where fertilizers were being used to improve soil.

These rivers were sampled at other times of the year, in order to observe variation in salt content. Obviously a number of factors may influence water conditions and the chemical composition of the water may alter even from day to day; flash flooding due to localized rain storms is probably the most important of these factors. The table of analyses (Table III) shows that during August, 1955, the South Rukuru sampled on 11/8/55 and 19/8/55 varied considerably in conductivity from 46 to 75 units respectively; while the Runyina sampled on consecutive days showed only a small change from 46 to 48 units of conductivity. A study of the table shows that this is

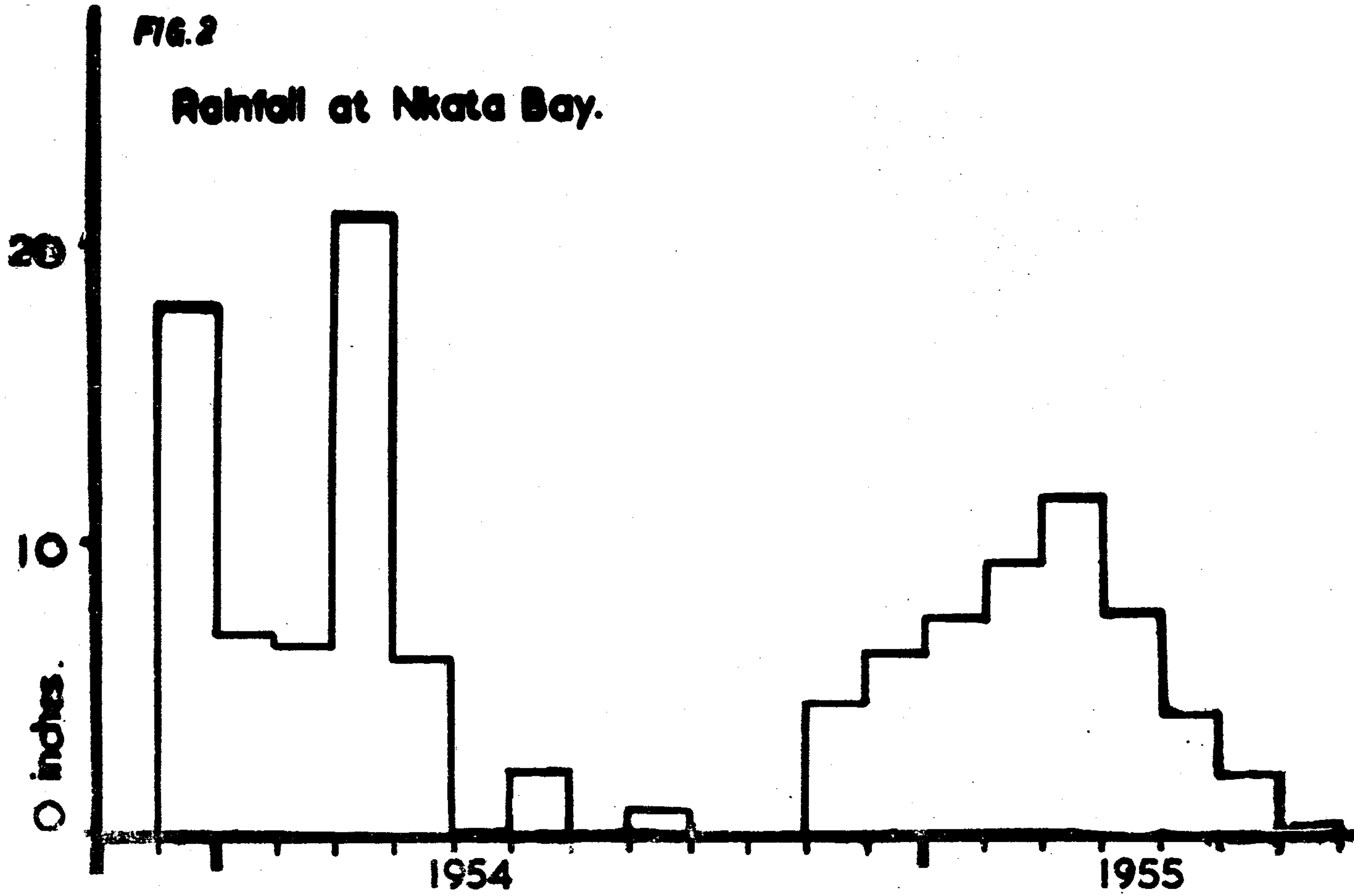

Fig. 2. Rainfall at Nkata Bay between November, 1953 and August, 1955.

true even for other periods of the year. It might well be expected that higher values of all ions might occur during the dry season when the flow of water in all the rivers is quite slow and leaching of the drainage area is more efficient. However, analyses were not sufficiently regularly made to give more than an indication of any seasonal trends which might exist; nevertheless there seems to be little seasonal variations. Analyses, therefore, are used here only as an indication of the amount of electrolytes supplied to the lake from this part of its catchment area.

Rivers draining the southern part of the Vipya Plateau and the mountains of the Central Province were visited only once during the dry season in August.

The rivers draining the southern Vipya highlands are the Luweya, Dwambadzi and Dwangwa; samples were taken several times in the Luweya, but only once from the Dwambadzi (Luwawa) and Dwangwa (Katete). The Luweya River was typical of all the rivers flowing from the Vipya Mountains in the north, being low in calcium and high in silicates. Luwawa Dam is a rather specialized case, but as its outflow feeds the Dwambadzi River it may be typical of the water of that river, and is included to show that it, too, is characteristic of all waters of this region. The Katete River had rather high calcium and magnesium values which were probably due to local use of fertilizers in the forestry estates through which this river flows.

All other rivers draining the central highlands showed high calcium and magnesium values, except the Bua River near the head waters. These flow off the crystalline limestone series (see geological map, described by Dixey, 1926) and in this respect differ considerably from those rivers draining the northern mountains, which consist of gniesses and schists with granite intrusions.

The main point to be made about the rivers flowing into the lake is that, although their waters may be more dilute than the lake, they are in fact a constant source of nutrient.

Evaporation from the 11,000 square miles of lake surface is very considerable, amounting to more than 60 per cent. of the total annual loss of water. The lake is therefore acting rather like an evaporation basin and the input of dissolved salts and suspended material (W. H. Halcrow, Annual Reports of Hydrological Department, Nyasaland) are extremely important to the economy of the lake as a whole. Perhaps the most important of the electrolytes entering via the rivers is the silicate ion, as it is present in much higher concentrations in all the rivers than in the lake. Silica is utilized by diatoms in their growth processes and is, therefore, very important. In this connection it may be mentioned that diatoms are very abundant in the phytoplankton of the lake and are used as food by *Tilapia* (Fish, 1951), and several other species of fish.

Discharge measurements (Table II) are taken regularly by the Hydrological Department of the Nyasaland Government. Their results show the relative importance of the northern rivers, which flow all the year round and discharge considerably more water into the lake than those of the Central Province. Even the two largest rivers, the Bua and Lintippe, both often dry up during the summer months. The largest river of all, the Ruhuhu, enters via the Tanganyika shore of Lake Nyasa and discharges as much as 6,800 cubic feet per second during the wet season. An analysis of water from the Ruhuhu was made in February, 1955, the results showing a low conductivity and a low calcium value comparable with those rivers which drain the northern part of Nyasaland. The similarity of these results is not unexpected as the Livingstone range from which the Ruhuhu drains has the same rock formation as the Nyika and Vipya Plateaux, and all belonged formerly to the same mountain system before the rift valley was formed (Gregory, 1921; Dixey, 1941).

Though the actual amount of water entering the lake via the rivers, compared with the total volume in the lake, is very small, mixing, which is confined only to the upper layers and water close inshore, is usually very thorough. The total rise and fall of the lake level as a result of river inflow is as much as four feet per annum. At least inshore, the effect is to dilute the upper layers, but even in the open water of the lake this dilution was often very marked (Tables III and IV). This seems to be the case even during the rainy season, when inflow is maximum. The inflowing water is generally colder than the surface water of the lake and, therefore, more dense. Thus during calm conditions river water flows into the lake along the bottom until it finds its own density level and this phenomenon has been recorded on one occasion at Nkata Bay as shown in fig. 3. However, it is most probable that turbulence inshore would disperse the river water rapidly throughout the surface layers, where it would assist in the annual cooling.

4. Water Temperatures and Chemistry of the Lake

Sampling of water in the lake began in March, 1954, and was continued until October, 1955. The main station where work was carried out during this period was a drift station about three miles NE. of Nkata Bay (Lat. 11°36′ South, Long. 34°5′ East) near that at which Beauchamp (1953) recorded his observations. The depth at the station varied between 300 and 350 metres, which may be considered to be the average depth of the lake. At rather irregular intervals observations were made at other stations during the survey, which ranged from the far north of the lake to Lake Malombe on the Shire River in the south.

Temperatures were read with the aid of a reversing thermometer attached to a Friedinger water sampling bottle, water samples and temperature being taken simultaneously. Later, when a thermistor became available, it was used in conjunction with the thermometer, and this instrument was eventually used with success down to 180 metres. Rapidity of reading temperatures was thus greatly accelerated and accuracy of reading increased from 0.05°C to 0.02°C. The thermistor was calibrated against the reversing thermometer used throughout the survey. Water samples collected in the field were taken to the laboratory for analysis after first fixing part of the sample for the estimation of dissolved oxygen. Standard methods of analysis were used for the estimation of the various ions. The result of these estimations are shown more fully in the Appendix. In March, 1954, the lake was thermally stratified, into hypolimnion and epilimnion, a well defined thermocline being recorded between 40 and 80 metres. These conditions remained more or less constant throughout March and early April. By mid-April, however, cooling had already begun to have an effect as a result of the low atmospheric temperatures which prevailed towards the end of the rainy season. The approach of winter and the onset of the *Mwera* season (when south-east trade winds blow continuously) brought about a radical change in conditions. Variable cloud cover, high winds, cooler air in contact with the lake surface and maximum inflows from rivers cooled the surface water very rapidly. This cooling continued throughout the months of May, June and July, and spread to the deeper waters by convection currents and turbulence caused by the constant high winds. As a result the thermocline descended gradually, reaching a maximum depth of approximately 150 metres by August.

By late July the water at 200 metres was only 0.9°C cooler than the surface water (fig. 4) and the " thermocline " was very ill defined. Such conditions persisted until the end of August (fig. 5) but during early September surface warming began again as a result of increasing temperatures. As shown by a record taken some 20 miles south-east of the regular station the lake stratified in its surface layers, and a secondary thermocline at approximately 35 metres was quite distinct in early September (fig. 6). At this period of the year, the winds blow irregularly in force and direction, the south-east trade winds begin to die out while warm winds from the NE. and NW. blow more frequently, heralding the approach of the wet season. During the day cloud cover is negligible and heating of the surface waters, in consequence, very rapid. Such conditions of warming are unstable and wind action cause further mixing to greater depths. Thermal stratification is often poorly defined as a result of the

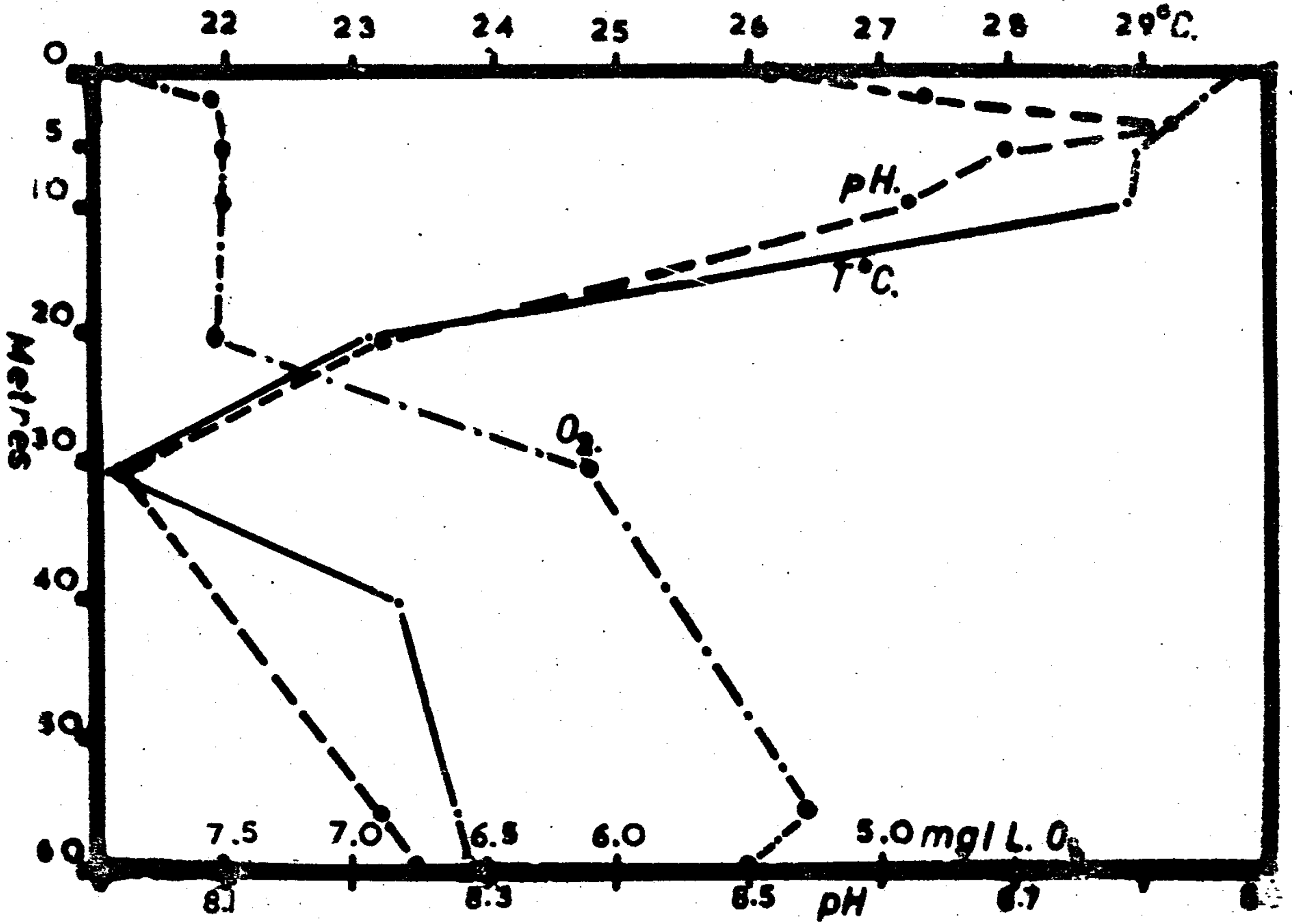

Fig. 3. Profiles of oxygen, pH and temperature in the South Bay, Nkata Bay, March, 1954 00

heating up process, but after a strong wind a very well defined thermocline was recorded, the water of the epilimnion being then homothermal (fig. 7a and b). During the months October to December the thermocline descended gradually and by 5th November it had reached a level between 50 and 100 metres, this approximating to its March level. Warming continued into the wet season and as winds were again irregular in force and direction during the pre-rainy season—being mainly associated with the thunderstorms of this period of the year—the thermocline remained a constant and distinct feature throughout, though it fluctuated both in level and intensity, in response to wind stress on the surface water (fig. 10).

The period of study from December, 1954, to August, 1955, proved interesting as the thermistor was used to record temperature change. On several occasions during this period thermoclines typical of temperate lakes were recorded from various areas of the lake (figs. 7 and 8), and a thermocline as defined by Birge's rule as the region where a change of 1°C or more per metre of depth occurs was observed. Such an observation has never previously been recorded as a feature of tropical lakes. It now seems likely that this rule may also apply, at least to tropical deep lakes especially if apparatus sensitive and accurate enough to measure the change is employed.

Much the same conditions as described above were recorded during the second winter, in 1955, but more accurate records were obtained with the use of the thermistor unit. Even during the coolest month of August when the temperature change between the surface water and water at 200 metres was only 1.6°C, a distinct change between surface and bottom water was observed (fig. 9).

Isotherms for the period March, 1954, to October, 1955, are given in fig. 10. These show both the winter cooling and summer warming, and also the fluctuating level of the thermocline, which indicates that a standing wave existed as a result of wind action at the surface. The second winter was particularly calm during the months of June, July and August, and although air temperatures over Nyasaland were the coldest for a number of years, water temperatures were similar to those of the previous year.

During the survey, temperature stratification in Lake Nyasa was of a permanent nature even though water temperatures were differentiated by less than 1°C in the top 200 metres at certain periods. The combination of higher temperatures, the greater change of density per degree Centigrade at these high temperatures, and the great depth of the lake allowed such conditions to exist continuously. Evidence contrary to this view has not yet been described, though Beauchamp (1953) suggested that an overturn might occur after a number of years of permanent stratification when bottom waters have warmed sufficiently to allow homothermal conditions to develop during a particularly cold winter. What evidence there is to support this theory is scant since no records have been kept between Beauchamp's work in 1939–1940, and the present investigation 1953–1955. Temperature records during the present survey showed bottom water to be warmer by 0.2°C than was recorded in 1939 by Beauchamp.

There can be little doubt that the permanency of the stratification is the probable cause of the relative infertility of the lake, as at all times it acts as a barrier between the richer bottom waters and the surface waters where biological production takes place. Only movements within the water mass itself can bring about mixing between the deep bottom water and the surface layers and that this occurs is borne out by analyses of water from various levels carried out throughout this survey. Hence the temperature seiche is extremely important to the fertility of the lake. The other method by which ions may reach the surface is by the slow process of molecular diffusion upwards from the richer, deep water. But this can only be secondary to the mixing caused by wind action and the temperature seiche, particularly during the cool season when temperatures are almost the same throughout the whole water mass; while during the period when a well developed thermocline exists diffusion may be of special importance to the general fertility of the water of the epilimnion.

The temperature seiche is a typical uninodal wave (Mortimer, 1955), its period varying from about 16 days during the summer months to approximately 25 days during the winter months, when a wave of considerable magnitude develops. An examination of the isotherm (fig. 10) and the temperature changes at a series of depths (fig. 11) readily indicates the fluctuations that occur. The 23°C isotherm was found to fluctuate between approximately 170 and 30 metres in July and August, 1954, but in August, 1955, this isotherm fluctuated between 160 and 80 metres. In addition, it may be noted that the 23.5°C isotherm fluctuated between 125 and 5 metres in a period of only fifteen to sixteen days.

It was during the months of September and August, when the seiche movement was maximum, that the main mixing occurred in both years. Higher values of oxygen in the deep layers as well as higher values of all other ions in the epilimnion were characteristic of October in both years, just after the major movements of water had taken place. The increase of the ionic concentrations in the epilimnion occurred rapidly towards the end of September, particularly in the case of the phosphate ion, which was detected even at the 50 metre level in September and October (fig. 12); on the other hand, the silicate concentration increased very rapidly in July, 1954, and again in October of both years. High values for silicate also occurred in March and April, when the effect of rivers, which are high in silicates, may be expected to have considerable influence on the surface layer (fig. 13). Other ions also increased in the epilimnion towards the end of September; of these calcium which was present in quantity throughout the year is of special import (Table V). Nitrites were never recorded in quantity except on one occasion at a station seven miles east of Monkey Bay (Table V). Nitrates and ammonia were recorded only infrequently, though the latter was detected usually as traces in the deep water at all times during the survey (Table V). Conductivity readings carried out in 1955 showed an increase during the winter months following the lower estimations recorded during March and April (fig. 14).

Utilization of these ions by the plankton, which live in the trophic zone of the epilimnion, takes place as soon as the ions become available. Consequently, the increased concentrations during the winter months were accompanied by a plankton " bloom " which continued into October and November of both years (fig. 15). Plankton peaks follow closely the period when phosphates are low at all levels down to 200 metres indicating that this ion is readily utilized for their growth processes. This opinion, however, requires further confirmation as our observations on the plankton were neither as detailed nor as extensive as desirable. A proper correlation between the presence of other ions and the production of planktonic organisms was not determined but at all events it seems likely that these ions are in sufficient quantity at all times. Though phosphate may well be the limiting factor in the growth and development of the plankton, other ions, in particular the sulphate ion, may also play an important role.

In addition to the station at Nkata Bay, other localities from which samples were taken for analysis were visited on various occasions. Of particular interest were samples collected in the south end of the lake at Monkey Bay and Salima. These showed much lower temperatures during the month of August, 1954, and were even lower than those recorded at Nkata Bay during the same month. These results can probably be best explained by the relative shallowness of the water which allows thorough mixing in these areas.

Temperatures were homothermal to within 20 metres of the surface at Monkey Bay and to within 40 metres of the surface at Salima indicating that this is indeed the case. Furthermore, at these stations the chemistry of the water showed higher silica and also higher oxygen values at all levels during this month (Table V). It is probable that the thorough mixing is aided by the seiche movement as during this period of the year the cooler, deeper bottom water would be near the surface in the south end of the lake, compensating for the wind effect which piles surface water against the northern shores.

Stations in the north have been sampled occasionally and exhibited similar conditions to those at Nkata Bay station. The results obtained at Usisya proved interesting in that very deep water was sampled at 600 metres on one occasion and showed that temperatures below the 300 metre level were constant at 22.4°C. The chemistry of these deeper waters shows little or no increase in concentration of ions from those of the 300 metre level (Table V and fig. 16).

Inshore water reflected in general the conditions prevailing in the surface waters of the open lake, except that temperatures were occasionally higher in shallow bays and that the chemistry was affected, for example, by flooding from the rivers. Thus lower values for all ions except silicates were always recorded near the mouths of the larger rivers flowing into the northern section of the lake (Tables III and IV).

APPENDIX

Notes on Methods of Analysis in Use During the Survey

DISSOLVED OXYGEN

The method in use was a modified Winkler technique, whereby small samples could be taken and analysed aboard the launch when under way.

REAGENTS

1. Manganese chloride solution: 100 grammes of pure crystalline $MnCl_2.4H_2O$ in 200 millilitres distilled water.

2. Winkler's Reagent: 100 gm. analar potassium hydroxide in 200 ml. distilled water plus 60 gm. analar potassium iodide.

3. N/10 sodium thiosulphate: 24.82 gm. analar $Na_2S_2O_3.5H_2O$ to one litre of distilled water.

4. Starch solution: 2 gm. soluble starch plus 30 ml. of 20 per cent. potassium hydroxide in 400 ml. distilled water. Stir until clear; stand for an hour and neutralize with dilute hydrochloric acid. Add 1 ml. of glacial acetic acid to preserve. This solution has good keeping qualities.

5. Concentrated analar sulphuric acid.

6. N/10 potassium dichromate—4.9039 gm. analar $K_2C{+}_2O$ per litre.

7. Potassium iodide crystals.

APPARATUS AND METHOD

Field equipment included 50 ml. sampling bottles and graduated 1 ml. pipettes. Samples were taken using a two litre Freidinger water bottle, fitted with a reversing thermometer, and about 500 ml. of the water sample were allowed to flow through the oxygen bottle during individual samplings. 0.5 ml. of each of reagents 1 and 2 are added and the stopper replaced to exclude bubbles of air, and the bottle shaken and stored under water until required for analysis.

Analyses were carried out on 10 ml. aliquots of samples which had been treated with 1 ml. of concentrated sulphuric acid. The Agla micrometer syringe was used as a burette, Fox and Wingfield (1938) and N/10 sodium thiosulphate was used without dilution, as the titrating solution. The sodium thiosulphate was standardized against suitable diluted N/10 potassium dichromate solution.

Saturation values for oxygen in water were calculated using the normogram constructed by W. E. Ricker (1934). A more comprehensive work by C. H. Mortimer (1956) is now available, which reviews the work of Ricker, Rawson and others and gives details of calculating oxygen saturation values in fresh waters.

CALCIUM AND MAGNESIUM

Calcium and magnesium were estimated using the versenate technique outlined below.

Reagents

1. Dissolve 2.5 gm. of sodium versenate (disodium ethylene diamine tetra-acetate) in 2 litres of distilled water. Add 0.54 grams of solid sodium hydroxide and dilute to 2500 ml. Adjust by titration against standard calcium solution so that 1 ml. is equivalent to 0.1 mg. of calcium, using Eriochrome Black T as indicator.

2. *Indicator for total hardness:* Mix together 1.0 gm. Eriochrome Black T; 1 ml. N/1 sodium carbonate and 30 ml. distilled water. Make up to 100 ml. with isopropyl alcohol.

3. *Calcium indicator.* Grind together 0.2 grm. ammonium purpurate and 100 gm. of sodium chloride. Keep dry.

4. Normal sodium hydroxide solution.

5. Borax buffer solution—Dissolve 40 grams of borax in 800 ml. distilled water. Dissolve 10 grm. of sodium hydroxide and 5 gm. of sodium sulphite ($Na_2S.9H_2O$) in 100 ml. of distilled water. Mix the two solutions and dilute to 1 litre.

6. *Standard Calcium solution.*

0.125 gm. pure dry calcium carbonate added to 100 ml. of distilled water and 25 ml. N/10 hydrochloric acid and made up to 1 litre, contains 50 mg. Ca†† /L.

Procedure

Produce a standard end point. To 10 ml. of distilled water (containing 5 mg/L Ca††) add 2 ml. N. sodium hydroxide and approximately 0.2 mg. of calcium indicator. Run in 5 ml. of sodium versenate to produce the end point tint. Titrate samples of the unknown water using the same amount of buffer and indicator, matching the end point tints with that of the standard end point. Each ml. of versenate= (0.1 mg. Ca†† in 100 ml. samples) 1 p.p.m. Ca††.

The standard end point fades rapidly under tropical conditions of temperature and has to be renewed frequently. Alternatively freshly titrated water samples may be used as the standard end point having obtained the first colour match with a known calcium standard.

Total hardness may be calculated by titrating slightly acidified boiled samples, buffered with 0.5 ml. of the borate buffer solution and using Eriochrome Black T as the indicator. The end point is much more distinct if the titration is carried out hot (at approximately 70°F). The colour change is from purple-blue to a light bluish green tint. Magnesium is calculated by subtracting the calcium value from the total hardness value, i.e. the total calcium and magnesium ions present. Each millilitre difference is equivalent to 0.61 Mg†† per litre.

The above technique was developed at the Windermere laboratory of the Fresh Water Biological Association and has since been published, Mackereth and Heron (1957), in a modified form.

Characteristics of the Resistance Thermometer in use during the Survey

The instrument used in the latter part of the survey on Lake Nyasa was built according to the description given in Mortimer and Moore, 1953. The instrument was calibrated over a range of temperature from 0 to 30°C and retained its characteristics throughout the eight to ten months it was in use. Calibration was carried out against a reversing thermometer used throughout the survey. The characteristics of this thermometer are given in the table and those of the thermistor in the graph. The thermometer could be read with accuracy only to 0.05°C, but from the curve (fig. 17) the resistance thermometer is accurate to 0.02°C.

REVERSING THERMOMETER NO. 509

Instrument Reading	*Correction*
0	0.0
10	0.0
15	0.0
20	0.0
25	0.1
30	0.0

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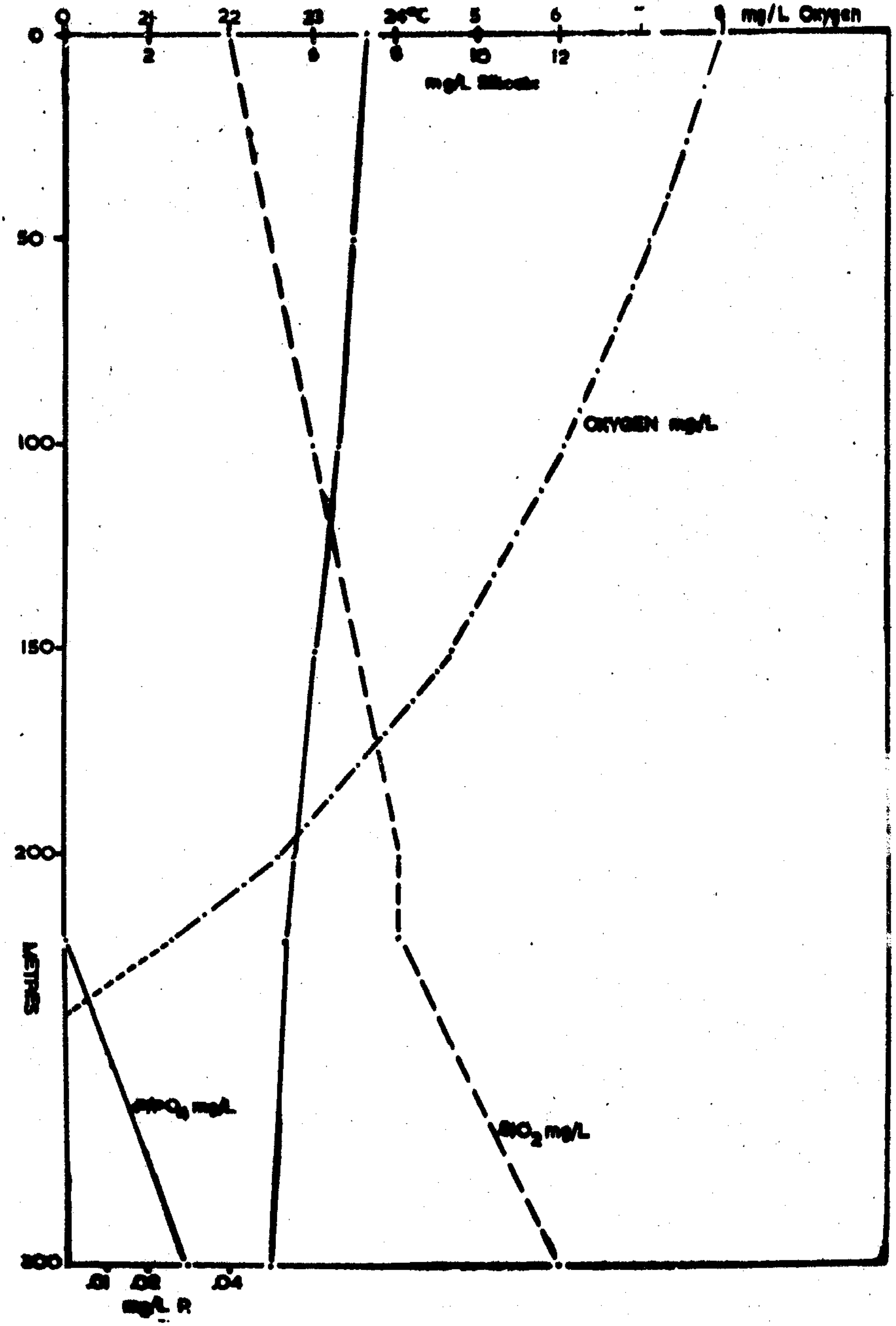

Fig. 4. Station I: Nkata Bay 28.vii.54. Distribution of temperature, oxygen silicate and phosphate in the top three hundred metres at this station

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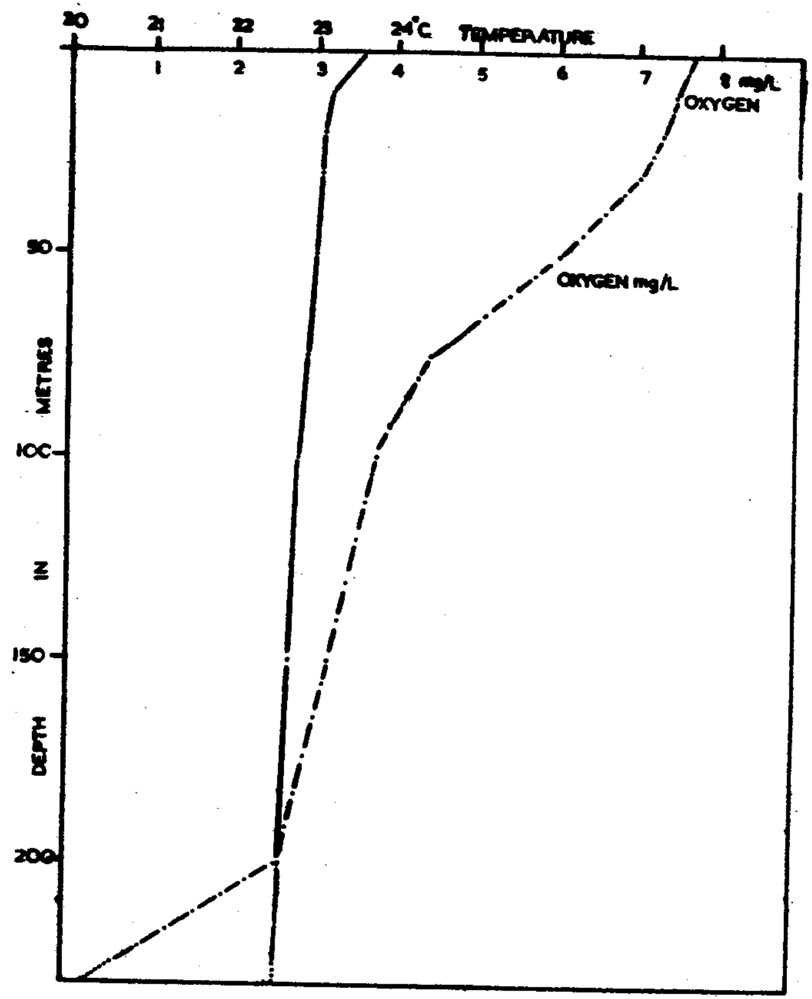

Fig. 5. Station I: Nkata Bay 2.ix.54. Temperature and oxygen profiles.

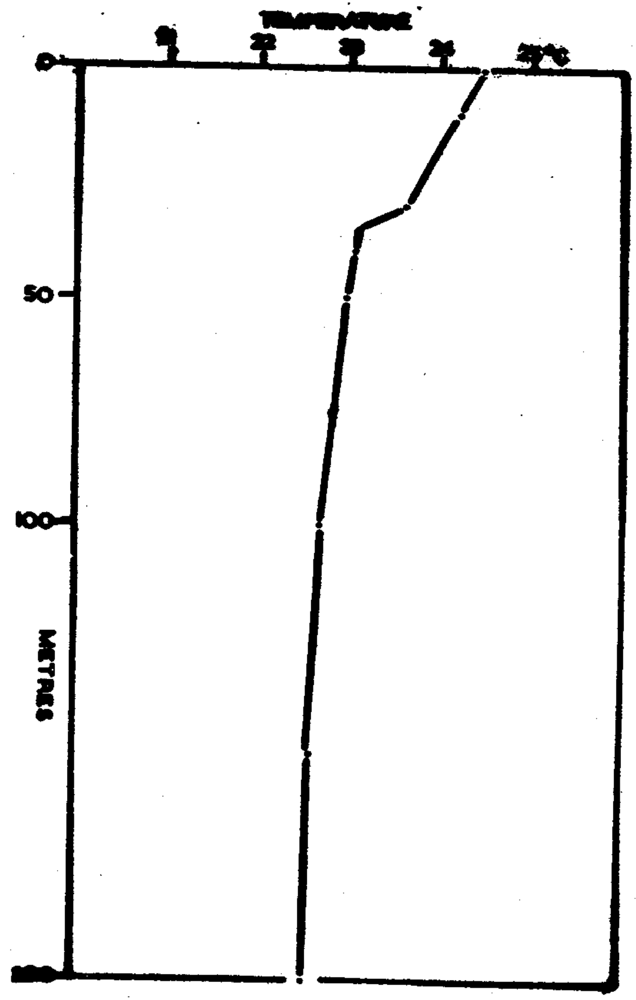

Fig. 6. Temperature distribution at a Station approximately 20 miles NNW. of Likoma Island. 14.ix.54

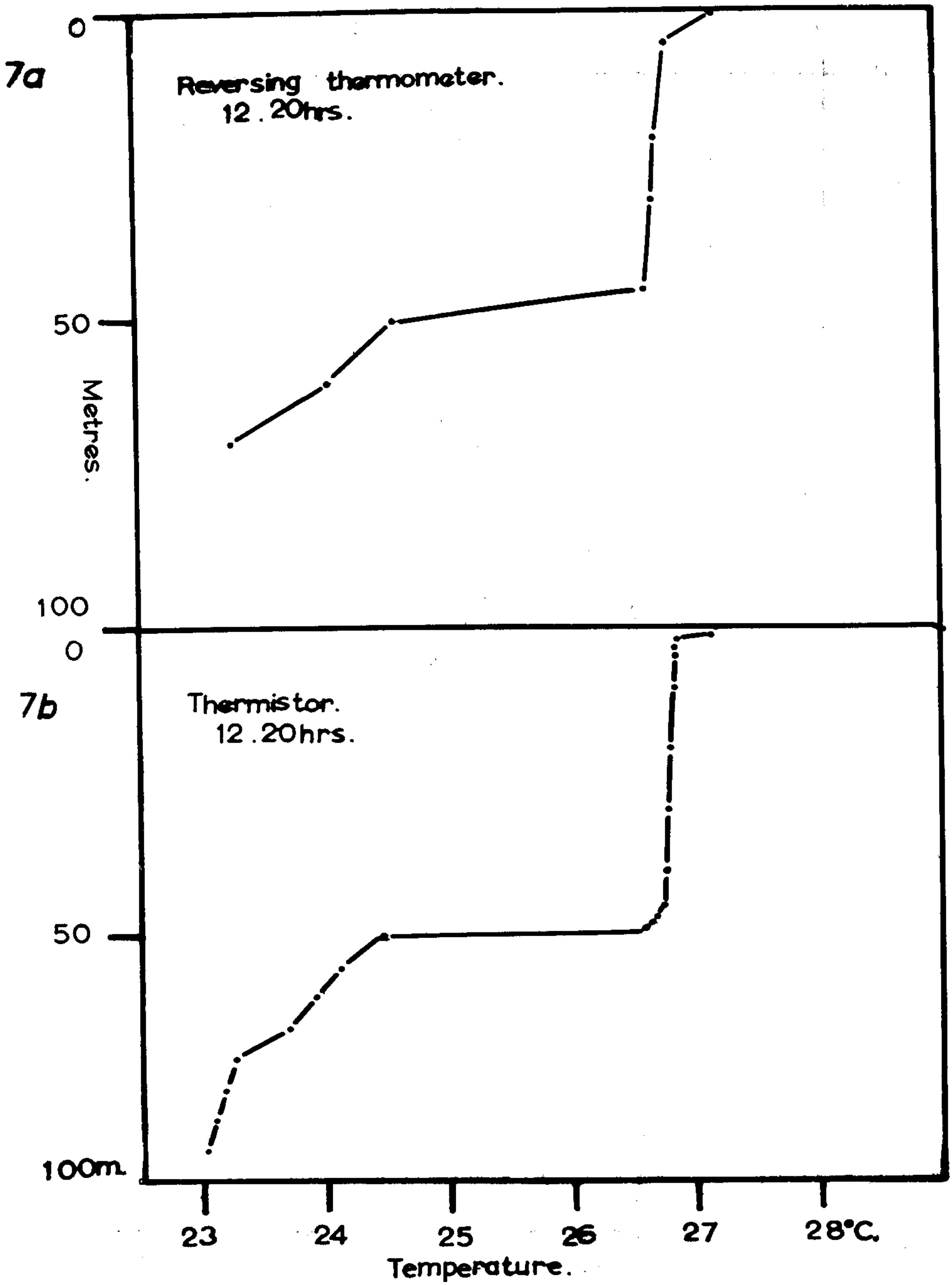

Fig. 7. Thermoclines recorded (*a*) with a Freidinger reversing thermometer and (*b*) a thermistor. Readings taken simultaneously at Nkata Bay near Station I, 3.xii.54 00

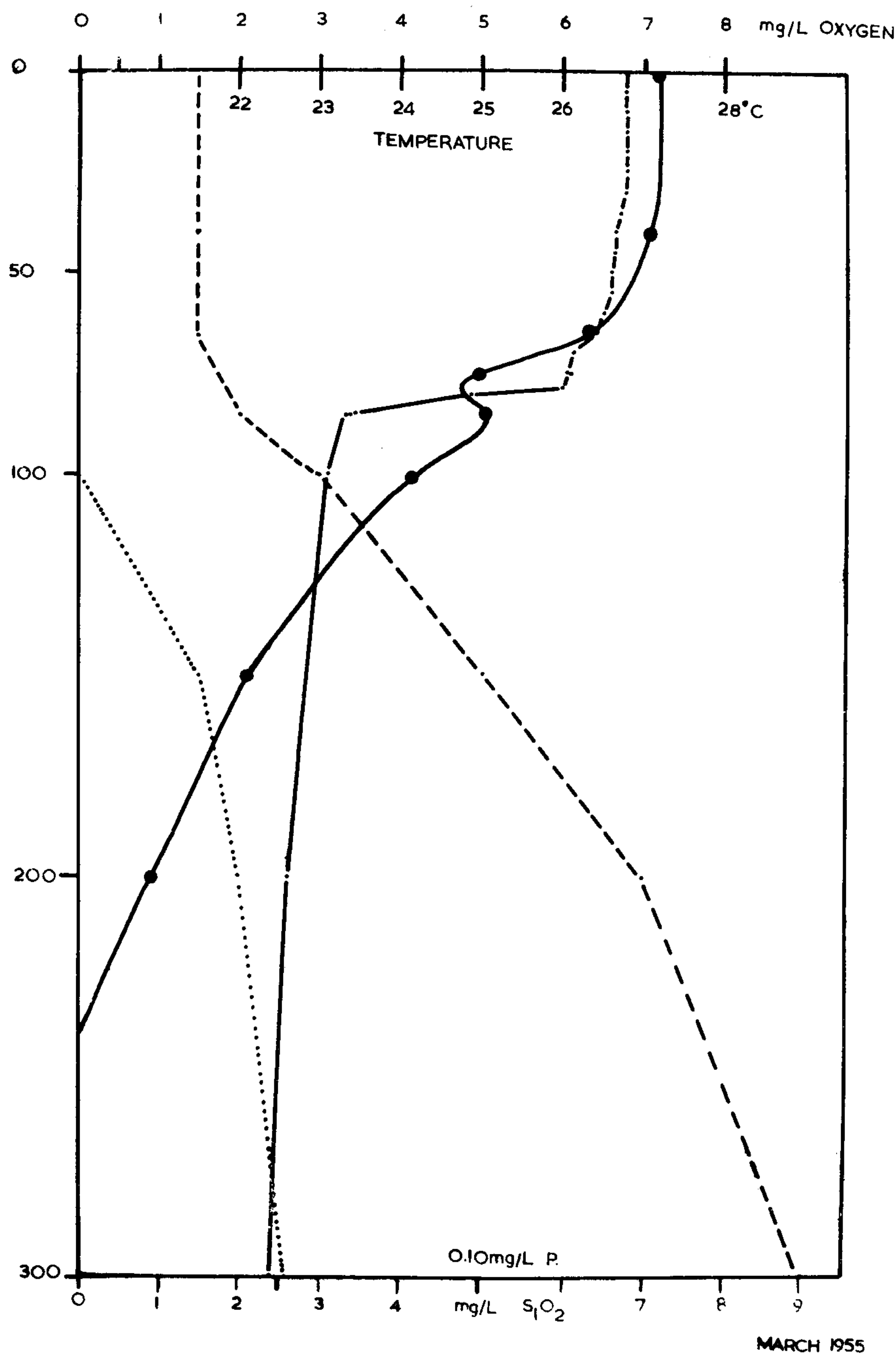

Fig. 8. Distribution of temperature, oxygen and silicate at Station I, Nkata Bay. 25.iii.55 00

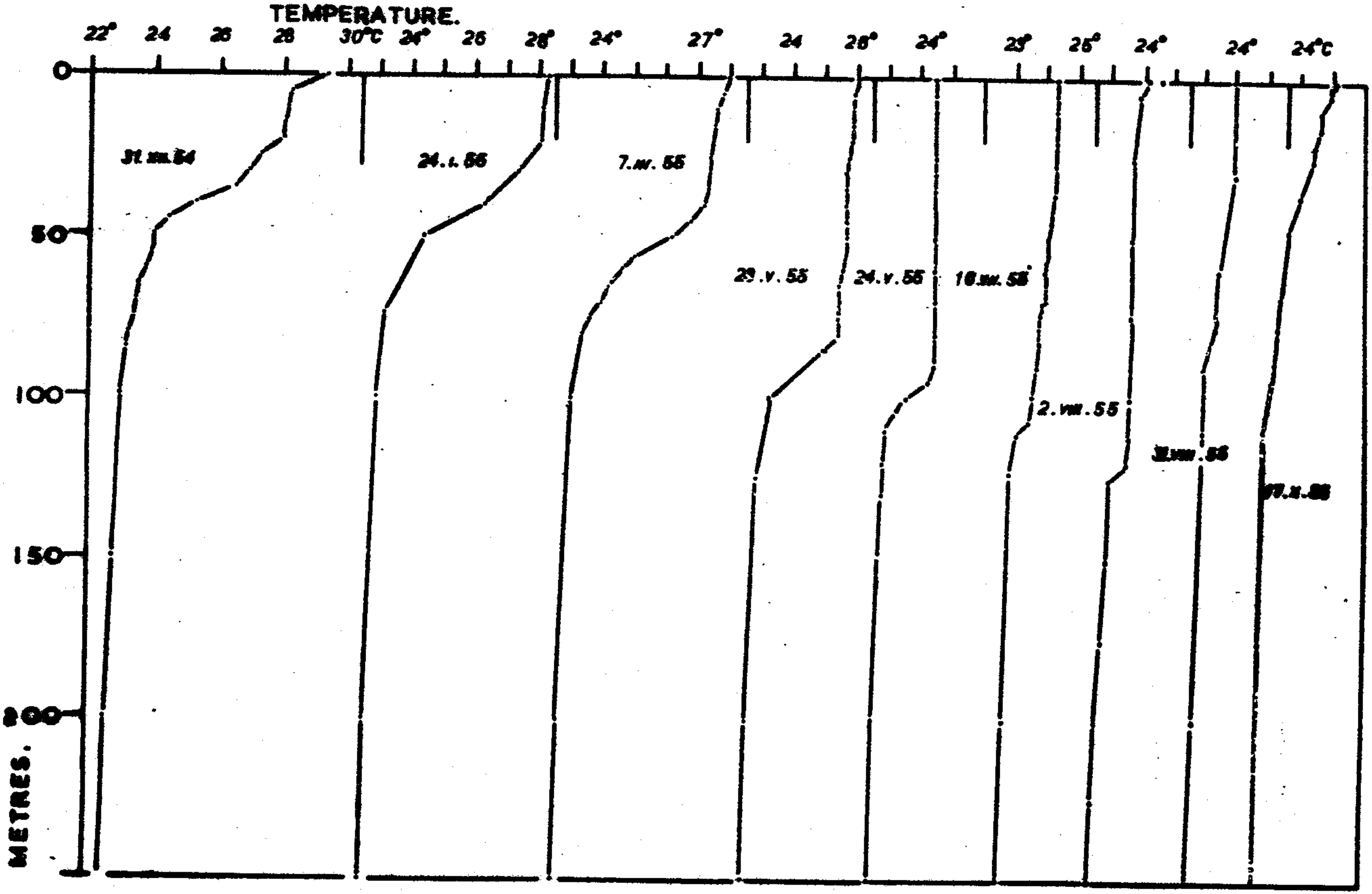

Fig. 9. Temperature profiles on several dates during 1954 and 1955 at Station I, Nkata Bay 00

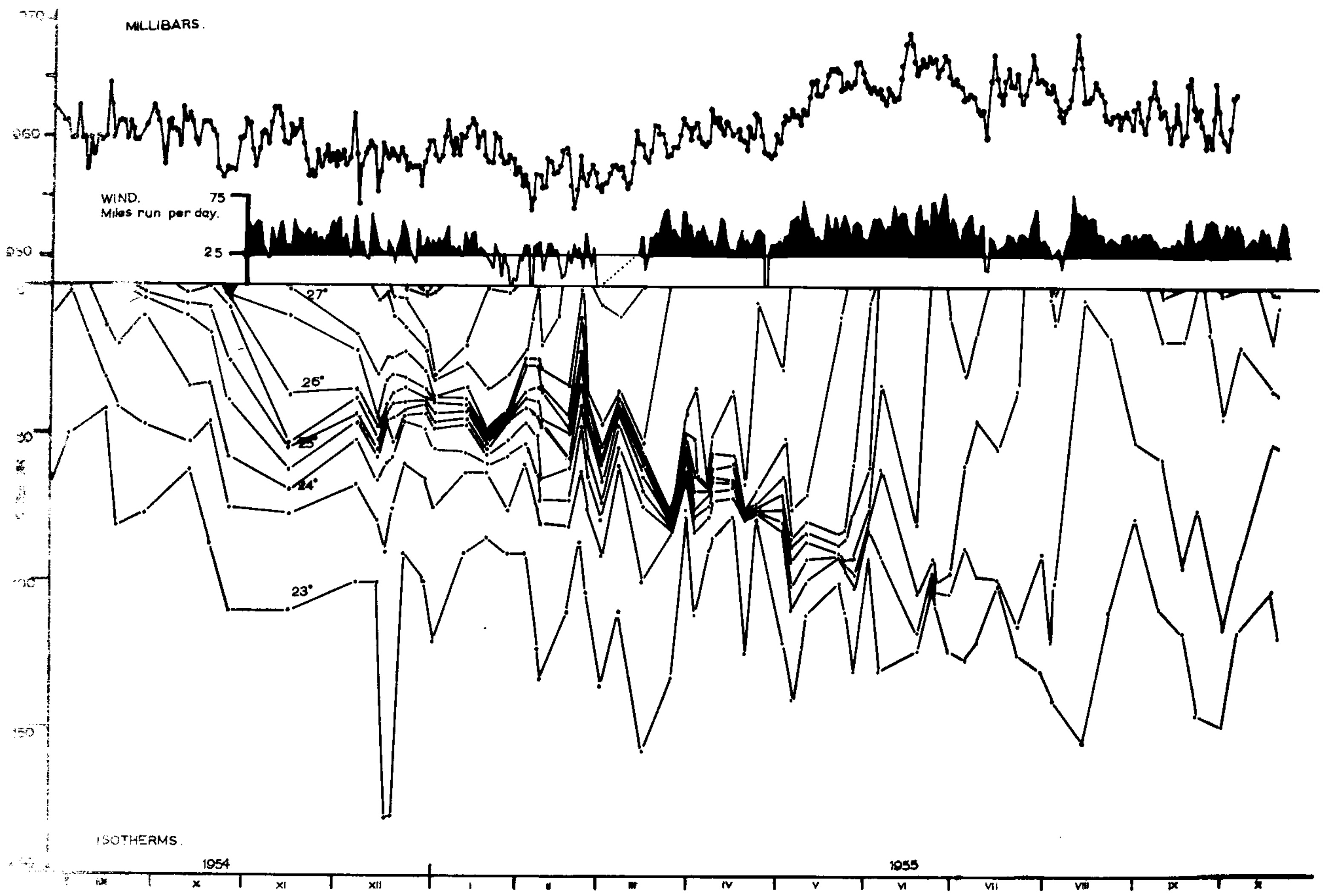

Fig. 10 Isotherms at Station I, Nkata Bay, between the months of September, 1954, and October, 1955. Wind speed and barometric pressure are included on the graph for the same period 00

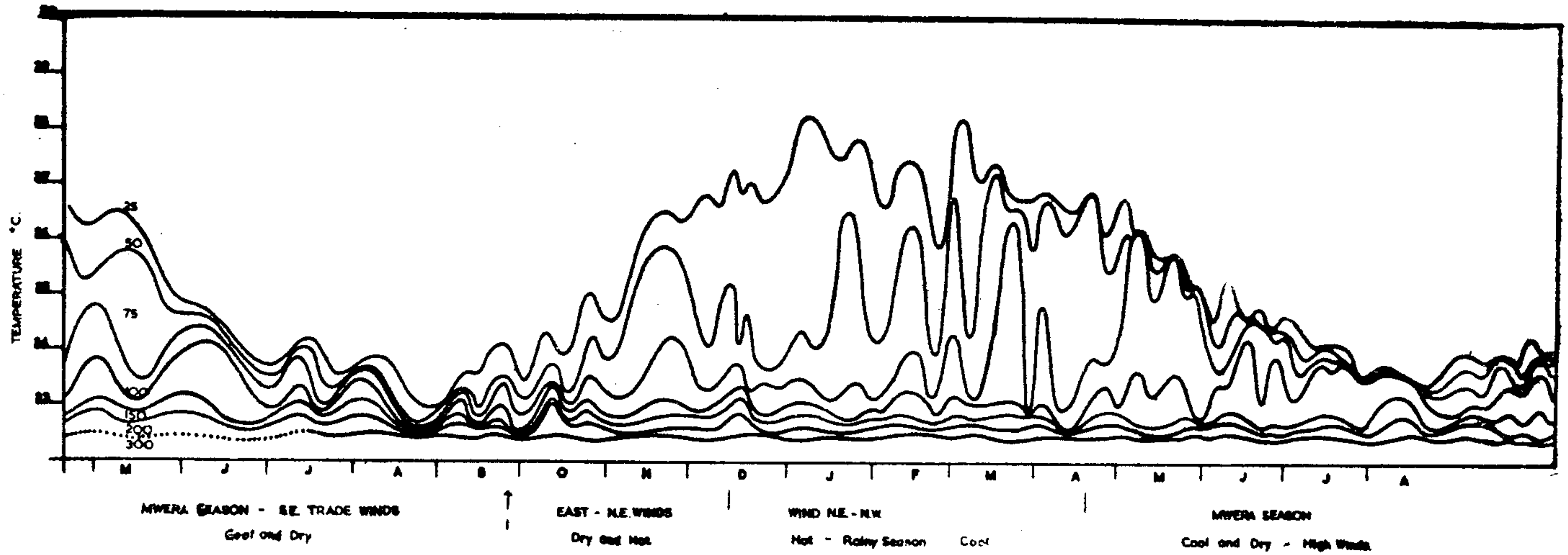

Fig. 11. Temperature change at seven depths, recorded at Station 1, Nkata Bay, between March, 1954, and October, 1955 .. .. ..

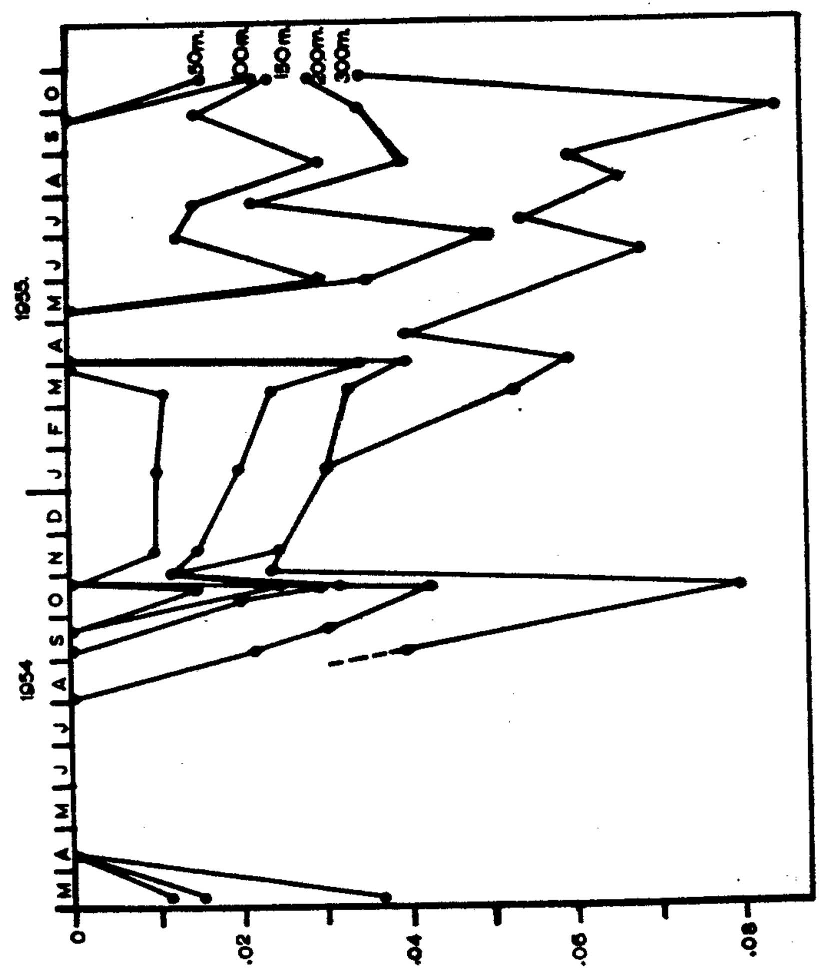

Fig. 12. Annual fluctuation in the phosphate content of water taken from five different levels at the Nkata Bay deep station during 1954 and 1955. Phosphate measured as mg./L. P. .. ..

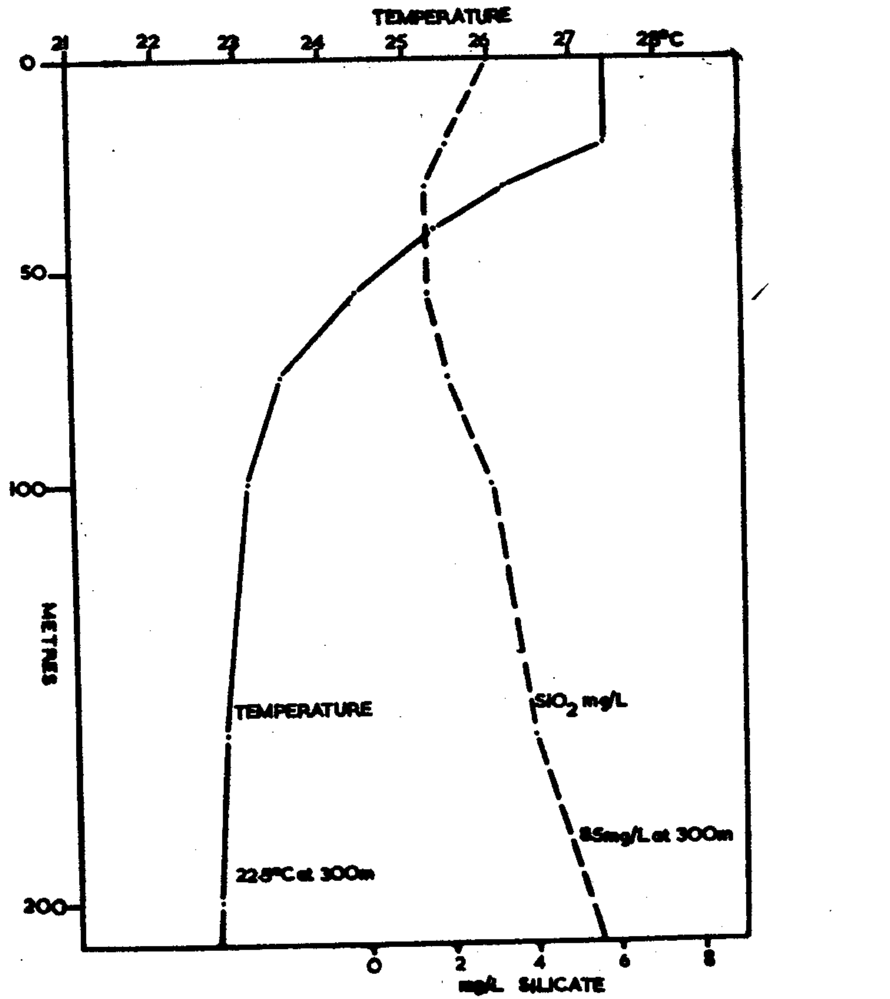

Fig. 13. Temperature profile and silicate distribution at Station I, Nkata Bay, on 7.ii.55 .. ..

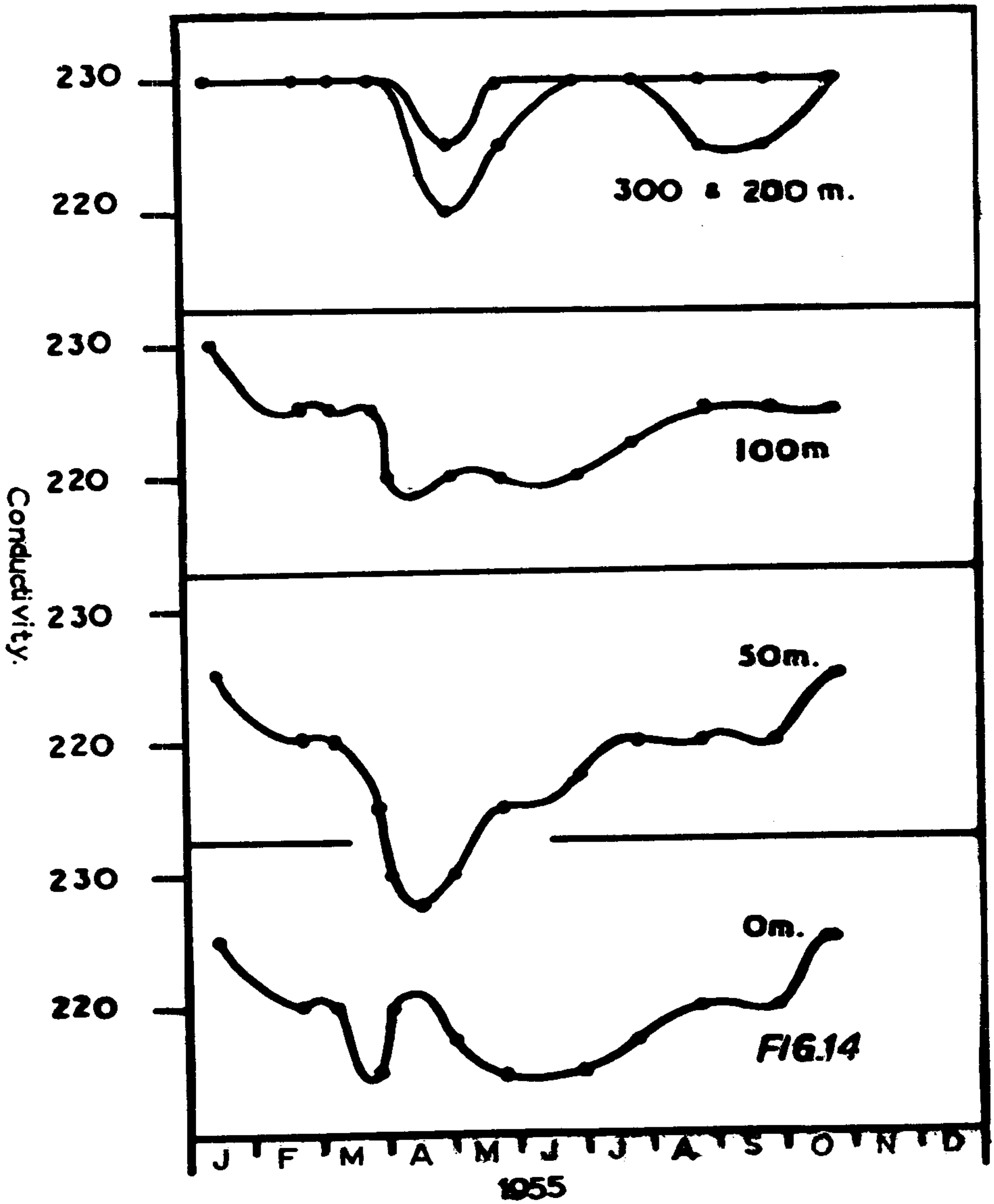

Fig. 14. Conductivity change (K corr) at 0, 50, 100, 200, and 300 metres, at Station I, near Nkata Bay 00

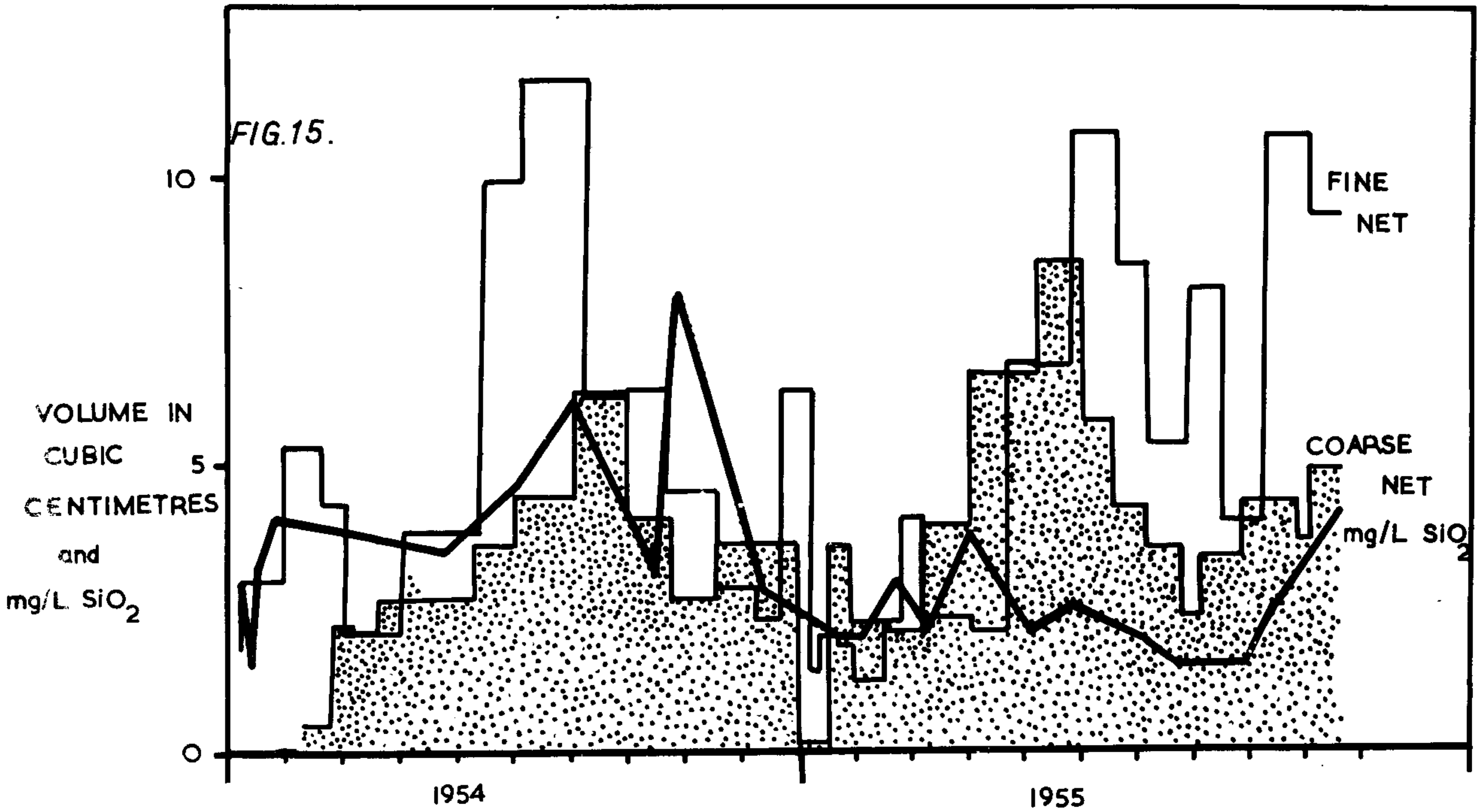

Fig. 15. Plankton volumes stained from the top hundred metres using coarse (60 m.p.i.) and fine (120 m.p.i.) nets. Volumes given are those sedimented from 7,070 litres of lake water. Silicate mean values in the top fifty metres are superimposed on the histogram. Station I, Nkata Bay, March, 1954, to October, 1955 00

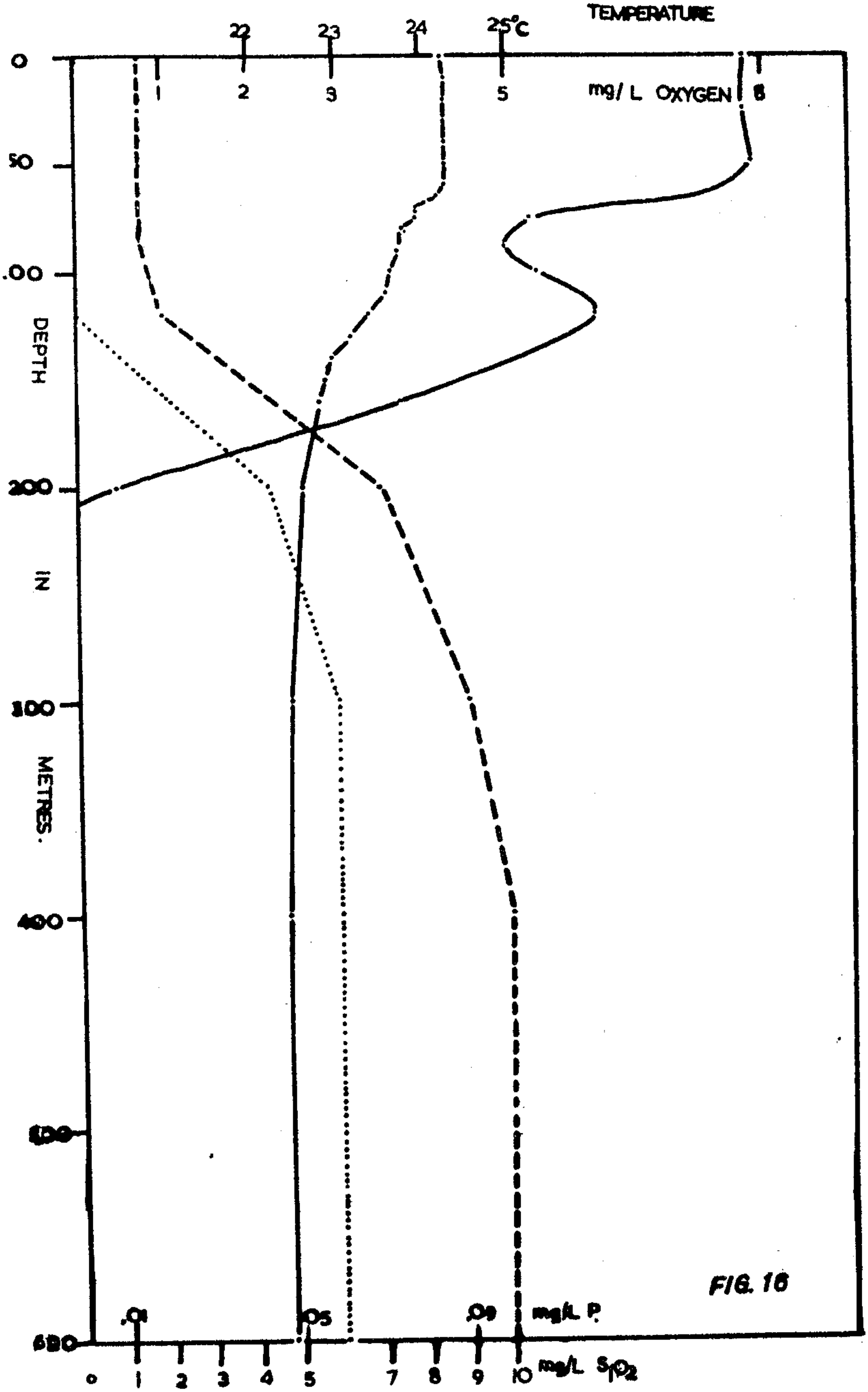

Fig. 16. Usisya Deep Station (over 385 fathoms). Profiles of temperature, oxygen, silicate and phosphate down to 600 metres. 21.vii.55

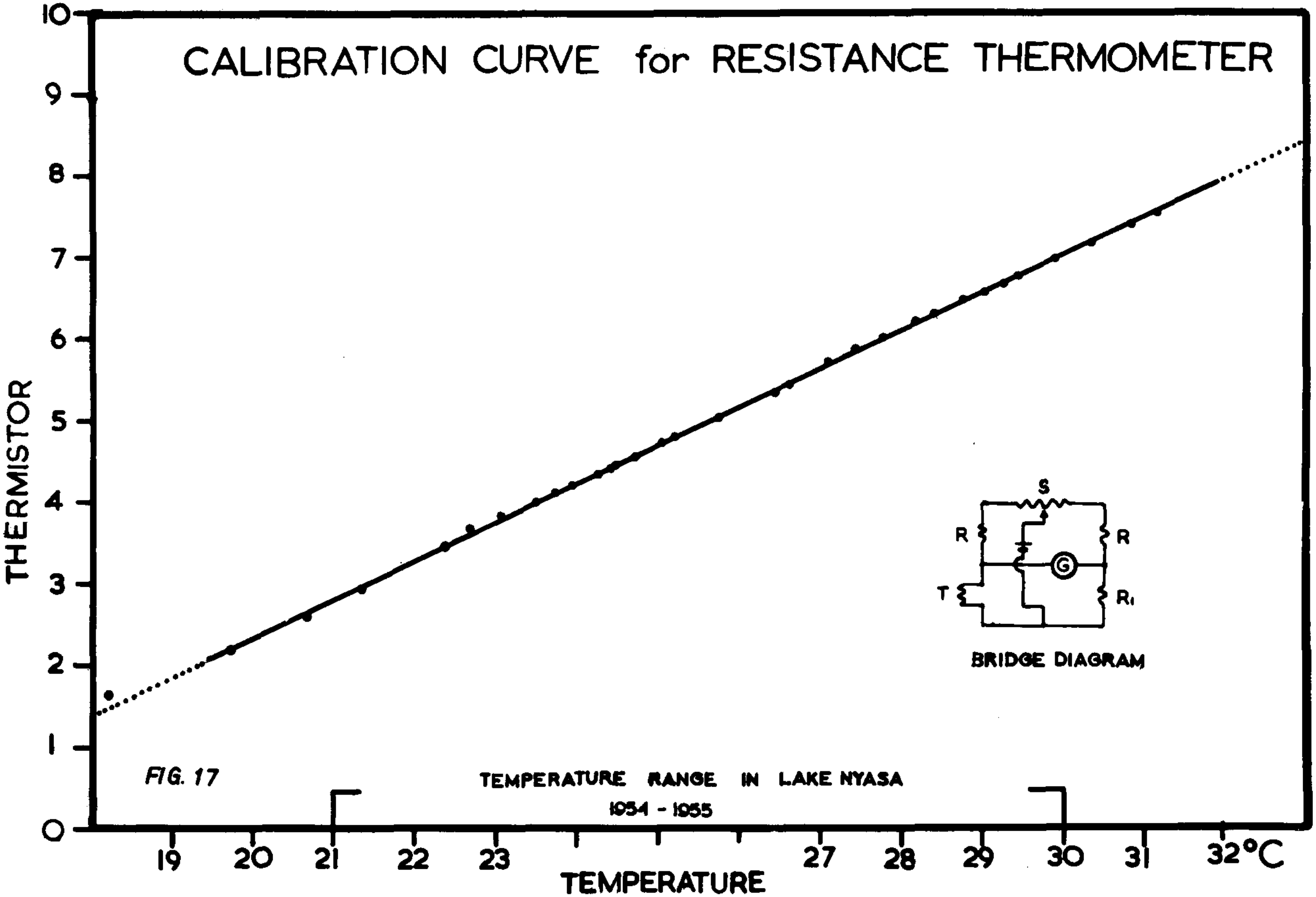

Fig. 17. Bridge diagram and calibration curve of a thermistor set used at Nkata Bay. Lettering: T= Stantel Type Thermistor (2311/300); S= Helical Potentiometer of 1,000 ohms resistance; Resistances: R_1= 1,600 ohms; R=2,500 ohms; G= galvonometer 3,000 ohms resistance with maximum sensitivity at the centre zero. The battery used in the circuit was a 1.34 v. Ruben Mallory Battery RMB-3 .. 00

TABLE I

Dimensions of Lake Nyasa

		Nautical Miles	*Miles*	*Kilometres*
Length of lake	Lat. 13°29′S to 14°25′S)	325	375	603
Length of lake measured along deepest part of the lake bottom	Total	327	377	606
	between 25fm Contours	312	359	579
	,, 50fm Contours	289	333	536
	,, 75fm Contours	272	314	504
	,, 100fm Contours	243	280	494
Length of South East Arm	(Lat. 14°S to 14°25′S)	29½	34	54½
Length of South West Arm		14½	17	27
Greatest width of lake	(Lat. 12°S)	47	54	87
Narrowest part of lake	(Lat. 13°40′S)	15	17½	28
Greatest width S.E. Arm		17½	20	32
Greatest width S.W. Arm	( )	19½	23½	36
Area of lake (Approximate)	11,000 sp. miles			
		Fathoms	*Feet*	*Metres*
Greatest depth		385	2,310	758
Average depth (approximate)		217	1,300	426
Height of surface above sea level		—	1,570	509

TABLE II

Monthly mean Flows (Cusecs) (Extracted from Annual Reports, Hydrological Department, Nyasaland)

E = Estimated

Year	Name of River	R.G.S.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1953	Lintippe	4/B/1	—	—	—	502	—	61.5	33.4	15.2E	3.9E	0.23E	Nil E	486E
1954	,,	,,	1,587	1,926	1,820	478	36.6	15.8	14.5	6.8	0.22	Nil	25.3	653.4
1955	,,	,,	1,097E	5,210	3,446	1,050	1,043	444	131	—	—	—	—	—
1954	Bua	5/D/2	—	—	—	—	93.5	38	12.9	Nil	Nil	Nil	Nil	4.3
1955	,,	,,	117.9	1,706	4,249	1,895	225	145	110.5	—	—	—	—	—
1953	Luweya	6/F/2	1,290.3	2,142.8	2,643	2,155	1,598	799	620	468	409	286	227	806
1954	,,	,,	801.3	1,182.4	2,074	1,997.8	757.8	605.8	387.1E	290.3	226	180	227	299
1955	,,	,,	387	725	1,044	2,778	1,909	1,231	730	—	—	—	—	—
1953	S. Rukuru	7/G/1	581.0	714.0	946.2	912.7	436.3	268.0	220.0	157.0	138.7	103.3	83.9	730.9
1954	,,	,,	1,392.0	2,288.0	2,110.0	989.7	429.4	311.2	242.4	183.5	120.0	69.0	59.0	330.0
1955	,,	,,	616.8	1,749.0	2,532.0	1,545.0	747.0	454.0	—	—	—	—	—	—
1954	N. Rukuru	8/A/3	—	—	—	—	—	—	96.8E	80.6E	33.3E	10.0E	6.0E	151.0
1955	,,	,,	968	1,012	1,233	624	307	206	—	—	—	—	—	—
1953	Wovwe	8/C/2	—	—	—	—	—	—	36.0E	28.0E	25.0E	18.0E	8.0E	74.2E
1954	,,	,,	93.5E	120.2E	109	64	48	36	31E	24	20	19	13	20
1955	,,	,,	47	157	147	177	132.9	81.3	—	—	—	—	—	—
1953	Songwe	9/B/1	—	—	—	—	—	—	544.0E	406.4	337.5	230	172	1,573
1954	,,	,,	1,388	1,233	1,606	1,598	1,509	645	446E	357E	228E	137E	168	1,051
1955	,,	,,	1,136	2,643	2,508	3,791	3,235	1,317	744	—	—	—	—	—
1953	Ruhuhu	T.3	—	—	—	—	—	—	—	—	—	1,673	1,314	2,719
1954	,,	,,	—	4,883	—	5,144	3,244	—	2,800E	2,555	2,290	1,800E	1,635	1,986
1955	,,	,,	2,917	5,459	5,992	6,859	3,984	3,176	—	—	—	—	—	—
1954	Kawiya	T.4	—	—	—	—	—	—	900E	740E	573E	421E	429	405
1955	,,	,,	607	887	1,663	6,033	3,800	1,300E	—	—	—	—	—	—

TABLE III

Analyses of Rivers Flowing into Lake Nyasa

	Temperature °C	K. corr.	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity. $Nx10^{-4}$	$CaCO_3$ mg/L	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Silicate mg/L SiO_2	Phosphate mg/L P	Comments
Nkata Bay Stream 29/1/1954	25.5	—	—	—	7.7	—	4.7	23.6	—	—	—	16	—	SO_4, Ammonia, Nitrates absent 1 ppm total iron
Hot Springs, Nkata 19/3/54														
1. ..	30.5	—	—	—	7.0	7.2	15.2	76.	8	0.5	—	24	.11	NH_3,NO_2,NO_3 and Fe not detected in either sample.
2. ..	36.2	—	—	—	7.5	7.7	21.4	—	10.6	3.9	—	28	.11	
Luwaya River:														
1. ..	—	—	—	—	7.3	7.4	6.5	32.5	5.3	0.6	—	8	0.06	NH_3 0.62 ppm in sample 1 and 04 ppm in sample 2. ND in sample 3 and 4. NO_2, NO_3 and Fe not detected.
2. ..	—	—	—	—	8.2	9.2	7.1	35.4	5.4	2.1	—	4	0.06	
3. ..	—	—	—	—	6.8	6.9	3.1	15.5	—	—	—	4	.01	
4. ..	—	—	—	—	7.4	—	9.1	45.6	—	—	—	—	—	
Banga Stream 10/3/1954 ..														
1. ..	26.2	—	5.11	—	6.7	—	5.1	25.7	3.1	1.3	—	18	TR	
2. ..	24.6	—	4.58	—	6.6	6.85	4.6	22.8	3.2	1.8	—	10	TR	1.6 ppm NH_3 *in sample 1.*
Dam Mzuzu 28/3/1954 ..	22.3	—	—	—	6.9	8.13	4.3	21.5	3.1	1.4	—	16	TR	Chloride TR in sample 1. NO_2, NO_3 SO_4 and Fe not detected.
Rumpi Chelinda 30/3/1954..	—	—	—	—	7.0	7.95	3.0	15	2.7	0.9	—	12	TR	Of the other important ions analyses showed only trace of ammonia in such places as the trout hatchery ponds; nitrate was found in those rivers draining through agricultural land e.g. Lura River 0.03 ppm, Lura 0.0.3 and Rumpi Chelinda River 0.07 ppm. Sulphate was not detected Ferric iron in only two hatchery ponds and the Runyina and Kasitu River 5.
Rumpi Chelinda 31/3/1954..	19.8	—	7.97	—	6.7	7.0	3.7	18.5	2.95	1.1	—	12	ND	
Nchena Stream 3/4/1954 ..	16.8	—	—	—	6.0	7.1	2.0	10	1.5	0.4	—	10	0.04	
Hatchery Inflow 3/4/1954 ..	16.7	—	8.24	—	6.7	7.95	1.9	9.5	1.0	0.8	—	9	TR	
Pond VI. 3/4/1954 ..	—	—	—	—	6.0	7.15	2.0	10	1.9	0.3	—	8	TR	

TABLE III—*(Continued)*

Analyses of Rivers Flowing into Lake Nyasa

	Temperature °C	K. corr.	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity. $N x 10^{-4}$	$CaCO_3$ mg/L	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Silicate mg/L SiO_2	Phosphate mg/L P	Comments
Pond I. 3/4/1954 ..	17.2	—	8.1	—	5.0	7.0	1.7	8.5	1.0	0.5	—	8	TR	1. Ferrous ion was not detected. Chloreds were present in traces, in all samples and in the hatchery ponds 0.5 ppm, in Kasitu River 2.0 ppm, in S. Rukuru River 1.1 ppm, in the Lunyangwa 0.7 ppm and the Kasitu 2 River 1.4 ppm.
Lura River 2/4/1954 ..	17.3	—	—	—	6.6	7.6	2.0	10	1.3	1.0	—	10	0.03	
Lura Pond 2/4/1954 ..	21.5	—	—	—	4.8	5.95	1.4	7	0.8	0.8	—	10	ND	
Lura Well 2/4/1954 ..	23.3	—	—	—	5.2	6.65	1.9	9.5	1.4	0.5	—	10	ND	
Wovwe River 4/4/1954 ..	20.8	—	—	—	6.6	8.1	5.2	26	3.1	2.4	—	16	ND	All the rivers in the lower reaches were fairly turbid, the Kasitu Rivers being a muddy brown colour and carried considerable sediment in suspension.
Muhutu River 4/4/1954 ..	18.9	—	—	—	6.8	7.7	3.4	17	3.0	ND	—	10	0.04	
S. Rukwa River 4/4/1954 ..	—	—	—	—	7.1	8.2	9.0	45	8.2	2.6	—	14	0.02	Those flowing off the Nyika Plateau e.g. the Nchena Stream were clear in their upper reaches but on reaching the Henga Valley and its agricultural land became quite turbid.
Runyina 5/4/1954 ..	19.5	—	—	—	6.3	7.92	4.9	24.5	3.7	1.4	—	14	0.02	
Kasitu 5/4/1954 ..														
1. ..	22.5	—	—	—	7.5	8.9	10.8	54	10.4	3.1	—	12	TR	
2. ..	23.0	—	—	—	7.5	8.63	16.3	81.5	14.7	6.7	—	14	0.02	
Lunyangwa 5/4/1954 ..	21.5	—	—	—	7.0	8.38	5.5	27.5	5.3	1.4	—	18	0.02	All rivers were in full spate.
Mbasi River 6/10/1954 ..	28.4	—	7.98	102	8.1	8.4	25.0	125	15.7	8.1	30.2	6	0.01	Near its confluence with Lake Nyasa.

TABLE III—(*Continued*)

	pH electrically	Alkalinity $N \times 10^{-4}$	$CaCO_3$ mg/L	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Silicate mg/L SiO_2	Phosphate mg/LP	Comments
Luweya River 1/6/1954 ..	8.3	7.8	39.0	5.2	—	—	14	—	In main stream. Temperature 20.8°C.
Luweya River 2/6/1954 ..	7.98	4.3	21.5	2.0	—	—	12	—	In shore amongst marginal vegetation. Temperature 22.9°C.
Southern Rivers									
Luwawa Dam	7.15	2.5	12.5	6.0	3.4	11.6	—	0.01	Ammonia 0.08 ppm and Nitrate 0.07 ppm.
Katete River	7.86	16.1	80.5	14.0	9.3	29.3	—	0.01	Collected on various dates during August 1954
Bua River	8.14	18.6	93.0	17.4	7.8	30.00	—	0.01	Ammonia traces in all samples.
Lilonawe River	8.0	26.9	134	31.3	16.2	58.9	—	0.01	
Diampwe River	7.0	25.8	129	26.2	16.1	52.5	—	0.01	
Dwambadzi River	7.9	42.4	212	51	35.4	110	—	0.01	
Lake Nyasa inshore water ..	8.53	25.5	127.5	17.9	10.2	34.6	—	ND	All the rivers at this time of the year are very low. These rivers in many cases were only small pools connected by trickles of water.
Matete River	7.4	18.7	93.5	49.1	15.1	49.1	—	0.01	
Sinde River	7.5	50.5	252.5	45.9	21.9	81.9	—	0.06	
Namilolo River	7.6	16.7	73.5	13.9	11.9	33.3	—	TR	
Bua River (Ft. Manning) ..	7.89	12.2	61	11.1	9.8	27.1	—	0.01	
Masindiri River	7.9	136	680	86.8	89.7	23.4	—	0.03	
Muzuzu Dam	8.4	26.9	134.5	23.5	15.1	48.2	—	0.01	
Luweya River 18/10/1954 ..	7.95	7.3	36.5	5.8	3.1	—	24	0.03	pH colorimetrically 7.5. Temperature 24.2°C.
Luweya River 16/3/1955 ..	7.32	7.7	39.5	—	—	—	28	—	River in full flood. Conductivity 58.
Luweya River 18/7/1955 ..	7.9	7.4	37	4.8	4.6	12.4	25	TR	Conductivity 63
Shire River May, 1955 ..	7.8	25.65	128.5	18.2	9.3	33.4	1.5	ND	Midway between the Shire Bar and Lake Malombe.
Nkata Bay Stream 18/9/1955 ..	7.3	10.9	54.5	5.9	10.1	16.1	24	ND	Ammonia 0.2 ppm and Nitrite present in traces. Conductivity 100.

TABLE III—(*Continued*)

S. Rukuru River System, 23rd-29th October, 1954

		Temperature °C	Oxygen mg/L	Oxygen percentage saturation	K corr.	pH colorimetric	pH electrically	Alkalinity Nx10⁻⁴	$CaCO_3$ mg/L	Silicate SiO_2
Lake Kasuni		23.00	6.96	79	380	8.2	7.63	32.0	160	16
S. Rukuru River		22.7	7.2	81	55	7.9	7.7	4.85	24.3	16
Chelinda River		22.7	7.26	82	44	7.4	7.3	4.3	21.5	18
Pokambwa River		20.81	7.6	84	72	—	7.5	7.2	36.0	32
Kaziwiziwi River		18.63	8.6	91	34	—	8.0	3.4	17.0	16
Junju River		22.16	—	—	54	—	7.8	5.8	29.0	24
N. Rumpi River		19.4	7.5	80	30	—	7.6	3.5	16.5	17
Lura River		18.85	—	—	18	—	7.3	2.2	11.0	12
Nchena Hatchery Ponds	1	18.85	5.3	56	20	6.6	6.56	2.0	10	11
	2	21.9	5.4	60	24	6.8	6.91	2.8	14	6
	4	—	—	—	24	5.9	6.9	2.4	12	8
Nchena River		16.1	7.9	79	17	7.3	7.23	2.1	10.5	11
Checheche River		17.5	—	—	16	—	7.5	2.0	10	7
Chinanga River		21.4	—	—	30	—	6.97	3.1	15.5	13
Katuli River		22.42	—	—	56	—	7.9	6.2	31.0	22
Luvira River		24.63	—	—	95	—	7.9	10.3	51.5	24
Runyina River		23.6	—	—	53	—	7.6	5.7	28.5	18
Muhuju River		20.5	—	—	21	—	7.3	2.5	12.5	10
Pond on Nyika Plateau		16.0	—	—	20	—	—	1.7	8.5	6
Kanga River		29.0	—	—	980	—	—	130.5	652.5	72
Chelinda Headwaters		—	—	—	24	—	—	3.1	15.5	7
Kasitu River		—	—	—	100	—	—	11.2	56	24

During this month all rivers are at their lowest level just prior to the rains.

TABLE III—(*Continued*)

S. Rukuru River System, 12th-13th July, 1955

	Temperature °C	K corr.	pH electrically	Alkalinity $Nx10^{-4}$	$CaCO_3$ mg/L	Silicate mg/L SiO_2	Phosphate mg/L	Calcium mg/L Ca··	Magnesium mg/L Mg··
Lunyangwa River ..	15.5	56	7.6	6.4	32.0	18	TR	5.3	2.1
Kasitu River 1	15.8	154	7.83	17.2	86.0	12	ND	17.2	6.9
Kasitu River 2	14.7	86	7.8	9.6	48.0	20	TR	8.9	3.4
Rukuru River	13.9	53	7.58	8.5	29	14	ND	5.1	1.9
Chelinda River	13.0	29	7.7	3.4	17	11	ND	2.6	2.1
Runyina River	12.8	35	7.93	4.2	21	16	ND	3.7	1.3
Nchena River	13.9	17	7.8	1.6	8	7	ND	1.3	0.8
Nchena Hatchery Pond ..	20.3	27.5	7.32	3.0	15	6	ND	2.8	1.4
Tipwiri Pond	—	45	7.3	5.2	26	23	ND	3.2	2.1
Luvira River	13.3	78	7.59	8.6	43	21	TR	7.7	3.7
Muhuju River	13.3	25.5	7.74	3.0	15	9	ND	2.0	1.9
Katuli River	13.6	37	7.68	4.4	22	14	ND	2.6	2.1
Junju River	14.5	45.5	7.72	5.2	26	20	0.01	3.9	2.2
N. Rumpi River	13.9	24	7.8	3.1	15.5	12	ND	1.9	1.8
Kaziwiziwi River ..	13.9	27	7.78	3.3	16.5	15	ND	3.8	0.3
Manchewe River ..	15.3	41	7.7	5.3	26.5	19	ND	3.9	4.1

River falling rapidly, the rains having ended in April.

TABLE III—*(Continued)*

S. Rukuru River System, August, 1955

Series 1.

	Date	pH electrically	K corr.	Alkalinity $N \times 10^{-4}$	Silicate SiO_2 mg/L	Calcium $Ca^{\cdot\cdot}$	Magnesium $Mg^{\cdot\cdot}$	Total $Fe^{\cdot\cdot}$
Kasitu 1	18/viii/1955	7.3	160	18.7	13	16.4	5.0	ND
Lunyangwa	18/viii/1955	7.68	50	5.7	16	3.2	1.3	0.2
Kasitu 2	25/viii/1955	7.25	80	8.9	15	7.8	2.6	0.12
Runyina	19/viii/1955	7.5	46	5.4	11	5.5	1.2	0.1
Rukuru	19/viii/1955	7.5	46	5.4	10	4.1	1.9	0.1
Chelinda	19/viii/1955	7.43	32	3.8	10	2.9	1.3	0.08
Muhuju	19/viii/1955	7.33	17.5	2.3	7	1.6	3.2	TR
Katuli	19/viii/1955	7.46	37	4.2	14	2.4	4.7	0.04
Nchena	19/viii/1955	7.55	14	1.9	7	1.1	1.4	ND
N. Rumpi	19/viii/1955	7.3	25	3.0	9	2.1	ND	ND
Chitumba	22/viii/1955	7.5	67	7.7	17	5.9	1.0	0.04
Junju	25/viii/1955	7.4	46	5.6	14	3.7	0.7	TR
Stream on Mt. Waller ..	22/viii/1955	7.02	27	3.5	19	0.6	0.8	ND

Above are given two sets of data collected from this river system during August. Rivers at this period were falling steadily to their dry season levels.

Series 2.

	Date	pH electrically	K corr.	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Discharge Cu. ft./sec.
N. Rumpi	12/viii/1955	7.76	33	9	2.3	1.3	168.8
Wauve	13/viii/1955	7.88	71	11	7.2	2.3	43.1
N. Rukuru	18/viii/1955	7.9	68	10	6.3	1.6	109.5
Songwe	17/viii/1955	8.05	100	14.5	7.9	3.3	451.7
Kambwia	11/viii/1955	7.64	39	9	1.45	1.1	50.2
Junju	12/viii/1955	7.9	62	18	4.2	1.9	14.6
Kaziwiziwi	12/viii/1955	7.66	40	10	2.2	1.2	56.2
Lufira	18/viii/1955	8.16	110	14	4.8	4.1	24.5
Muhuju	11/viii/1955	7.63	30	7	1.9	1.2	9.2
Runyina	20/viii/1955	7.73	48	14	3.4	1.6	106.0
Rumpi Chelinda	20/viii/1955	7.7	44	11	3.1	1.2	—
S. Rukuru	11/viii/1955	7.85	75	8	6.8	2.1	268.6

TABLE IV

Analyses from Several Rivers Where They Enter Lake Nyasa and the Lake Water Inshore During February, 1955

	pH electrically	K corr.	Alkalinity $N \times 10^{-4}$	$CaCO_3$ mg/L	Silicate mg/L SiO_2	Calcium mg/ $LCa^{\cdot\cdot}$
Ruhuhu River	8.18	69	7.2	36	—	6.7
Lake Inshore at Karonga	8.58	220	24.0	120	3	17.3
Karonga Station II	8.7	215	24.3	121.5	3	17.5
Lake water near Mbasi River inflow	7.68	215	24.0	120	4	6.7
Lufiria River	8.26	89	8.3	41.5	10	8.2
Lake Water near Songwe River inflow ..	8.2	210	24.3	121.5	3	16.1
Deep Bay Station 9	8.66	215	24.1	120.5	4	16.6
Kambwe Lagoon	8.7	200	22.6	113.0	4	15.9
Songwe River	7.9	62	6.5	31.5	—	4.7

TABLE V

Depths in Metres	Temperature °C	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity $N \times 10^{-4}$	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Comments
***Station** 1A. Nkata Bay* 7/iii/1954																
0	28.3	7.63	97	8.2	—	22.8	114	ND	.76	ND	ND	3	17.6	6.1	27.6	Open water of lake just outside South Bay. 1. bottom at 160 metres. Station moved 500 yards further out. 2nd bottom 200 metres. Secchi Disc. visible down to 11.3 m. Sulphate not detected.
10	28.2	7.76	99	8.2	—	22.9	114.5	ND	.2	ND	ND	3	17.1	6.7	28.1	
50	24.6	5.96	70	8.2	—	24.85	124.3	.012	.76	ND	ND	3	18.2	6.85	29.7	
100	23.7	4.08	60	8.2	—	24.95	124.8	.016	.72	ND	ND	5	18.2	7.3	30.2	
160	23.9	1.06	12	8.2	—	25.4	127	.037	.32	ND	ND	7	18.2	7.3	30.2	
175	23.3	1.89	21	7.8	—	25.1	125.5	.037	.32	ND	ND	7	18.0	—	—	
195	23.6	0.15	2	7.7	—	25.75	128.8	.037	TR	ND	ND	8	18.2	7.9	31.1	
***Station** 1A. Nkata Bay* 15/iii/1954.																
0	28.8	7.1	89	8.2	—	23.2	116	—	.13	ND	ND	3	16.4	7.3	28.4	Sulphate not detected. Chloride 1.5 ppm, 0. to 75 m. 2 ppm at 100 m. and 2.5 ppm at 190.
25	27.5	7.13	90	8.1	—	23.0	115	—	.03	ND	ND	4	16.2	7.4	28.5	
50	25.7	5.77	70	8.0	—	24.8	124	—	.02	ND	ND	3	17.9	6.95	29.3	
75	23.4	6.08	70	7.9	—	25.2	126	—	.04	ND	ND	2	18.1	7.7	30.7	
100	23.1	4.75	54	7.8	—	26.3	131.5	—	.07	ND	ND	3	18.1	8.1	31.4	
190	22.8	—	—	7.5	—	24.8	124	—	.21	ND	ND	3	18.3	8.1	31.4	
***Station** 1. Nkata Bay* 24/iii/1954																
0	27.4	6.98	89	—	—	24.1	120.5	—	.08	ND	ND	4	16.4	7.3	28.4	Station 1 is 3 miles N.E. of Nkata Bay. The depth at Station 1 on the Echo Sounder varied between 170 and 180 fathoms and the position is: Long. 34°20′55 E, Lat. 11°36′S. Sulphate not detected.
25	27.2	7.04	88	—	—	—	—	—	ND	ND	ND	4	16.5	7.1	28.1	
100	22.9	4.18	48	—	—	—	—	—	ND	ND	ND	3	19.4	7.8	32.2	
190	22.7	0.87	10	—	—	15.6	128	—	ND	ND	ND	2	19.5	7.2	31.3	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity $Nx10^{-4}$	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 1. *Nkata Bay* 10/v/1954																
0	27.4	7.41	93	8.2	—	23.6	116	ND	ND	ND	ND	3	17.9	6.05	27.8	Calm, slight ripple on surface, wind light, little cloud. 10.00 hrs. C.A.T. Secchi Disc. visible to 17.4 m. Sulphate not detected.
25	26.6	7.12	87	8.2	—	—	—	—	—	—	—	3	—	—	—	
50	26.0	6.82	82	8.2	—	23.5	115	ND	ND	ND	ND	3	16.9	—	—	
60	25.5	6.83	81	8.2	—	—	—	—	—	—	—	3	—	—	—	
75	23.3	5.55	64	8.0	—	24.4	112	ND	ND	ND	ND	4	—	—	—	
100	23.1	4.93	57	7.8	—	24.4	112	ND	ND	ND	ND	4	17.8	—	—	
150	22.9	4.03	46	7.5	—	24.4	112	ND	ND	ND	ND	6	18.9	—	—	
190	22.7	1.71	20	7.5	—	25.5	127.5	ND	ND	ND	ND	8	20.6	6.15	30.7	
Station 1. *Nkata Bay* 21/iv/1954																
0	27.2	7.48	92	—	8.2	23.2	116	ND	ND	ND	ND	—	15.1	—	—	Heavy swell, wind N.W. considerable drift off-shore, 3/8 cloud. 09.40 hrs. Sulphate not detected.
30	26.4	7.48	91	—	8.2	24.5	122.5	ND	ND	ND	ND	—	17.6	6.9	28.9	
60	25.2	7.0	84	—	8.1	24.9	124.5	ND	ND	ND	ND	—	18.5	—	—	
100	23.2	5.3	62	—	8.1	24.9	124.5	ND	ND	ND	ND	—	19.2	—	—	
195	22.7	1.43	16	—	8.1	26.8	134.0	ND	ND	ND	ND	—	20.9	—	—	
Station 1. *Nkata Bay* 3/v/1954																
0	26.9	6.4	79	—	8.85	24.2	121	ND	ND	ND	ND	3	16.8	—	—	Wind moderate, 5/8 cloud mainly to N.W. Considerable drift off-shore. Sampling at 09.00 hrs. Secchi Disc. visible at 17.2 m.
25	26.3	7.04	86	—	8.8	24.6	123	ND	ND	ND	ND	3	—	—	—	
50	25.5	7.44	90	—	8.8	24.6	123	ND	ND	ND	ND	3	17	—	—	
75	24.7	6.95	82	—	8.78	24.8	124	ND	ND	ND	ND	4	17.5	—	—	
100	23.3	6.18	71	—	8.8	24.3	121.5	ND	ND	ND	ND	—	17.9	—	—	
195	22.9	5.08	57	—	8.58	25.2	127	ND	ND	ND	ND	—	17.96	—	—	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity Nx10⁻⁴	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 17. *Likoma Island* 17/vi/1954																
0	—	—	—	—	8.78	24.2	121	—	—	—	—	3	16.6	7.15	28.3	
50	—	—	—	—	8.95	25.9	129.5	—	—	—	—	3	17.0	7.4	29.2	
Station 1. *Nkata Bay* 7/vii/1954																
0	24.0	7.53	89	—	8.63	24.3	121.5	TR	ND	ND	ND	4	17.2	7.6	32.9	Moderate swell, variable in direction, no wind. Sun bright ea. 3/8 clouds. Sampling at 10.00 hrs. over 185 fathoms. Sulphate not detected.
60	23.75	7.53	88	—	8.58	24.5	122.5	TR	ND	ND	ND	6	17.9	7.3	33.0	
90	23.2	5.72	66	—	8.57	24.75	124	TR	ND	ND	ND	6	16.4	7.4	31.8	
100	23.1	5.51	64	—	8.1	24.8	124	TR	ND	ND	ND	7	—	—	—	
115	23.1	4.67	54	—	8.12	24.9	124.5	TR	ND	ND	ND	6	18.2	8.1	34.8	
125	23.05	4.67	54	—	—	25.0	125	TR	ND	ND	ND	—	—	—	—	
150	23.0	3.08	35	—	8.2	25.0	125	TR	ND	ND	ND	6	—	—	—	
210	22.75	2.64	30	—	8.03	25.1	125.5	TR	ND	ND	ND	8	18.8	7.7	34.7	
Station 2. *Usisya* 17/vii/1954																
0	24.9	8.86	106	8.4	8.76	25.0	125	ND	—	—	—	3	19.8	9.3	35.5	A station off Usisya 30–35 N. of station 1. Position Lat. 11°10′S, Long. 34°19′E. Depth 385 fathoms. Calm, slight breeze, 4/8 cloud, none over station. Sampling at 13.40 hrs. Sulphate not detected.
30	24.1	8.63	101	8.65	8.75	24.8	124	ND	—	—	—	3	19.9	—	—	
60	23.45	5.81	67	8.55	8.33	25.0	125	ND	—	—	—	4	19.9	—	—	
80	23.1	6.67	77	8.6	8.49	25.15	125.7	ND	—	—	—	4	20.0	—	—	
100	23.05	5.34	60	8.1	8.18	25.45	127	ND	—	—	—	4	20.0	8.1	33.3	
180	22.75	2.89	33	8.0	7.82	25.8	129	ND	—	—	—	7	20.9	—	—	
220	22.6	ND	—	8.0	7.89	25.7	128.5	ND	—	—	—	8	21.4	8.2	35.0	
250	22.55	ND	—	8.0	7.85	25.9	129	ND	—	—	—	8	21.6	8.0	35.0	
300	22.5	ND	—	7.9	7.89	25.9	129	ND	—	—	—	9	21.5	—	—	
Station 1. *Nkata Bay* 28/vii/1954																
0	23.65	7.99	94	—	8.7	24.7	123.5	ND	—	ND	ND	4	—	—	—	Sampled over 175 fathoms. Wind moderate, southerly choppy. 1/8 cloud, drift N.E. moderate. Sulphate not detected.
100	23.3	6.04	70	—	8.38	25.0	125	ND	—	ND	ND	6	—	—	—	
200	22.75	2.59	29	—	8.03	25.8	129	ND	—	ND	ND	8	—	—	—	
220	22.65	1.31	15	—	7.05	25.8	129	TR	—	ND	ND	8	—	¼	—	
300	22.45	ND	—	—	7.7	26.3	131.5	TR	—	ND	ND	12	—	—	—	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K corr	Oxygen mg/L	Oxygen percentage saturation	pH electrically	Alkalinity Nx10^{-4}	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 25. *Salima* 21/viii/1954																
0	23.1	—	7.36	84	7.6	25.2	126	0.02	0.12	ND	ND	4	19.2	8.0	32.3	This station is more than 100 miles S. of station 1.
10	22.85	—	—	—	7.6	—	—	0.02	—	—	—	—	—	—	—	
20	22.85	—	6.87	78	7.9	25.0	125	0.02	0.1	ND	TR	4	19.4	7.9	32.3	Lat. 13°33′S, Long. 34°43′E. The depth of water was 81 fathoms. Sea moderate, wind S.E. fresh, force 3, bright sun 12.30 hrs. C.A.T.
40	22.65	—	7.52	86	8.0	25.2	126	0.02	ND	ND	ND	4	19.0	7.9	31.9	
60	22.65	—	7.89	91	8.2	25.5	127.5	0.02	ND	ND	TR	4	18.6	7.8	31.4	
80	22.6	—	8.02	91	8.3	25.0	125	0.02	TR	ND	ND	4	18.4	8.5	32.3	
100	22.45	—	7.7	87	8.3	25.4	127	0.03	0.6	ND	ND	3	18.4	8.4	32.2	Sulphate not detected. Chloride 2.5 ppm throughout.
150	22.4	—	6.3	71	8.3	24.8	124	0.03	0.6	ND	ND	3	18.3	8.1	31.6	
Station 26. *Monkey Bay* 26/viii/1954																
0	24.8	—	8.46	101	7.6	20.0	100	0.02	TR	ND	ND	6	20.1	6.9	31.4	This station is situated about 6 miles N.E. of Monkey Bay. Position; Lat. 14°S, Long. 35°2′E. Calm, no wind, bright sun, 10.15 hrs. C.A.T.
10	22.4	—	8.32	95	8.2	19.1	95.5	0.02	ND	0.004	ND	4	18.6	7.9	31.5	
20	22.25	—	7.97	90	8.3	24.8	124	0.02	ND	0.03	0.11	4	18.3	7.9	31.2	
40	22.2	—	7.87	89	8.4	24.7	123.5	0.02	ND	ND	0.18	4	18.3	7.9	31.2	
70	21.8	—	7.81	87	8.4	24.9	124.5	0.02	ND	ND	0.10	4	19.4	7.3	31.4	
Station 27. *S. E. Arm of Lake Nyasa.* 26/viii/1954																
0	23.1	—	¼	—	8.1	25.2	126	0.02	0.7	ND	ND	3	19.0	9.15	34.0	Sulphate not detected. Cloride 4 ppm.
Station 1. *Nkata Bay* 2/iv/1954																
0	23.6	—	7.66	89	8.5	25.8	129	ND	ND	ND	0.7	10	19.9	7.6	32.3	Depth of water at the station 168 fathoms. Secchi disc. visible to 9.2 metres. Calm, slight breeze from S.E. Bright sun, no cloud. 09.15 hrs. C.A.T. Sulphate not detected.
10	23.2	—	7.44	86	8.3	25.7	128.5	ND	ND	ND	0.44	5	19.6	7.7	32.3	
20	23.1	—	7.28	84	8.3	24.5	122.5	ND	ND	ND	0.45	5	18.4	8.3	32.1	
50	23.0	—	6.0	68	8.3	24.4	122	ND	ND	ND	0.27	5	18.3	8.8	32.8	
100	22.8	—	3.74	43	8.3	24.4	122	TR	ND	ND	0.27	7	19.2	8.6	33.3	
200	22.6	—	2.59	30	8.2	25.6	128	0.02	ND	ND	0.2	10	19.6	8.1	32.9	
225	22.6	—	0.61	6	7.9	26.4	132	0.034	TR	ND	0.15	11	19.6	8.5	33.8	
300	22.5	—	ND	—	7.9	26.5	132.5	0.04	TR	ND	0.15	13	20.4	7.5	32.6	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K. corr.	Oxygen mg/L	Oxygen percentage saturation	pH electrically	Alkalinity Nx10^{-4}	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Comments
Station 1. *Nkata Bay* 18/iv/1954																
0	24.2	—	8.35	98	8.3	25.1	125.5	0.104	ND	ND	TR	6	17.6	8.2	31.1	Slight breeze N.W., swell moderate from N.E. Bright sun 15.00 hours C.A.T. Sulphate not detected. Qualitatively.
25	23.95	—	8.3	97	8.6	25.8	129	ND	ND	ND	TR	—	17.4	8.2	31.0	
50	23.25	—	8.0	92	8.6	25.2	126	ND	ND	TR	TR	6	—	—	—	
75	23.2	—	6.54	74	8.2	25.8	129	TR	ND	ND	TR	—	—	—	—	
100	22.8	—	3.62	42	8.4	25.8	129	TR	ND	ND	TR	—	—	—	—	
150	22.7	—	2.37	27	8.5	27.1	125.5	TR	ND	ND	TR	8	18.3	8.5	32.1	
200	22.6	—	1.73	20	8.0	25.6	128	.03	ND	ND	TR	—	20.2	8.2	33.7	
300	22.5	—	ND	—	—	—	—	.05	ND	ND	TR	8	—	—	—	
Station 13. *Karonga* 10/x/1954																
0	24.75	230	8.45	100	8.8	25.2	126	ND	ND	ND	ND	3	20.4	—	—	This station was approximately 80 miles north of station 1. Its position: Lat. 9°40′S, Long. 34°5′ E. Moderate sea, wind force 2. 05.00 hrs. C.A.T.
25	24.0	230	7.46	87	8.67	24.95	124.8	ND	ND	ND	ND	3	20.4	—	—	
50	23.4	230	3.64	42	7.89	24.9	124.5	ND	ND	ND	ND	7	21.4	—	—	
100	22.85	230	3.63	42	8.06	25.8	129	0.015	ND	ND	ND	6	21.3	—	—	
150	22.75	230	0.71	7.5	8.0	26.5	132.5	0.015	ND	ND	ND	7	21.9	—	—	
200	22.6	230	0.26	3	7.91	26.25	131.3	0.06	ND	ND	ND	8	—	—	—	
300	22.45	230	ND	—	7.77	26.5	132.5	0.06	ND	ND	ND	11	22.5	—	—	
Station 1. *Nkata Bay* 11/x/1954																
0	25.75	—	7.82	95	8.3	25.4	127	ND	ND	ND	ND	2	18.4	8.2	31.9	Bright sun, calm, no cloud 16 hrs.
30	24.15	—	8.05	95	—	—	—	ND	ND	ND	ND	6	17.0	7.8	29.7	
50	23.75	—	6.38	75	—	—	—	ND	TR	ND	ND	8	20.0	8.1	33.5	
150	22.65	—	3.73	43	7.9	—	—	0.02	TR	ND	ND	8	19.7	8.2	33.2	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K. corr.	Oxygen mg/L	Oxygen percentage saturation	pH electrically	Alkalinity Nx10^{-4}	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 1. *Nkata Bay* 19/x/1954																
0	25.4	—	7.58	91	8.5	25.2	126	ND	0.03	ND	ND	2	18.6	7.7	31.2	Bright sun, moderate swell, wind fresh from N.N.E. ca. $\frac{3}{8}$ cloud. 10.30 hrs. C.A.T. Sulphate not detected.
20	24.3	—	7.47	88	8.2	25.4	127	TR	ND	ND	ND	3	18.3	7.9	31.7	
50	23.2	—	6.2	71	8.0	25.5	127.5	TR	ND	ND	ND	4	19.8	7.4	31.8	
60	23.2	—	5.18	59	7.9	25.1	125.5	0.02	ND	ND	ND	4	19.2	7.9	32.2	
100	22.9	—	4.44	52	7.9	25.7	128.5	0.02	ND	ND	ND	6	19.7	8.1	33.0	
180	22.65	—	3.89	44	7.5	25.3	126.5	0.03	ND	ND	ND	7	20.8	7.5	33.1	
Station 1. *Nkata Bay* 26/x/1954																
0	27.6	255	8.68	109	8.5	25.9	129.5	TR	ND	ND	TR	7	18.5	6.4	29.2	Calm, bright sun ca. $\frac{3}{8}$ cloud, slight breeze, variable in direction, but mainly N.E. 08.30 hrs. C.A.T.
25	24.95	225	7.38	88	8.4	25.6	128	ND	ND	ND	ND	8	18.3	7.7	31.2	
50	24.25	225	7.36	87	8.3	24.6	123	TR	ND	ND	ND	8	18.3	7.7	31.2	
60	24.0	225	8.26	96	8.2	25.5	127.5	TR	ND	ND	ND	8	—	—	—	
100	23.05	225	5.12	59	8.1	25.4	127	TR	TR	ND	ND	9	18.8	7.6	31.4	
150	22.85	120	4.0	46	7.8	20.0	130	.02	TR	ND	ND	10	19.4	7.5	31.9	
200	22.7	230	3.14	36	8.1	25.9	129.5	.02	TR	ND	ND	10	19.8	7.4	32.1	
300	22.5	120	ND	—	7.7	26.1	130.5	.03	.08	ND	ND	16	19.4	7.7	32.3	
Station 1. *Nkata Bay* 15/xi/1954																
0	27.05	225	8.0	99	8.4	25.4	127	ND	ND	ND	ND	2	18.2	7.9	31.2	
5	26.55	225	8.03	98	8.4	25.2	126	0.01	ND	ND	ND	3	18.2	—	—	
30	26.1	225	7.45	90	8.73	25.0	125	ND	ND	ND	ND	3	18.2	7.7	30.8	
50	25.75	230	7.95	96	8.98	25.9	129.5	ND	ND	ND	ND	—	18.2	7.75	30.9	
70	23.95	225	7.2	85	8.72	24.6	123	TR	ND	ND	ND	3	18.2	8.0	31.4	
100	23.05	225	3.55	41	8.2	25.0	125	0.01	ND	ND	ND	3	18.8	7.8	31.6	
150	22.75	230	1.9	22	8.5	16.0	130	0.015	ND	ND	ND	7	19.5	8.3	33.2	
200	22.55	230	0.68	8	7.92	25.7	128.5	0.025	TR	ND	ND	8	—	—	—	
300	22.5	230	ND	—	7.78	25.8	129	0.025	TR	ND	ND	9.5	20.0	8.0	33.1	

TABLE V—*(Continued)*

Depth in Metres	Temperature °C	K corr	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity $N \times 10^{-4}$	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 1. *Nkata Bay* 8/xii/1954																	
0	27.4	—	7.28	98	—	8.78	25.6	128	—	ND	ND	—	2	—	—		Calm, no wind at first; slight from E. later.
30	27.15	—	7.52	93	—	—	25.6	128	—	ND	ND	—	2	—	—		Bright sun, $\frac{7}{8}$ cloud, storm centre
38	25.65	—	7.09	86	—	8.63	25.6	128	—	ND	ND	—	3	—	—		K.S.E. 10.00 hrs. C.A.T.
40	25.4	—	6.85	82	—	—	—	—	—	ND	ND	—	—	—	—		
45	24.7	—	6.84	81	—	8.65	26.1	130.5	—	ND	ND	—	4	—	—		
50	24.15	—	6.48	76	—	—	—	—	—	ND	ND	—	—	—	—		
60	23.7	—	5.26	61	—	8.39	25.6	128	—	ND	ND	—	4	—	—		
100	23.0	—	4.89	56	—	8.29	26.1	130.5	—	ND	ND	—	7	—	—		
200	22.6	—	0.99	11	—	7.91	26.3	131.5	—	ND	ND	—	8	—	—		
Station 1. *Nkata Bay* 31/xii/154																	
0	29.75	—	7.83	102	8.5	—	25.0	125	—	—	—	—	1.5	—	—		Sampling over 160 fathoms.
15	28.0	—	7.4	94	8.5	—	25.2	126	—	—	—	—	1.5	—	—		Calm, bright sun, slight swell, no wind. 9.30 hrs. C.A.T. ca. $\frac{5}{8}$ cloud.
30	26.95	—	7.65	95	8.5	—	25.1	126.5	—	—	—	—	1.5	—	—		
35	26.5	—	7.9	97	8.4	—	25.3	126.5	—	—	—	—	1.5	—	—		
40	25.25	—	7.46	90	8.3	—	25.3	126.5	—	—	—	—	1.5	—	—		
45	24.4	—	7.14	85	—	—	—	—	—	—	—	—	—	—	—		
50	23.94	—	6.59	77	8.15	—	25.3	126.5	—	—	—	—	1.5	—	—		
100	23.0	—	5.03	58	7.97	—	25.3	126.5	—	—	—	—	3	—	—		
150	22.8	—	4.65	53.5	—	—	—	—	—	—	—	—	—	—	—		
200	22.6	—	3.1	35.0	7.85	—	25.9	129.5	—	—	—	—	5	—	—		
Station 25. *Salima* 5/i/1955																	
0	27.95	220	7.18	90	—	8.92	24.8	124	ND	—	—	—	2	—	—		Complete cloud cover, overcast, raining. Wind E.S.E. force 3, moderate swell. 08.30 hrs. C.A.T.
20	27.80	220	7.04	89	—	8.82	24.6	123	ND	—	—	—	3	—	—		
30	26.7	220	7.08	87	—	8.88	24.4	122	ND	—	—	—	3	—	—		
40	25.15	225	6.41	77	—	8.46	24.1	120.5	ND	—	—	—	2	—	—		
50	24.10	225	5.52	65	—	8.55	24.8	124	ND	—	—	—	3	—	—		
60	23.6	225	5.63	65.5	—	8.32	24.2	121	TR	—	—	—	3	—	—		
75	23.6	225	5.48	64	—	7.78	23.9	119.5	TR	—	—	—	3	—	—		
100	23.1	230	4.09	47	—	8.22	24.6	123	0.03	—	—	—	4	—	—		
150	22.6	230	0.48	5	—	7.52	24.9	124.5	0.026	—	—	—	8	—	—		

TABLE V—*(Continued)*

Depth in Metres	Temperature °C	K corr	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity Nx10^{-4}	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Comments
Station 26. *Monkey Bay* 6/i/1955																	
0	27.8	220	7.39	92	—	8.93	24.3	121.5	ND	—	—	—	1.5	—	—		⅜ cloud, bright sun. Wind S.S.E. force 2. Swell moderate. 06.30 hrs. C.A.T.
20	27.8	220	7.20	90.5	—	8.95	24.4	122	ND	—	—	—	2	—	—		
30	26.55	230	7.06	87	—	8.1	26.3	131.5	ND	—	—	—	2	—	—		
40	25.45	225	6.32	76	—	8.74	24.4	122	ND	—	—	—	2	—	—		
50	24.55	225	5.81	69	—	8.52	24.7	123.5	ND	—	—	—	2	—	—		
60	23.7	225	4.14	48	—	8.32	24.7	123.5	ND	—	—	—	3	—	—		
80	23.1	225	4.59	53	—	8.36	25.1	125.5	ND	—	—	—	5	—	—		
Station 1. *Nkata Bay* 14/i/1955																	
0	28.1	—	7.6	96	—	8.91	24.5	112.5	ND	ND	ND	ND	1.5	18.3	9.1	33.2	Cloudy over cast, complete cloud cover, wind slight from N.E. Calm. 9.30 hrs. C.A.T. Sulphate not detected.
10	28.1	—	7.03	89	—	8.9	25.1	125.5	ND	ND	ND	ND	1.5	18.6	9.3	33.8	
20	28.05	—	7.95	101	—	8.9	25.2	126	ND	ND	ND	ND	1.5	18.4	8.8	32.9	
30	27.35	—	7.50	94	—	8.9	25.2	126	ND	ND	ND	ND	1.5	19.0	8.6	33.0	
40	26.3	—	7.46	91	—	8.82	—	—	ND	ND	ND	ND	2	19.3	8.1	32.4	
50	24.4	—	—	—	—	8.68	25.2	126	ND	ND	ND	ND	2	19.2	8.3	32.8	
100	22.95	—	5.05	58	—	8.22	25.2	126	0.01	ND	ND	ND	3	19.9	8.2	33.7	
200	22.6	—	1.19	13	—	7.9	26.2	131	0.03	ND	ND	ND	8	20.8	8.1	34.2	
250	22.55	—	ND	—	—	7.78	25.6	128	0.03	ND	ND	ND	9	20.4	8.5	34.2	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K Corr	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity Nx10^{-4}	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L Ca··	Magnesium mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 1. *Nkata Bay* 23/ii/1955																	
0	27.10	220	7.24	89	—	8.63	24.6	123	—	ND	ND	ND	3	17.4	—	—	Sampling at 09.45 hrs. N.W. wind light. Slight ripple on water. Calm. Bright sun, $\frac{5}{8}$ cloud. 10.00 hrs. C.A.T.
10	27.06	220	7.14	88	—	8.74	24.6	123	—	ND	—	ND	3	16.7	—	—	
25	25.60	220	7.13	86	—	8.62	—	—	—	ND	ND	ND	3	16.6	—	—	
35	24.9	220	6.84	81	—	8.48	25.2	126	—	ND	ND	ND	3	16.7	—	—	
43	24.3	220	6.53	77	—	8.34	25.4	127	—	ND	ND	ND	3	17.9	—	—	
50	23.85	225	6.20	72	—	8.20	25.2	126	—	ND	ND	ND	5	18.0	—	—	
75	23.15	230	5.02	58	—	7.88	25.8	129	—	ND	ND	ND	7	19.3	—	—	
100	22.85	—	3.77	43	—	—	—	—	—	ND	—	—	—	—	—	—	
157	22.6	230	183	20	—	7.83	25.8	129	—	ND	ND	ND	9	19.1	—	—	
250	22.55	230	ND	NIL	—	7.70	25.9	129.5	—	TR	ND	ND	10	20.2	—	—	
300	22.5	—	ND	NIL	—	—	—	—	Bottle failed to close.				—	—	—	—	
Station 1. *Nkata Bay* 7/iii/1955																	
0	27.75	220	8.2	103	—	8.92	23.7	118.5	ND	ND	ND	ND	2	16.6	8.4	30.0	Bright sun, slight swell. $\frac{3}{4}$ cloud. Wind about force 2 gusty; drift considerable to North.
10	27.5	220	7.44	92.5	—	8.84	24.2	121	ND	ND	ND	ND	2	17.3	7.8	30.1	
30	27.2	220	7.22	89	—	8.88	24.4	122	ND	ND	ND	ND	2	17.6	7.5	30.1	
65	23.95	220	5.57	67	—	8.42	24.8	124	ND	ND	ND	ND	5	18.1	7.4	31.2	
100	23.05	225	4.34	50	—	8.30	24.9	124.5	0.012	ND	ND	TR	4	18.1	8.0	31.2	
150	22.8	225	1.72	19	—	8.09	25.0	125	0.024	ND	ND	TR	6	18.9	7.9	31.8	
200	22.7	230	ND	NIL	—	—	25.4	127	0.033	TR	ND	ND	8	18.9	7.6	31.4	
300	22.55	230	ND	NIL	—	—	25.3	126.5	0.053	0.5	ND	ND	11	18.8	7.5	31.1	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K corr	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity $N \times 10^{-4}$	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Comments
Station 1. *Nkata Bay* 25/iii/1955																	
0	26.75	215	7.18	88	—	8.55	24.5	122.5	ND	ND	ND	ND	1.5	16.9	—	31.1	Moderate swell, slight wind from S.E. Complete cloud cover. 08.30 hrs. C.A.T.
40	26.65	215	7.05	86	—	8.5	24.6	123	ND	ND	ND	ND	1.5	16.7		30.1	
75	26.1	215	4.94	59	—	8.5	24.6	123	ND	ND	ND	ND	1.5	17.2		30.0	
85	23.45	220	5.06	58	—	8.25	24.8	124	ND	ND	ND	ND	2	17.5		30.8	
100	23.1	225	4.19	47.5	—	8.02	25.4	127	TR	ND	ND	ND	3	18.2		31.3	
150	22.85	230	2.10	23.5	—	8.33	25.2	126	0.03	TR	ND	ND	5	18.0		—	
200	22.6	230	0.79	8	—	7.78	25.5	127.5	0.04	0.10	ND	ND	7	18.5		31.6	
Station 1. *Nkata Bay* 2/iv/1955																	
0	26.88	220	7.36	89	—	7.9	25.3	126.5	0.012	ND	ND	ND	7	19.4		31.4	Sampling after a week of rough weather with strong S.E. winds. 08.30 hrs. C.A.T. Bright sun, cloudy, heavy swell, wind moderate. Easterly.
25	26.6	210	7.47	91	—	8.7	24.5	122.5	ND	ND	ND	ND	2	18.4		31.3	
50	26.4	210	7.13	87	—	8.7	24.5	122.5	ND	ND	ND	ND	2.5	18.4		31.5	
75	23.5	210	4.99	57	—	8.7	24.5	122.5	ND	ND	ND	ND	2.5	18.3		31.5	
100	22.9	220	4.15	47	—	8.36	25.0	125	ND	0.07	ND	ND	3	19.2		31.9	
150	22.7	225	1.97	22.5	—	8.34	25.0	125	ND	0.2	ND	ND	3	19.2		32.4	
200	22.6	230	1.35	15	—	7.99	26.0	130	TR	0.2	ND	ND	6	19.8		33.0	
Station 1. *Nkata Bay* 23/v/1955																	
0	26.0	215	7.48	90	—	8.7	24.3	121.5	ND	TR	TR	0.02	2	17.4		31.0	11.30 hrs. C.A.T. Calm, moderate swell, drift to North. Bright sun ca. ⅜ cloud.
50	25.64	215	6.95	83	—	8.63	24.4	122	ND	TR	ND	0.01	3	17.5		31.0	
70	25.4	220	6.96	83	—	8.42	24.6	123	ND	TR	ND	TR	3	18.1		31.2	
85	25.0	220	6.64	77	—	8.53	24.3	121.5	ND	TR	ND	0.03	3	18.4		31.4	
100	23.25	220	4.64	53	—	8.18	24.8	124	TR	ND	ND	0.08	3	19.0		31.7	
125	22.85	225	4.16	47	—	8.08	25.1	125.5	0.02	TR	ND	0.06	4	19.0		31.3	
200	22.6	225	0.11	2	—	7.8	25.6	128	0.036	TR	ND	0.05	6	19.9		31.6	
250	22.5	230	ND	NIL	—	7.78	25.4	127	0.05	0.02	ND	0.06	7	20.0		32.8	
300	22.45	230	ND	NIL	—	7.7	—	—	0.06	0.25	—	0.06	8	—		—	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K corr	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity $Nx10^{-4}$	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Comments
Station 1. *Nkata Bay* 28/vi/1955																	
0	24.6	215	7.8	92	—	9.08	24.9	124.5	ND	0.15	ND	ND	2	17.3		32.6	Moderate swell. Bright sun, ca. ⅜ cloud. Wind force 3 drift slight to N.W. on shore.
25	24.35	215	7.54	89	—	9.08	25.0	125	ND	0.39	ND	ND	2	18.2		32.4	
50	24.2	220	7.52	88	—	8.6	25.6	128	ND	0.67	.004	TR	2	18.5		32.2	
80	24.2	220	6.82	80	—	8.91	24.9	124.5	ND	TR	ND	ND	2	18.5		32.2	
100	23.8	220	5.55	64	—	8.68	25.0	125	ND	TR	ND	ND	3	18.6		32.4	
180	22.55	230	0.53	5.5	—	8.1	25.5	127.5	.04	.18	ND	ND	6	19.2		33.5	
250	22.45	230	ND	NIL	—	8.05	—	—	.06	.2	ND	ND	7	19.3		33.6	
350	22.4	230	ND	NIL	—	7.70	25.8	129	.06	.39	ND	ND	7	19.3		34	
Station 2. *Usisya* 21/vii/1955																	
0	24.26	215	7.78	91	—	8.68	24.9	124.5	ND	ND	—	ND	1.5	16.1		32.3	Slight swell, wind force 1, calm. Bright sun. 14.30 hrs. C.A.T.
25	24.32	215	7.78	91.5	—	8.73	24.9	124.5	ND	.17	ND	ND	1.5	17.6		32.2	
50	24.32	215	7.83	92.5	—	8.8	25.0	125	ND	TR	.002	ND	1.5	17.1		32.4	
75	23.94	220	5.28	61	—	8.73	25.1	125.5	ND	TR	.0015	ND	1.5	17.5		32.4	
100	23.38	225	6.06	69	—	8.62	25.4	127	TR	ND	ND	.03	2	17.2		33.0	
200	22.6	225	0.43	5	—	8.23	25.6	128	0.044	TR	.002	ND	7	18.9		34.0	
300	22.45	230	ND	NIL	—	8.0	25.7	128.5	0.06	.2	ND	ND	9	18.9		34.0	
400	22.4	230	ND	NIL	—	7.94	25.7	128.5	0.06	.2	ND	ND	10	18.9		34.0	
600	22.4	235	ND	NIL	—	7.70	26.1	130.5	0.06	.24	ND	ND	10	18.9		35.0	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K corr	Oxygen mg/L	Oxygen percentage saturation	pH colorimetric	pH electrically	Alkalinity $Nx10^{-4}$	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_2	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L $Ca^{\cdot\cdot}$	Magnesium mg/L $Mg^{\cdot\cdot}$	Total Hardness as Calcium and Magnesium mg/L $Ca^{\cdot\cdot}$	Comments
Station 1. *Nkata Bay* 23vii/1955																	
0	24.2	220	7.58	89	—	8.5	25.8	129.0	ND	0.04	ND	TR	1.5	18.4	8.8	33.1	No wind at first freshening to force 2 later. Bright sun ⅜ cloud, slight swell. Drift to N.E. Sulphate not detected.
25	24.0	220	7.51	88	—	8.53	24.6	126	ND	TR	ND	ND	1.5	18.6	8.5	32.8	
50	23.85	220	7.31	65	—	8.53	25.1	125.5	ND	0.24	ND	TR	1.5	19.7	8.45	33.8	
75	23.8	220	6.96	80.5	—	8.48	24.8	124	ND	ND	ND	ND	2	18.2	8.6	32.6	
100	23.75	220	6.96	80	—	8.58	24.8	124	ND	ND	ND	ND	2.5	19.5	8.2	33.2	
125	22.8	220	5.29	60	—	8.42	25.1	125.5	TR	ND	ND	TR	3	19.2	8.85	34.0	
150	22.75	225	2.93	33.5	—	8.05	25.0	125	0.015	ND	ND	ND	4	20.6	8.0	34.0	
175	22.6	230	1.38	15.5	—	7.95	25.0	125	0.02	ND	ND	ND	6	20.6	8.0	34.0	
200	22.6	230	1.11	12.5	—	7.94	25.1	125.1	0.02	ND	ND	TR	6	20.4	8.0	34.0	
300	22.4	230	ND	NIL	—	7.70	25.8	129.0	0.06	0.27	.001	ND	9	20.7	8.15	34.6	
Station 1. *Nkata Bay* 20/viii/1955																	
0	24.0	220	7.6	8.9	—	8.5	24.7	123.5	TR	ND	ND	ND	1.5	17.4	8.6	31.8	09.30 hrs. C.A.T. Bright sun, wind force 2, offshore N.W. swell moderate from S.E. ⅜ cloud mainly over mountains.
50	23.35	220	6.96	80	—	8.5	24.6	123	TR	ND	ND	ND	2	18.5	8.0	31.9	
100	23.15	225	5.15	59	—	8.2	24.8	124	TR	ND	ND	ND	2.5	18.1	8.25	31.9	
125	22.95	225	3.94	44.5	—	8.15	24.8	124.	.03	ND	ND	ND	3	18.2	8.0	31.6	
150	22.75	225	2.99	34	—	8.05	24.9	124.5	.035	ND	ND	ND	5	18.7	7.95	32.0	
200	22.6	225	0.38	4	—	8.99	25.4	127	.04	ND	ND	ND	7.5	18.9	7.9	32.1	
225	22.6	230	0.3	3	—	7.93	25.3	126.5	0.6	ND	ND	ND	7.5	18.8	8.25	32.6	
250	22.55	230	0.19	2	—	7.88	25.35	126.8	.06	ND	ND	ND	8	20.1	7.85	33.2	
300	22.5	230	ND	NIL	—	7.82	25.4	127	.06	ND	ND	ND	9	20.4	7.8	33.3	

TABLE V—(*Continued*)

Depth in Metres	Temperature °C	K corr.	Oxygen mg/L	Oxygen percentage saturation	pH electrically	Alkalinity Nx10^{-4}	$CaCO_3$ mg/L	Phosphate mg/L P	Free Ammonia mg/L N	Nitrite mg/L NO_3	Nitrate mg/L N	Silicate mg/L SiO_2	Calcium mg/L	Magnesium Ca·· mg/L Mg··	Total Hardness as Calcium and Magnesium mg/L Ca··	Comments
Station 1. *Nkata Bay* 24/ix/1955																
0	24.2	220	—	—	8.45	25.1	125.5	ND	ND	ND	ND	3	18.8	8.8	35.5	Drift to S.E. offshore, considerable moderate swell. Sampling at 7.30 hrs. C.A.T. 0.15 mg/L of total iron was found in the 300 m sample. Sulphate not detected.
50	23.7	220	—	—	8.5	24.9	124.5	ND	ND	ND	TR	3	18.3	8.6	32.7	
100	23.3	220	—	—	8.38	24.75	123.8	TR	ND	ND	TR	3.5	18.4	8.1	31.8	
200	22.65	225	—	—	8.07	25.5	127.5	0.035	ND	ND	TR	6	19.2	8.1	32.6	
300	22.45	230	—	—	7.73	25.9	129.5	0.08	0.13	ND	ND	12	19.2	8.0	32.5	
Station 1. *Nkata Bay* 19/x/1955																
0	25.6	225	7.85	94.5	8.24	25.3	126.5	0.16	ND	ND	ND	4	20.5	9.2	35.9	Wind offshore N.W., 08.00 hrs. C.A.T. Sun bright, little cloud, choppy sea. No iron detected in samples. No sulphate detected.
25	24.1	225	7.63	90	8.28	25.5	127.5	0.16	ND	ND	ND	5	21.2	8.9	36.1	
50	23.65	225	7.46	86	8.26	25.3	126.5	0.16	ND	ND	ND	3.5	20.3	10.1	37.2	
75	23.25	224	7.28	84	8.25	25.4	127	0.16	ND	ND	ND	4	20.4	9.5	36.3	
100	23.10	225	6.37	72.5	8.34	25.3	126.5	0.22	ND	ND	TR	4.5	20.0	9.8	36.4	
125	22.95	225	5.6	64	8.17	25.1	125.5	0.24	ND	ND	TR	5	20.1	11.0	38.5	
150	22.9	230	4.8	54.5	7.96	25.4	127	0.24	ND	ND	.075	5.5	20.1	11.4	38.8	
200	22.75	230	4.03	45	7.90	25.8	129	0.34	TR	ND	.05	7	21.6	11.2	39.0	
300	22.5	230	ND	NIL	7.89	25.5	129.5	0.40	TR	ND	.025	8.5	21.6	11.2	39.0	
Lake Malombe 16/v/1955																
—	—	225	—	—	—	25.3	126.5	ND	ND	ND	ND	2	18.4	8.35	32.1	Sampled about 500 yards from the Shire inflow.

CHAPTER THREE

STUDIES ON THE INVERTEBRATES WITH ESPECIAL REFERENCE TO CRUSTACEA

1. Free-Living Crustacea

The free-living Crustacea constitute an important element of the fauna of most of the waters of Nyasaland, including Lake Nyasa, and many of them can be considered as key members of the communities in which they exist. Although with few exceptions these organisms are small or microscopic in dimensions this is compensated for by their abundance. Their importance lies in the fact that, directly or indirectly, they serve as food for many species of fishes of diverse habits and affinities and, quite apart from this obvious role, they play, in many habitats, an important part in the circulation of nutrient substances.

This latter role is probably very important in the pelagial zone of Lake Nyasa and it is worth while considering for a moment why this is so. As is shown in the section dealing with the hydrology of the lake, Lake Nyasa consists essentially of two layers of water: an upper, relatively shallow, epilimnion, and a much deeper hypolimnion. Only the former is inhabited by aerobic organisms, and between the two layers interchange of dissolved substances is probably confined to relatively slow diffusion. Now, consider the lake if it contained no crustaceans in the plankton. The constituents of the phytoplankton would utilize such dissolved substances as existed in the epilimnion until some factor became limiting and prevented further increase. On their death they would sink below the thermocline and the nutrient substances which they had built up into plant protein would to all intents and purposes be lost for they would become locked in the depths of the hypolimnion. The epilimnion would thus fairly soon become depleted of essential plant nutrients save such small amounts as were swilled in from the surrounding land or diffused through the thermocline.

In fact, however, many of the crustaceans of the plankton graze on the phytoplankton whose protein is broken down into simple substances again, such as simple nitrogenous compounds and phosphates which are liberated into the water. Detailed studies on the feeding rates of the planktonic crustaceans of Lake Nyasa remain to be made, but it is certain that, during the course of their life, many of them break down quantities of protoplasm greatly in excess of those which make up their own bodies. Thus dissolved substances are kept in circulation and the fertility of the lake is maintained.

Some losses of organic matter from the epilimnion naturally take place when the crustaceans themselves die and sink below the thermocline, but by the time they do so they may have prevented the loss of a much greater amount of plant protein. This loss is also minimized in two ways. First, considerable quantities of zooplankton (essentially crustaceans) are eaten by plankton-feeding fishes which, in general, eat the larger and therefore the older stages of these organisms, whose component substances are thus either returned to circulation by way of the excretory products of the fishes or are converted into fish protein. The second way hinges on the fact that animal protein is much more rapidly broken down after death than is plant protein and on the fact that the waters of Lake Nyasa are maintained at a high temperature. Now many of the crustaceans of the plankton must, by virtue of their adaptations to a pelagic existence, sink very slowly after death. At the high temperatures prevailing in the epilimnion of the lake, bacterial decomposition can go on at a rate, much more rapidly, for instance, than in lakes in the temperate zones. It seems probable, therefore, that some of the animal protein will be broken down during the period in which it is sinking through the epilimnion and all of it will not be lost below the thermocline on the death of the animal. At present these statements are based largely on supposition, and it would be of great interest and importance to attempt a quantitative assessment of these phenomena in Lake Nyasa by experiments, for in few lakes in the world can they be of such importance.

Within the lake proper, crustaceans occur in all aerobic environments. However, the oligotrophic nature of Lake Nyasa is reflected in the relatively low total of species which it harbours. The plankton supports an assemblage of species which, while not lacking in taxonomic diversity, is by no means rich in this respect. On the other hand the littoral fauna is certainly qualitatively sparse, and one group, the Cladocera, of which a dozen or more species can often be found at the margins of eutrophic lakes, appears to be represented by only three species, none of which is common, and in fact even these species appear to be completely absent from the exposed shores, both rocky and sandy, in the northern part of the lake. The absence or scarcity of the Cladocera from large lakes with exposed shores appears to be a fairly general phenomenon in both temperate and tropical latitudes, for it holds good also in Lake Tanganyika (Africa), Baikal (Siberia) and Toba (Sumatra). In the case of the two former it applies to the plankton as well as to the littoral fauna, but this is not the case in Lake Nyasa.

A few general remarks on the crustacean plankton permit one to enumerate the species of which it is comprised and to comment on certain differences, both qualitative and quantitative, which have been observed between the plankton of the northern and southern parts of the lake. First, however, it should be emphasized that the crustaceans of the zooplankton comprise by far its most important component in all parts of the lake which have been investigated; other groups, with the exception of the larvae of the midge *Corethra edulis* Edwards, being of considerably less importance.

In the northern part of the lake the number of species of planktonic crustaceans is small, consisting only of the Calanoid Copepod *Diaptomus* (*Tropodiaptomus*) *kraepelini* Poppe and Mrazek*, two cyclopoid Copepods *Mesocyclops leuckarti* Claus and *M. neglectus* Sars, and three Cladocerans *Diaphanosoma excisum* var *stingelini* Jenkin, *Bosmina longirostris* (O. F. Muller), and *Bosminopsis deitersi* Richard.† Of these only the first two can be considered as really common, and although *Diaphanosoma excisum* is sometimes found in fish guts in large numbers.

Another Calanoid Copepod, the striking *Lovenula africana* (Daday), was recorded from the northern part of Lake Nyasa by Daday (1910) but has not been seen during the recent survey. If it occurs at all it must be rare. *Diaptomus kraepelini* and

*This species was described by Sars (1909) as *D. cunningtoni*. For recent comments on the morphological peculiarities of the form found in Lake Nyasa see Fryer (1957).

†*Bosminella anisitsi* Daday.

Mesocyclops leuckarti are undoubtedly the key members of this community. These constitute the bulk of the food of the commercially important plankton-feeding fishes of the genus *Haplochromis* which comprise the so-called *Utaka* group, the small but important *Usipa* (*Engraulicypris sardella* Gunther), and some of the long gill-rakered clariid species which have, rather surprisingly, taken to feeding on plankton. These crustaceans, and particularly the two key species noted above, also serve as the main or sole food of several other fishes, such as *Sanjika* (*Barilius microcephalus* Gunther) and *Binga* (*Haplochromis kiwinge* Ahl), during the early stages of their existence.

In the southern part of the lake plankton is, at certain seasons at least, both qualitatively and quantitatively richer than in the northern part. Here the Cladoceran *Daphnia lumholtzi* Sars and the endemic Calanoid Copepod *Diaptomus* (*Thermodiaptomus*) *mixtus* Sars appear to be important elements in the fauna, and occur together with all the species recorded from the northern part of the lake. It is interesting to note in this connexion that the so-called *Nkungu* fly *Corethra edulis*, whose larvae are quite common in the plankton in the northern part of the lake, appears to be absent from the southern part. These differences in the composition of the zooplankton reflect the different ecological conditions prevailing in the northern and southern parts of the lake, but the basic underlying causes of their existence, which are probably connected with water movements, the chemical composition of the water and the complex dynamics of phytoplankton productivity, remain as yet unexplained.

In order to facilitate identification of the Crustacea of the plankton of Lake Nyasa outline illustrations of all the species present are given in fig. 1. These, while not intended as detailed drawings, should be sufficient to enable even closely related species to be easily identified.

Although represented by few species the littoral crustaceans of the lake are also of considerable importance. On exposed rocky shores one might expect them to be virtually absent and indeed this is so as far as species living in what might be termed the "usual" habitats are concerned. However, among the algal covering of the rocks occur vast numbers of tiny Ostracods, mostly of the genus *Cypridopsis*, and of the Harpacticoid Copepod *Schizopera consimilis* Sars. Large numbers of these little crustaceans can be obtained by scraping from a rock with a knife the algae among which they live. One estimation made at Nkata Bay indicated that in such situations the Ostracods alone totalled some 198,000 individuals per square metre of rock surface. This information was obtained during a detailed study of this type of environment, the results of which are published elsewhere (Fryer, 1959), which revealed the supreme importance of these little crustaceans in the general economy of such habitats. Many fishes utilize these crustaceans, or the larger invertebrates which prey upon them, as food.

Another member of the rocky shore community of crustaceans, the crab *Potamonautes lirrangensis* Rathbun, is discussed separately below.

Sandy shores have a complement of Copepods and Ostracods which act as important links in food chains, the terminal members of which are fishes of economic importance. Some of these Copepods found during the recent survey proved to be new to science and have been described elsewhere (Fryer, 1957). A prawn of the family Atyidae, *Caridina nilotica* Roux, which is widespread in Africa, also occurs on sandy shores wherever beds of *Vallisneria* are present, and is eaten to some extent, though less than might be expected, by fishes. Unfortunately it is too small and insufficiently abundant to exploit commercially as a food.

Of more general than truly economic interest is the fauna of the psammon, which nevertheless merits brief mention. In the interstices between the sand grains on both submerged sandy beaches and below the water line of those which are exposed to the air live countless millions of minute and highly specialized animals including both Copepods and Ostracods. Several previously undescribed species of both Cyclopoid and Harpacticoid Copepods, including a representative of a new genus of the former group, have been discovered during the survey and have been described elsewhere (Fryer, 1956).

Outside the lake, in weedy estuaries, lagoons, swampy rivers, pools and dams one finds an almost entirely different series of crustacean faunas. The number of species present is much greater than in the lake and the habits of the individual species are much more diverse. In such habitats for instance one finds cladocerans which browse on muddy bottoms or even burrow into the mud, species which hide among tangled masses of vegetation, and others which swim beneath the surface film. Detailed studies on the ecology of these species remain to be made, but various scattered items of information acquired during the survey are published elsewhere (Fryer, 1955, 1956 *a*, 1957, 1957 *a*, *b*). At present, however, there are still taxonomic problems to be solved, and probably new species to describe for several such were encountered during this part of the survey.

The crab *Potamonautes lirrangensis* Rathbun, formerly called *Potamon orbitospinus* and thought to be endemic to Lake Nyasa, but now considered to be more widespread, is an infinitely larger animal than those discussed above and, unlike them, is at present more of a nuisance than an asset. It frequents rocky shores, hiding under rocks by day, and in such situations is apparently distributed all round the lake and on rocky islands. It is by habits an omnivorous scrounger which ventures forth in quest of food, sometimes by day, but apparently mostly by night. This food sometimes consists of fishes entangled in gill nets and it not infrequently so mutilates them as to render them commercially valueless, and may even remove almost the whole of the flesh. It also does damage to the nets themselves both by severing the twine (especially if it be made of terylene) and also by becoming entangled in the meshes from which it can often be extricated only at the expense of damage to the nets. It also eats the bait from the hooks of bottom-set long-lines, and enters traps in which it devours both the bait and, if it can seize them, the trapped fishes.

This crab is edible and quite fit for human consumption though the amount of flesh obtainable from even large specimens scarcely compensates for the effort entailed in their preparation. Furthermore, Africans of certain tribes cannot be induced to eat them, this applying for instance to the Atonga tribe in whose area they are particularly abundant. They might conceivably be converted into poultry food, but again the effort involved may at present be incommensurate with the material reward.

We are, in this respect, indebted to Dr. C. F. Hickling for a suggestion as to how rice hullings, which is a very big waste product of the rice industry at Kota Kota and elsewhere, may be mixed with crab meat and shell and converted to poultry food. The method is to spread an inch or two of rice hullings on to a hard, flat, preferably concrete, surface. Crabs are caught by means of wicker traps, easily constructed by Africans, and baited with fish. The crabs are then strewn over the rice hullings and crushed with a heavy roller, so that the blood and body juices are absorbed by the hullings. The mixture is then left to dry for a day or two, and the larger fragments of shell, which make excellent fowl grit, are broken down further, either by hand or with the aid of a mill. Maize hullings may be used in the same way.

It is possible that other crabs occur in Lake Nyasa, though it is more probable that those recorded from the lake actually occurred in adjacent rivers and streams, for no other species has been seen in the lake during the survey. Thus Cunnington (1907) records from Lake Nyasa, under the name *Potamon inflatus*, the crab *Potamonautes depressus* (Krauss), and according to Bott (1955) there is in the Humbolt Museum, Berlin, a specimen of *Deckenia mitis* Hilgendorf labelled " Nyassa-See ".

Other crabs certainly do frequent the rivers and streams of Nyasaland. These too can be a nuisance, in this case to the builders of dams and fish ponds, as they are adept at constructing burrows in the walls of these structures.

The following list of papers covers the most relevant publications on the free-living Crustacea of the Nyasa area. Those marked with an asterisk deal almost exclusively or in detail with the crustacean fauna of the area; the others contain more general information or refer only partly to the area.

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2. Parasitic Crustacea

(a) *General*

Certain crustaceans have taken to a parasitic mode of life, and various freshwater fishes serve as hosts for these organisms. Two groups, the Copepoda and the Branchiura, are represented in Lake Nyasa, which is remarkable for the large number of species of these organisms which is to be found within its confines. In fact the total of at least 13 parasitic copepods and 4 branchiurans, some of which have been discovered as a result of the survey, exceeds that recorded from any other lake in the world. This high total is at least in part a reflection of the great diversity of fishes capable as serving as hosts which exist in Lake Nyasa and the long period during which the lake has been in existence. Several of the Nyasan species, and particularly representatives of the genus *Lernaea*, have not been reported from areas outside its confines and are almost certainly endemic. Indeed most of the species of *Lernaea* comprise a species flock.

While some of these parasites such as *Lamproglena clariae* Fryer, *Afrolernaea longicollis* Fryer, and occasionally *Lernaea bagri* Harding and *L. tilapiae* Harding can cause serious damage to their hosts even in natural populations, others, under such circumstances, appear to have few detrimental effects. This is fortunate as, in a lake the size of Nyasa, control measures are quite impracticable. In fish ponds, however, conditions are quite different, and should a parasite be introduced it is possible for it to multiply and become a serious pest. This is because, in nature, the chances of the free-living larval stages of these organisms locating a new host are very low, probably never more, and usually much less, than 100:1. In a fish pond, however, the area over which dispersal is possible is less and, because man makes it so, the fish population is much denser. Obviously, therefore, the chances of a larva locating a new host are greatly enhanced. The greater the infection rate the greater is the rate of egg production by the parasite population, and the chances of reinfection in the pond are increased even more, the whole effect being cumulative. It is not surprising therefore that serious cases of fish mortality are reported from time to time as a result of the accidental introduction of species of *Ergasilus*, *Lernaea* and *Argulus* (all three genera of which have representatives in Lake Nyasa) from countries in which fish culture in ponds is an established practice. In order to emphasize how serious such infections may become a few facts recorded by Schaperclaus (1954) can be quoted. From this authority we learn that as many as 4,250 specimens of a European species of *Argulus* have been taken from a single Tench, 28 cm. in length, which weighed 252 gm., and that the gills of another Tench were found to harbour about 3,100 specimens of the common European species of *Ergasilus*. No fish is capable of surviving long under such conditions.

In view of these facts further warnings of the need to scrutinize with extreme care any Nyasan fishes which are to be used for pond stocking purposes should not be necessary.

In order to facilitate the recognition of these parasites a key suitable for use in the field is appended, and a number of outline sketches illustrating the general form of some of them is also added. No dissection of specimens is necessary when using the key but the use of a hand lens is recommended. All the species recorded from Lake Nyasa and its affluents are included but the key is *not* intended for use in other parts of Africa. A list of Nyasa species and their hosts is also given.

Between them the papers by Harding (1950) and Fryer (1956) listed below give a comprehensive account of the parasitic Crustacea of Lake Nyasa, but those by Thiele (1900, 1904) and Sars (1909) are also useful. The book by Schaperclaus (1954) gives the most up-to-date information on means of combating these parasites should infection take place.

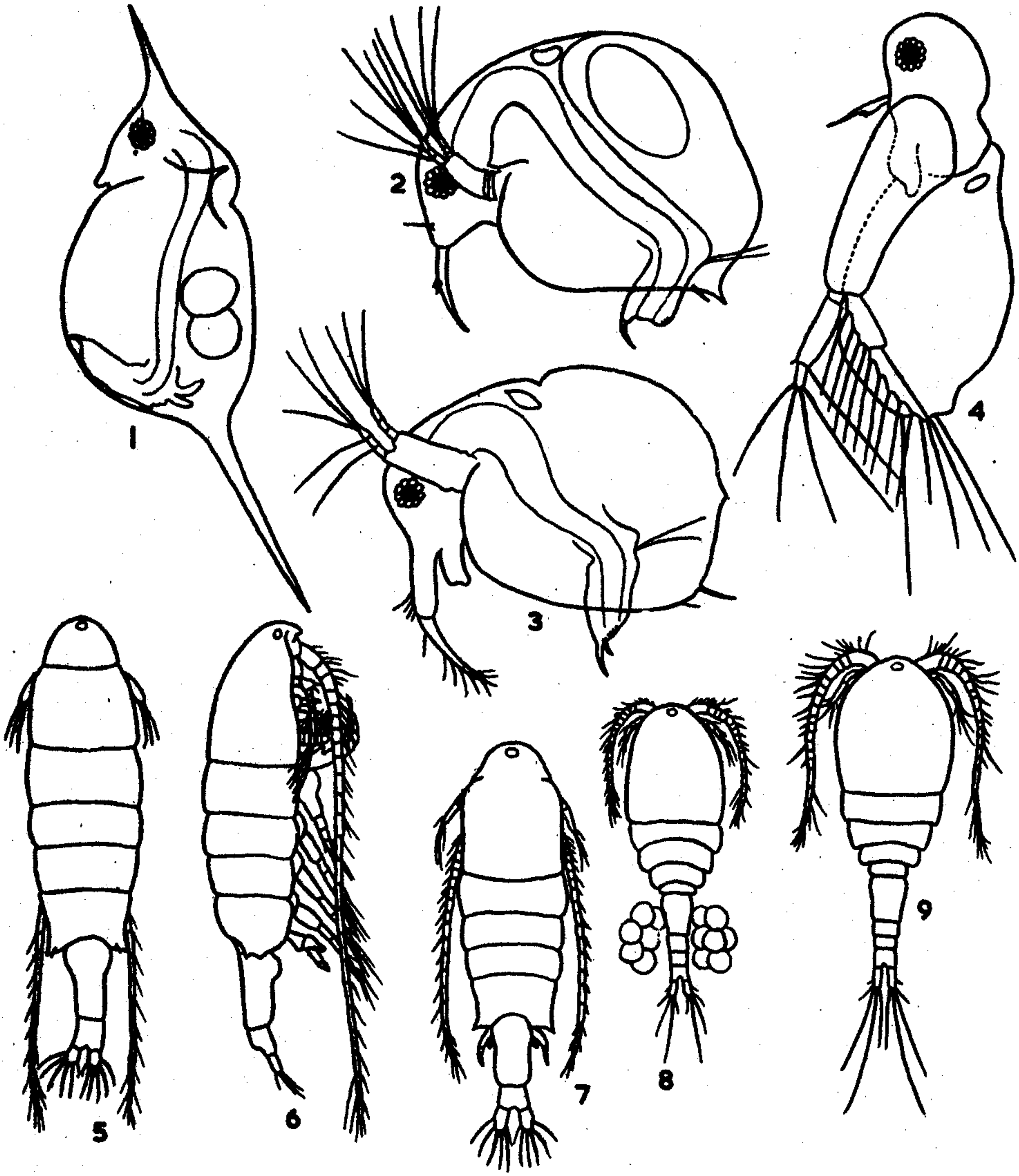

Fig. 1. The Planktonic Crustacea of Lake Nyasa

1. *Daphnia lumholtzi*. 2. *Bosmina longirostris*. 3. *Bosminopsis dietersi*. 4. *Diaphanosoma excisum*. 5. *Diaptomus* (*Thermodiaptomus*) *mixtus*. 6. *D. mixtus* (another view). 7. *Diaptomus* (*Tropodiaptomus*) *kraepelini*. 8. *Mesocyclops neglectus*. 9. *Mesocyclops leukarti*.

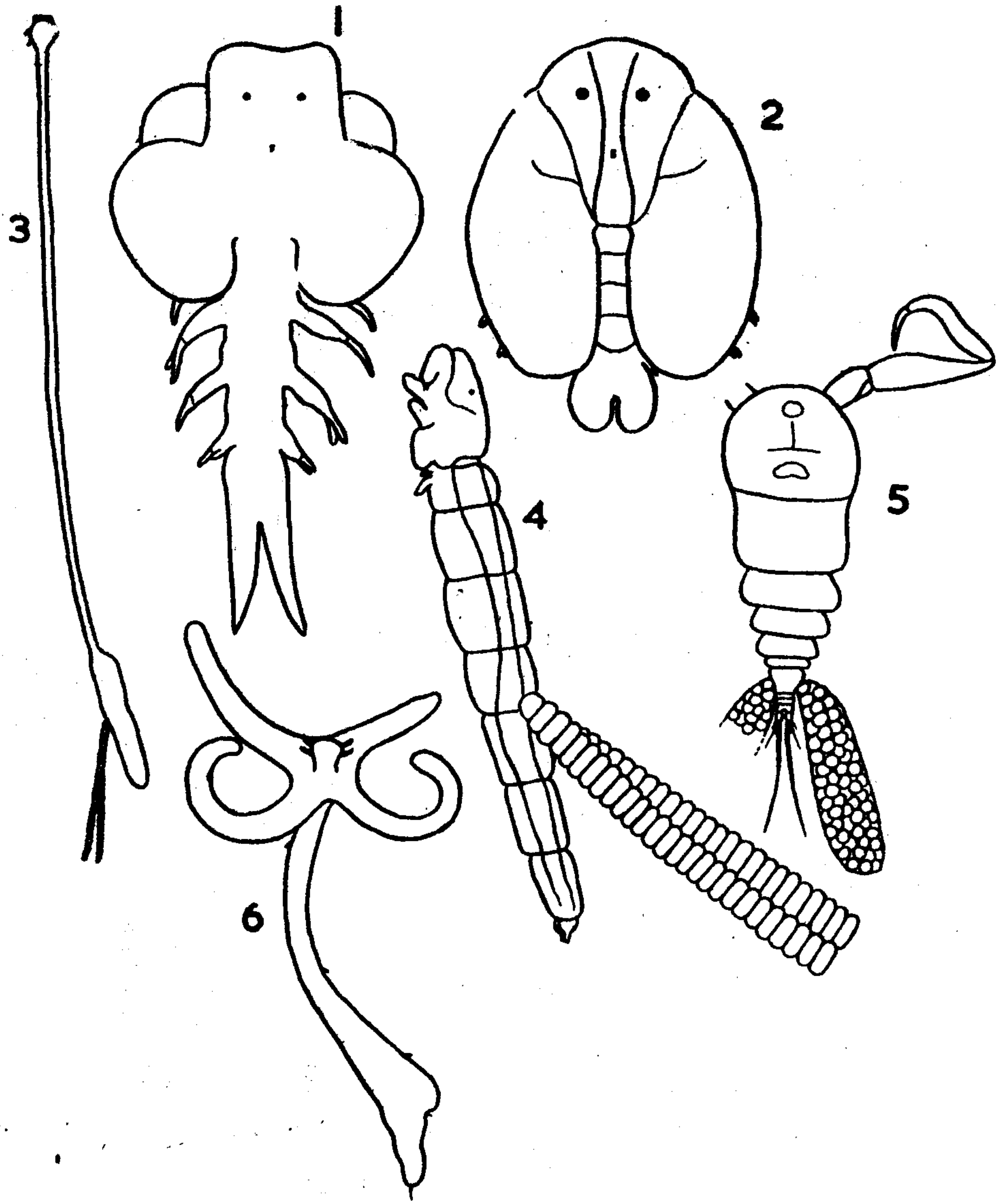

Fig. 2 Examples of the Crustacean parasites of the fishes of Lake Nyasa

1. *Chonopeltis inermis*. 2. *Argulus africanus*. 3. *Afrolernea longicollis*. 4. *Lamproglena nyasae*. 5. *Ergasilus cunningtoni*. 6. *Lernea bagri*.

TABLE I

List of parasitic Crustacea known from Lake Nyasa and its inflows and their hosts

Parasite	*Hosts*
BRANCHIURA	
Argulus africanus Thiele ..	Many species but with a particular preference for smooth skinned fishes such as *Bagrus meridionalis*, Clariids, and *Anguilla*. Rare on scaly fishes.
Argulus amblop lites jollymani Fryer	*Haplochromis* spp. possibly with a preference for the more open water species.
Dolops ranarum (Stuhlmann) ..	Clariids, especially on *C. mossambicus* in rivers and swamps.
Chonopeltis inermis Thiele ..	Clariidae.
COPEPODA	
Ergasilis macrodactylus (Sars) ..	Many cichlid fishes. Also *Alestes imberi*.
Trigasilus minutus Fryer	Cichlids (probably several genera).
Lamproglena monodi Capart ..	Inshore-living cichlids of several genera.
Lamproglena clariae Fryer ..	Clariidae.
Lernaea bagri Harding ..	*Bagrus meridionalis*.
Lernaea barilii Harding ..	*Barilius microlepis*.
Lernaea tuberosa Harding ..	*Engraulicypris sardella*.
Lernaea barnimiana (Hartmann) ..	*Barbus eurystomus*.
Lernaea lophiara Harding ..	Probably all cichlid genera.
Lernaea hardingi Fryer ..	Probably all cichlid genera.
Lernaea tilapiae Harding ..	*Tilapia* spp.
Lernaea palati Harding ..	Haplochromis of the " Utaka " group.
Afrolernaea longicollis Fryer ..	*Mormyrus longirostris* and *Mormyrops deliciosus*.

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(*b*) *Key to the species of Parasitic Copepoda and Branchiura of Lake Nyasa*

1 (2)	Body markedly flattened and with a definite carapace; capable of independent locomotion ..	BRANCHIURA 3
2 (1)	Body not flattened and without a carapace; usually not capable of independent locomotion	COPEPODA 9
3 (4)	Carapace covering only first pair of thoracic legs, colour dirty white. Capable only of slow " walking" movements	*Chonopeltis inermis*
4 (3)	Carapace covering at least bases of all four pairs of thoracic legs, colour not dirty white. Capable of very active swimming movements	5
5 (6)	Maxillule represented by a pair of hooks. No suckers present	*Dolops ranarum*
6 (5)	Maxillule represented by a pair of conspicuous suckers	7
7 (8)	Carapace overlapping posterior lateral corners of head shield. Carapace overlapping abdomen ..	*Argulus amblopiites jollymani*
8 (7)	Carapace confluent with posterior lateral corners of head shield. Carapace not overlapping abdomen ..	*Argulus africanus*
9 (10)	Parasites of gill filaments	11
10 (9)	Parasites of other parts of body	17
11 (12)	Armed with a pair of conspicuous clasping antennae anteriorly. Not more than 1.5 mm. in length (exclusive of furcal setae)	*Ergasilus macrodactylus*
12 (11)	Not armed with a pair of clasping antennae anteriorly. More than 2 mm. in length	13
13 (14)	With enormously elongated " neck ". Devoid of thoracic appendages. Parasitic on Mormyridae ..	*Afrolernaea longicollis*
14 (13)	" Neck " not elongate. With thoracic appendages. Not parasitic on Mormyridae	15
15 (16)	Body very distinctly segmented. Length not more than 4 mm. Parasitic on Cichlidae	*Lamproglena monodi*

16 (15)	Body indistinctly segmented. Length more than 6 mm. Parasitic on Clariidae	*Lamproglena clariae*
17 (18)	Length less than 1 mm. Body cyclopiform. Armed with a pair of 3 pronged antennae anteriorly. Head not embedded in flesh of host	*Trigasilus minutus*
18 (17)	Length, when fully developed, at last 6 mm. Body elongate; not cyclopiform. Not armed with 3-pronged antennae. Head embedded in flesh of host	19
19 (20)	Head with four anchor arms of which dorsal are forked	21
20 (19)	Head with 4 anchor arms none of which are forked	23
21 (22)	Ventral (unforked) anchor arms considerably longer than head. Body somewhat swollen posteriorly. Parasitic on *Barilius*	*Lernaea barilii*
22 (21)	Ventral (unforked) anchor arms considerably longer than head. Body not swollen posteriorly. Not parasitic on *Barilius*	*Lernaea barnimiana*
23 (24)	Anterior part of body and anchor arms covered with peg-like protruberances. Parasitic on *Engraulicypris sardella*	*Lernaea tuberosa*
24 (23)	Anterior part of body and anchor arm without protruberances. Not parasitic on *Engraulicypris sardella*	25
25 (26)	All four anchor arms elongate. Not attached to fins of Cichlid fishes	27
26 (25)	All four anchor arms very short. Attached usually to fins of Cichlid fishes	*Lernaea lophiara*
27 (28)	Dorsal anchor arms curved. Parasitic on *Bagrus meridionalis*	*Lernaea bagri*
28 (27)	All anchor arms straight. Not parasitic on *Bagrus meridionalis*	29
29 (30)	Anchor arms exceptionally long; more than half length of body in fully developed females. Parasitic on species of *Tilapia*	*Lernaea tilapiae*

3. Notes on some other Invertebrate Fauna

As in other aquatic communities the invertebrate animals of Lake Nyasa play a vital part in its biological economy. At present, however, our knowledge of these important organisms is distinctly patchy, some groups having received a certain amount of attention, others being virtually unknown. Among the major groups which are known largely as a result of casual collections can be included the Protozoa, Platyhelminthes, Nematoda, Annelida, and Mollusca, and even the insects have never received the undivided attention of a field entomologist for any prolonged period. The recent survey has enabled a certain amount of attention to be paid to the Crustacea, both free-living and parasitic, whose importance is quite considerable.

Brief mention might be made here of one insect which can scarcely be missed by a visitor to the northern part of the lake and which is of some economic importance.

This is the so-called " Nkungu " fly or " lake fly " *Corethra edulis* Edwards which periodically emerges in vast swarms from the surface of the lake, often at great distances from the land. This fly belongs to the family Chaoboridae and not to the Chironomidae as has been popularly supposed by those who have subjected it to only a casual examination. This apparently trivial technicality is of profound importance as, had the fly belonged to the Chironomidae, its larvae must have occurred on the bottom beneath the thermocline, presumably existing in an anaerobic environment and, at their time of emergence, bringing back into circulation material from the profundal region. This has indeed been tacitly assumed in scientific papers. In fact the larvae—the so-called " phantom larvae "—belong to the only group of insects which at this stage of their life history lead a pelagic existence. They are thus in no way concerned with events taking place in the profundal regions.

These larvae are eaten by plankton-feeding fishes, as are the pupae at times of mass emergence, while the adults form food for both fish and humans. When a swarm is blown ashore by wind its density is often sufficiently great to permit large numbers of individuals being caught by women who sweep baskets through the swarm. The captured insects, whose nutritive value is probably quite high, are then roasted and eaten.

Because of the important part they play as food for inshore dwelling fishes some invertebrates of various groups have been the subject of ecological studies. The information obtained is contained in a recent publication (Fryer, 1959). Not all the invertebrates of the lake are beneficial. In fact some are seriously detrimental on account of their parasitic habits. The parasitic invertebrates of the lake which infest fishes belong to diverse groups, and even casual observations of the fishes have revealed representatives of the Protozoa, Trematoda, Cestoda, Acanthocephala, Nematoda, and Hirudinea, as members of the Copepoda and Branchiura which have been especially studied. Among the fishes of Lake Nyasa the Protozoans are responsible for various " spot " diseases some of which are not uncommon: the trematodes have been scarcely studied but are probably quite important: the cestodes are represented by various species, the most striking of which is perhaps a species of *Ligula* whose plerocercoid stage is a solid looking " worm " as much as 10 cm. in length of which two or even three individuals may be found in a single specimen of various species of *Barbus*, such as *B. johnstonii* Boulenger, often only about twice their own length. Nematodes abound in the alimentary canal of many fishes, particularly the Mormyrids, and others are sometimes found ancysted in the flesh of other fishes: almost every cichlid fish and many of other families harbour acanthocephalans in the gut, and leeches are occasionally found, usually bloated with food, on the external parts of various fishes. It has not been possible to study these organisms in detail, but one group, the parasitic Crustacea, has received a considerable amount of attention and is dealt with in this report.

CHAPTER FOUR

THE FISHES OF NYASALAND WITH ESPECIAL REFERENCE TO NORTHERN LAKE NYASA

1. STUDIES ON SYSTEMATICS AND ECOLOGY

A. Introduction

As the fish fauna of Nyasaland and more especially of Lake Nyasa is so large, varied and interesting, a great deal of study of its systematics, or classification, has taken place in the past and is still proceeding. The ecology, or relationship to their environment and to each other of the fishes, has been less well known and speculations as to their mode of evolution and how they have adapted to their way of life are still being formed. A knowledge of all three of the above aspects is essential to gain an understanding of the fishes in the lake, so necessary, for example to the proper management of the fisheries. But the information at present gained is contained in a large number of books and papers, which have come out over the past 80 years, most of which (even the important one published in 1942) are out of print and completely unavailable for study except in a very few of the larger libraries. Apart from Boulenger's " Catalogue of the Fresh-Water Fishes of Africa " mentioned below, which dealt purely with the systematics of African freshwater fishes known at that time, no work has appeared which deals with the study of all the fishes, and which gives keys and other means of identifying them. The nearest approach to such a general work is the " Report on the Fish and Fisheries of Lake Nyasa " by C. K. Ricardo Bertram, H. J. H. Borley and Ethelwynn Trewavas, which was published in 1942 and is now completely unobtainable. This useful work gives a list of all fishes known from Lake Nyasa at the time and supplies means of identification of some of them.

The opportunity is therefore taken here to include a check list of the fishes of Lake Nyasa and its adjacent waters and to include notes on the habitats, etc., of the various species so far as these are at present known. Time did not allow of this check list to be a complete revision of the fish fauna. Such a revision is certainly necessary, particularly in the genera *Haplochromis*, *Lethrinops* and *Rhamphochromis*, and will no doubt remove a number of " museum species " from the list and add a few extra species to it. In the meantime it is to be hoped that this check-list will be of use to those who are interested in the natural history and management of Nyasaland fishes, as well as to any workers who undertake a systematic revision of the species. A discussion of the major ecological zones occurring in the rivers and lakes is also given.

B. Broad Ecological Zones in the Nyasan Area

It is possible and convenient, at this stage, to examine the general distribution of fishes in the Nyasan area, which consists of Lake Nyasa, its fringing waters, the rivers which flow into the lake and the upper Shire River above the Murchison Cataracts (which prevents access of most Zambesi fishes into the upper river and lakes) and to list certain major ecological zones occurring herein. Each major zone, and more particularly those which occur within the Lake itself, is of course subdivided into very numerous microhabitats, which are very important as leading to a wide divergence of the fish fauna. The major zones, however, are important in enabling the fish fauna to be divided into large primary groups.

With the exception of a few generalized types, fishes are rigidly limited to one area by reason of their association with the ecological factors obtaining in that area; these ecological factors of substrate, temperature, etc., limit their distribution and they are not to be found where any one factor exceeds the limits which that particular species can tolerate. Such ranges of tolerance are, however, more narrow for the endemic lake fishes than they are for those eurytopic fishes of wider distribution. *Labeo cylindricus*, for example, is a fish widely spread over Central Africa, though only where its primary biotope, a shallow rocky substrate, is to be found. Otherwise it has a wide ecological tolerance; in Lake Nyasa it is widespread wherever the bottom is rocky and shallow while it has also been found in Nyasaland in the South Rukuru River several thousand feet above the lake, where conditions of temperature, pH, etc., are different. Again many fishes do not spend their whole lives in one particular habitat but may migrate from one to another at various times. This is particularly common in breeding and in young fishes. Many fishes move to a different area, e.g., shallow water of rivers, to spawn, and many young fishes, particularly those of pelagic or bathylimnetic species, hug the shore of shallow water in little shoals when very small, moving into the open lake or into deep water when they grow older.

With these reservations in mind it is possible to list, as stated above, a number of major ecological zones in Lake Nyasa and the adjacent water, and thus to predict with fair accuracy the species of fishes which will occur in many parts of the lake or adjacent waters. These areas will be listed in descending order, from the highest levels of rivers down, and, though the northern part of Nyasaland is primarily considered, hold good for the whole country.

ZONE I. UPPER REACHES OF RIVERS

Here the flow is torrential, the water cold and highly oxygenated. Although there may be no waterfalls or other obstacles to the progress of fishes who may wish to move up from the lake, they are yet barred from doing so as effectively as if such barriers were present. The reverse is, of course, also the case; these are the " trout rivers " of Africa, and trout introduced into the high mountain streams seldom venture into the warmer water and do not breed if they do. Few indigenous fishes inhabit this area; apart possibly from one or two cyprinids, the two catfishes *Amphilius platychir* and *Clarias carsonii* are the only species known.

ZONES II AND III. THE MIDDLE AND LOWER REACHES OF RIVERS

These two zones are here treated together as not enough is known to enable an accurate definition to be made between their central limits, e.g., the lower end of the " middle " zone of rivers, where the water warms and the flow becomes slower, and the upper end of the lower reaches. The lower reaches (Plate IIH) are usually quiet reedy stretches often expanding into or associated with large lagoons or stagnant pools. Therefore, although ecologically separate these zones must be treated together until more is known. A large fish fauna is harboured, particularly remarkable for the fact that most species are non-endemic. A fair amount of fishing is carried out in these areas by the local people, with nets, baskets and traps set in weirs which frequently bar the whole stream. *Clarias mossambicus* is abundant over the whole area, with the mollusc-eating *Clarias mellandi*, and the small *Clarias theodorae*, which is associated mainly with vegetation, occurring lower down. Some cichlids occur here and of these the endemic *Haplochromis callipterus* is perhaps the most widespread although *Haplochromis moffatii*, *Tilapia melanopleura*, *T. sparrmani* and *Serranochromis robustus*, most of which are not found very high up rivers, are more important economically. Other fishes frequently encountered are *Alestes imberi*, *Marcusenius discorhynchus*, *Petrocephalus catostoma* and *Gnathonemus nyasensis*. In addition numerous cyprinids occur here, of which some are seasonal migrants from the lake, passing up rivers on their way to spawn and being heavily fished *en route;* these include *Barilius microcephalus* and *Barilius microlepis*, and also *Barbus eurystomus* and *B. johnstoni*. Non-lacustrine cyprinids in this area include *Barbus paludinosus*, *B. rogersi* and *B. choloensis*, and also *Labeo cylindricus*.

ZONE IV. ESTUARIES AND SHELTERED LAKE WATERS

The next main ecological zone is the shallow sheltered lake water, such as the south-east arm below Boadzulu Island and many shallow sheltered bays and inlets and estuaries of rivers which are contiguous with the lake and generally lacustrine in character. In some ways these waters are ecologically similar to zone III, particularly where the zones approach each other, and many though not all of the widely-spread non-endemics occur here as well. In addition a great many more of the endemic fishes of the lake occur in this zone, such as the *Tilapias*. The species *T. shirana*, *T. saka*, *T. squamipinnis* and *T. lidole* form a series inhabiting increasingly openwater areas, stretching as it were right across this zone, the end species overlapping into zones III and V in each case. Other endemics include *Haplochromis similis*, *H. auromarginatus*, *H. woodi*, *H. subocularis*, *H. labifer* and many others. Of the big cyprinids *Labeo mesops* and *Barbus eurystomus* are important food fishes.

All other zones are associated with the open lake, what might almost be called Lake Nyasa proper, and are more characteristic of the middle and northern regions, which form the bulk of the lake area, in that their conditions are most characteristic of this huge inland sea, with its sandy beaches, rocky coasts, deep and pelagic zones, waves, currents and storms, and other attributes more generally associated with marine conditions. In these zones are to be found most of the endemic species-flock members.

ZONE V. SANDY SHORES OF THE MAIN LAKE (*Plate II A, B*)

Many fishes from the previous area are found in water with a muddy or sandy substrate, and in addition many endemics occur here, in varying habitats or preying upon fish in these habitats. Fryer (1959) gives a detailed account of fishes from zone V, and only a few of the characteristic fishes need be mentioned here. Fishes from this type of habitat include *Haplochromis rostratus*, *H. johnstoni*, *H. placodon*, *H. mola*, *H. dimidiatus*, *H. eucinostomus*, *H. lepturus*, nearly all species of the genus *Lethrinops* and *Barbus rhoadesii*. *Clarias mossambicus* very occasionally ventures into these areas, while *Bathyclarias rotundifrons* is a more characteristic Clariid which occurs here, in deeper waters.

ZONE VI. ROCKY SHORES OF THE MAIN LAKE

Rocky shores down to about five or six fathoms have, among other fishes, a very striking and distinct fauna of small endemic fishes, often brightly coloured, which are a source of great attraction as they can readily be seen in the bright clear water. These are known collectively as " Mbuna " and a long paper on these and other fishes of the zone has recently been published by Fryer (1959) to which the interested reader is referred. Mbuna consist largely of closely-related species of the genus *Pseudotropheus* which include *P. tropheops*, *P. zebra*, *P. williamsi*, *P. minutus* and many others, each of which is beautifully specialized particularly to a distinct food habit. Other and equally well specialized Mbuna include *Labeotropheus fuelleborni*, *Petrotilapia tridentiger*, *Cynotilapia afra* and *Genyochromis mento*. Other fishes characteristic of this zone are the Cyprinids *Varicorhinus nyasensis* and *Labeo cylindricus;* the crab-eating catfish *Bathyclarias worthingtoni* occurs here down to considerable depths, and *Haplochromis polyodon*, *H. pardalis*, *H. fenestratus*, *H. ornatus* and *H. euchilus* are to be found in this area. Finally mention may be made of the eel-like *Mastacembelus shiranus* which commonly lurks among the rocks, though seldom seen because of its secretive habits.

ZONE VII. AREAS OF THE SHORE INTERMEDIATE BETWEEN ROCK AND SAND

This area is treated by Fryer (*op. cit.*); while not very large it is a distinct ecological zone harbouring a fauna of several fish peculiar to it, of which several belong to monotypic genera, *Cyathochromis obliquidens*, *Hemitilapia oxyrhynchus* and *Aulonocara nyasensis* being among the most interesting. A single member of the *Pseudotropheus* species-flock, *P. lucerna*, also occurs exclusively in this zone.

ZONE VIII. THE OPEN WATER

Open-water fishes comprise firstly those midwater fishes, not truly pelagic, which are seldom found far out in the lake but which nevertheless have feeding habits associated with open water rather than the bottom. Of the non-predatory *Haplochromis* of this habitat those of the *H. selenurus* group are most abundant. Bright blue specimens are often seen from vessels at anchor floating in ones and twos a few feet below the surface. There are a number of others which are predatory mainly on bottom feeding fishes, but also on pelagic and open water types. These include *Haplochromis kiwinge, H. spilorhynchus, H. macrostoma* and *H. compressiceps*. Non-cichlid predators include *Bathyclarias longibarbis, Barbus rhoadesii* and *Barilius* species, though these also feed on pelagic fishes of the next group.

ZONE IX. PELAGIC WATERS

Fishes from this area are either zooplankton-eating or predatory in habit. Only one species of Nyasa fish may be said to be truly pelagic in habit, in the sense that it has planktonic eggs and larvae; this is the " Usipa ", *Engraulicypris sardella*. All other pelagic fishes are attached to the shore at least for the purpose of spawning, though they spend the rest of their life in shoals, sometimes far out in the lake, but more generally in the vicinity of underwater rocks, etc., not far from the shore. They comprise most of group known as the " Utaka ", small haplochromids with protrusible mouths, which have recently been the subject of study by Iles (1959), to which the reader is referred for further details. Typical species include *H. quadrimaculatus, H. verdi*, and *H. chrysonotus*. Preying on these are a number of species of *Rhamphochromis*, the widespread *Bagrus meridionalis*, the deep-living *Diplotaxodon argenteus* and certain others. Large catfishes such as *Bathyclarias lowea* are often found far out in pelagic waters feeding on the emerging " Nkungu " fly (*Corethra edulis*).

ZONE X. DEEP BOTTOM WATERS

Finally the deep bottom waters harbour a fauna of bathylimnetic fishes, down to about 300 ft. or the limits of dissolved oxygen, about which, and particularly their habits, not a general deal is at present known. It seems certain that some species of Utaka penetrate to these depths, as do certain species of *Rhamphochromis*, e.g. *R. ferox*, and *Bagrus meridionalis* are also commonly caught in gill nets at depths of 200 feet or more. Certain members of the endemic *Bathyclarias* species-flock occur at these depths, down to the limits of dissolved oxygen, such as *B. nyasensis, B. foveolatus, B. rotundifrons* and *B. gigas*. *Mormyrus longirostris, Synodontis njassae* and *Haplochromis heterotaenia* occur at the greatest depths, though the habitats vary and juveniles of some may be found in quite shallow water.

C. Check-List of the Fishes of Nyasaland

A list of the fishes at present known from the Nyasa area is given here, together with some references to the relevant literature, synonyms being given only where relevant to the Nyasa area. Brief notes on habits, etc., are given; these must of necessity in numerous cases be cursory or absent, as little is yet known about many of the fishes. A non-endemic fish is indicated by the letters NE, with mention of other waters in which such non-endemics are known to occur. The Roman figures indicate the major ecological area or areas as indicated in Chapter 1B in which the fish either exclusively or mainly occurs. Native names are given with their locality (see Appendix) in brackets, after which are given English names, if any. The whole of Nyasaland is treated except for the lower Shire River, below the Murchison Cataracts, and the rivers which drain into the lower Shire. This small part of Nyasaland has a lower Zambesi fish fauna and is not considered here.

I. FAMILY MORMYRIDAE

Genus: *Mormyrops* Muller

1. *Mormyrops deliciosus* (Leach)

Leach (1818), p. 410. Boulenger (1909–16), (i), p. 32, fig. 20, (iv), p. 152. Worthington (1933), p. 295. Bertram *et al.* (1942), pp. 19, 22, 58, fig. 20. NE, Congo, Tanganyika, West Africa, Zambesi. III, IV, IX, X. Nyanda (NMB, ND.B, NNB), Njolo, (NLi), Bottlenose, Cornish Jack.

A well known fish very widely distributed in rivers and lakes, of some angling and economic value. In the main lake known from deep water, but more usually found in more sheltered environments such as Kambwe Lagoon. Generally not very common in the lake but more so in the Upper Shire. Predatory on other fishes of small size, even the largest specimens only going for small prey.

Genus: *Petrocephalus* Marcusen

2. *Petrocephalus catostoma* (Gunther)

Gunther (1866), vi, p. 222. Boulenger (1909–19), (i), p. 57, fig. 42. Worthington (1933), p. 295. Betram *et al.* (1942), pp. 110, 124. NE, Rovuma R. (P.E.A.). II, III. Ntachi (NKK).

A little fish, mainly insect-eating, not uncommon in pools and streams, but not from the main lake.

Genus: *Marcusenius* Gill

3. *Marcusenius discorhynchus* (Peters)

Peters (1852), p. 275. Boulenger (1909–16), (i), p. 81, fig. 64. Worthington (1933), p. 295. Bertram *et al.* (1942), pp. 58–110.
NE, Tanganyika, Rukwa, Zambesi. III, IV. Mputa (NMB), Ntachi (NKK), Parrot Fish.

Another fish of estuaries and sheltered waters, found by us to be common in such a habitat as Bana Lagoon; rarely found in the bay in shallow water Nkata Bay. Mainly insect eating.

Genus: *Gnathonemus* Gill

4. *Gnathonemus macrolepidotus* (Peters)

Peters (1852), p. 175. Boulenger (1909–16), i, p. 112, fig. Worthington (1933), p. 296.
NE. Zambesi, Upper Congo. II, III. Mputa (NMB), Ntachi (NKK).

A fish of rivers and lagoons rather than the open lake, not common, insect-eating.

5. *Gnathonemus nyasensis* Worthington

Worthington (1933), p. 295, fig. 2.
(Mputa, Ntachi as 4, Nchemba NNB). III, IV.

More common than the previous species, in lagoons and sheltered estuaries. Common in Limpasa Dambo, 9 miles from Nkata Bay. Insect- and weed-eating.

Genus: *Mormyrus* Linn.

6. *Mormyrus longirostris* Peters

Peters (1852), p. 275. Boulenger (1909–16), 1, p. 139, fig. 115. Worthington (1933), p. 297. Bertram *et al.* (1942), pp. 57, 110. Lowe (1952), pp. 89, 120, 121. NE, Upper Congo, Zambesi, Tanganyika, Rukwa. IV, X. (Chigonde NFJ, Mbelewele NMB, Panda NNB), Snout-fish.

A very common and important food fish. A bottom-living species found wherever there is suitable habitat, in Lake Nyasa and the Upper Shire. Feeds by grubbing about on muddy or sandy bottom in search of Chironomid larvae and other small animal food. At Nkata Bay commonly caught in deep gill nets down to the limits of dissolved oxygen, and appears in Lake Nyasa generally to prefer the deeper water where possible. Appears to have a prolonged breeding season, and at Nkata Bay are mainly caught in the 4″ gill net, the best months being August, September and October. A breeding migration probably occurs. In Lake Malombe they grow to a very large size, weighing 20 lb. or more in the case of some specimens.

II. FAMILY CHARACIDAE

Genus: *Alestes* Muller and Troschel

7. *Alestes imberi* Peters

Peters (1852), p. 276. Boulenger (1909–16), i, p. 209, fig. 156. Fryer (1959), p. 202, figs. 76–77.

NE, Upper Congo, Zambesi, Rovuma, Rukwa. III, IV. Nkalala (general), Spot-tail.

This widespread little fish, the only Characin in the area, occurs in little shoals in shallow and sheltered areas, being particularly common in the southern part of the lake and in sheltered spots such as the coast of Bana and Kota Kota. In the northern lake at least, they seem to move about a lot as the shoals are sporadic in appearance. An omnivorous feeder, it eats insects, tiny fish and vegetable matter. Often caught by angling of the bent-pin variety. Of fair importance as a prey fish.

III. FAMILY CYPRINIDAE

Genus: *Barilius* Hamilton Buchanan

8. *Barilius microlepis* (Gunther)

Gunther (1864), p. 314. Boulenger (1909–16), ii, p. 208, fig. 183. Worthington (1933), p. 306. Bertram *et al.* pp. 22, 50, 110, fig. 2 (0). Lowe (1952), pp. 72–75, 89.

Mpasa (general), Lake Nyasa Salmon. II, III, IV, V, VI, VII, VIII, IX. (At various stages of life history.)

A more detailed account of this important food and fine angling fish is given elsewhere in this report. Still more needs to be learnt about it. Juveniles are commonly seen along the shores of the open lake, grabbing plankton and any other animal matter. Caught trolling from boats, prefers a bright silver spinner to one of any other colour. Often caught by African fishermen in the lake by this method; one caught 27 while crossing Mbampa Bay, Likoma Island (Map 4), in his canoe by trailing a spinner behind it.

9. *Barilius microcephalus* (Gunther)

Gunther (1864), p. 314. Boulenger (1909–16), ii, p. 205, fig. 180. Bertram *et al.* (1942), p. 51.
Sanjika (general).

A smaller fish than number 8 above, and hence not such a good angling fish. The other remarks made above apply here also.

Genus: *Engraulicypris* Gunther

10. *Engraulicypris sardella* (Gunther)

Gunther (1868), viii, p. 292. Boulenger (1909–16), ii, p. 210, fig. 184. Worthington (1933), p. 307. Lowe (1952), p. 89.
(Usipa, general), Lake Nyasa Sardine. VII, IX.

An important economic and bait fish, but little is known of its habits. The only truly pelagic species in the lake, its larvae have been taken by this survey in plankton nets in the surface waters of the open lake. It appears sporadically inshore (1953 was a good year, 1954 a bad year) in greater or smaller shoals, and is much fished by Africans when it does; see Chapter V for details of the fishery.

The sporadicity of appearance of "Usipa" shoals is an important problem because of the intrinsic economic importance of this fish, which is considerable, and also because it appears to be probable that its abundance is linked with the abundance of other fishes, such as the migratory *Barilius* shoals, of which, during the lacustrine phase, it is an important prey, and also that it is connected with the "Batala" (*Rhamphochromis*) line fishery. Furthermore, a good year for Usipa is associated with a good year for Utaka, presumably because both depend on an abundance of plankton.

Magnificent for bait, the very best, but they must be absolutely fresh.

Genus: *Labeo* Cuvier and Valenciennes

11. *Labeo mesops* Gunther

Gunther (1868), vii, p. 51. Boulenger (1909–16), i, p. 313, p. 331. Worthington (1933), p. 297. Bertram *et al.* (1942), pp. 19, 22, 41-3, 61, 64, 66, 84, 110. Lowe (1952), pp. 66–70, 118–124.

Nchila (general), Mkukuwawa (young), (NNB, Ntuwa, NFB). III, IV.

An important shoaling endemic *Labeo*, one of the major food fishes in the lake. While present in most places round the lake, it is most abundant off sandy shores in relatively sheltered water where large numbers are caught in seine or gill-nets (see section V). In such places, e.g. off Kota Kota, large shoals are sometimes seen a mile or more off the shore. Shoals have been seen off Chinteche and Bandawe. Ascends rivers and flooded areas to spawn, particularly in the southern half of the lake, but never as high as the *Barilius* species.

12. *Labeo cylindricus* Peters

Peters (1852), p. 684. Boulenger (1909–16), (i), p. 331, fig. 249, (iv), p. 204. Worthington (1933), p. 298. Bertram *et al.* (1942), pp. 22, 43, 110. Lowe (1952), pp. 84, 89. Fryer (1959), p. 189, figs. 52–55.

NE, Zambezi, Upper Congo, Tanganyika. II, III, IV, VII. (Ningwi (general), Nyampotu (young), NNB, Nbununu NKK).

A rock-haunting *Labeo* abundant in the lake wherever a rocky substrate on which grows the algae on which this species feeds is to be found, and also in the middle and lower reaches of rivers where a similar environment occurs. The lake forms differ in colour from the river ones by being darker and less uniformly silvery, and having a dark brown stripe on the side, but no morphological difference can be discerned. In the lake has a well marked breeding season, around December, and the breeding season is very short, eggs being laid among the rocks.

13. *Labeo intermedius* Worthington

Worthington (1933), p. 297.
Not seen by survey.

Genus: *Varicorhinus* Rueppel

14. *Varicorhinus nyasensis* Worthington

Worthington (1933), p. 299. Fryer (1959), p. 191.
Chalulumawe NMw. VI.

A species of rocky shores on which it occurs in small shoals. Feeds chiefly on the algae growing on rocks. Probably ascends rivers for spawning purposes during the rainy season.

Genus: *Barbus* Cuvier

15. *Barbus rhoadesii* Boulenger

(*Barbus litamba* Keilhack 1908). Boulenger (1908), p. 238. Boulenger (1909–16), ii, p. 72, fig. 50, p. 143 (*B. litamba*). Norman J. R. (1925), p. 315. Worthington (1933), p. 300. Bertram *et al.* (1942), p. 20, fig. 2M, pp. 22, 53, fig. 7E. Lowe (1952), pp. 68, 73, 89. Fryer (1959), p. 202.
Tamba (general). II, IV, V, VII, VIII.

An easily recognizable predatory species sometimes in shoals, not uncommon, all round the lake though seldom very far from shore, also in the lower reaches of rivers. Feeds on fish and insects and is often caught by angling with fish bait, occasionally caught in fair numbers on surface long lines and in chirimila nets. Not in sufficient abundance to be of much economic importance.

16. *Barbus eurystomus* Keilhack

Keilhack (1908), p. 166. Boulenger (1909–16), ii, p. 64. Worthington (1933), pp. 300, 301, fig. 5. Bertram *et al.* (1942), fig. 2P, pp. 20, 52, 84, 110.
Kadyakola (NFJ, NMB, NDB), Kuyu NKK, NLi, Chikasu NNB. III, IV, VI.

A very large Barbus not uncommonly caught in gill nets and a valuable food fish. Diet mainly molluscs (Betram *et al.* (1942), q.v.) Proceeds up rivers to spawn, though not so far as *Barilius* species.

17. *Barbus johnstonii* Boulenger

Boulenger (1907), 488. Boulenger (1909–16), ii, p. 90, fig. 69. Worthington (1933), p. 302, fig. 6. Bertram *et al.* (1942), pp. 22, 54. Lowe (1952), pp. 84, 89.
(Nkumbwa (NFJ), Ngumbo (NMB, NFB), Chimwe (large specimen: NNB, NKK). II, III, IV, V, VI, VIII.

Most of those caught are of medium size but this fish can grow to ten pounds or more and is a useful angling fish, fighting stubbornly when hooked and boring deep into the water. Omnivorous but also predatory, taking small fish. Penetrates far up rivers and spawns there.

18. *Barbus globiceps* Worthington

Worthington (1933), p. 303, fig. 7.

Not seen by survey.

19. *Barbus njassae* Keilhack

Keilhack (1908), p. 165. Worthington (1933), p. 304.

Not seen by survey; believed by Worthington (*op. cit.*) to be young of one of the preceding species.

20. *Barbus trimaculatus* Peters

Peters (1852), p. 683. Boulenger (1909–16), iii, p. 103, fig. 82. Worthington (1933), p. 304.
NE, Upper Congo, Zambesi, Limpopo. (Matemba (NMB), Kongowe, NKK); these appear to be general names given to all small minnows and apply to all the *Barbus* species following.) Minnow. III.

A very widespread little minnow, found by us in stagnant weedy water in the Limpasa Dambo, Banga River, 8 miles from Nkata Bay.

21. *Barbus paludinosus* Peters

Peters (1852), p. 683. Boulenger (1909–16), ii, p. 115. Worthington (1933), p. 304. Lowe (1952), p. 85. Jackson (1959), p. 297.
NE, Upper Congo, Zambesi. III.

Another very widely spread small *Barbus*, with a strong serrated spine in the dorsal fin. As its name implies is chiefly found in marshy swampy places, never in the open waters of Lake Nyasa. Extremely abundant in Lake Kazuni on the south Rukuru River, where it grows to the largest size yet seen in this fish (14 cm.).

22. *Barbus eutaenia* Boulenger

Boulenger (1904), p. 218. Boulenger (1909–16), ii, p. 131, fig. 108. Worthington (1933), p. 314.

Not seen by the survey in Nyasaland; elsewhere found to be a pretty little fish with its lateral body stripe extending through the eyes and round the nose, fluviatile in habit.

23. *Barbus choloensis* Norman

Norman (1925), p. 315. Worthington (1933), p. 309.
II.

Not seen by survey, described from twelve specimens (55–130 mm. long) from the Nswadze River, Cholo, 2,700 feet, collected by Mr. R. Wood. Has a black lateral band on posterior half of body.

24. *Barbus banguelensis* Boulenger

Boulenger (1905), p. 143. Boulenger (1909–16), ii, p. 151, fig. 128. Worthington (1933), p. 304.
NE, Upper Congo. IV.

Not seen in Nyasaland, recorded from this area by Worthington from 18 specimens collected by Christy, said to come from Bar House and Deep Bay.

25. *Barbus innocens* Pfeffer

Pfeffer (1896), p. 66. Boulenger (1909–16), p. 160, fig. 137. Worthington (1933), p. 305.
NE, Rukwa, Wavi and Mkata Rivers, Tanganyika. III, IV.

Found by the survey to be one of the more common of the small *Barbus* adjacent to the Lake. In the Nkata Bay stream (Crocodile Creek), estuaries and also along the sandy shore in south bay, Nkata Bay, occasionally.

26. *Barbus arcislongae* Keilhack

Keilhack (1908), p. 167. Boulenger (1909–16), ii, p. 169. Worthington (1933), p. 305.

Not seen by survey.

27. *Barbus rogersi* Boulenger

Boulenger (1909–16), ii, p. 180, fig. 158. Worthington (1933), p. 305.
NE, Upper Zambesi. ? IV.

Possibly occurs in Crocodile Creek though this may be a misidentification for *B. innocens*.

28. *Barbus macrotaenia* Worthington

Worthington (1933), p. 305.

Not seen by survey.

IV. FAMILY BAGRIDAE

Genus: *Bagrus Cuvier*

29. *Bagrus meridionalis* Gunther

Gunther (1893), p. 626. Boulenger (1909–16), ii, p. 312, fig. 148. Worthington (1933), p. 312. Bertram *et al.* (1951), pp. 70, 71, 89.
(Kampango (general), Kampoyo (NLi), Kansosole (NFJ), Ntungamba (NMW), Mbuvu NNB). IV, VI, VIII, X.

A species of major economic importance particularly in the northern part of the lake, being strongly represented in gill-net catches in deep water (see Chaps. 4.2) and 5.1). Predatory and relatively swift for a catfish it is sometimes caught on a spinner if trolled deep as it appears to frequent middle and bottom rather than surface waters. The breeding season is from about October to March. It comes inshore to breed, a nest being made in shallow water on a sandy substrate. The female, after laying the eggs, leaves the nest in charge of the male (which is generally smaller than the female) and goes back to deep water. This accounts for the disparity in sex ratio found between this and the 1939 survey gill-net figures. In 1939 the fishing done mainly off Kota Kota, Monkey Bay, etc., in shallow water showed males and females in equal numbers. This survey, where nets were set deep off Nkata Bay, etc., found an overall sex ratio of about 2:1 in favour of the females.

V. FAMILY CLARIIDAE

Genus: *Clarias* (Gronovius) Scopoli

30. *Clarias mossambicus* Peters

Peters (1852), p. 682. Boulenger (1909–16), p. 232, fig. 195. Worthington (1933), p. 307. Bertram *et al.* (1942), pp. 47–48. Lowe (1952), pp. 70, 71, 84, 85. Jackson (1955), p. 683. Jackson (1959), p. 111.
Mlamba (General), Catfish, Barbel. II, III, IV. NE, Upper Congo, Zambesi, Tanganyika.

This catfish is the commonest species in rivers, lagoons and estuaries and is not representative of the open lake, though occasionally venturing into it, especially opposite rivers when they are in flood. Very tolerant to muddy water and conditions of low dissolved oxygen. Omnivorous, a general scavenger. Seen tearing at skinned crocodile carcases at Bana. Very abundant in Lake Kazuni even in the muddiest and shallowest water. Of considerable importance as a food fish, particularly in inland areas.

31. *Clarias mellandi* Boulenger

Boulenger (1905), p. 644. Boulenger (1909–16), ii, p. 238, fig. 198. Worthington (1933), p. 310. Bertram *et al.* (1942), p. 49. Jackson (1955), p. 683. Jackson (1959), p. 111.
Sute (general). NE, Upper Congo, Zambesi. III.

Another clariid of medium size which is found in river estuaries and similar habitats. Has a mainly mollusc-eating diet, to which its broad plate of vomerine teeth is adapted, but also eats insects and other animal matter. Widespread but not very common in the Nyasan region.

32. *Clarias theodorae* M. Weber

M. Weber (1897), p. 150. Boulenger (1909–16), ii, p. 262, fig. 218. Boulenger (loc. cit.), p. 363 (*C. fouloni*). Worthington (1933*a*), p. 311. Jackson (1959), p. 111.
(Kobo, general). II, III. NE, Upper Congo, Zambesi, Ngami.

A small catfish characteristic of weedy stagnant lagoons and estuaries where it skulks among vegetation. Has a mainly insect-eating diet.

33. *Clarias carsonii* Boulenger

Boulenger (1903), p. 362. Boulenger (1909–16), ii, p. 243, fig. 202. Jackson (1955), p. 683. Jackson (1959), p. 110.
NE, Tanganyika, Uganda. I

This little catfish, wrongly attributed to Lake Nyasa by early collectors, actually occurs nowhere near the lake but inhabits the high cold mountain streams of zone I. It lurks under stones feeding on aquatic insect life and other animal matter washed down by the current. Very active and turns round and bites the hand when seized. Seldom seen but can be caught on a line with a worm or meat bait.

Genus: *Bathyclarias* Jackson

34. *Bathyclarias nyasensis* (Worthington)

Worthington (1933), p. 308, fig. 10 (*Clarias nyasensis*). Bertram *et al.* (1942), p. 48. Jackson (1955), p. 683. Jackson (1959), p. 113.
(Sapuwa, Nkomo), catfish. VIII, IX, X.

This is the first of the closely-related species-flock of clariids comprising a genus endemic to Lake Nyasa, the others at present known being listed below. They are all closely related, have the accessory breathing organs very much reduced, and may be separated from the non-endemics of the rivers and lake fringes by the lateral position of the eye, a very striking character unique in the family.

Sapuwa is the most common of the lake clariids particularly the granular-headed kinds. It is mainly though not entirely an eater of plankton and the pupae of " Nkungu " flies (*q.v.* p. 54) and for this its long and close-set gill-rakers are adapted. At present considered to occur in two subspecies, with a smooth and granular head respectively, though future workers may split these and other lake clariids into further separate species. This species is of considerable importance as a food fish in the northern lake, being frequently caught in gill-nets at all depths down to the limits of dissolved oxygen. Of the Nyasa endemics, some at least probably enter river estuaries and other flooded areas during the rains.

35. *Bathyclarias loweae* Jackson

Jackson (1959), p. 114, fig. 1.
Nkomo. IX, X.

A massive, heavy species of open and deep waters. Little is known of its habits, but may eat fish as well as plankton and "Nkungu" flies. Has a broad tail and wide flat, caudal peduncle. Very commonly caught on long lines, seldom in gill-nets. Pelagic, it is one of the few fish that penetrates far out into the open water and feeds on emerging " Nkungu " fly.

36. *Bathyclarias ilesi* Jackson

Jackson (1959), p. 116, fig. 2.
" Black Sapuwa ". IX, X.

A species closely related to *C. nyasensis*, itself a variable species, from which it differs in the possession of black gill rakers and gill filaments. A thick black mucus coats the body which is readily removable so that when one is brought aboard a boat streaks of tarry black mucus come off on the hands, clothes and boat.

37. *Bathyclarias longibarbis* (Worthington)

Worthington (1933), p. 309 (*Clarias longibarbis*). Jackson (1959), p. 117.
Kabwili (NNB). VIII, IX.

This species has a shorter head and longer barbels than other clariids and is more active in its habits. Mainly a fish-eater, it is caught on lines baited with fish, and is also an important food fish, being fairly abundant especially in the northern lake,

38. *Bathyclarias foveolatus* (Jackson)

Jackson (1955), p. 681, fig. 1 (*Clarias foveolatus*). Jackson (1959), p. 118. (Chimwanapumba general). X.

A very striking and easily recognizable species from deep water, with its humped back, stubby barbels and pitted body. A fish eater, it is probably sluggish in habits, skulking among the rocks and mud at great depths; it is invariably caught in the bottom few meshes of deep gill-nets. Of no economic importance as many Africans refuse to eat it, fearing that smallpox might be contracted from its pock-marked skin.

39. *Bathyclarias worthingtoni* Jackson

Jackson (1959), p. 192, figs. 56–58. Fryer (1958).
Nkopora, NNB, VI.

A fairly small endemic clariid found mostly among rocks in the northern part of the lake, where it is quite a valuable food fish, being caught in gill-nets and traps, rarely also in *Chirimila* nets when these are fished for Utaka. Occasionally marbled greenish or yellowish in colour, and easily recognizable by the characteristic dorsal shape of the head. Feeds largely but not entirely upon the crab *Potamonautes lirragensis*, itself confined to a rocky habitat.

40. *Bathyclarias rotundifrons* Jackson

Jackson (1959), p. 118, fig. 3.
(Nkomo general). V, X.

Rather rare, this large catfish is predatory on other fishes, and is occasionally taken in deepest gill-nets of large mesh. It has a markedly rounded fleshy head, with no trace of granulation.

41. *Bathyclarias gigas* Jackson

Jackson (1959), p. 125.
IX. Ntanda (NNB), Pwefu (NKK).

Further work may reveal that these enormous fishes belong to several species. The type in the British Museum (Nat. Hist.), weighed 70 lb. and was 5 feet long. Not rare but seldom caught owing to their large size.

42. *Bathyclarias euryodon* Jackson

Jackson (1959), p. 120, fig. 4.
IX, X. Pwefu.

Belongs to the short gill-rakered group of endemic clariids but differs from all others in the possession of a very wide vomerine tooth band with the teeth fused together. Rare, only a few specimens seen.

43. *Bathyclarias filicibarbis* Jackson

Jackson (1959), p. 120, fig. 5.
V, X.

A remarkable clariid, two specimens only having been recorded, with the barbels broad and flat, frilled at the edges. It may penetrate into quite shallow water, but very little is known about it.

VI, FAMILY AMPHILLIDAE

Genus: *Amphilius* Gunther

44. *Amphilius platychir* Gunther

Gunther (1864), (v), p. 134. Boulenger (1909–16), (ii), p. 357, fig. 277. Worthington (1933), p. 313. Bertram *et al.* (1942), p. III. Jackson (1955), p. 683.
Mountain Catlet. I, II.

This little fish is very characteristic of ecological zone I being found, for example, in the high mountain streams which drain off the Nyika Plateau, such as the Rumpi and Nchenachena streams. Eggs are laid under stones, from which hatch out larvae which look from above exactly like tadpoles and which swim with the same wriggling motion, so that very close inspection is needed to reveal the fact that they are fishes. These fishes are carnivorous in habit and were wrongly attributed to the Lake Nyasa fauna. In fact they never occur anywhere near the lake.

VII. FAMILY MOCHOKIDAE

Genus: *Synodontis* Cuvier

45. *Synodontis njassae* Keilhack

Keilhack (1908), p. 168. Boulenger (1909–16), ii, p. 451 (*S. zambesensis*). Worthington (1933), p. 313 (*S. zambesensis*). Betram *et àl.* (1942), p. 111 (*S. zambesensis*). Lowe (1952), pp. 73, 89 (*S. zambesensis*). Jackson (1955), p. 683 (*S. zambesensis*). Jackson (1959), p. 300.

(Nkolokolo, general, Njekayeka, NKK) Squeaker. IV, V, VI, X.

Extremely abundant in Lake Nyasa, this catfish has since the publication of Volume II of Boulenger's Catalogue in 1911 been incorporated into the species *Synodontis zambezensis* Peters. Comparisons of specimens from Lake Nyasa and the Zambesi show, however, that Keilhack's species must stand as a Lake Nyasa endemic. While closely related to *S. zambezensis*, *S. njassae* is smaller in size, and is invariably spotted, while *S. zambezensis* is usually if not always plain grey in colour.

S. njassae is an omnivorous scavenger like all other synodontids and is very widely spread all over the lake off sandy and rocky shores and also down to the limits of dissolved oxygen. Many are caught in deep-laid traps baited with "Nsima", balls of boiled cassava, in the north, especially set for them. Also taken in Chirimila nets.

Genus: *Chiloglanis* Peters

46. *Chiloglanis neumanni* Boulenger

Chiloglanis deckenii (non Peters) Hilgendorf, 1905, p. 411.
Boulenger (1909–16), ii, p. 481, fig. 359. Jackson (1959), p. 303.

This widely distributed little catfish was discovered in Nyasaland for the first time during the J.F.R.O. survey, among stones with a sandy substrate both in the lake and rivers. Not common and very inconspicuous because of its retiring habits.

VIII. FAMILY CYPRINODONTIDAE

Genus: *Nothobranchius* Peters

47. *Nothobranchius orthonotus* Peters

Peters (1868), iv, p. 61, pl. xii, fig. 1. Boulenger (1909–16), iii, p. 33, fig. 24. Worthington (1933), p. 313.
NE, Mozambique, Tanganyika Territory, Beira.

Not seen by either the J.F.R.O. survey or the 1939 survey of Bertram, Borley and Trewavas, nor by Lowe during her Tilapia survey. Six specimens from the Christy collection are in the British Museum, the locality being given as Bar House and Monkey Bay (Worthington loc. cit.). Probably a species of marshy areas.

Genus: *Aplocheilichthys*

48. *Aplocheilichthys johnstoni* (Gunther)

Gunther (1893), p. 627. Boulenger (1909–16), iii, p. 69. Worthington (1933), p. 314.

Not seen by J.F.R.O. survey.

IX. FAMILY ANABANTIDAE

Genus: *Ctenopoma* Peters

49. *Ctenopoma ctenotis* Boulenger

Boulenger (1919), p. 399. Worthington (1933), p. 314.

One specimen in the British Museum from the Nyasa area collected by Dr. Christy. Not seen by any survey since, but an anabantid is present in streams and marshes, although it cannot be abundant.

X. FAMILY CICHLIDAE

Genus: *Tilapia* A. Smith

50. *Tilapia sparrmani* A. Smith

A. Smith (1840), pl. v. Boulenger (1909–16), iii, p. 206, fig. 132. Bertram *et al.* (1942), p. 40. Lowe (1952), p. 87.
NE, Limpopo, Zambesi, Congo. III. (Chimbente NKK). Bream.

Not present in Lake Nyasa, this fish was recorded from Nyasaland for the first time by the 1939 survey, from the Kampambe lagoon near Kota Kota. It has since been found in Lake Chilwa by Lowe and in lagoons in the Banga River by J.F.R.O. It is a small and hardy little *Tilapia*, and the most widely distributed species of the genus, living in streams and pools from Natal to the Upper Congo Basin. Omnivorous.

51. *Tilapia melanopleura* A. Dum.

A. Dumeril (1859), p. 252, pl. xxii, fig. 1. Boulenger (1909–16), (iii), p. 190, fig. 123. Regan (1921), p. 677. Trewavas (1941), p. 294. Bertram *et al.* (1942), pp. 22, 39, 89, 112. Lowe (1952), pp. 3, 10, 11, 35–37, 60, 85, 90. NE, Zambesi, Upper Congo. II, III, IV. (Katukusi NFJ, Nyungutsali, NFJ). Redbreasted Bream.

A well known and widely distributed species, one of the main *Tilapia* used in fish farming. Feeds directly on higher plant life and according to Lowe (1952), is associated with the *Ceratophyllum* beds in its habitat. Rare in the northern part of the lake.

52. *Tilapia shirana* Boulenger

Boulenger (1896), p. 916, fig. (*Oreochromis shiranus*). Boulenger (1909–16), iii, p. 151, fig. 98. Regan (1921), p. 677. Trewavas (1941), p. 294. Bertram *et al.* (1942), pp. 37–39, 89–112. Lowe (1952), numerous refs. Lowe (1953), pp. 1935–1941. Fryer (1956), p. 5.
(Katakuzi (NFJ), Fwilili (NMB), Nkututu (NKA)). III, IV.

Endemic to the Lake Nyasa Basin, this fish has a scaled tail as have all other Nyasan Cichlids except the two mentioned above and *Haplochromis callipterus* and *H. moffatii*. It may be immediately differentiated from the other endemic *Tilapias* by the fact that it has four and not three anal spines. It is closely related to *T. mossambica* of the Middle and Upper Zambesi. Higher vegetation, and bottom detritus eater, does well in fish ponds.

53. *Tilapia squamipinnis* (Gunther)

Gunther (1864), p. 311 & (1893), p. 621, pl. (iii) (*Chromis squamipinnis*). Boulenger (1909–16), iii, p. 183, fig. 118. Regan (1921), p. 677. Trewavas (1935), p. 72. Trewavas (1941), p. 294. Bertram *et al.* (1942), pp. 22, 25–36, 77, 81, 86, 90, 92, 111–2, 126, fig. 4, 5. Lowe (1952), pp. 1–65, 78–9, fig. 1–19, tables, plates I–IV. Lowe (1953), pp. 1035–1041.
Chambo (general), Lisanga Nka.

Breeding male (Blue):—Chinganga (NFJ), Nchisichesi (NMB), Ngwalu (NKK). Immature fish or small mature females:—Zeya (NFJ).
Young:—Kasawala (general). Lake Nyasa Bream. IV.

A famous food fish, over 3,000 tons per year of Chambo, largely this species, are at present being taken out of the south-east arm of Lake Nyasa. See Lowe (1952), for a comprehensive study; here it can only be said that it is a shoaling mouth-breeding species, inhabiting open water of zone IV, and feeding on algae, phytoplankton when this is available and diatoms, etc., on the bottom when planktonic algae are not plentiful.

54. *Tilapia saka* Lowe

Lowe (1952), pp. 1–65, 78–79, tables, figs. especially p. 5, pl. 1, fig. 18. Lowe (1953), p. 1035.
Chambo (General); Langasime (dark coloured specimens).
Breeding males and black breeding females:—Saka (General), Biriwiri (NKK), Manindi (Nka)
Breeding females:—Chidyakolo
Young:—Kasawala (General). IV.

Closely related to *T. squamipinnis*, this fish has been described by Lowe as being a different species mainly on physiological grounds, having distinct breeding and feeding grounds. Apart from *T. shirana* the most inshore of the zone IV *Tilapias.*

55. *Tilapia lidole* Trewavas

Trewavas (1941), p. 294, ff. Trewavas in Bertram *et al.* (1942), pp. 22–25, 34–37, fig. 6. Lowe (1952), pp. 1–65, figs, tables. Lowe (1953), pp. 1035–41.
General:—Chambo.
General and adult female:—Lidole (NFJ), Galamulu (NMB), Lolo (NKK).
Breeding male:—Chinkulu (NFJ, NMB, NKK).
Immature fish (20–26 cm.):—Zeya Dole (NFJ, only occasionally).
Young:—Kasawala Dole or Kasawala.

This species, described by Trewavas after the 1939 Fisheries Survey, is the most open water living of the endemic *Tilapias*, and is a valuable and important economic species in the southern part of the lake.

56. *Tilapia karongae* Trewavas

Trewavas (1941), p. 294, ff. Trewavas in Bertram *et al.* (1942), p. 23, figs. 5 & 6. Lowe (1952), pp. 11, 31.
Manindi (black male), (NKa). IV.

Closely related to the preceding three, this species may be distinguished from them by its smaller head and the fact that the toothed area of the pharyngeal bone is straight and not concave. Limited in distribution to the northern part of the lake and not as abundant as its southern relatives because suitable habitat is not as extensive in the north as in the south.

XI. GENUS: *Haplochromis hilgendorf*

57. *Haplochromis moffatii* (Cast.)

Castelnau, F. de (1861), p. 16. Boulenger (1909–16), ii, p. 300. *Haplochromis moffatii* (Cast.) Bertram *et al.* (1942), p. 112.
NE, Upper Congo, Zambesi, Limpopo. Kamoto (NKK). III, II.

This widely spread little *Haplochromis* was recorded from the Nyasa basin for the first time during the 1939 Fisheries Survey, from the Kampambe Lagoon, Kota Kota. Found by us to be widespread in rivers, even found in the higher reaches, e.g. it has colonized the fish ponds at Nchenachena, high up in zone I. An omnivorous species, it may be distinguished from the similar but endemic *H. callipterus* (58) by the fact that it has a rounded and not a truncate tail, while both these fluviatile species differ from the Lake Nyasa endemics in that the latter invariably possess a forked or emarginate tail, never a rounded or subtruncate one.

58. *Haplochromis callipterus* (Gunther)

Gunther (1893), p. 623, pl. IV, fig. B (*Chromis callipterus*). Pellagrin (1904) (*Astatotilapia calliptera*). Boulenger (1909–16), (iii), p. 222, fig. 145 (*Tilapia calliptera*). Regan (1921), p. 680. Nichols and Lamonte (1931), fig. 3 (*Haplochromis centropristoides*). Trewavas (1933), pp. 66–89; (1946) p. 241.
Kolokoto (NKK). III, IV.

A very abundant little species which frequents lagoons and the lower reaches of rivers rather than open lake. Found in Lakes Chilwa and Kazuni. Large specimens eat molluscs and may be useful in bilharzia control in ponds.

59. *Haplochromis livingstonii* (Gunther)

Gunther (1893), p. 625, pl. lvi, fig. B. (*Hemichromis livingstonii*). Boulenger (1909–16), (iii), p. 286, fig. 194 (part). Regan (1921), p. 688. Trewavas (1935), p. 89. Bertram *et al.* (1942), pp. 60, 113. Fryer (1956*b*), p. 1.
Fisi (General), Kaligono (NNB). V, VIII.

A very handsome carnivorous species, associated with underwater beds of Masimbe (*Vallisneria*) and hence occurs only where this is abundant. The fish seems to be commoner on the eastern than the western coast. Some juveniles from the mouth of a breeding female from Likoma Island lived in an aquarium for some time and the tiny fishes showed exactly the same well-marked blotches as the adults. The name " Kaligono ", meaning " the sleeper ", is given to this fish on account of its habit of lying flat on the bottom and shamming death, presumably until some unsuspecting little fish comes within " striking distance."

60. *Haplochromis pardalis* Trewavas

Trewavas (1935), p. 89. Fryer (1959), p. 189, figs. 47–49.
IV.

The type is from Deep Bay near the north end of the lake; found among rocks Nkata Bay. Carnivorous.

61. *Haplochromis polystigma* Regan

Regan (1921), p. 688, pl. i. Trewavas (1935), p. 89.
Fisi (NKK), Gufifi (NLi), Nyalubwe (NNB). VI.

A brown-mottled, hence its Chinyanja name " Hyaena " and Chitonga name " Leopard ", rock-frequenting species, caught by angling with fish bait on a small hook, and by small-meshed gill-nets set over rocky places.

62. *Haplochromis maculimanus* Regan

Regan (1921), p. 689. Trewavas (1935), p. 89.

Known only from the type, 190 mm. in total length.

63. *Haplochromis venustus* Boulenger

Boulenger (1908), p. 241. Boulenger (1909–16), iii, p. 287, fig. 195. Regan (1921), p. 722 (*Cyrtocara venusta*). Regan, ibid, p. 689, fig. 5 (*H. simulans*). Trewavas (1935), p. 89.
Fisi (General), Kaligono (NNB). V.

A sand-frequenting carnivorous species probably also inhabiting *Vallisneria* swards. A specimen from Bana had fish bones in its stomach. Breeding males a most beautiful peacock blue with a sulphur-yellow blaze down the nose.

64. *Haplochromis fuscotaeniatus* Regan

Regan (1921), p. 696, fig. 12. Trewavas (1935), p. 90.
Liwele (NFJ), Mbele NMB.

Not seen by survey, apparently occurs mainly in the south end of the lake.

65. *Haplochromis johnstoni* (Gunther)

Gunther (1893), p. 622, pl. liv, fig. A (*Chromis johnstoni*). Boulenger (1909–16), iii, p. 249, fig. 197 (*Tilapia johnstoni*). Regan (1921), p. 691. Regan (ibid), p. 692, fig. 7 (*Haplochromis sexfasciatus*). Trewavas (1935), p. 90. Fryer (1959), p. 198.
Kachimanga NNB, Masimbe NNB. V.

An abundant and distinctive little fish very characteristic of the sandy shores of the main lake. Associated with *Vallisneria* to such an extent that, at Nkata Bay, both the fish and the plant bear the same name. A female with young has been seen to deposit her brood on to the *Vallisneria*, swim round and protect them, and take them up into her mouth again.

66. *Haplochromis rostratus* (Boulenger)

Boulenger (1909–16), iii, p. 255, fig. 172. Regan (1921), p. 718. Regan (ibid), p. 717, fig. 28 (*H. macrorhynchus*). Trewavas (1935), p. 90. Fryer (1956*b*), p. 2.
Chimbenje (General), Chigumbuli (NNB). V.

This well-marked fish is one of the lake cichlids most commonly seen. Like certain sea fishes its long snout is used for burrowing in the sand over which it lives. Able to bury itself in the sand to escape seine-nets.

67. *Haplochromis compressiceps* (Boulenger)

Boulenger (1908), p. 248 (*Paratilapia*). Boulenger (1909–16), iii, p. 331, fig. 222. Regan (1921), p. 717. Trewavas (1935), p. 90. Fryer (1959), p. 208.
Kapula (NFJ), Chimpeni (NNB), Kalikolombe (NLi). VI, VII, VIII.

A fish easily recognizable by its very thin face as well as by its colour pattern. Predatory on other fish, it inhabits mainly zone VI, intermediate between rock and sand. Not abundant.

68. *Haplochromis macrostoma* Regan

Regan (1921), p. 719, pl. iv, fig. 2. Trewavas (1935), p. 90.

A heavily built predator, probably more common at the south end of the lake, though known from the north and often caught in small-mesh gill nets.

69. *Haplochromis polyodon* Trewavas

Trewavas (1935), p. 90. Fryer (1959), p. 187, figs. 44–46.
VI.

Not uncommon at Nkata Bay over rocky shores, where it is one of the most important piscivorous species.

70. *Haplochromis maculiceps* Ahl

Ahl (1927), p. 57. Trewavas (1935), p. 90.
VI.

Another predator with big head and large mouth, probably mainly over rocks in fairly deep water. Mainly from the north end of the lake.

71. *Haplochromis urotaenia* Regan

Regan (1921), p. 695, fig. 11. Trewavas (1935), p. 90.
Kachimanga (NNB). V.

A predatory fish from sandy shores principally in the southern part of the lake. Not common.

72. *Haplochromis spilopterus* Trewavas

Trewavas (1935), p. 91.
Kamwena (NNK), Mbaba (NFJ), Kadyapola (NMB). V.

Rarely seen during the survey, caught off Kota Kota in 2½" gill-net over a sandy bottom. A predator on other fishes.

73. *Haplochromis triaenodon* Trewavas

Trewavas (1935), p. 91.

Twenty-six specimens in the British Museum from the Christy collection, all from the south end of the lake. Very closely related to No. 74.

74. *Haplochromis fenestratus* Trewavas

Trewavas (1935), p. 91. Fryer (1959), p. 187, figs. 41–43.
Yesa (NKK). VI.

Common on rocky shores where, although showing relatively few specializations, it is one of the very few successful non-predatory species of *Haplochromis*. An omnivorous feeder on the fauna and flora of rock surfaces.

75. *Haplochromis similis* Regan

Regan (1921), p. 693, fig. 8. Trewavas (1935), p. 91. Fryer (1959), p. 198.
Kambuzi (General), Namdyatsini, Chidyabango (NMB). IV, V.

A very common and abundant little fish, found in estuaries and river mouths as well as in the main lake. A vegetarian.

76. *Haplochromis marginatus* Trewavas

Trewavas (1935), p. 91.
Mbaba Nyali (NKK). IV, V.

Another common little cichlid of sheltered sandy-bottomed waters, hence more abundant in the south and at places such as Kota Kota. Trewavas (*loc. cit.*), has recognized two subspecies, one from the north and one from the south end of the lake. Superficially very similar to *H. similis* but actually a quite distinct species, with teeth of jaws and pharynx smaller and pharyngeal bones more slender.

77. *Haplochromis leuciscus* Regan

Regan (1921), p. 716, fig. 26. Trewavas (1935), p. 92.
Kadyemphoka (NKK). IV, V.

Little is known about this fish which is not common but probably also a calm-water sand-frequenting species.

78. *Haplochromis spilonotus* Trewavas

Trewavas (1935), p. 92.

A rare, fairly large cichlid with a longitudinal stripe. J.F.R.O. has one from Nkata Bay.

79. *Haplochromis insignis* Trewavas

Trewavas (1935), p. 92.

Not seen during the survey. Five specimens from Monkey Bay collected by Christy.

80. *Haplochromis annectens* (Regan)

Regan (1921), p. 723, fig. 30 (*Cyrtocara annectens*). Trewavas (1935), p. 92.
VIII.

A handsome blue fish, not common, found usually in midwater close to shore a few feet off the bottom.

81. *Haplochromis taeniolatus* Trewavas

Trewavas (1935), p. 93.
V.

Uncommon, occasionally taken in seine nets from deepish water over sand.

82. *Haplochromis breviceps* Regan

Regan (1921), p. 694, fig. 6. Trewavas (1935), p. 93.
Chionge (NFB), Chimalambeu (NMa).

Not seen by our survey, probably very local in distribution.

83. *Haplochromis microcephalus* Trewavas

Trewavas (1931), p. 93.
Mbundangi (NMa).

Not seen; only two specimens (collected by Christy) known from Monkey Bay.

84. *Haplochromis nigritraeniatus* Trewavas

Trewavas (1935),p. 93.

Not seen during the survey. Nine specimens in British Museum from Monkey Bay (Christy collection).

85. *Haplochromis serenus* Trewavas

Trewavas (1935), p. 93, fig. 13A.
Chipara (NNB). VIII.

A handsome blue fish living in midwater off the bottom.

86. *Haplochromis purpurans* Trewavas

Trewavas (1935), p. 93.

Not seen by either our or the 1939 survey. Fifteen specimens (Christy collection) from the north end of the lake.

87. *Haplochromis pleurotaenia* (Boulenger)

Boulenger (1901), p. 4. Boulenger (1909–16), iii, p. 247, fig. 166 (*Tilapia pleurotaenia*, Tanganyika). Regan (1920), p. 39 (*Limprotilapia pleurotaenia*, Tanganyika). Regan (1921), p. 695, fig. 10 (*Haplochromis microstoma* Nyasa). Trewavas (1935), p. 93 (*Haplochromis microstoma*). Trewavas (1946), p. 244 (*Haplochromis pleurotania*).

Systematic Note:

This species, collected from Lake Nyasa by J. E. S. Moore, was wrongly labelled as being from Lake Tanganyika by him, the mistake being discovered by Trewavas (1946), who in the same paper places *H. microstoma* Regan in the synonomy of this species.

Occasionally taken in seines from deeper water with a sandy bottom.
V.

88. *Haplochromis kirkii* (Gunther)
Gunther (1893), p. 624, pl. lvi, fig. A (*Chromis kirkii*). Boulenger (1909–16), iii, p. 251, fig. 169. Regan (1921), p. 693. Trewavas (1935), p. 93.
Mbaba (NFJ). IV, V.

A common and abundant little fish with heavy pharyngeal bones from sandy shores and sheltered waters. Insect and mollusc remains have been found in the stomach.

89. *Haplochromis labridens* Trewavas
Trewavas (1935), p. 94.
IV, V.

Closely related to the preceding species but not as abundant and occurring mainly in the south end of the lake.

90. *Haplochromis virgatus* Trewavas
Trewavas (1935), p. 94.
VI.

Also closely related to *H. kirkii*, J.F.R.O. took one specimen in a small-meshed gill-net over rocks at Nkata Bay.

91. *Haplochromis phenochilus* Trewavas
Trewavas (1935), p. 94.
V, VIII.

A well-marked fish, the pallor of the lips is very striking. J.F.R.O. has specimens from Mwafufu near Nkata Bay, from the Intermediate Zone. Said occasionally to be caught in large numbers by seine net in the south-east arm and is then of fair economic importance.

92. *Haplochromis festivus* Trewavas
Trewavas (1935), p. 94.

Not seen during the survey, one specimen collected by Christy in the British Museum from Nkudzi.

93. *Haplochromis ornatus* Regan
Regan (1921), p. 691. fig. 6. Trewavas (1935), p. 94. Fryer (1959), p. 185.
VI.

A rock frequenting species which feeds on the insect nymphs and larvae which occur on and under rocks. Not very common.

94. *Haplochromis lobochilus* Trewavas
Trewavas (1935), p. 94.

Described from one specimen (Christy collection) from Deep Bay. Not seen by J.F.R.O.

95. *Haplochromis euchilus* Trewavas
Trewavas (1935), p. 94. Fryer (1959), p. 184, figs. 37–40.
Namlepetu (General). VI.

A very striking fish, both in its colour pattern and the way its lips are produced into large lobes. Fairly common but not abundant, associated with a rocky habitat.

96. *Haplochromis holotaenia* Regan
Boulenger (1909–16), iii, p. 360, fig. 244 (*Paratilapia dimidata* part). Regan (1921), p. 697 (*Haplochromis holotaenia*). Trewavas (1935), p. 95.
Chilingwi (NMB). VII.

A predatory fish, seldom seen but taken by us near rocks over sand and *Vallisneria* interspersed with rocks. A predatory species.

97. *Haplochromis kiwinge* Ahl.

Ahl. (1927), p. 56. Ahl. (ibid), p. 58 (*Haplochromis fuelleborni*). Trewavas (1935), p. 95. Fryer (1956*b*), p. 4. Fryer (1959), p. 185.
Binga (General). V, VIII.

A well-known and important species. Adults are predators on other fish and frequently caught by anglers on spoons and with bait. Breeding males are frequently caught by spinners trolled over their sand scrape nests as they rise up and attack the spinners, usually getting foul-hooked. Caught also in seines and gill-nets. This is a valuable food and sporting fish. Breeding males are a beautiful blue with each scale flecked by a golden spot.

98. *Haplochromis strigatus* Regan

Regan (1921), p. 697, fig. 13. Trewavas (1935), p. 95.
V, VII.

An easily recognized mild predatory fish from sand and *Vallisneria* patches. Eats insects, tiny fish and vegetable remains have also been found in stomach.

99. *Haplochromis dimidiatus* (Gunther)

Gunther (1864), p. 313 (*Hemichromis dimidiatus*). Gunther (ibid), p. 312 (*Chromis lateristriga*, part). Boulenger (1909–16), p. 360, fig. 244 (*Paratilapia dimidiata*). Trewavas (1935), p. 95. Fryer (1959), p. 199.
V.

A moderately large predatory species associated with sandy bottoms.

100. *Haplochromis subocularis* Gunther

Gunther (1893), p. 621, pl. liv, fig. B (*Chromis subocularis*). Boulenger (1909–16), iii, p. 249 (*Tilapia johnstoni* part). Regan (1921), p. 691 (*Haplochromis subocularis*). Trewavas (1935), p. 95.
IV, V.

A sheltered water, sand-dwelling species apparently restricted to the south end of the lake.

101. *Haplochromis lateristriga* (Gunther)

Gunther (1864), p. 312 (*Chromis lateristriga* part). Boulenger (1909–16), iii, p. 253 (*Tilapia lateristriga* part). Boulenger (ibid), p. 254 (*Tilapia lethrinus*, part). Regan (1921), p. 705, fig. 18 (*Haplochromis lateristriga*). Trewavas(1935), p. 96.
V.

Taken by us in seine net at Palm Beach, south-east arm. Feeding habits unknown. Not common.

102. *Haplochromis incola* Trewavas

Trewavas (1935), p. 96.
V.

A species with heavy pharyngeal teeth from *Vallisneria* swards. Probably a mollusc eater, mostly from the south.

103. *Haplochromis mola* Trewavas

Trewavas (1935), p, 96. Fryer (1959), p. 199.
V.

Closely related to the preceding species but more abundant in the north. Not uncommon; taken in seine nets off sandy beaches, Nkata Bay. A mollusc eater.

104. *Haplochromis sphaerodon* Regan

Regan (1921), p. 703, fig. 16. Trewavas (1935), p. 96.

A third species closely related to 102 and 103 but differs in having a smaller head. Habits probably similar.

105. *Haplochromis ericotaenia* Regan

Regan (1921), p. 704, fig. 17. Trewavas (1935), p. 97.

Closely related to the preceding three species. J.F.R.O. has no data.

106. *Haplochromis plagiotaenia* Regan

Regan (1921), p, 706, fig. 19. Trewavas (1935), p. 97.
IV, V.

A fish of sandy shores and calm sheltered waters, more common in the south.

107. *Haplochromis labidodon* Trewavas

Trewavas (1935), p. 97.

Described from five specimens from Mwaya and Deep Bay (Christy collection). Not seen by J.F.R.O.

108. *Haplochromis balteatus* Trewavas

Described from three specimens from Karonga and Vua (Christy collection). Not seen by J.F.R.O.

109. *Haplochromis melanotaenia* Regan

Regan (1921), p. 706, fig. 20. Trewavas (1935), p. 97.
V.

An uncommon species frequenting sandy shores and *Vallisneria* patches. One taken by J.F.R.O. in a seine net, Monkey Bay.

110. *Haplochromis epichorialis* Trewavas

Trewavas (1935), p. 97.

Nothing is known about the habits of this fish. Two from Deep Bay in the Christy collection.

111. *Haplochromis spilorhynchus* Regan

Regan (1921), p. 711, pl. vi, fig. 2. Regan (ibid), p. 712, pl. v, fig. 2 (*Haplochromis longipes*). Trewavas (1935), p. 98.
Tabwa (NFJ), Damphila (NMB), Njeruwa (NNB). IV, V.

A well-known large *Haplochromis*, predatory upon other species, especially from the south-east arm and Upper Shire. Fairly valuable as food.

112. *Haplochromis caeruleus* (Boulenger)

Boulenger (1908), p. 240 (*Paratilapia caerulea*). Boulenger (1909–16), iii, p. 433, fig. 295 (*Champsonchromis caeruleus*). Regan (1921), p. 712 (*Haplochromis caeruleus*).
Nchyochyo (NMB). V, VIII.

Closely related and of similar habits to the preceding, but is probably of a more mid-water habit, having been caught by J.F.R.O. more frequently in gill than in seine nets.

113. *Haplochromis melanonotus* Regan
Regan (1921), p. 708, fig. 21. Trewavas (1935), p. 98.
Sasamchenga (NKK). V.

More common in the south, the dentition of this fish suggests a specialized feeding habit, but it is not known what it is.

114. *Haplochromis semipalatus* Trewavas
Trewavas (1935), p. 98.

Not seen by survey, described from four specimens from Deep Bay and Kapora (Christy collection).

115. *Haplochromis guentheri* Regan
Boulenger (1909–16), iii, p. 2531, fig. 170 (*Tilapia lateristriga* part). Regan (1921), p. 707. Trewavas (1935). Fryer (1959), p. 187, figs. 50–51.
VI.

A rock-frequenting species with specialized dentition. Picks certain algae from rock surfaces, and often shows a high degree of selectivity in feeding.

116. *Haplochromis mollis* Trewavas
Trewavas (1935), p. 98.
IV, V.

A rare sand-frequenting species of the south lake. One taken by J.F.R.O. off sand at Palm Beach, south-east arm.

117. *Haplochromis orthognathus* Trewavas
Trewavas (1935), p. 99.
Chongwe (NNB). VII.

One specimen from Nkata Bay taken by J.F.R.O., four from the Christy collection were taken in rather deep water in the south-west arm of the lake. The vertical mouth and thick lips are very striking. Probably inhabits intermediate rock sand zone.

118. *Haplochromis lepturus* Regan
Regan (1921), p. 709, fig. 22. Regan (ibid). p. 710 (*Haplochromis rhoadesii*, part). Ahl (1927), p. 55 (*Haplochromis gigas*). Trewavas (1935), p. 99. Bertram *et al.* (1942), p. 60. Lowe (1952), p. 90.
Khota (NKK). V.

A common large *Haplochromis* predatory on other fish, characteristic of the sandy beaches of the open lake. A good angling fish and often taken in seine nets. Not common in the south, more often found from Kota Kota northwards.

119. *Haplochromis nototaenia* (Boulenger)
Boulenger (1902), p. 79 (*Paratilapia nototaenia*). Boulenger (1909–16), iii, p. 359. Regan (1921), p. 709. Trewavas (1935), p. 99. Bertram *et al.* (1942), p. 60. Lowe (1952), p. 90.
Dimba (NMB), (NKK), Ngungu (NFJ). IV, V.

Another large predatory member of the species-flock. Lives over sand in sheltered waters and takes the place of the preceding species in the south. Common and well known.

120. *Haplochromis rhoadesii* (Boulenger)
Boulenger (1908), p. 239 (*Paratilapia rhoadesii*). Boulenger (1909–16), iii, p. 361, fig. 245. Regan (1921), p. 710. Trewavas (1935), p. 99. Bertram *et al.* (1942), p. 60.
Kavunguti (NMB). IV, V.

A predatory fish of the southern lake whose habits are not yet known.

121. *Haplochromis heterotaenia* Trewavas

Trewavas (1935), p. 99.
Mzomba (NNB). VI, X.

A very large fish-eating *Haplochromis* that penetrates to all depths to the limit of dissolved oxygen, and was found to be an important food fish when fished for by deepset gill-nets. Commoner in the northern part of the lake.

122. *Haplochromis atritaeniatus* Regan

Regan (1921), p. 711, fig. 23. Trewavas (1935), p. 99.
Tong'o (NFJ), (NMB). IV, V.

A predatory fish-eating species of the southern lake and Upper Shire, possibly associated with weed.

123. *Haplochromis oculatus* Trewavas

Regan (1921), p. 709 (*Haplochromis nototaenia*, part). Trewavas (1935), p. 100.
To'ngo (NFJ), (NMB). IV, V.

A predatory fish-eating species, closely related to *Haplochromis nototaenia* and its allies, from the south lake.

124. *Haplochromis spectabilis* Trewavas

Trewavas (1935), p. 100.

Not seen by survey. If a valid species will be predatory and fish eating. Numbers 117–124 are extremely closely related.

125. *Haplochromis obtusus* Trewavas

Trewavas (1935), p. 100.

Not seen during the J.F.R.O. survey. Described from one specimen from the southern lake.

126. *Haplochromis formosus* Trewavas

Trewavas (1935), p. 100.
VI.

A rare species occasionally found off rocks.

127. *Haplochromis gracilis* Trewavas

Trewavas (1935), p. 100.

Described from three specimens—not seen by J.F.R.O.

128. *Haplochromis spilostichus* Trewavas

Trewavas (1935), p. 100.

Described from a single specimen from Monkey Bay; not seen during the J.F.R.O. survey.

129. *Haplochromis ahli* Trewavas (nom. nov.)

Ahl (1927), p. 64 (*Haplochromis serranoides* non Regan). Trewavas (1935) (*Haplochromis ahli*), p. 101.

Described by Ahl from a large specimen. There are 19 specimens in the British Museum from both ends of the lake in the Christy collection. No data from the J.F.R.O. survey.

130. *Haplochromis pleurospilus* Trewavas

Trewavas (1935), p. 101.

Described from one specimen collected by Christy from a sand bank in the northern lake. Not seen by J.F.R.O.

131. *Haplochromis auromarginatus* (Boulenger)

Boulenger (1908), p. 241 (*Tilapia*). Boulenger (1909–16), p. 180, fig. 115. Trewavas (1935), p. 101.
Sasamchenga (NKK). IV, V.

A handsome little cichlid which feeds off bottom epiphytes in shallow water. Has been seined, gill-netted and occasionally taken in chirimila nets from Fort Johnston to Nkata Bay and Likoma.

132. *Haplochromis ovatus* Trewavas

Trewavas (1935), p. 101.
Chakuta (NMB), (NLi), possibly Chipara (NNB). VI, VIII.

A very handsome blue fish, often with bronzy yellow streaks down the nose which floats about in mid-water near the shore. Often seen from ships at anchor.

133. *Haplochromis woodi* Regan

Regan (1921), p. 702, pl. ii. Trewavas (1935), p. 101. Bertram *et al.* (1942), p. 60. Lowe (1952), p. 90.
Mbawala (NKK), Katsatsi (NMB), PiChirico (NFJ). V, VI, VIII.

A well-known, easily recognized and widely distributed predatory species, caught in seines, gill-nets and by angling.

134. *Haplochromis modestus* (Gunther)

Gunther (1893), p. 625, pl. lvii, fig. A. Boulenger (1909–16), iii, p. 327. Regan (1921), p. 701. Trewavas (1935), p. 102.

A species of doubtful validity, only the type being known.

135. *Haplochromis pholidophorus* Trewavas

Trewavas (1935), p. 102.

Described from a single specimen from Vua. Not seen by J.F.R.O. survey.

136. *Haplochromis tetrastigma* Gunther.

Gunther (1893), p. 623, pl. lvi, fig. C. (*Tilapia tetrastigma*). Boulenger (1909–16), iii, p. 250, fig. 168. Trewavas (1935), p. 102, fig. 9.
Mbaba (NFJ). IV. V.

A fish commoner in the south where it is sometimes of commercial importance, being seined occasionally in large numbers. Probably a bottom feeder on sandy shores. Very close to the genus *Lethrinops*.

137. *Haplochromis heterodon* Trewavas

Trewavas (1935), p. 102. Fryer (1956*b*), p. 2, figs. 1 and 2.

Recorded by J.F.R.O. from Nkata Bay and Likoma Island. The males of this species, although usually only 13–17 cm. in length, build a circular " nest " in the sand which has a diameter of about 50 cm. and is raised up 15–20 cm. above the ground on which it is built. Details of the process and an illustration of such a nest are given by Fryer (*loc. cit.*).

138. *Haplochromis tetraspilus* Trewavas

Trewavas (1935), p. 103.

A fish of the southern lake. No data from J.F.R.O.

139. *Haplochromis chrysogaster* Trewavas

Trewavas (1935), p. 103.

No data on this fish has been obtained by J.F.R.O. Known from three specimens, one from Karonga and two from the south-east arm.

140. *Haplochromis labifer* Trewavas

Trewavas (1935), p. 104.
V.

A member of the bottom feeding sandy beach fauna, often caught in large shoals in seine nets operated in bays.

141. *Haplochromis speciosus* Trewavas

Trewavas (1935), p. 104.
Saguga (NMB).

No data collected by J.F.R.O. Possibly a fish of the southern lake only, as described from two specimens from Vua and Monkey Bay.

142. *Haplochromis decorus* Trewavas

Trewavas (1935), p. 104.
Kambuzi wa Vumanga (NLi).

No data collected by J.F.R.O.

143. *Haplochromis argyrosoma* Regan

Regan (1921), p. 713, text-fig. 25. Trewavas (1935), p. 104.
VI, VIII.

Not abundant, over rocks and open water.

144. *Haplochromis selenurus* Regan

Regan (1921), p. 679, text-fig. 1 (*Otopharynx selenurus*). Trewavas (1935), p. 104 (*Haplochromis selenurus*).
IV, V, VIII.

A midwater species, not abundant and more common in the south.

145. *Haplochromis moorii* (Boulenger)

Boulenger (1902) (*Cyrtocara moorii*). Boulenger (1909–16), iii, p. 445, fig. 304. Regan (1921), p. 724. Trewavas (1935), p. 105 (*Haplochromis moorii*). Fryer (1959), p. 200.
Chinkongo (NKK), Kabale (NKK), Kabibi (NLi). V.

A blue-coloured species distinctive by virtue of its possessing a large frontal hump above and between the eyes. A bottom liver mainly of sandy areas. Has been observed skulking round other fishes such as *H. rostratus* digging in the sand and snatching food in the disturbed sand and mud.

146. *Haplochromis placodon* Regan

Regan (1921), p. 700, fig. 15. Trewavas (1935), p. 105.
Chamwala (NKK), (NFJ), Ndowolo (NLi). V, VII.

A well-marked, easily recognized species common on sandy bottom and *Vallisneria* swards all over the lake. Feeds on molluscs and has heavy pharyngeal dentition to crush the shells.

147. *Haplochromis nitidus* Trewavas
Trewavas (1935), p. 105.
Kabanana (NLi), Mbaba Katsatsi (NMB).

No data from J.F.R.O. survey.

148. *Haplochromis pictus* Trewavas
Trewavas (1935), p. 105.

No data from J.F.R.O. survey.

149. *Haplochromis intermedius* (Gunther)
Gunther (1864), p. 312 (*Hemichromis intermedius*). Boulenger (1909–16), iii, p. 363, (*Paratilapia intermedia*). Regan (1921), p. 701 (*Haplochromis intermedius*). Trewavas (1935), p. 105.
Mbaba Katsatsi (NMB), Yera (NKK). VIII ?

A fish of the southern lake, no data from J.F.R.O. Probably a plankton-eater.

150. *Haplochromis inornatus* (Boulenger)
Boulenger (1908), p. 242 (*Tilapia incornata*). Boulenger (1909–16), iii, p. 263, fig. 178. Regan (1921), p. 715. Trewavas (1935), p. 106. Iles (1960), p. 259.

Utaka (general) for fishes of this group (Nos. 150–167) which are mainly shoaling plankton eating, and of great economic importance especially in the northern lake (see chapter 5).

Known only from the types, never seen since. If a valid species probably associated with sand and of very limited occurrence.

151. *Haplochromis eucinostomus* Regan
Regan (1921), p. 716, pl. iv, fig. 1. Trewavas (1935), p. 106. Iles (1960), p. 258.
Mloto Mchenga (NNB). V.

Twenty-two specimens in the British Museum, collected by Christy. Specimens collected by seine during this survey, a sand-loving fish, which were building nests on sand, are for the present referred to this species.

152. *Haplochromis prostoma* Trewavas
Trewavas (1935), p. 106. Iles (1960), p. 266.
? Ukongola (NNB). ? V.

Six specimens in British Museum from Vua and Deep Bay. Has the protrusible snout pointing definitely downward, possibly connected with a bottom, sand-frequenting habit.

153. *Haplochromis chrysonotus* (Boulenger)
Boulenger (1908), (*Paratilapia chrysonota*). Boulenger (1909–16), iii, p. 362, fig. 246. Regan (1921), p. 702 (*Haplochromis chrysonotus*). Trewavas (1935), p. 107. Iles (1960), p. 266. Silibanga (General), Kabananga (NNB).

A fish of widespread distribution, found as far apart as Monkey Bay and Karonga. Prefers open water, congregates round floating objects such as logs and boats at anchor. Rare, caught at chirundus (underwater rock formations).

154. *Haplochromis nkatae* Iles
Iles (1960), p. 268.
IX. " Utaka sergeant " (NNB).

Closely related to but less common than the above, occasionally caught at chirundus.

155. *Haplochromis jacksoni* Iles

Iles (1960), p. 270.
VI. Kabananga (NNB).

Appears occasionally at chirundus in shoals. Similar in general appearance to *H. chrysonotus* but with more spines and rays in dorsal fin, as well as other differences.

156. *Haplochromis mloto* Iles

Iles (1960), p.
Mloto (NNB). V VI.

Found occasionally in association with *H. virginalis*, but probably prefers a more sandy habitat and has sometimes been taken in beach seines.

157. *Haplochromis virginalis* Iles

Iles (1960), p. 262.
VI. Kaduna Kajose (NNB), Nyakauru, (Breeding male, (NNB), Msaruli. (NLi).

Common, even abundant in places, can be caught all the year round at chirundus. One of a complex, probably two species involved.

158. *Haplochromis trimaculatus* Iles

Iles (1960), p. 267.
Chakuta (NNB, NLi).

Widespread in rocky habitats, moderately common. In young stages shoals near chirundus, when older and larger tends to be more solitary, and then caught occasionally inshore in 2½" and 3" gill-nets. This and the following two species distinguished by a special feeding habit.

159. *Haplochromis pleurostigmoides* Iles

Iles (1960), p. 273.
Chakuta (NNB, NLi).

Apparently more localized in distribution than the above species which it resembles. Smaller generally and at Nkata Bay more common at chirundus. Conforms much more closely to the "Utaka" type than does *H. trimaculatus* but is nevertheless generally very similar to it, e.g. it is not differentiated from it by local fishermen. Does not apparently occur at Likoma Island though *H. trimaculatus* does.

160. *Haplochromis borleyi* Iles

Iles (1960), p. 272.
Chafinya (NNB, NLi, NUS). VI.

Moderately widespread, relatively inshore in rocky habitats, found at deep chirundus, usually in small numbers. Seems to have a wider range of habitat among the rocky shores than other Utaka. Male in breeding dress is especially brilliantly coloured and smaller than the female.

161. *Haplochromis boadzulu* Iles

Iles (1960), p. 264.

A remarkable local species, found only at White Rock and Boadzulu Island, south-east arm, but in a typical chirundu habitat. Such habitats are very uncommon in this part of the lake.

163. *Haplochromis flavimanus* Iles

Iles (1960), p. 259.
Mloto mchenga (NNB). V.

Closely related to but deeper bodied than the above, and with a larger eye. More sporadic in occurrence, caught for instance in chirimilas in March near chirundus, otherwise not abundant. Zooplankton feeder, but both this and *psammophilus* generally found with sand grains in stomach as well.

165. *Haplochromis quadrimaculatus* Regan

Regan (1921), p. 703. Trewavas (1935), p. 107. Iles (1960), p. 275.
Mbaruli (General adult).
Mbaba (General juveniles). IV, X.

Widespread over the lake, the most important economic species. Fished during the breeding season, the peak being May, June and July. Caught by chirimilas at chirundus, also by small-mesh gill nets on rocky shores. Young remain inshore until 110-120 mm., caught very near rocks. Adults rarely caught outside breeding season; some of them probably range out into the open lake, further than any other species of Utaka.

166. *Haplochromis likomae* Iles

Iles (1960), p. 277.

Very similar to *H. quadrimaculatus* and at Likoma occurs occasionally with it, but has more numerous gill-rakers.

167. *Haplochromis cyaneus* Trewavas

Trewavas (1935), p. 88, 107.

A Utaka species from the south end of the lake, not seen by the present survey.

168. *Haplochromis longimanus* Trewavas

Trewavas (1935), p. 108.

No data from J.F.R.O. survey.

169. *Haplochromis micrentodon* Regan

Regan (1921), p. 715, text-fig. 27. Trewavas (1935), p. 108.

168 and 169 are closely related, from the south end of the lake. No data from the J.F.R.O.

Genus: *Corematodus* Boulenger

170. *Corematodus shiranus* Boulenger

Bouleger (1893), p. 919, fig. 4. Boulenger (1909-16), iii, p. 494, fig. 342. Regan (1921), p. 677. Trewavas (1935), p. 108. Bertram *et al.* (1942), p. 60. Fryer *et al.* (1955), p. 1089.
Yinga (NKK), Chaombawere (NMB), Nandere (NFJ). (VI).

A highly specialized Nyasa endemic which mimics *Tilapia* of the *squamipinnis* group and is parasitic on them, swimming among shoals of *Tilapia* and feeding by rasping off scales from the caudal peduncle with its broad bands of file-like teeth. Found in small numbers among *Tilapia* shoals, in the south only.

171. *Corematodus taeniatus* Trewavas

Trewavas (1935), p. 108. Bertram *et al.* (1942), p. 61. Fryer *et al.* (1955), p. 1089.
Chindikhila (NMB), Sadyakapola (NMB). IV, V.

In habits parasitic like the preceding species but this species is smaller and has a different colour-pattern, mimicking and preying on *Lethrinops* and other cichlids which have an oblique black band from the nape to the base of the caudal fin.

Genus: *Docimodus* Boulenger

172. *Domimodus johnstoni* Boulenger

Boulenger (1896), p. 917. Boulenger (1909-16), iii, p. 282, fig. 192. Regan (1921), p. 722. Trewavas (1935), p. 108. Bertram *et al.* (1942), p. 61.
Chindikhila (NMB), Chiluma (NKK), Kawisa (NNB). VI.

An easily recognized fish with an oblique black stripe and heavy powerful jaws with strong cutting teeth. In gill-nets off rocks, Nkata Bay.

Genus: *Lethrinops* Regan

Fishes of this genus are difficult to differentiate and have not yet been studied, so that little is known of their habits and ecology. No species of *Lethrinops* is known to occur off rocks; some, e.g. *Lethrinops praeorbitalis*, are found in deep water off a sandy bottom, and most are to be found off sandy shores, often associated with *Vallisneria* swards, various species exhibiting some zonation in depth. All are so far as is known, carnivorous, but none are predatory. Food includes crustacea and other fauna of *Vallisneria* beds, chironomid larvae and molluscs. Work on the micro-habitats of these fishes, half a dozen species of which are frequently pulled up in a single haul of the seine, would make a most interesting study. As so little is yet known, the following is a list of the known species only, with only one or two remarks on isolated species.

Collective African names are Tonde, (NMB), Chigong'o (General). V.

172. *Lethrinops varabilis* Trewavas

Trewavas (1931), p. 139, figs. 2, 3a, 4c.
Kanyanti (NKK). IV, V.

Appears to be more abundant in the south.

173. *Lethrinops liturus* Trewavas

Trewavas (1931), p. 139

174. *Lethrinops brevis* (Boulenger)

Boulenger (1908), p. 248 (*Tilapia brevis*). Boulenger (1909–16), iii, p. 262, fig. 177. Regan (1921), pp. 7–9 (*Haplochromis brevis*). Trewavas (1931), p. 140, fig. 3B, 4B. Fryer (1959), p. 195.
Kambusi wa Chigongo (NLi). V.

A small and one of the more abundant species. Digs chironomid larvae out of the sand of sandy beaches.

175. *Lethrinops trilineata* Trewavas

Trewavas (1931), p. 141, fig. 5c.

176. *Lethrinops microstoma* Trewavas

Trewavas (1931), p. 141, fig. 5c.

177. *Lethrinops parvidens* Trewavas

Trewavas (1931), p. 141.
Kukuku (NKK). IV, V.

Quite common in the south-east arm.

178. *Lethrinops macrophthalmus* (Boulenger)
Boulenger (1809) p. 242 (*Tilapia macrophthalma*). Boulenger (1909–16), iii, p. 261, fig. 176 (part). Regan (1921), p. 714 (*Haplochromis macrophthalmus*). Trewavas (1931), p. 143.

179. *Lethrinops aurita* (Regan)
Regan (1921), p. 699, fig. 14. (*Haplochromis auritus*). Regan (ibid), p. 712, fig. 24 (*Haplochromis macrochir*). Trewavas (1931), p. 144.

180. *Lethrinops longimanus* Trewavas
Trewavas (1931), p. 145.

181. *Lethrinops cyrtonotus* Trewavas
Trewavas (1931), p. 145.

182. *Lethrinops macracanthus* Trewavas
Trewavas (1931), p. 145.

183. *Lethrinops alta* Trewavas
Trewavas (1931), p. 146.

184. *Lethrinops argentea* Ahl.
Ahl. (1927). Trewavas (1931), p. 146.

185. *Lethrinops lethrinus* (Gunther)
Gunther (1893), p. 622, pl. lv. A. (*Chromis lethrinus*). Boulenger (1909–16), iii, p. 254, fig. 171 (*Tilapia lethrimus* part). Regan (1921), p. 720. Trewavas (1931), p. 146.

186. *Lethrinops leptodon* Regan
Regan (1921), p. 721. Trewavas (1931), p. 147.

187. *Lethrinops lunaris* Trewavas
Trewavas (1931), p. 148.

188. *Lethrinops oculata* Trewavas
Trewavas (1931), p. 148.

189. *Lethrinops alba* Regan
Boulenger (1909–16), iii, p. 261 (*Tilapia macrophthalma* part). Regan (1921), p. 719. Trewavas (1931), p. 148.

190. *Lethrinops furcifer* Trewavas
Trewavas (1931), p. 149. Fryer (1959), p. 195, figs. 68–71.

A common species on sandy shores, at least in the northern part of the lake. It has evolved a specialized feeding mechanism which enables it to collect the chironomid larvae which occur buried in the sand on such beaches (See Fryer, 1959 for details).

191. *Lethrinops furcicauda* Trewavas
Trewavas (1931), p. 149.

192. *Lethrinops christyi* Trewavas
Trewavas (1931), p. 150.

193. *Lethrinops laticeps* Trewavas
Trewavas (1931), p. 150.

One of the largest species.

194. *Lethrinops praeorbitalis* (Regan)

Boulenger (1909–16), iii, p. 154 (*Tilapia lethrinus*, part). Regan (1921), p. 717, pl. iii (*Haplochromis praeorbitalis*). Regan (ibid), p. 720 (*Lethrinops macrorhyrchus*). Ahl (1927), p. 1 (*Lethrinops fasciatus*). Trewavas (1931), p. 151. Bertram *et al.* (1942), p. Fryer (1959), p. 208.
Cheti (NKK). VI, VIII.

The largest species of the genus and of fair economic importance in some areas. Penetrates fairly deep down, taken by us in large numbers in 40 metres of water off Monkey Bay and the southern lake. Caught in large seines off Kota Kota in fair numbers. Feeds on the bottom, largely on *Chaoborus* larvae.

195. *Lethrinops intermedia* Trewavas

Trewavas (1935), p. 109.

This species has the middle posterior teeth of the pharyngeal enlarged and blunt.

Genus: *Pseudotropheus* Regan. VI.

Fishes of this and the following seven genera are known as the " Mbuna " group, this being the collective name for this assemblage of small, mainly rock-frequenting species. Most are closely related, and show beautiful adaptations in their methods of feeding. For a general ecological study of the Mbuna see Fryer (1959).

196. *Pseudotropheus zebra* (Boulenger)

Boulenger (1899), p. 137, pl. xii, fig. 2 (*Tilapia zebra*). Boulenger (1909–16), iii, p. 144, fig. 163. Regan (1921), p. 682 (*Pseudotropheus zebra*). Trewavas (1935), p. 74, fig. 2. Fryer (1959), p. 177, figs. 16–18, and pl. 2.

No fewer than four very distinctive colour forms of this species occur in the lake and although their relative abundance varies from place to place, all four co-exist in some localities. One of the commonest species on rocky shores where it subsists on algae scraped from rock surfaces.

197. *Pseudotropheus williamsi* (Gunther)

Gunther (1893), p. 624, pl. Lci, fig. C. (*Chromis williamsi*). Boulenger (1909–16), ii, p. 255, fig. 147 (*Tilapia williamsi*). Regan (1921), p. 682. Trewavas (1935), p. 74. Fryer (1959), p. 178.

A species readily recognizable by the presence of two horizontal series of spots on the flanks. Not one of the commonest of the Mbuna.

198. *Pseudotropheus livingstonii* (Boulenger)

Boulenger (1899), p. 134, pl. xi, fig. 2 (*Tilapia livingstonii*). Boulenger (1909–16), iii, p. 243, fig. 162. Regan (1921), p. 682 (*Pseudotropheus williamsi*, part). Trewavas (1935), p. 74, fig. 1 (*Pseudotropheus livingstonii*). Fryer (1959), p. 177.

Recent work has produced only four specimens of this species. All these came from rather deeper water than that frequented by most of its relatives.

199. *Pseudotropheus auratus* (Boulenger)

Boulenger (1897), p. 155 (*Chromis auratus*). Boulenger (1909–16), iii, p. 246, fig. 164 (*Tilapia aurata*). Regan (1921), p. 683 (*Pseudotropheus auratus*). Trewavas (1935), p. 75. Fryer (1959), p. 179, fig. 96.

A very beautiful and not uncommon fish on rocky shores, and one which exhibits remarkable sexual dimorphism; the females being gold with three horizontal black stripes (including that in the dorsal fin) while in the males the ground colour is black and the horizontal bars are electric blue.

200. *Pseudotropheus fuscus* Trewavas.

Trewavas (1935), p. 75. Fryer (1959), p. 178, figs. 19–22.

A rather sombrely coloured Mbuna of skulking habits which lives very close to the shore-line. Not uncommon.

201. *Pseudotropheus elegans* Trewavas

Trewavas (1935), p. 73.

Not seen during J.F.R.O. survey. Only one specimen known from Deep Bay, collected by Christy.

202. *Pseudotropheus elongatus* Fryer

Fryer (1956), p. 84, fig. 3. Fryer (1959), p. 180.

Known only from a few specimens, but these came from both east and west sides of the lake. Like most members of its genus it is an algal browser.

203. *Pseudotropheus minutus* Fryer

Fryer (1956), p. 82, figs. 1–2. Fryer (1959), p. 179.

As its name implies this is a very small fish; being in fact in all probability the smallest cichlid found in Lake Nyasa. Not uncommon in shallow water on rocky shores.

204. *Pseudotropheus fuscoides* Fryer

Fryer (1956), p. 86, figs. 4–7. Fryer (1959), p. 179, figs. 23–24.

Unlike most species of *Pseudotropheus* this species feeds not on algae but on insects. Known only from a few specimens collected at Nkata Bay.

205. *Pseudotropheus novemfasciatus* Regan

Regan (1921), p. 683. Trewavas (1935), p. 75.

Only doubtfully distinct. Not seen during recent survey.

206. *Pseudotropheus tropheops* Regan

Regan (1921), p. 683, fig. 3. Ahl (1927), p. 54 (*Pseudotropheus macrophthalmus*). Trewavas (1935), p. 75. Trewavas (loc. cit.), p. 75. (*Pseudotropheus microstoma*). Fryer (1959), p. 180, figs. 25–27.

One of the most abundant and most variable of the Mbuna. The variability extends to both structural features and coloration.

Genus: *Petrotilapia* Trewavas

207. *Petrotilapia tridentiger* Trewavas

Trewavas (1935), p. 76. Fryer (1959), p. 175, figs. 12–15.
Mbunya kumwa (NNB). VI.

A very handsome fish whose coloration is very variable. By attaining a length of about 20 cm., it can probably claim to be the largest of the Mbuna. Common and widespread on rocky shores, and penetrates to the limits of dissolved oxygen, occasionally caught in deepset gill-nets.

Genus: *Labeotropheus* Ahl

208. *Labeotropheus fuelleborni* Ahl

Ahl (1927), p. 52. Ahl (ibid.), p. 53 (*Labeotropheus curvirostris*). Trewavas (1935), p. 76. Fryer (1956*c*), p. 280. Fryer (1959), p. 172, figs. 3–7.
Mbuna. VI.

A very common species on rocky shores where it obtains its livelihood by scraping algae from rocks by means of its remarkable straight tooth-lined jaws. Like *Pseudotropheus zebra* it exhibits polymorphism; there being two very distinct colour from among the females.

209. *Labeotropheus trewavasae* Fryer

Fryer (1956*c*), p. 280, fig. 2. Fryer (1959), p. 174.

Extremely closely related to the foregoing and like it exhibiting colour polymorphism.

Genus: *Cyathochromis* Trewavas

210. *Cyathochromis obliquidens* Trewavas

Trewavas (1935), p. 77. Fryer (1959), p. 204, figs. 78–81.

A species of areas where rocky and sand shores merge. Here it is often the most abundant fish, yet it seldom ventures among rocks and seldom or never into true sandy beaches.

Cenus: *Gephyrochromis* Boulenger. VI.

211. *Gephyrochromis moorii* Boulenger

Boulenger (1901), p. 4. Boulenger (1909–16), iii, p. 458, fig. 313. Trewavas (1935), p. 77 (*Christyella nyassana*). Trewavas (1946), p. 244.

212. *Gephyrochromis lawsi* Fryer

Fryer (1957), p. 347, figs. 1–15. Fryer (1959), p. 181.

Genus: *Cynotilapia* Regan

213. *Cynotilapia afra* (Gunther)

Gunther (1893), p. 626, pl. lvii, fig. B (*Hemichromis afra*). Boulenger (1909–16), iii, p. 325, fig. 218 (*Paratilapia afra*). Regan (1921), p. 684 (*Cynotilapia afra*). Trewavas (1935), p. 77. Fryer (1959), p. 181, figs. 28–31.

Mbuna. VI, VIII.

Although very closely related to other Mbuna this species has quite different habits for it occurs in open water just off rocky shores (and apparently never off sandy shores) where it subsists largely on zooplankton.

Genus: *Melanochromis* Trewavas

214. *Melanochromis melanopterus* Trewavas
Trewavas (1935), p. 79, fig. 4B, 5. Fryer (1959), p. 184.
Mbuna. VI.

A fairly active insect-eating species whose habits are still imperfectly known.

215. *Melanochromis vermivorus* Trewavas

Trewavas (1935), p. 79, fig. 4C.
Mbuna. VI.

216. *Melanochromis brevis* Trewavas

Trewavas (1935), p. 79, fig. 4A.

217. *Melanochromis perspicax* Trewavas

Trewavas (1935), p. 79.

218. *Melanochromis labrosus* Trewavas

Trewavas (1935), p. 79.

Known only from the holotype, collected at Deep Bay.

Genus: *Genyochromis* Trewavas

219. *Genyochromis mento* Trewavas

Trewavas (1935), p. 79. Fryer *et al.* (1958), p. 1089. Fryer (1959), p. 182, figs. 32–36.

This species has the remarkable habit of scraping large scales from other fishes, particularly *Labeo*. These scales seem to form the basis of its diet and appear to be completely broken down in the alimentary canal. The teeth are specially adapted to permit this scale scraping to take place.

Genus: *Labidochromis* Trewavas

220. *Labidochromis vellicans* Trewavas

Trewavas (1935), p. 80. Fryer (1959), p. 175, figs. 8–11.

A small inshore dwelling fish of rocky shores with sharp needle-like teeth which function as minute forceps for the picking up of the insects which comprise the food of this species. Quite common.

221. *Labidochromis caeruleus* Fryer

Fryer (1956), p. 88, figs. 8–9. Fryer (1959), p. 175.

Closely related to the foregoing but readily recognizable by its beautiful cobalt blue coloration. Probably a rather rare species.

Genus: *Rhamphochromis* Regan. VIII, IX, X.

A group of silvery elongate cichlids, predatory on other fish, with large heads and jaws with spaced conical teeth. Living an open water or pelagic existence, some species penetrating down to the limits of dissolved oxygen. Occasionally form shoals and are a valuable economic and sporting group, caught in gill-nets, by hand lines, and on silver spinners or fish bait, fresh Usipa being the best bait. Most species are closely related and the genus is in need of revision.

Mcheni, Batala General. VIII, IX, X.

222. *Rhamphochromis longiceps* (Gunther)

Gunther (1864), p. 313 (*Hemichromis longiceps*). Boulenger (1909–16), iii, p. 434 (*Champsochromis longiceps*). Regan (1921), p. 724 (*Rhamphochromis longiceps*). Trewavas (1935), p. 112. Bertram *et al.* (1942), p. 60. Mcheni (general).

223. *Rhamphochromis macrophthalmus* Regan

Regan (1921), p. 275, pl. vi., fig. 1. Trewavas (1935), p. 112.

224. *Rhamphochromis brevis* Trewavas

Trewavas (1935), p. 112.

225. *Rhamphochromis woodi* Regan

Boulenger (1909–16), iii, p. 434, fig. 296 (*Champsochromis longiceps*, part). Regan (1921), p. 725 (*Rhamphochromis woodi*). Trewavas (1935), p. 112.

226. *Rhamphochromis ferox* Regan

Boulenger (1909–16), iii, p. 434 (*Champsochromis longiceps* part). Regan (1921), p. 725. Trewavas (1935), p. 112.

227. *Rhamphochromis lucius* Ahl
Ahl (1927), p. 57. Trewavas (1935), p. 113.

228. *Rhamphochromis esox* (Boulenger)
Boulenger (1908), p. 240 (*Paratilapia esox* part). Boulenger (1909–16) iii, p. 435, fig. 297, (part.) Regan (1921), p. 726. Trewavas (1935), p. 113

229. *Rhamphochromis leptosoma* Regan
Boulenger (1908), p. 240 (*Paratilapia esox* part). Regan (1921), p. 726 (*Rhamphochromis leptosoma*). Ahl (1927), p. 60 (*Rhamphochromis melanotus*). Trewavas (1935), p. 113.

Genus: *Trematocranus* Trewavas

230. *Trematocranus brevirostris* Trewavas
Trewavas (1935), p. 113, fig. 14B.

No data from J.F.R.O.

231. *Trematocranus microstoma* Trewavas
No data from J.F.R.O.

232. *Trematocranus auditor* Trewavas
Trewavas (1931), p. 114.

No data from J.F.R.O.

Genus: *Aulonocara* Regan

233. *Aulonocara nyassae* Regan
Regan (1921), p. 727, pl. V, fig. 1. Trewavas (1935), p. 116. Fryer (1959) p. 206, figs. 82–85.
Tondo (NMB). VI.

An insect-eating species living where rocky and sandy shores merge. Probably widespread but as the optimum conditions for its existence are of relatively rare occurrence it is never very abundant.

234. *Aulonocara rostrata* Trewavas
Trewavas (1935), p. 116.

No data from J.F.R.O.

235. *Aulonocara macrochir* Trewavas
Trewavas (1935), p. 116.

Not seen by J.F.R.O.

Genus: *Diplotaxodon* Trewavas

236. *Diplotaxodon argenteus* Trewavas
Trewavas (1935), p. 116.

Mcheni Madzi (NMB). VIII, X.

A distinctive, rather uncommon species with a large eye, usually found in open and deepish water. Predatory on other fishes, is usually taken by gill-net, but a number of very small juveniles were taken in a seine net near the Ruhuhu River in February, 1955.

Genus: *Lichnochromis* Trewavas

237. *Lichnochromis acuticeps* Trewavas
Trewavas (1935), p. 117.
VI.

Rare, one specimen taken in a gill-net off rocks.

Genus: *Aristochromis* Trewavas

238. *Aristochromis christyi* Trewavas
VI, X.

A handsome fish from the vicinity of rocks in deepish water, mainly in the northern part of the lake. A predator on other fishes. Like most Lake Nyasa cichlids the male has a beautiful blue breeding dress.

Genus: *Hemitilapia* Boulenger.

239. *Hemitilapia oxyrhynchus* Boulenger.
Boulenger (1909–16), iii, p. 489, fig. 339. Regan (1921), p. 677. Trewavas (1935), p. 110. Fryer (1959), p. 207, figs. 86–88.
Masimbe (NNB). VII.

Common in *Vallisneria* swards, browsing algae and insects from the leaves, in the Intermediate Zone.

Genus: *Serranochromis* Regan

240. *Serranochromis robustus* (Gunther)
Gunther (1864), p. 312 (*Hemichromis robustus*). Boulenger (1909–16), iii, p. 328 (*Paratilapia thumbergi* part). Regan (1921), p. 685 (*Serranochromis thumbergi*). Trewavas (1935), p. 118. Bertram *et al.* (1942), p. 55. fig. 7C Trewavas (1957), p. (*Serranochromis robustus*).
Sungwa (general), Ndiyembundiyani (NFJ). III, IV, VI.

The only species of its widespread genus in the area, and endemic to the Nyasa region. Predatory on other fishes, it is more characteristic of zone IV, than any other, being for example especially abundant at Fort Johnston, but also occurs in the lower reaches of rivers and off rocks in the open lake.

XI. FAMILY ANGUILLIDAE

Genus: *Anguilla* Shaw

241. *Anguilla nebulosa labiata* Peters
Peters (1852), p. 684. Boulenger (1909–16), iii, p. 7, fig. 5 (*Anguilla bengalensis*). Ege V. (1939). Jackson (1959*b*), p. 304.
Nkhungu (NMB). VI.

The true eel was first recorded from the Nyasa area in April, 1954, by a specimen caught near the J.F.R.O. laboratory, Nkata Bay, on a long line. Since then several other specimens have been recorded from Fort Johnston and other parts of the lake. The eels in Lake Nyasa have migrated from the sea, negotiating the Murchison Cataracts, which other fish from the Zambesi are unable to do. While in Lake Nysaa eels feed mainly on fish and crabs.

XII. FAMILY MASTACEMBELIDAE

Genus: *Mastacembalus* Gronov

242. *Mastacembalus shiranus* Gunther

This elongate fish is not uncommon in among rocks in shallow water of the main lake. Very shy in habit, it coils up under stones and dashes to another shelter if the stone is disturbed. Also found in among weeds in the lower courses of rivers. Carnivorous, feeds on insects and another small animals. Since the discovery of the eel in in the lake this species has frequently been mistaken for an eel, but may readily be distinguished by the presence in *Mastacembalus* of a row of short sharp spines along the bank in front of the dorsal fin, as well as by a smaller mouth and many other features.

D. Notes on Zambesi Fishes

1. *Malapterurus electricus* Gmelin.

2. *Eutropius depressirostris* Peters.

These two siluroids have for long figured on lists of fishes from Lake Nyasa, but they are of the Lower Zambesi fauna and do not occur in the Nyasa area above the Murchison Falls. They were mistakenly placed in the Lake Nyasa species list by Boulenger, on the strength of two specimens of *Malapterurus electricus* and one of *Eutropius depressirostris* collected for the British Museum by Mr. R. C. Wood. As these two species were found to be unknown in the Lake Nyasa and the Upper Shire, Mr. Jackson asked Mr. Wood personally about these fishes. Mr. Wood told him that he remembered clearly that these two fishes were not collected by him in 1920, when he made a large and valuable collection from Lake Nyasa for the British Museum, but were collected and sent to the British Museum together with other fishes in 1913 from Chiromo, on the Lower Shire River below the Murchison Falls. Mr. Wood thought that Dr. Boulenger must have confused the 1913 collection with Mr. Wood's 1920 collection and added the names of these two species to the British Museum's records of Nyasa fish, where they were found by Dr. Worthington and included in his paper (1933 a, p. 313).

There is no doubt that some confusion such as this did take place with Mr. Wood's two collections as both these fishes are totally absent from the Nyasa area, and they are accordingly herewith deleted from the list of fishes of Nyasaland above the Murchison Falls.

3. *Ctenopoma multispinis* (Peters).

4. *Ctenopoma ctenotis* (Boulenger).

No anabantids have been seen either by the J.F.R.O. survey, Miss Lowe's survey or the 1939 survey of Bertram, Borley and Trewavas. The British Museum has a record of a single specimen of the first species *Ctenopoma multispinis*, from Lake Nyasa collected by Mr. Wood. As it is probable that the remarks made above with regard to confusion between Mr. Wood's 1913 and 1920 collections apply to this species also. It has been omitted from the Nyasa species list until another and more definite record is made.

The second species, *C. ctenotis*, is included in this species list on the strength of " a single specimen of 36 mm. in Dr. Christy's Nyasa collection " (Worthington 1933 a, p. 314). If it does occur in the area it undoubtedly does not occur in Lake Nyasa but in streams and marshes.

There is theoretically no reason why anabantids should not occur in Nyasaland above the Murchison Falls, as their ability to move about out of water on damp grass, etc., using their opercular spines as an ambulatory mechanism, is well known. It would be interesting to have more definite records.

5. *Nothobranchius orthonotus* (Peters).

6. *Aplocheilichthys johnstoni* (Gunther).

No cyprinodonts have, again, been recorded from the Nyasa area since the days of the Christy collection in 1925. They probably do occur in the area, however, more particularly in the southern part. Like most of the other non-endemics they are certainly absent from Lake Nyasa proper and have been wrongly recorded from there, probably from fishes caught in adjacent streams. Both species are included in this list from specimens in the British Museum collected by Sir Harry Johnston and Dr. Cuthbert Christy.

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2. NOTES ON THE BIOLOGY OF *BAGRUS MERIDIONALIS* GUNTHER

A. Breeding

(1) *Sex Ratio*

2,650 fish were examined and sexed by the survey. Of these 1,767 were females and 883 males. Bertram *et al.* (1942) quotes figures of 239 females and 205 males. Table I expresses these figures as percentage males and females and also as the sex ratio

$$\frac{\text{Number Females}}{\text{Number Males}}$$

TABLE I

	Present Survey	1939 *Survey* (Bertram *et al.* 1942)
Number females	1,767	239
Per cent. females	66.7	53.8
Number males	883	205
Per cent. males	33.3	46.7
$\frac{\text{Number females}}{\text{Number males}}$	2.00	1.17

The difference between the two sex ratios, 2.00 and 1.17, is highly significant, but it can be explained in terms of the selectivity of gill nets. The 1939 survey used nets of mesh size from 2″ to 5″ stretched, at 1″ intervals. These were fished as fleets, usually containing one net of each size, so that each mesh size was used an equal number of times. The 2″ nets would of course catch smaller fish and the 5″ larger fish, but because each net was set the same number of times, the whole size population of fish exploited by the mixed fleet can be considered to be fished equally. The present survey did not use mixed fleets, and by far the greatest fishing effort was carried out by nets of 5″ mesh which accounted for 73 per cent. of all fish caught. A particular size range of population was therefore exploited differentially and in this size range a very high percentage of females was recorded, higher than for nets of smaller mesh. Table II gives the percentage males and females for each mesh size used by the present survey.

TABLE II

	$2\frac{1}{2}''$	$3''$	$3\frac{1}{2}''$	$4''$	$5''$	*Total*
Number males	19	48	43	205	568	883
Per cent. males	38.0	56.4	52.4	38.9	29.1	
Number females	31	37	39	329	1,331	1,767
Per cent. females	62.0	43.6	47.6	61.6	70.9	

Fig. 1 shows how the percentage of males varies with the length of fish caught. Below 40 cm., equal numbers of males and females are recorded (the data is from all gill-net catches), while above 60 cm. four females were caught, for every male, so that any sex ratio found for *Bagrus meridionalis* would be influenced greatly by the relative fishing effort for each size of gill-net. It is unlikely that females are so much more vulnerable to capture than males in the larger size groups, but probable that females grow to a larger size than the males, and that the 5″ net exploits the size range of the population at which the females predominate, i.e. above the mean maximum for males and nearer the mean maximum for females. This undoubtedly explains much of the discrepancy in sex ratio, although whether the larger size is because the females live longer or they grow faster cannot be decided.

There are however indications that another factor is involved connected with the breeding behaviour of *B. meridionalis.*

(2) *Breeding Cycle*

The breeding cycle is best illustrated with reference to females only, since the gonads in this sex are more easily classified according to the stage of activity reached. Table III shows the numbers and percentage of each stage, recorded month by month, the records for the three years 1954–1956 being combined.

The most obvious point to be noticed is the low occurrence in the survey nets of females at the later stages of the breeding cycle. Of the 1,751 females examined, above the minimum breeding size of 32 cm. recorded by this survey, only 1.2 per cent. were recorded as being ripe-running and only 4.8 per cent as being ripe or ripe-running. If we compare records for the first three months of the year, the 1939 survey recorded 61 out of a total of 142, i.e. 43 per cent. which were ripening or spent while the present survey records 112 out of a total of 661 or 18 per cent., at equivalent stages. For the male even fewer individuals near peak breeding stage were found, and none at the ripe-running stage. The present survey fished mainly in deeper water, below 30 metres and down to about 90 metres, and there is strong evidence, therefore, that at about this stage in the breeding cycle a migration occurs from this depth range. Since the 1939 survey fished in much shallower water and recorded higher numbers of individuals at peak breeding stage, it is possible that this migration is toward shallow water and is probably a breeding migration. On one occasion in March, 1956, nets were set closer inshore in shallow water, and a large proportion of ripe running females were recorded, which supports this view.

Since the later breeding stages of *B. meridionalis* are not well represented in gill-net catches, the breeding cycle is best represented by the percentage of inactive females found in each month of the year and this is shown in fig. 2. Also shown is the percentage of active and active to ripe fish, considered together, these stages being the last two well represented in the catch.

The highest percentage of inactive females was recorded during the period July to October, and from then until January this percentage falls rapidly until in the first three months of the year it is below 10 per cent. The period January to March is therefore a period of peak breeding activity for the species. It is during this period too, that the highest percentage of active fish are found. The smallest female recorded with ripe gonads, was 32 cm. long, a little longer than the smallest found by the 1939 survey, and the largest over 80 cm. so that breeding obviously can occur a number of times in the life of an individual. No information on growth rates can be gained from the study of the length frequencies of breeding fish as this would reflect only the selectivity of the gill-nets for size, and in particular, that of the 5″ net.

The percentage of males represented in gill-net catches varies throughout the year and this variation is shown in fig. 3. The data is again for the period of three years. A low percentage of about 30 continues from January until about July, but it is followed by a rise so that in December 45 per cent. of all fish caught in this net are males. This represents a considerable and significant change in the sex ratio. The figures and percentages are given in Table IV for each month of the year, and Table IVA gives the combined figures for two periods, from January to August, and for September to December. An x^2 test of significance on these figures and comparing the two periods gives a very low probability below .001, so that the difference in the

TABLE III

Bagrus Meridionalis

NUMBERS AND PERCENTAGES OF EACH STAGE OF BREEDING THROUGHOUT THE YEAR (RECORDS FOR 1954–1956 COMBINED).

Month	*Inactive*		*Inact-Act*		*Active*		*Active-Ripe*		*Ripe*		*R-running*		*Spent*		TOTAL
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
January ..	18	10.4	23	13.3	88	50.4	24	13.9	12	6.9	—	—	8	4.6	173
February ..	9	4.9	18	9.8	96	52.2	40	21.7	15	8.2	—	—	6	3.3	184
March ..	20	6.6	44	14.5	89	29.3	80	26.3	21	6.9	16	5.3	34	11.2	304
April ..	13	20.3	6	9.4	24	37.5	13	20.3	2	3.1	—	—	6	9.4	64
May ..	45	25.0	33	18.3	56	31.1	42	23.3	2	1.1	1	.5	1	.5	180
June ..	55	35.2	28	18.0	49	31.3	21	13.5	3	2.0	—	—	—	—	156
July ..	64	61.0	12	11.4	28	26.7	1	1.0	—	—	—	—	—	—	105
August ..	82	49.4	31	18.7	38	22.9	15	9.0	—	—	—	—	—	—	166
September ..	66	57.4	12	10.4	26	22.6	8	7.0	3	2.6	—	—	—	—	115
October ..	26	47.2	9	16.4	8	14.6	11	20.0	1	1.8	—	—	—	—	55
November ..	34	31.8	14	13.0	39	36.5	20	18.7	—	—	—	—	—	—	107
December ..	41	28.9	16	11.2	63	44.4	14	9.9	4	2.8	4	2.8	—	—	142
TOTAL ..	473	27.0	246	14.1	604	34.5	289	16.5	63	3.6	21	1.2	55	3.1	1,757

TABLE IV

Bagrus Meridionalis

Variation in Percentage Males throughout the year. (Records for 1954–1956 Combined).

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. Males	78	37	109	25	80	60	41	78	96	58	69	126	857
No. Females	181	91	309	64	181	120	145	169	118	75	111	154	1,781
Total ..	259	128	418	89	261	180	186	247	214	133	180	280	2,575
% Males	30.1	28.9	26.1	28.1	30.6	33.3	22.0	31.6	44.9	43.6	38.4	45.0	33.3

percentage of males found is one that would not be expected by chance, and it must be assumed that the appearance in September on the fishing grounds in deep water of a higher proportion of males indicates a fairly sudden shift of a proportion of the male population to deep water.

TABLE IVA

Bagrus Meridionalis

PERCENTAGE MALES FOR TWO PERIODS DURING THE YEAR
(RECORDS FOR 1954–1956 COMBINED)

	Jan.-Aug.	Sept.-Dec.
No. Males	508	349
No. Females	1,260	458
TOTAL ..	1,768	807
% Males	28.7	43.2

It is possible, on the basis of the foregoing facts, to suggest that:

(1) *Bagrus meridionalis* breeds in shallow water. In areas where it feeds in deeper water throughout the year, a breeding migration occurs as the individual reaches peak breeding activity.

(2) The males stay on the breeding ground for a longer period and are thus caught in smaller numbers in deeper waters.

(3) The female grows to a larger size.

(4) The breeding season has a peak during the early months of the year.

It was with great interest, therefore, that it was learned that at Likoma Island a small fishery exists which exploits breeding fish in shallow water, and that accounts and information obtained from fishermen engaged in this fishery agree with the suggestions made above. The fishery has not been seen in operation but the information given is of great interest and is substantiated in general terms by other observations and by accounts obtained from other parts of the lake, including Nkata Bay.

(3) *Breeding Behaviour*

Two places known to be sites of the above-mentioned fishery, and therefore breeding grounds for *B. meridionalis* are at Ulisa and Makulawe on Likoma Island. The breeding grounds, where the sandy substrate is interspersed with rocks, are found in more or less sheltered places and the rocks may reach the surface from a depth of about two fathoms. Nests are observed where the sand and rocks are adjacent, and are often so built that the rock gives extra cover. They are circular or oval, about 3 feet in diameter, and fish have been observed excavating them by pushing sand away from the centre to the outside, forming a raised rim. The centre is therefore below the substrate level.

Nests are first seen in December, and from this month until about April fishing is carried out. The position of a nest or a number of nests is first observed from the shore or from a canoe, and a net is laid on the bottom at some little distance away so that, as effectively as possible, it blocks escape to deeper water. The net, a type of gill-net, is about 40 yards long, of about 2″ mesh and it is not more than a few feet high so that it does not reach the surface.

Fish are often, during this period, observed on nests, and others are also, but less often, seen stationary nearby, or circling the nest itself. The one on the nest is described as being usually smaller than the one nearby, and is more often caught. When it is, it is described as being a male in the " milt " condition. The larger fish when caught is invariably a female, so that the nest-building fish, on this information, is the male.

Young of this species are also seen on the nest in large numbers in the early months of the year. At Likoma these are called Kampoyo, a derivative of Kampango, which is the name commonly given to the adult in many parts of the Lake. Several fishermen claim to have removed Kampoyo from nests, and to have seen both young and adult fish on the nests at the same time and one claimed that the young may enter the mouth of the nesting fish for shelter.

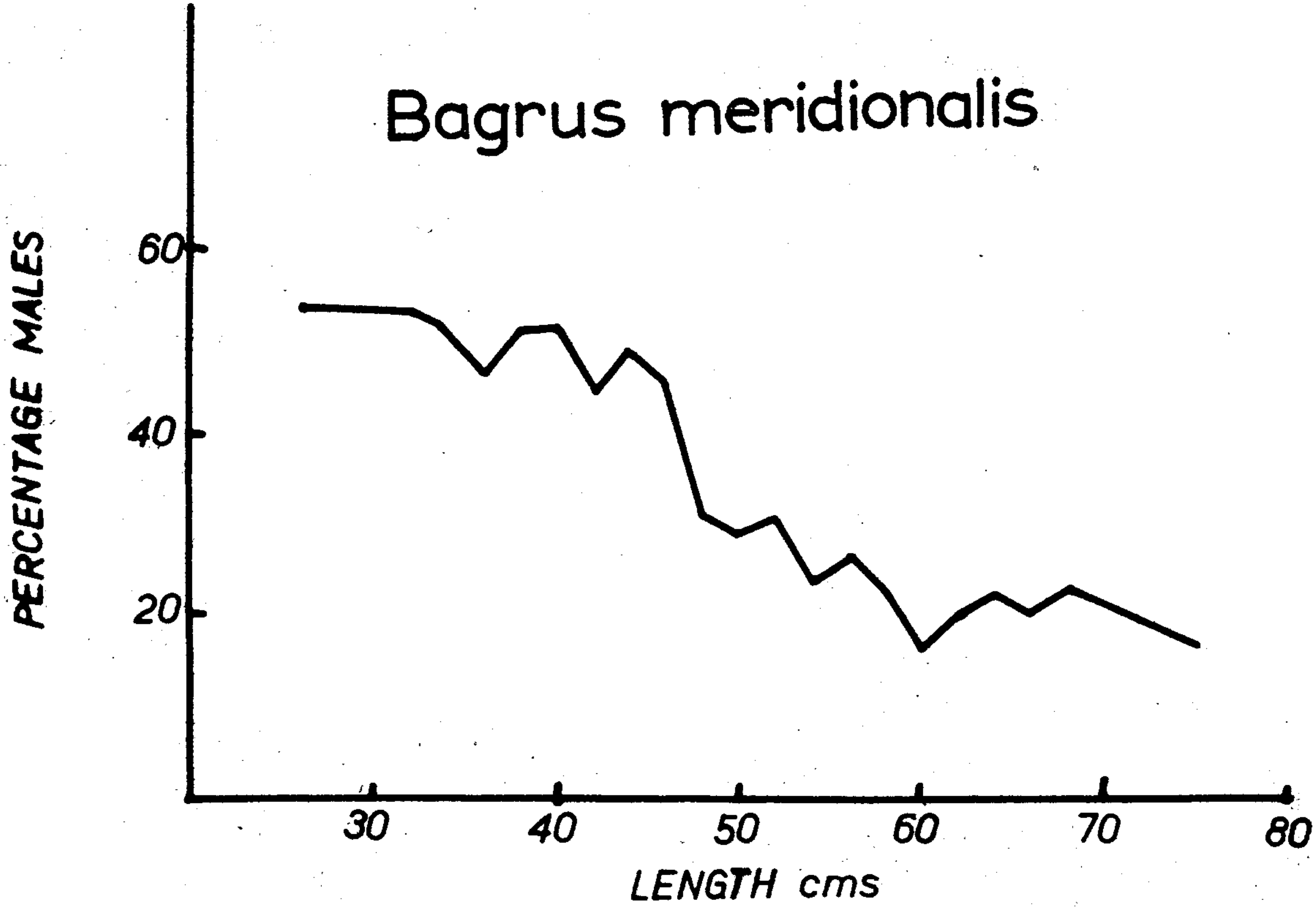
At Nkata Bay, a similar story is told. Here the young are referred to as Kayendeyende, meaning the " wanderer " as they apparently leave the nest when they are approached, to scatter to nearby rocks for shelter, returning later if not further disturbed. Breeding sites have been indicated near the lighthouse north of Nkata Bay, at Mayoka, and Chikali, all of which afford the type of habitat apparently preferred by the breeding fish. It was near the lighthouse that ripe running and spent females were caught in gill-nets set close to the shore in March, 1956, and here too, in 1957, juveniles of length about 120 mm. were caught in March, when the Chilimila net was used close inshore. At Chikali beach in 1957 an adult *B. meridionalis* was seen inshore in April where rock and sand intermingle, and recently a fisherman from Kota Kota reported that this species made nests about 3 feet in diameter in the sand. Many other similar reports have been made, to give a reasonably consistent account of the general breeding behaviour of this species.

The absence of ripe running males from the survey net used in deep water, the low proportion of ripe running females found, the change in the proportion of males during the year, the evidence that the females grow to a larger size, and other evidence discussed above, all support the assumption that *Bagrus meridionalis* breeds in shallow water, is a nest builder, that the male offers a considerable degree of parental care to the offspring, and builds and guards the nest.

Lowe (1952) reports that two *B. meridionalis* were watched at Benje Island in about 14 feet of water circling near the bottom over a sandy patch between rocks, reported to be a nest, and that one was larger than the other. It is extremely likely that these represented a breeding couple.

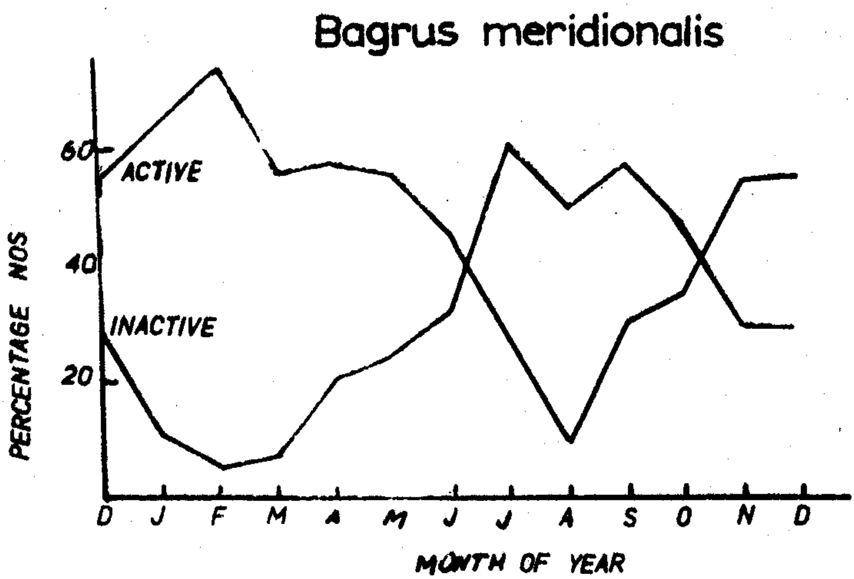
The discrepancy between the sex ratio as found by the 1939 survey and the present one, and partly or perhaps largely, explained on the basis of a selectivity of the larger females by the larger nets used most frequently by us, is further accounted for by the fact that the males spend a longer period on the breeding grounds, and are therefore out of the area of the effectiveness of deep set nets for a longer time. The 1939 survey fished in places such as Kota Kota, Malonda, Fort Johnston and Monkey Bay in relatively shallow water, and probably therefore exploited both the breeding and feeding populations, giving a more equitable division of the sexes, and probably representing more accurately the real sex ratio for the species.

FIG. 1



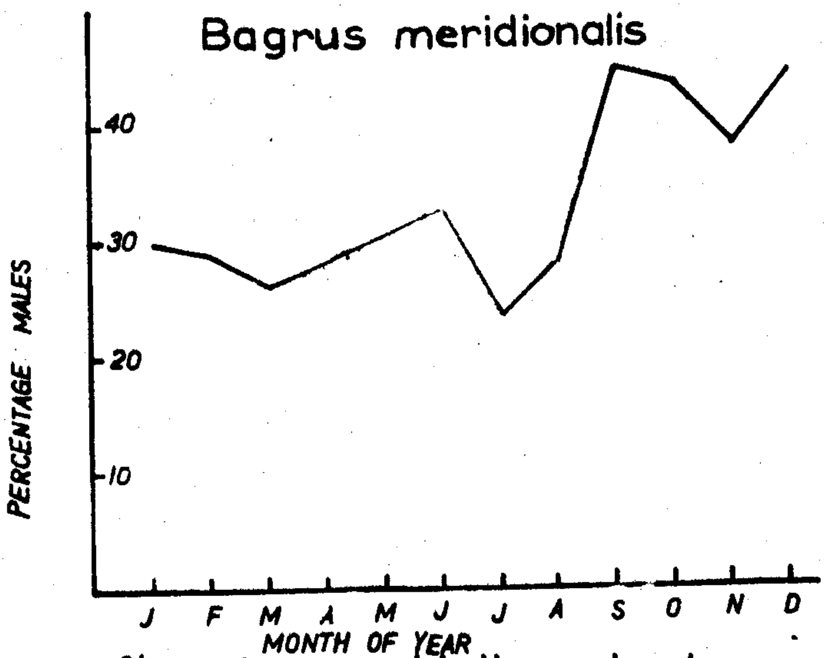
Variation of % males with length

FIG. 2



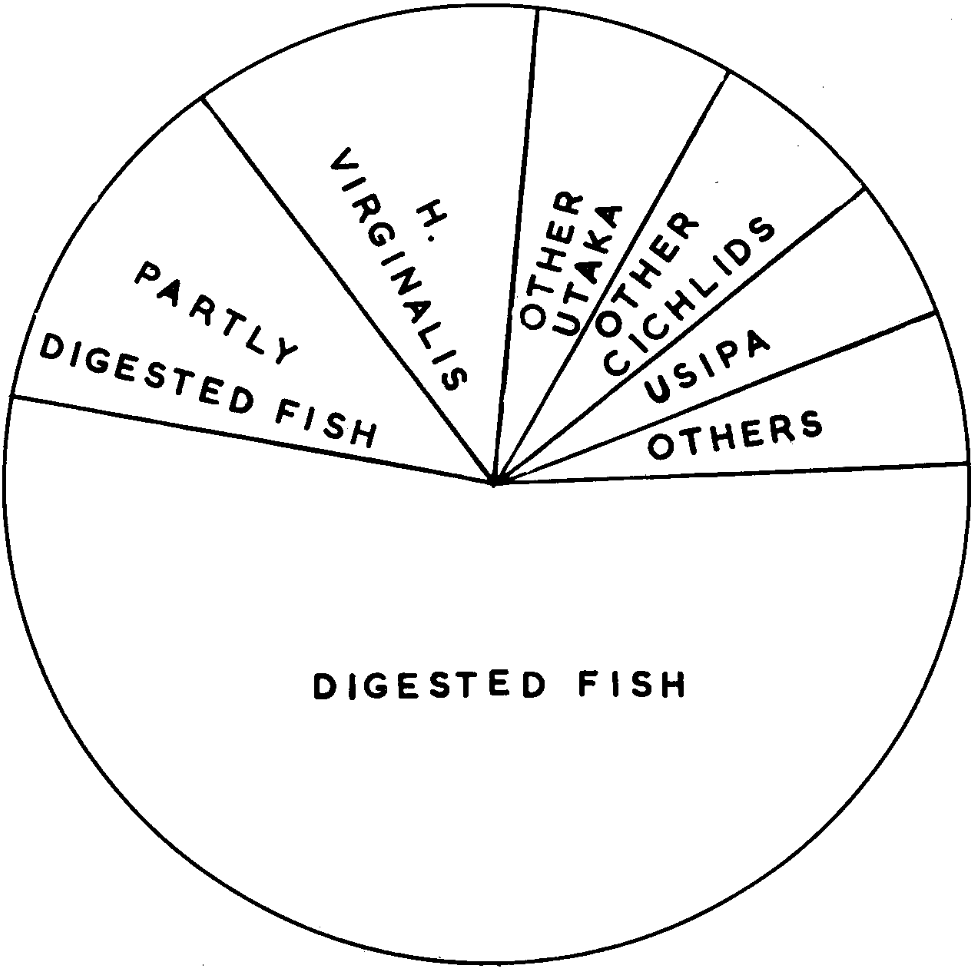
Breeaing cycle of female

FIG. 3



% males caught throughout year

FIG. 4



Bagrus meridionalis

STOMACH CONTENTS

B. Feeding

Most of the specimens examined were caught in bottom laid gill-nets at night, a very few being caught by surface longlines or other methods. Of a sample of 1,094 stomachs examined, 449 or nearly 50 per cent. were empty, 363 empty but distended indicating that the contents had been regurgitated and 232 contained food at various stages of digestion. In the total of more than 2,000 stomachs, 410 were found with food remains, but in only 140 was it possible to identify the food with any certainty. The contents are depicted in fig. 4.

Bagrus meridionalis is a bottom-living fish and at Nkata Bay and in the north of the lake prefers a rocky type of habitat; where gill-nets were laid off sandy beaches relatively few were caught even if the nets were set deep, whereas in the south-east arm of the lake, this species is caught in quantity in gill-nets set on sandy or muddy substrates. The preferences in the Nkata Bay area for rocky substrates is accounted for by the fact that it is in this type of habitat that a more abundant food supply is found. The commonest food species for *Bagrus* in the north is *Haplochromis virginalis* Iles, a member of the Utaka group which is associated with a rocky habitat, and there is a predator-prey relationship which determines the distribution of the predator. Other members of the Utaka group are found in stomachs of *B. meridionalis* as are members of the genus *Rhamphochromis* which are associated with the Utaka shoals and other species such as *H. caeruleus* and *Diplotaxodon argenteus* which prey on this plankton feeding group. In addition members of the genus *Pseudotropheus* and other rock living genera, and *Synodontis njassae,* both of which show an overlap of habitat preference with *B. meridionalis* occur in the food, though not forming a high proportion. In July, 1954, and in the later months of 1956 a large proportion of the stomachs of *B. meridionalis* contained Usipa (*Engraulicypris sardella*). The places fished at this time were near sites of a seasonal fishery for Usipa and it would appear that at this time and in similar places, Usipa may displace *H. virginalis* and its allies as a source of food to a certain extent.

It would seem that *Bagrus meridionalis* is essentially a bottom living fish whose habitat preference and even depth distribution may be determined by the availability of the food supply. In the south-east of the Lake the presence of shoals of *Tilapia* spp. in relatively shallow sandy or muddy waters is responsible for the occurrence of *B. meridionalis* in this type of habitat in larger numbers. In the north, these habitats are relatively barren, and it is in the deeper and more rocky places, where *H. virginalis* and its allies occur, that *B. meridionalis* is found in numbers, feeding on this group and on any other fishes associated with the Utaka, or found near the rocky substrate. The predator-prey relationship is not a permanent one, however, and seasonal variations in feeding habits may occur where, say, Usipa are found inshore.

The ability of *B. meridionalis* to change its distribution and habit preference in relation to the available food supply is typical of a predatory species, though atypical of the tightly-knit ecological communities in Lake Nyasa, and it is interesting to notice that this species, though nothing like so voracious a predator, resembles in this respect the ferocious *Hydrocyon* spp. and *Lates* spp. of other waters far more than the rest of the Nyasa predators, all of whom are more or less firmly restricted to certain definite environments.

List of Figures Chapter 4, 2.

3. THE GENERAL BIOLOGY OF UTAKA

A. Systematics

The systematics of Utaka have been discussed elsewhere (Iles, 1960) and in the check list but it must must be realized that any treatment of this subject must, at our present stage of knowledge, be superficial. Species of Utaka are more restricted in distribution than might be expected for a plankton feeding group of fish and their association with the inshore regions and with particular types of inshore habitats in many instances, is more marked than had been thought. The different types of inshore habitats shown in various parts of the lake may therefore prove partial or even complete ecological barriers to certain species, and the possibility of geographical variation, which results in inter or in a specific differentiation at different parts of the lake, is great. Sufficient information is not yet available to give a complete picture of the distribution of the various systematic units of Utaka over the lake as a whole, and it is only at Nkata Bay itself that a general picture of the interrelationship of the various species can be given.

A list of species found commonly at Nkata Bay is given below, together with their equivalent local names.

Local Name	
Mbarule ..	.. *H. quadrimaculatus* Regan—adult breeding male and female
Mbaba ..	.. *H. quadrimaculatus*—juveniles and young fish
Kaduna (Kajose)	.. *H. virginalis* Iles
Nyakaulu ..	.. *H. virginalis* Iles—breeding males of Kaduna and Kajose
Mloto	.. *H. mloto* Iles
Utaka Sergernt ..	.. *H. nkatae* Iles
Kabananga ..	.. *H. chrysonotus* (Boulenger) *H. jacksoni* Iles
Chakuta ..	.. *H. trimaculatus* Iles *H. pleurostigmoides* Iles
Mbala ..	.. *H. pleurostigmoides* Iles—breeding female
Chafinya ..	.. *H. borleyi* Iles
Mloto Mchenga ..	.. *H. eucinostomus* Regan
Kajose Mchenga	.. *H. flavimanus* Iles
Ukongola ..	.. *H. prostoma* (?) Trewavas

Table I shows how many times each of the more common species of Utaka were represented in the catches resulting from 92 fishing operations with the small-meshed chilimila net. Also are shown the occurrence of rock fish of the genus *Pseudotropheus* and its allies (Mbuna), *Lethrinops* species, which are associated with sandy habitats, and species of *Rhamphochromis*, which often apparently shoal with the Utaka as plankton feeders when juvenile and which prey on the Utaka when larger.

B. Habitats and Abundance

The type of habitat fished by the chilimila varies considerably. The variations in the exact position and depth of the net in the fishing area, and the volume of water fished by the net are such that at many places, and at different times, the net may have fished either near a sandy substrate or near a precipitous rocky shore. For instance at Mayoka (see Map 6, area 5) a steep rocky shore gives way some distance out to a sandy substrate which may be interspersed with rocks, and here on different occasions *Lethrinops* and *Pseudotropheus* species are caught with the Utaka, indicating that two entirely different habitats have been sampled. This makes the definition of the habitat preference of the individual species difficult to delimit and define but it has been possible to gain a general impression of the local distribution of the various species concerned and of their general habitat preferences although it is not possible to give these in any detail.

H. virginalis is both the commonest and the most abundant species. It has been recorded at all places fished at Nkata Bay but never seems to be closely associated with a sandy substrate. It is never found in shore seine hauls, for instance, although it is caught off rocks where the substrate is sandy. It must therefore be considered to be mainly a rock associated form. It is never found in large quantities inside the bays or in sheltered water and it is only at the virundu such as Nos. 1–4 on the map and when a good current is flowing, that it is caught in numbers by the small meshed net.

H. mloto, when recorded, has always been found with *H. virginalis* and in smaller numbers. It has probably the same general type of distribution and has never been caught in seine hauls. Its more pelagic type of body form might, however, indicate that it does move about in the surface waters but probably keeps to inshore regions.

H. trimaculatus and *H. pleurostigmoides* are often caught together in the chilimila. *H. pleurostigmoides* is however more widely distributed in the rocky habitat and is more abundant, and the larger specimens of *H. trimaculatus* are usually caught only in gill-nets set close inshore. Although these species have been caught at all places fished, their association with the rocky shore or substrate is apparently more marked even than is that of *H. virginalis*. Their distribution in rocky places is wide-spread but they never occur in large numbers and do not form large shoals, as large as those of *H. virginalis* or *H. quadrimaculatus*, even at the deep chirundu and when a current is flowing. Neither is seined.

H. borleyi, also a common fish, is associated with a general rocky type of habitat as closely as is *H. pleurostigmoides* but again is rarely found in large numbers at any one place. It is never seined from sandy beaches but has been recorded from all the places fished by the chilimila.

H. quadrimaculatus is, in most places where the chilimila is used, the subject of a seasonal fishery of the breeding adults which are known as Mbarule. The season lasts from May to July, and most of the weight of the Utaka caught by African nets is normally accounted for by this species. At Nkata Bay few were caught either by the survey or by local nets in the years 1955 and 1956. Some adults were caught close inshore in small-meshed gill-nets, and it is possible that in the breeding season these fish can be found at any rocky places. Usually, however, the largest quantities are caught at deep virundu when a current is flowing, and at Likoma and Chizimulu catches may be very large, of the order of one ton per single haul. The juveniles, called Mbaba, are also found associated with a rocky habitat but it is thought that they are more restricted in distribution than are say *H. virginalis*. They are not as commonly caught inside bays and are probably more closely connected with the definite type of chirundu habitat. This species has never been recorded in shore seine hauls.

H. flavimanus has only been recorded occasionally, probably during a breeding period for this species, and then near sandy places, No. 5 for instance. This species may be associated much more closely with a sandy habitat and with the substrate than are most species of Utaka, since the gut contents often include sand grains as well as zooplankton.

H. chrysonotus is more of an open water species, i.e., it is found less often associated with features of the shore or the substrate but it is only found in sheltered waters. It is often seen at Nkata Bay near a launch mooring in about 40 feet of water (No. 9 on the map) and near the surface, and at Monkey Bay, many have been seen and caught near the large floating dock moored there in fairly deep water. At Kambwe Lagoon in the north of the lake a specimen was seined in a sand spit where the shore gave way abruptly to deeper water and Bertram *et al.* (1942) report that this species is seined from the shore when breeding but probably occurs some distance out as it was only found in seine nets when the hauling warps were very long. It is only very rarely indeed found at or near a chirundu and even in its more open water habitat does not appear to range very far in its search for food, preferring inshore sheltered habitats.

H. nkatae and *H. jacksoni*, with *H. chrysonotus*, form a rather closely related group, morphologically and biologically. They all tend to show a definite greenish coloration and are caught only occasionally at virundu. *H. nkatae* often occurs with *H. chrysonotus* at Nkata Bay at the launch anchorage, but has also been recorded from places where a rocky shoreline gives way to a sandy substrate. At Sanga, a little south of Nkata Bay between May and September, specimens, apparently breeding, are caught in beach seines along a stretch of shore at which Usipa seining is carried out. Although few have been recorded from beach seines at Nkata Bay they appear to be the main species caught in the ngongongo net when it is fished at night and particularly when fished in the south bay near the mouth of the small Nkata Bay stream, at site No. 6 on the map, where a sandy shelf gives way to deep water rather abruptly. *H. jacksoni* is not found with *H. chrysonotus* often but it has been recorded with *H. nkatae* near rocky shores where there is a sandy substrate nearby (No. 5). Little is known of its distribution apart from the fact that its association with a rocky habitat is apparently not particularly well marked.

H. eucinostomus is seined at Mayoka beach (see map) and in quite shallow waters where it builds nests. The young can also be seen close inshore and near the substrate. This species has also been found near rocks where a sandy substrate is found close by (No. 5). At Sanga, a breeding male was found washed up on the beach in July at a time when heavy swell conditions existed.

No large catches of Utaka were ever recorded at any place other than virundu and only then while a current was flowing. This is despite the fact that at many places where the net is hauled from the shore, as discussed in Part V, the volume of water fished by the small-meshed chilimila and even the rate at which the net moved through the water, was much the same as on those occasions when large catches were obtained at the virundu. The general impression gained is that the shoals in these places, particularly of *H. virginalis*, were smaller and the fish more dispersed than at the virundu. At Nkukuti point where a rocky shelf gives way to deep water (No. 2), and when the lake is calm, it has been observed that when no current is flowing the fish are apparently moving randomly in small groups. Large shoals are not usually seen at or near this place under these conditions, and local fishermen do not attempt to fish those which are seen. When a strong current is found, however, it has been possible on some occasions to observe shoals from the surface or from below the surface with the aid of a diving mask. They seem to be larger, more concentrated and localized at particular places at the virundu, and all the individuals were found to be facing in the same direction, i.e., toward the current, and feeding.

It is possible on these facts and on others to put forward a hypothesis which gives a reasonably convincing picture of the relationship between the current conditions and the distribution of some of the species of Utaka, particularly that of *H. virginalis*. This species, in common with many of its group, shows a strong rheotaxy, i.e., it will take up a position relative to the current. When no current occurs at the chirundu, it moves randomly within its general habitat preference and small groups are then found wherever suitable conditions occur, for instance near by any rocky shore. As a current is set up at a chirundu, small groups moving into its sphere tend to remain there and take up a stationary position in relation to the chirundu and the current, so that at such places when the current is established, the population of the surrounding areas becomes concentrated. Whereas, during the dispersed phase the fish would be feeding on the standing plankton of the inshore region, while they are concentrated at the chirundu, the current would bring plankton probably of partly off-shore origin, so that in this concentrated phase a particular stationary position can be maintained without depleting the plankton in the volume of the water occupied by the shoal, the amount of plankton being constantly renewed. Echo sounding traces indicate that the large shoals occur commonly only at virundu and not merely at any place where currents exist. Thus at Bandawe on one occasion, although the current was well marked at distance of about a quarter of a mile from the chirundu, a shoal was observed to maintain a very definite and stationary position and did not extend for more than fifty yards at the most from the underwater outcrop. This close association may well be explained by the preference of the species concerned for a rocky habitat afforded by the chirundu in the first place, and also by the fact that at these underwater features, the currents are deflected by the chirundu and give suitable conditions for feeding. Indeed if we are to assume, as seems highly probable, that *H. virginalis* and other species are inshore fish, and that populations of this species are associated with particular habitats in particular areas, some explanation is needed to explain the presence in these areas of populations as large as are known to exist. The standing plankton crop of the inshore waters would not seem to be sufficient to support them unless it was replenished and supplemented in some such way as has been described.

The chirundu, and the current found there, may not only be responsible therefore for the concentration of the fish populations, but also the presence of these topographic features and the frequency of their occurrence may well determine the size of the Utaka population in the surrounding area. The currents provide, it would seem, the bulk of the plankton resources on which the population can exist. This makes possible the occurrence, in a lake with a relatively low plankton density, of species of fish which although primarily in-shore living, have taken up the plankton feeding habit exclusively or almost exclusively, and which do not of necessity have to range for any distance in search of food and therefore do not lose what seems to be essential biological association with the substrate.

There are further implications. Many species of Utaka are found all the year and at all sizes at inshore virundu any one chirundu will be frequented only by the population of those species from a limited area in the vicinity of this chirundu, the area being determined by the amount of random movement shown by the fishes in the "dispersed" phase. It is possible, therefore, that such a local population could be overfished, especially if long periods of suitable fishing conditions occurred. This possibility should be realized, for certain species of Utaka it is local populations, and not populations from a large area of the open lake, which will have to stand the strain of fishery development at any one place. However, at present, *H. virginalis*, the most abundant of such species, is not exploited to any great extent by local methods, and the introduction of the small-meshed net would make use of a potential which is not yet utilized to its fullest extent.

The seasonal fishery for Mbarule represents a rather different picture. The evidence is that this species spends its third and any subsequent year away from the shore, and returns only during the breeding season. A given area therefore is the site of a fishery which exploits the yield of what is probably a greater area of the lake, and fish which, much more directly, make use of the plankton resources of the open water. Even if at a particular place, the breeding population is heavily fished it is likely that this would have little effect on the size of the breeding population visiting the area the following year, so that unless the entire breeding population over the whole of the length of shore which is available for breeding purposes is also fished heavily, it is less likely that the extension of the fishing at good grounds for Mbarule would lead to depletion of the stocks of the lake as a whole.

Even so, it is essential that catch data for this, and all species of Utaka, be accumulated, particularly at well known and good fishing areas, and that development of new fisheries go hand in hand with the extension of services designed to control them.

C. Feeding

The Utaka have been described as a group of species which feed on zooplankton (Lowe, 1951) and the " minute crustacea of the plankton " (Bertram, Borley and Trewavas, 1939) but this must not be taken to mean that only zooplankton are ingested. There are in fact well-marked differences in feeding habits shown between the various species for which information is available. Of these, *H. virginalis*, *H. mloto*, *H. boadzulu* and *H. quadrimaculatus* take in almost entirely zooplankton but occasionally, and in some of these species even, elements of phytoplankton have been found in the stomach and intestine. Some individuals of *H. virginalis* have been found with both *Botryococcus* and zooplankton in the stomach, although the zooplankton predominated and usually formed nearly all of the gut contents. In any case the *Botryococcus* is almost certainly not digested, there is no sign that the cell wall has been broken down even in samples obtained from the hind end of the intestine. On one occasion both adults and juveniles of this species were caught together and it was found that the size of the individuals of the zooplankton in the stomachs of the juveniles was smaller than that in the stomachs of the adults, so that there is possibly a correlation between the size of the fish and the size of the plankton taken in, but this is by no means certain. A large proportion of the individuals taken during the day time had stomachs which were not more than half full, and many had almost empty stomachs, but this is not to mean that feeding is necessarily restricted during the daytime as most of these were taken at places where perhaps the plankton resources are not as great as at the chirundu. Whenever this species has been observed under water, at the chirundu the individuals have been found to be feeding. The protrusible mouth is shot out and withdrawn continuously, and as this is done, slight changes occur in the direction in which the head is facing and the movement of the mouth does not take place at regular intervals indicating that selection of individual elements of the zooplankton is going on. This general type of feeding behaviour has been observed also with *H. chrysonotus*, *H. nkatae*, and *H. quadrimaculatus*.

H. mloto, and *H. quadrimaculatus* give essentially the same picture as does *H. virginalis*, but the fact that at a deep chirundu adult breeding males of *H. quadrimaculatus* have been found with almost full stomachs indicates that the breeding male fish do not necessarily stop feeding when they come inshore, although of course it is not likely that mouth-brooding females feed.

Other species are commonly found with elements of phytoplankton in the gut, and of these *H. chrysonotus*, *H. nkatae* and *H. jacksoni* are good examples. Diatoms, *Botryococcus*, colonial and filamentous green algae have been found in the stomach and the intestine of these species, but again there is no indication that there is any breakdown of the phytoplankton. It is more likely that the phytoplankton is taken in unavoidably with the zooplankton and not digested.

In all these species so far mentioned the zooplankton in the stomach and intestine is never fragmented, and the stomach itself is quite small. *H. trimaculatus* however differs greatly. Its local name is Chakuta, which can be translated as meaning replete, and in fact every specimen examined has been found to have a greatly distended stomach. The stomach contents include always a high proportion of *Botryococcus*, as well as zooplankton, but the latter is so fragmented as to make it extremely difficult to identify individual elements. Moreover, the intestine of this species is extremely long in comparison with that of other species of Utaka, and it is possible that the phytoplankton is not only taken in, but also digested to a certain extent. *H. pleurostig-*

moides and *H. borleyi* have a similar type of feeding habit, and it has been recorded that a fairly large amount of phytoplankton has been found in the gut and that the zooplankton is fragmented, but individuals with almost empty stomachs have also been seen and the length of the alimentary canal for both these species is relatively much shorter than that of *H. trimaculatus.*

Little is known of the feeding of *H. eucinostomus*. *H. flavimanus* has a rather distinctive feeding habit indicated by the fact that on the few occasions it has been found, the stomach of all specimens has contained zooplankton, phytoplankton, filamentous algae and also sand grains. Morphologically this species with its rather few gill-rakers and relatively short premaxillary pedicle is not perhaps a typical Utaka, but it cannot be excluded from the group and represents morphologically and biologically a borderline case.

While therefore the Utaka complex can be considered to be primarily a zooplankton feeding group, the various species can show wide variation in the type of feeding mechanism employed, and the type of food taken in, and it is possible even that some species may digest plant material, to a certain extent. However the most abundant species undoubtedly obtain all or nearly all their food from the zooplankton.

D. Breeding and Growth Rate

The estimation of the growth rate of species of Utaka presents many difficulties. Attempts to determine the age of individuals by scale readings or opecular bone readings have never been successful. Although in some individuals rings could be observed on some of the scales, it was impossible to interpret them with any accuracy and estimates of growth rates could therefore only be made by analysing length frequency distributions. This method has its limitations, and for some species, those with a less defined breeding season for instance, it is not possible to make even estimates of the growth rate and life span.

The small size of many of the species, indicating a relatively slow absolute growth rate, also means that a considerable part of the life span, that represented by fishes below about 60 mm., is not sampled easily even with the small-meshed chilimila net, and the greatest difficulty lies in obtaining regular and adequate samples of each species. The chilimila net, which is almost the only method available for sampling, can only be used when conditions are suitable, and in many months relatively few hauls could be made.

Despite these and other difficulties it has been possible, for some species, to estimate growth rates and life span, and while these estimates cannot be taken to give great accuracy, they indicate reasonably the probable rate of growth.

(I) HAPLOCHROMIS QUADRIMACULATUS

(a) *Breeding*

This species both potentially and actually is the most important economically in the north of the lake. At Likoma Island and Chizumulu Island the adult breeding fish, Mbarule, are caught in season in large quantities. At Nkata Bay, during the survey period at least, it was not abundant, but at other places such as Ruarwe and Usisya the fishery seems to be more important, although even there, it is not as important as at Likoma and Chizumulu.

Both male and female adult fish are called Mbarule, although the male has a spectacular breeding dress which makes it very distinctive. Fish below about 140 mm. are called Mbaba in most places, but at Ruarwe they may sometimes be referred to as Chipapi. The name Mbaba is used only for young *H. quadrimaculatus*, which is not confused with other species in the north.

At Nkata Bay, male Mbarule in various stages of the development of the breeding coloration appear in small numbers in March or April. In April and May females are found with active or ripe gonads, and by the end of May and early June the majority are ready to lay eggs. In June fertilized eggs are found in the buccal brood pouch of the female, and by July most of the females are brooding young fish in the mouth. The numbers of Mbarule caught falls off in July and by August Mbarule is usually scarce. It would appear that males and females disappear from the inshore region at about the same time, and very few are caught outside the period March to August. At Likoma Island it is reported that individual males or small groups begin to appear in March and that by April or May both males and females are caught in large numbers. Females with eggs in the buccal pouch are found in May, and by June or July most of the females are brooding young fish. August usually sees the end of the season. At Ruarwe the females appear in May with developing ovaries, while in June or July eggs and young are found in the pouch.

Mbarule are caught either at virundu in deep water, No. 1 (Map 5) being considered the best at Nkata Bay, or near the shore, and night fishing near rocky shores in the season is common at Nkata Bay, Ruarwe and Usisya. Survey nets, of 2½" and 3" set inshore near rocks in fairly shallow water of about four or five fathoms, caught both breeding males and females, and in May quite large numbers of them, including a high proportion of males, were recorded both at Nkata Bay and at Likoma Island in these nets. The numbers at Nkata Bay were highest at the end of May and early June and it is at this time that the best catches from chilimila nets pulled near the rocks, are recorded (No. 8 on the map is one such locality). It seems clear that the breeding season of *H. quadrimaculatus* is short and well defined and synchronized at many well separated places in the north of the lake, with the peak activity period, during which a majority of the eggs are fertilized, at the end of May or the beginning of June. A rocky habitat seems to be essential, and it is likely too that breeding takes place mainly inshore. The fish caught in the gill-nets were nearly all ripe running or spent, whereas at the virundu earlier stages of breeding are also found. The almost complete absence, outside the breeding season, of fish larger than about 140 mm. from the inshore regions fished by the chilimila and other fishing methods, indicates that there is a shift of the distribution of the larger fish away from the shore and later, a breeding migration to return to the inshore habitat. A distinction is made by local fishermen between two types of Mbaba, which although not rigid is informative. The smaller specimens below about 100 mm. are commoner apparently between December and March, while the larger ones at about 130 mm. are not commonly found after the breeding season. These may represent two separate year classes and the larger specimens of Mbaba are thought to migrate offshore at the end of the breeding season, to return as adult breeding fish the next year.

The size of breeding fish ranges from 150 mm. to 200 mm., and fig. 1 shows the length frequency of breeding fish for the 2½" gill-net, the 3" gill-net and the chilimila net. The gill-nets are highly selective for size, and the chilimila data reflect more accurately the length distribution of breeding fish. The range for the chilimila net is from about 150 to 200 mm. with a peak at about 170 mm., lower than the peak shown for either of the gill-nets. It can be deduced from this that a gill-net of slightly smaller mesh size than the 2½" would give a higher catch per unit effort, but it is doubtful whether even with this, it would be economical to gill-net breeding Mbarule inshore. The colour of the breeding male is described by Iles (1960).

(*b*) *Growth Rate*

The short breeding season makes it possible to give estimates of growth rate, but the absence of certain groups from chilimila catches at certain times of the year makes it difficult to follow the growth of individual year classes month by month. The figures for the length frequencies are given in Appendix 1 and some are represented graphically in fig. 2.

There are clear indications in some records that three years classes are represented. In April, 1956, three peaks can be distinguished at about 80 mm., 130 mm. and about 170 mm. In May, 1955, again these can be seen. In April, 1955, two classes are obvious, the second at about 124 mm. predominating, with another at about 170 mm., and in March, 1956, a class at 76 mm. and another at 120 mm. can be distinguished. The first year growth, therefore, probably results in fish of length about 90 mm., the second year the growth is to about 130 mm., and during the third year the main breeding length of 170 mm. is reached. The presence of occasional fish up to a length of 200 mm. may indicate that some live for a fourth year and breed for a second time, but this cannot be established definitely.

It is possible to follow the growth of one year class, that assumed to have been born in June, 1954, and this is shown in fig. 3, the mean size of the year class being plotted against the month of the year. The curve is produced at both ends to its origin and to the mean breeding size assumed to be reached in June, 1957.

The non-appearance in chilimila catches of the larger Mbaba, i.e. those beginning their third year's growth, indicates that this species spends this period away from the inshore habitat. If this is so then *H. quadrimaculatus* is the only species of the Utaka found in the north which can be shown to lead true open water existence, or at least one which is not bound intimately with a particular inshore habitat, and even for this species it is for only a part of its life history.

(II) HAPLOCHROMIS VIRGINALIS

(*a*) *Breeding*

The study of the breeding and the growth rate of this species is complicated by the fact, not recognized until late in the survey, that two forms are recognized whose systematic positions are not yet clear. They are known by local fishermen as Kaduna and Kajose, and the more experienced can separate a mixture of both on the basis of size, colour and slight differences in shape, into two components which are then found to differ significantly in other ways, chiefly in the spination of the dorsal fin and in the length of the caudal peduncle. The two forms are often found together, and appear together in chilimila catches, the breeding males of both are called by the same name, Nyakaulu, and the breeding seasons appear to show an almost complete overlap. It is possible that these will eventually be separated as two sympatric and very closely related species, but they are here treated as being conspecific. The most important difference between the forms as far as growth is concerned, is that Kajose breeding fish are larger than Kaduna, probably because of a greater growth rate rather than a longer life span. This makes it difficult to estimate the growth rate for the species, but in many cases, analysis of the spination of the dorsal fin, which was routine, indicated that one or other of the forms predominated, even in catches made before the presence of two forms was confirmed, so that proper allowances can be made in the interpretation of the length frequency.

In February, females of breeding size and with developing ovaries have been found and in March males in breeding dress and ripe females occur together. In April many of the females are ripe running and some are found with eggs in the buccal brood pouch. In June and July eggs or young are found in the brood pouch of the females and in August and even as late as September some females are found which appear to be spent. The breeding season extends therefore from about March to July with the peak period in May or June. The breeding colour of males of Kaduna and Kajose are described elsewhere (Iles, 1960). The sizes of breeding fish, both males and females separately, are given in fig. 4.

(*b*) *Growth Rate*

Table II in the Appendix gives the length frequency distributions throughout the years 1955, 1956 and part of 1957 month by month, and fig. 5 shows some of the monthly records graphically.

In many months, two classes can be recognized as giving separate peaks. In July, 1955, one peak at about 80 mm. and one at about 100 mm. can be seen. In October, 1955, one at about 85 mm. and another at about 105 mm., in November one at about 87 mm. and again at about 105 mm. In January, 1956, juveniles at about 55 mm. and larger specimens with a peak near 92 mm. were recorded, and in February these are represented by peaks at 60 mm. and 95 mm. respectively, and similar separated peaks are found in the records for April and June, 1956, and in February, April and May, 1955.

It is fairly certain therefore that two separate year classes are represented and that this species breeds at the end of the second season. From fig. 6 it can be seen that the range of breeding size is large, but this is more likely to represent the difference in breeding size of the two forms, rather than the majority of individuals living a third year and breeding again.

Assuming May to be the peak of the breeding season it is possible to follow the growth of one year class. In February, 1955, a group of length about 58 mm. appeared which is assumed to have been born in May, 1955. Fig. 6 shows its growth until June, 1956, when it formed the breeding population of that year. While this growth curve cannot be taken to represent an accurate picture there are indications that growth is more rapid in the early months of the year.

(III) HAPLOCHROMIS PLEUROSTIGMOIDES

(*a*) *Breeding*

The breeding season for this species cannot be determined with the same degree of accuracy as for the preceding two species, as specimens of breeding size have only been recorded during certain months of the year.

At Nkata Bay the breeding female is called Mawala, and at Ruarwe, Bala, and in March, 1956, a single haul of the chilimila gave a number of specimens of these, the size being around 130 mm., with active gonads. No males were recorded and it is possible that the species shoal separately at this stage. In April and May, ripe running and spent fish of both sexes have been caught together with other individuals with active gonads. The range of size of these fishes was from 115 mm. to 150 mm., but most of the breeding females were larger than 130 mm., which is taken as the normal minimum breeding size. No individuals of length greater than 150 mm. have been recorded which determines the probable upper range of the length for this species. In August individual females brooding young in the mouth have been found at Nkata Bay, and at Ruarwe in September, 1955, a shoal of females with young in the brood pouch was fished. The young were rather large, the yolk sac had disappeared and they were about ready to take on an independent existence. During April and May and as late as July, males in breeding dress have been recorded at Nkata Bay and in September, 1955, females of breeding size but with inactive gonads were recorded.

Breeding probably takes place therefore in the first half of the year and there is apparently a fairly well-defined period of peak activity during which fertilization takes place, in the period April to June. It would appear that the breeding females may shoal together both before and after mating as females with young in the mouth are usually found together, and with few males present. The size range of breeding males and females is about the same and there is no evidence of a disparity of size and growth rate between the sexes.

(*b*) *Growth Rate*

The length frequencies data for *H. pleurostigmoides* is given in Table III. Relatively little information is available for this species and the data for each haul in which numbers of this species were recorded is given separately. Assuming the breeding season to extend from April to June with a peak of activity in May or June, the appearance in January and the early months of the year, of populations distributed around the 60–70 mm. size range, possibly indicates a mean growth rate to about that size in about nine months, and the appearance in May of shoals with peaks at about 80 mm. supports this and indicates that the first year's increment of growth is about 80 mm. In November, 1956, a population with a well marked peak at 100 mm. was recorded and in October, 1955, populations with less well marked peaks at 96 mm. and 102 were measured, indicating possibly that during the first six months or so of the second year's growth 20 mm. are added. In May, 1956, fish of 120 mm. were recorded on one occasion and at this size they may have bred. It is more likely however that during the third year growth, a size of between 130 and 150 mm. is reached which is normal breeding size. It is probable therefore that *H. pleurostigmoides* breeds at the end of the third year and that the sizes reached in the three years are about 80 mm., 120 mm. and 140 mm. respectively.

(IV) HAPLOCHROMIS MLOTO

(a) Breeding

This species occurs often with *H. virginalis* from which it was easily distinguished by its shallow body, long caudal peduncle, slightly fewer gill-rakers and more silvery colour. It is similar in form and colour to *H. eucinostomus* but has more gill-rakers and a more stout appearance. It is more often a " chirundu " form and is rarely taken near a sandy habitat.

Most of the specimens taken by the survey were caught in the months of August, September and October, and relatively few were caught from March to August, when *H. virginalis* is common. In June, 1955, starting, and some active, females were recorded but it is in August that the first breeding male was recorded. In August, too, active and ripe fish of both sexes have been recorded together. The first ripe running fish were found in October, both sexes being represented in about equal numbers and of lengths from 115 to 140 mm. The males seemed to be slightly larger than the females and both sexes were considerably larger than the starting and active fish caught in August. A spent female has been found in December. Breeding therefore possibly takes place in later months of the year with a possible peak of activity at about the beginning of October. The breeding range is rather large and length frequency for males and females are given in fig. 9.

(b) Growth rate

Length frequency data are given in Table IV of the Appendix.

Assuming the peak of the breeding season to be in October, the appearance in March and April, 1956, of the individuals whose length is distributed about a mean of 70 mm. or so indicates a fairly rapid growth rate over this period. In March, 1956, another peak at about 102 mm. appeared and in August, 1955, one at about 90 mm. which probably corresponds to one found in September at about 94 mm. The estimated growth of the species therefore is that in the first year reaches a length of about 90 mm. There is no evidence of more than two peaks in length frequency distribution so that it is likely that this species reaches the breeding size of 120–130 mm. at the end of the second year.

(V) HAPLOCHROMIS BORLEYI

Breeding and growth rates

Breeding specimens of this species have been found throughout the year, and it has not been possible to show at any one period that there is a marked increase in the percentage of breeding fish over the breeding size range. It is presumed therefore that the breeding season extends throughout the year and it is not possible to give estimates of the growth rates by the length frequency method.

Fig. 7 shows the length frequency histograms of males and females of this species which have been recorded with gonads at the active stage, or more advanced than this stage. There is a marked difference in breeding size between the sexes. Ripe females as small as 94 mm. have been found, and the largest breeding female recorded was 112 mm. in length. Only on rare occasions have males less than 110 mm. been seen and the smallest in breeding dress was 120 mm. long. This marked disparity in breeding size between the sexes is apparently unusual in the Cichlidae and it is not possible to say whether it is the result of an increased growth rate or because the males live for a longer period.

This species is common and widespread in distribution. It nearly always figures in chilimila catches but never occurs in large shoals and is very closely associated with a rocky habitat. Breeding males, which are very distinctive, have been found inshore near rocks and in shallow water and occasionally catches have been made up entirely of breeding males, indicating possibly that the sexes may shoal separately at some stages of the breeding cycle.

(VI) OTHER SPECIES

(a) *Breeding*

Little is known of the breeding of the other species. On one the occasions when *H. flavimanus* were recorded in March, 1957, a large proportion of the individuals were ripe females. *H. nkatae* is reported to be seined as breeding fish off a sandy beach at Sanga, south of Nkata Bay between May and September, and it is at this time of the year that the largest catches are reported for this species in the Ngongongo net. *H. chrysonotus* apparently breeds on a sandy substrate some distance from shore, it being seined at the breeding stage (Bertram *et al.*, 1942), and during December at Monkey Bay ripe individuals of both sexes were found, while as late as May breeding fish have been recorded at Nkata Bay. *H. eucinostomus* is a nest builder on sand, and the males have often been seen at Mayoka Beach (see map 5) in shallow water and over raised circular nests about 9″ in diameter, but the exact extent of the breeding season has not been delimited. It does seem clear that in the Utaka group there is a considerable variation in breeding habits. The various species are associated with either a sandy or rocky substrate for breeding. These would include on the one hand *H. quadrimaculatus*, *H. trimaculatus*, *H. pleurostigmoides*, *H. virginalis*, *H. borleyi* and probably *H. cyaneus*, *H. likomae* and *H. boadzulu*, preferring a rocky habitat, and on the other *H. eucinostomus*, *H. nkatae*, *H. chrysonotus*, *H. prostoma*, *H. flavimanus*, preferring a sandy breeding site.

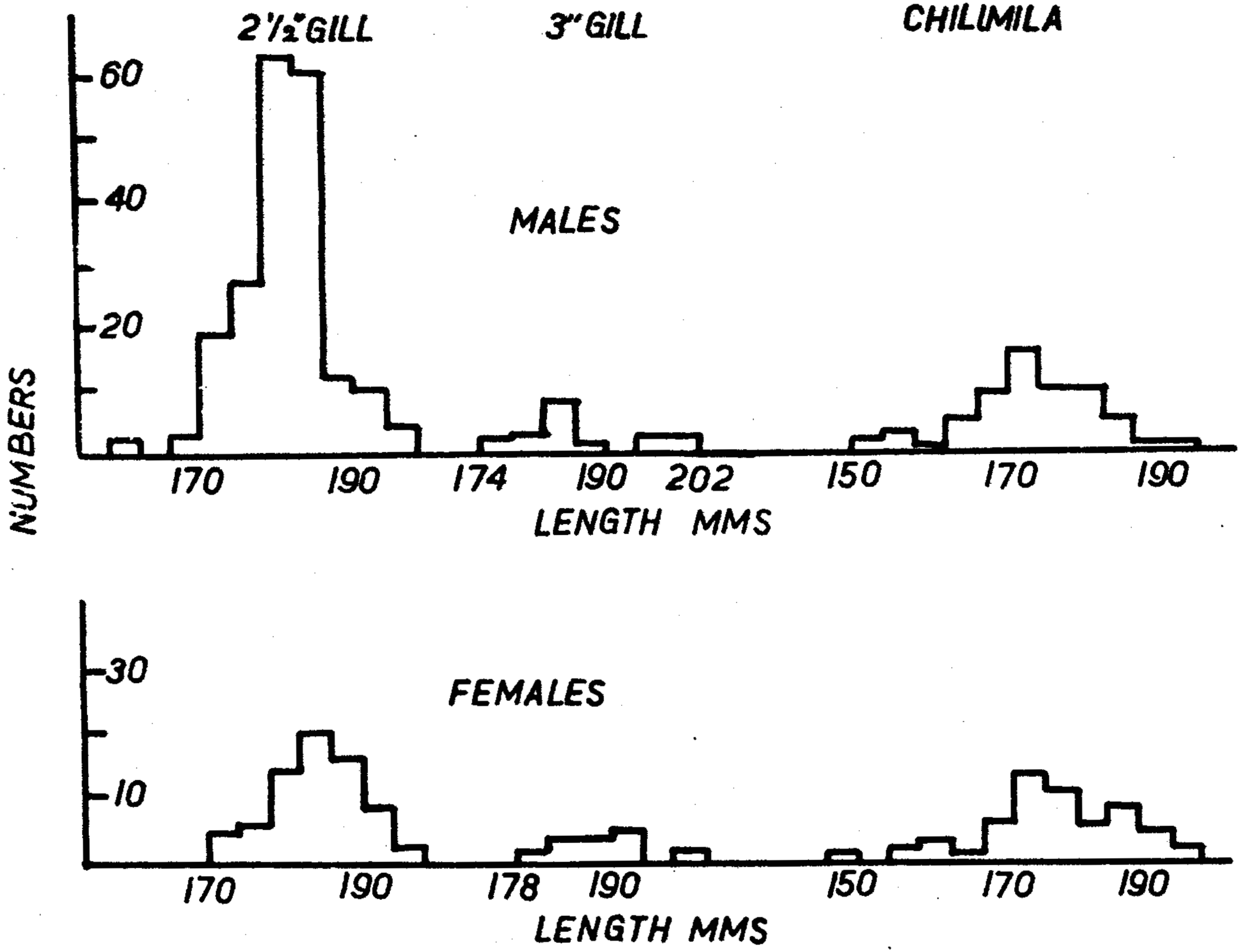
The breeding season may be short and well defined as it is for *H. quadrimaculatus* and *H. virginalis*, or not confined to any period of the year, but even in those species which do show a fairly short breeding season there is a great overlap, and at no time of the year can it be said that breeding does not go on in the group, indicating perhaps that breeding is not, in the group as a whole, influenced and determined by seasonal climatic factors. It may well be that in species which might be expected to compete for a particular type of breeding niche, a staggering of the breeding seasons prevents undue competition, and it is perhaps significant that those species which are most abundant, *H. quadrimaculatus* and *H. virginalis* also have the most restricted breeding season, but the factors which determine and control the breeding cycles for the Utaka species are not known.

(b) *Growth Rates*

Although estimates of growth rates are only available for some of the species, it is possible to come to some general conclusions. As might be expected for such small species, growth rates are low, lower for instance than those given for the *Tilapia* species investigated by Lowe in the south-east arm, but even so the Utaka species do seem to have short life histories, and many species are thought to live only for two

Haplochromis quadrimaculatus

FIG. I.



Length frequency breeding fish

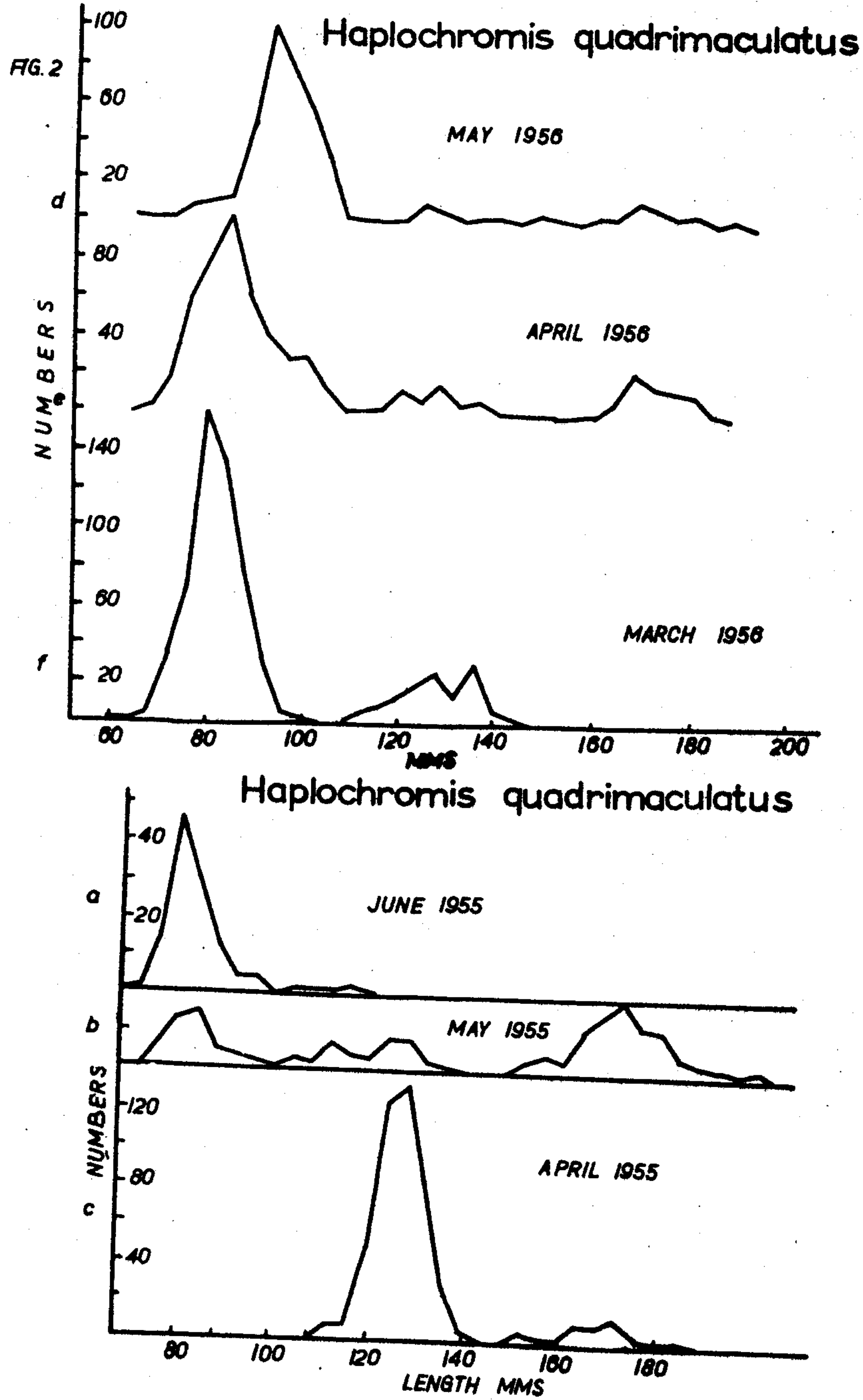


FIG. 2 Length frequency

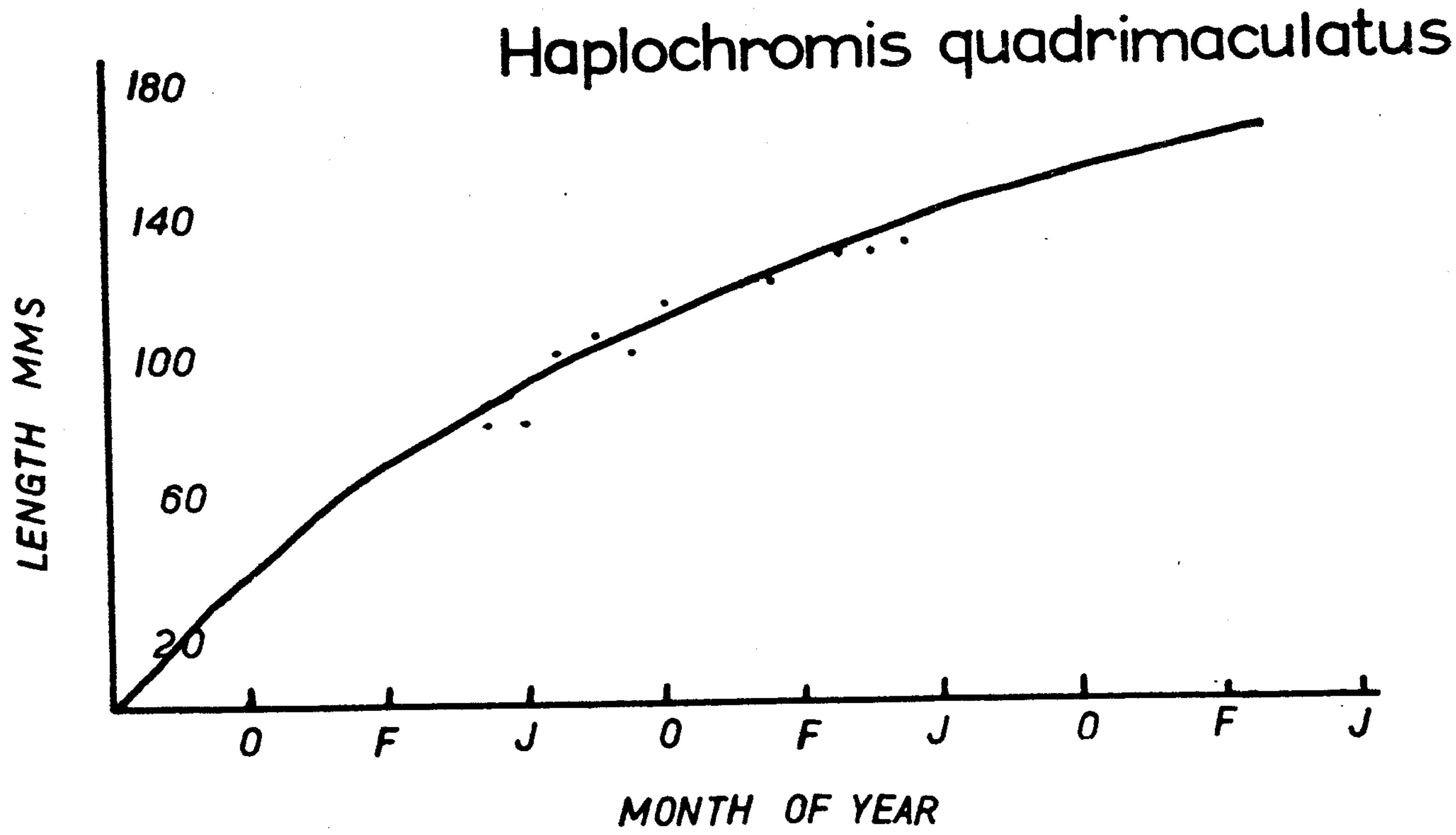
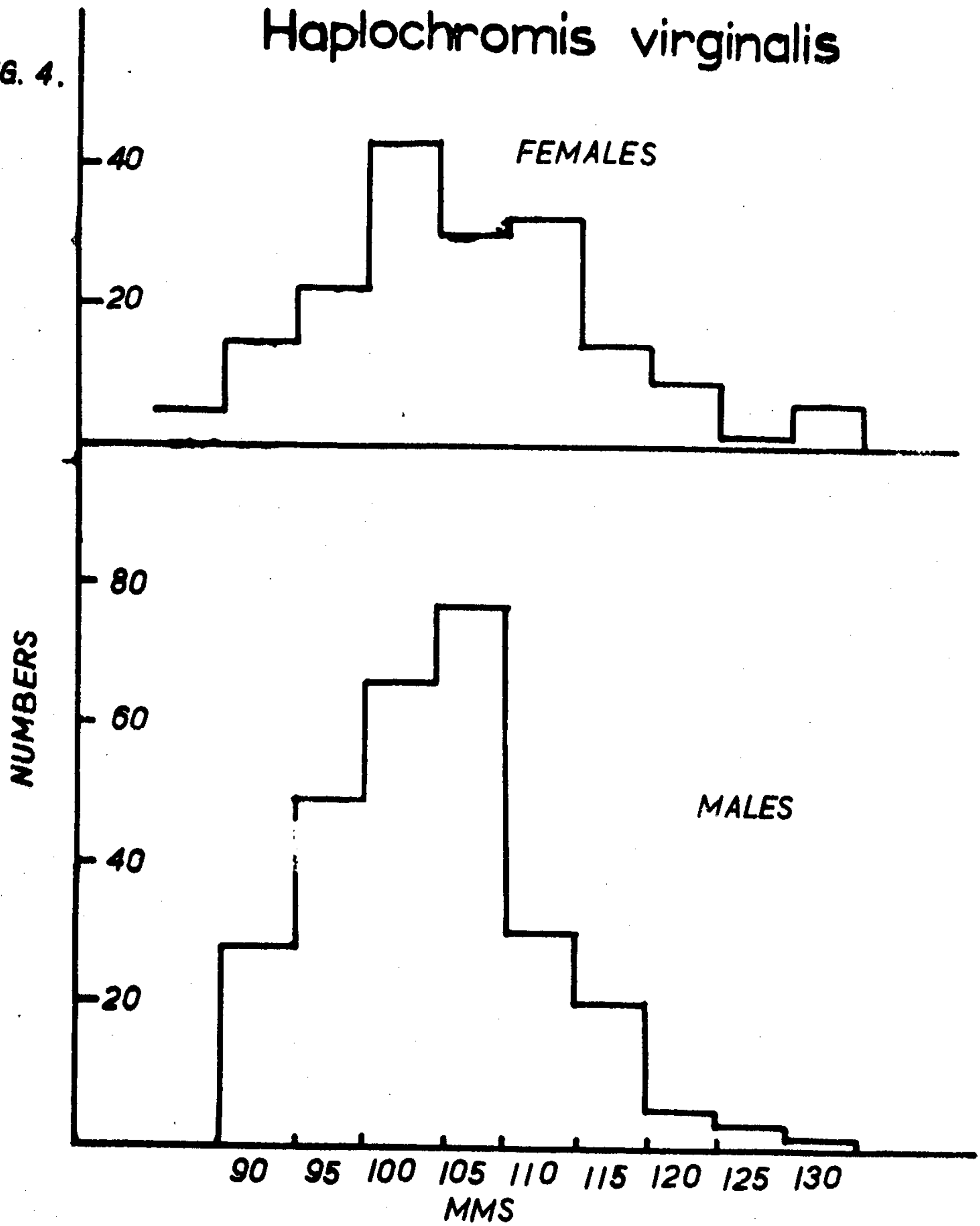


FIG. 3

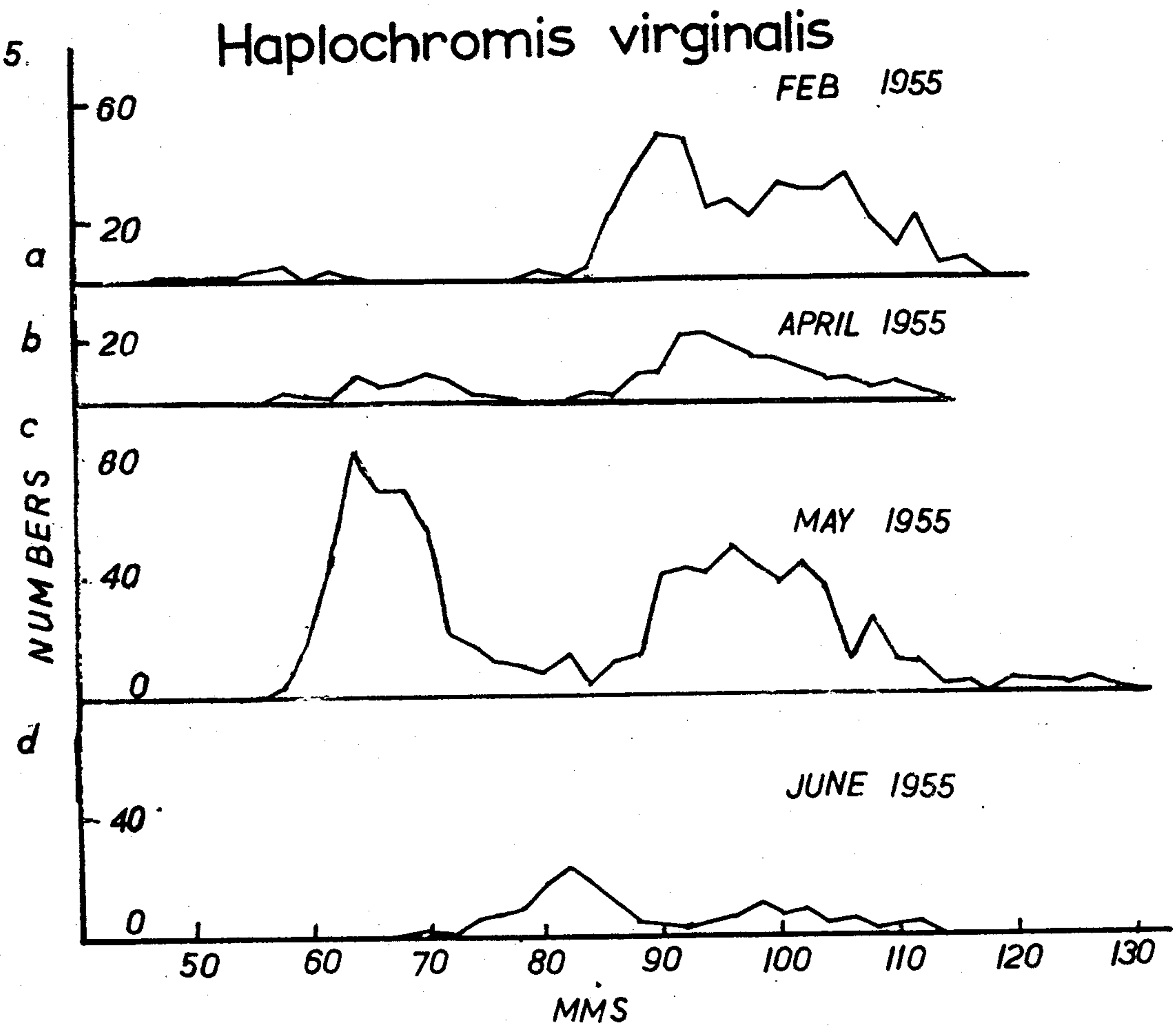
Growth of 1954 year class

FIG. 4.



Length frequency - breeding fish

FIG. 5.



Haplochromis virginalis
FEB 1955
APRIL 1955
MAY 1955
JUNE 1955
a
b
c
d
NUMBERS
60
20
20
80
40
0
40
0
50
60
70
80
90
100
110
120
130
MMS

FIG. 5.

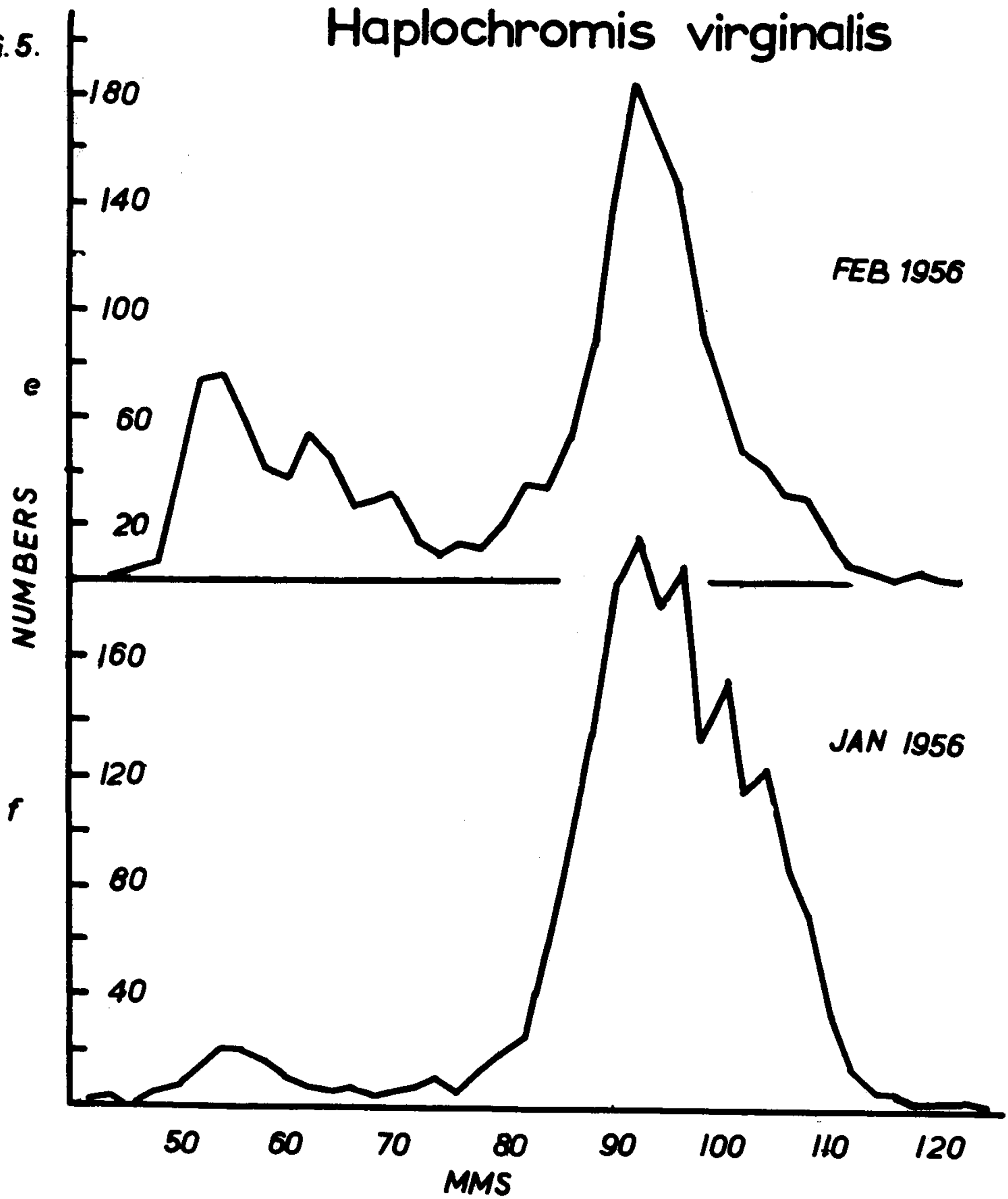
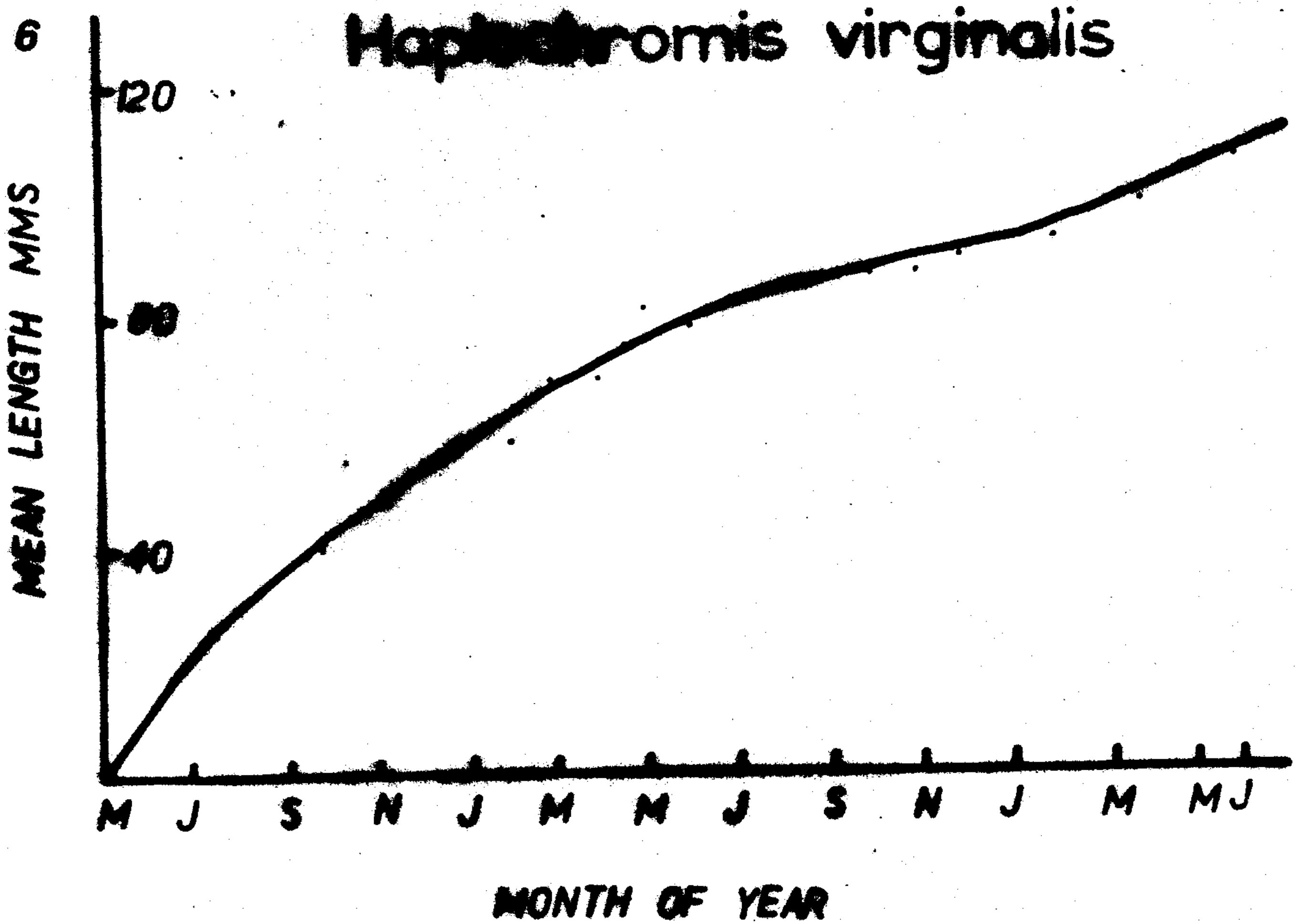

Haplochromis virginalis
180
140
100
60
20
160
120
80
40
e
f
NUMBERS
FEB 1956
JAN 1956
50
60
70
80
90
100
110
120
MMS

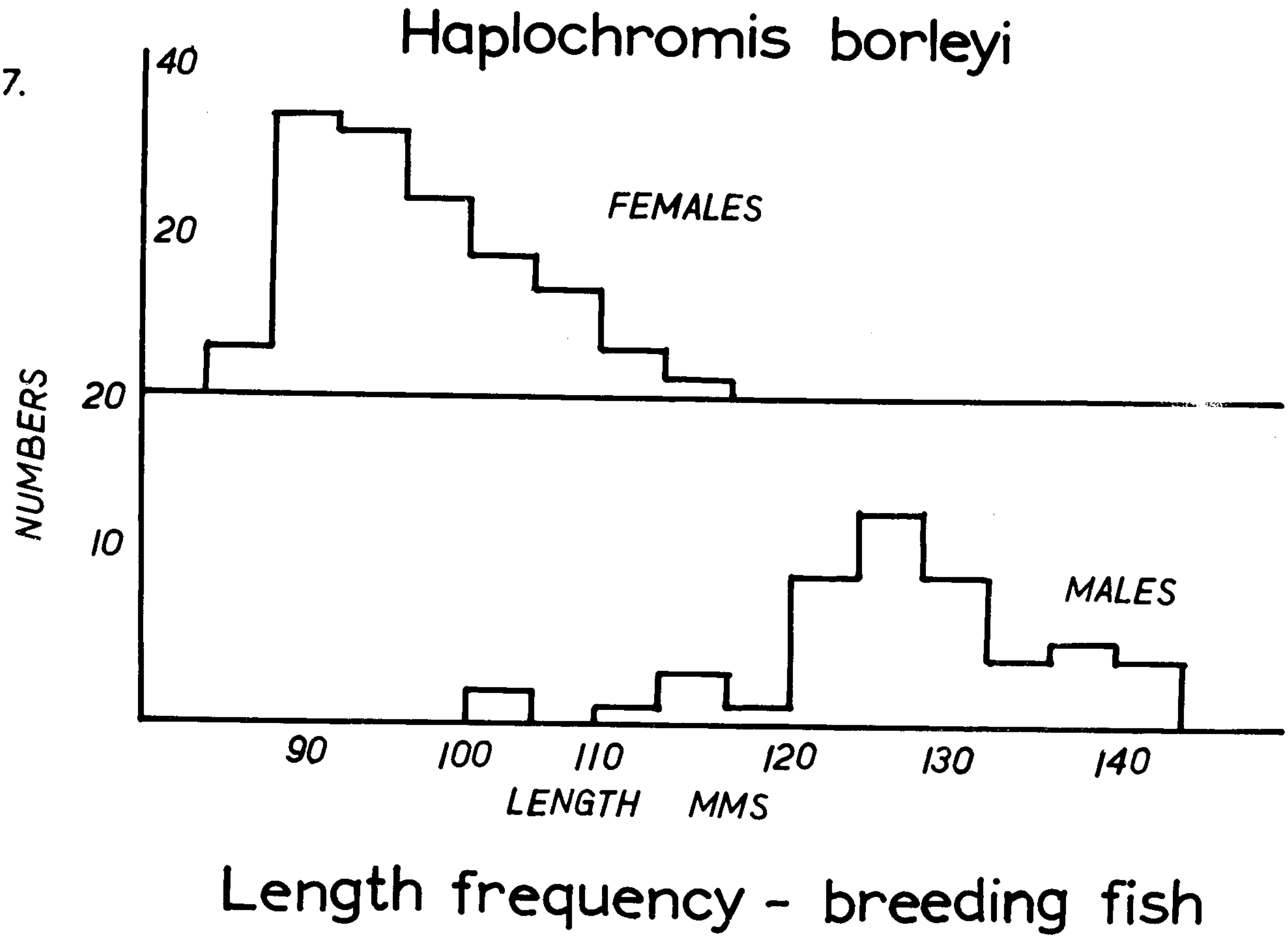
FIG. 6

Haplochromis virginalis



Growth of 1954 year class

FIG. 7.


Haplochromis borleyi
40
20
FEMALES
NUMBERS
20
10
MALES
90
100
110
120
130
140
LENGTH MMS
Length frequency - breeding fish

years and to breed only once. The larger species, including *H. quadrimaculatus* and *H. trimaculatus*, probably live for three and possibly a fourth year, and do not show a markedly greater growth rate. Fish with a relatively short life span might be expected to show rather marked fluctuations in numbers from natural causes and also from the effects of over-fishing which would become quickly apparent. It also means that fishing tends to exploit breeding populations or those which would be expected to breed within a short time, and this is true certainly of the two most important economic species, *H. quadrimaculatus* and *H. virginalis*.

The latter is a small species, the maximum size being about 130 mm. and the small-meshed net exploits mainly those individuals in their second and probably final year's growth. While it seems undesirable on the grounds that there is rather less reserve potential outside the exploited range, such a state of affairs is inevitable and there are circumstances which improve the situation.

It has already been suggested that there is little true competition for plankton amongst the group, and that population size may depend as much on the availability of " living space " and perhaps particularly of breeding space. If this is so it is possible that exploitation of breeding stock may be possible to quite a high degree before it has a marked effect on the size of the following generation. The mouth breeding habit is very efficient and provides a considerable reserve of reproductive potential, so that although overfishing may be felt quickly it is also to be expected that recouping would also be rapid. The question of control will however be dealt with in greater detail later.

List of Figures Chapter 4, 3.

TABLE I

H. Quadrimaculatus

Month	Length MM.																															
	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	148	152	156	160	164	168	172	176	180	184	188
Feb. 1955										6	8	7	24	2	3	4																	
Apr. 1955													1	7	8	48	124	133	82	29	5			4	2	2	9	9	12	3	1	1	
May 1955					6	13	15	5		2	1	3	2	7	4	3	8	8	2	1				3	4	3	11	16	19	13	12	5	3
June 1955				1	14	45	30	12	3	4		1	1	1	2																		
July 1955					1	3	15	21	104	137	157	142	106	43	18	3	5	3	3	2	2	1	1			1	1	4	2				
Aug. 1955									3	16	51	73	102	53	27	8																	
Sept. 1955							2	1	9	9	12	10	4	1																			
Oct. 1955	6	4	1	7	2	1				10	21	65	108	154	185	135	74	27	6	2													
Jan. 1956													7	3	3	3	2																
Mar. 1956			3	31	70	159	134	52						5	8	13	10	27	13	32	7	3											
Apr. 1956			4	21	58	86	11	63	41	29	13	15	3	3	3	13	8	16	5	7	2	2				1	8	23	16	14	12	2	
May 1956		2	1	1	7	9	24	47	99	58	26	2	1			1	9	5	1	3	3		4	2	1	4	3	12	9	4	5	1	4
TOTAL . .	6	6	9	61	158	316	231	201	259	271	289	318	359	279	261	231	240	219	112	76	19	6	5	9	7	11	32	64	58	34	30	9	7

TABLE II

H. Virginalis

Length MM. (44–92)

	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
Feb. 1955		2		2		2	6	3		3	1			1					3	4	5	24	38	49	48
Apr. 1955								2	1	1	8	5	6	9	7	2	1			1					
May 1955							2	5	20	45	83	71	71	57	21	18	12	11	9	13	4	12	14	41	43
June 1955													1	1	1	6	8	16	18	22	17	11	4	3	2
July 1955													1	8	13	19	26	31	33	16	25	29	14	32	48
Aug. 1955																2	9	15	17	34	39	43	59	65	62
Sept. 1955												1	5	5	14	35	59	106	208	277	297	241	223	197	166
Oct. 1955																	2	6	28	37	55	88	62	63	50
Nov. 1955																		8	10	18	33	43	48	47	31
Dec. 1955															3	1	2	3	6	13	24	40	44	36	40
Jan. 1956	1		7	9	14	20	19	10	7	5	5	2	2	3	10	5	3	15	23	39	75	110	156	215	179
Feb. 1956	2	2	11	54	85	61	48	30	49	54	40	27	33	21	14	11	13	14	22	46	38	71	89	174	175
Mar. 1956					4	8	12	14	7	8	10	15	11	11	22	20	19	10	15	19	22	49	97	190	245
Apr. 1956								5	10	19	32	55	75	58	67	29	30	12	8	18	26	45	60	96	103
May 1956														2	5	25	60	109	114	90	48	26	10	3	
June 1956															2	2	28	40	51	29	13	9			
Sept. 1956	4	11	17	27	38	31	29	23	17	12	13	4	2	3	3										

Length MM. (94–138)

	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138
Feb. 1955	25	22	22	33	31	31	36	21	11	22	6	7											
Apr. 1955									3	3													
May 1955	42	50	43	38	44	37	12	26	19	18	4	4		4	4	2	5	3					
June 1955	4	5	10	7	8	4	5	3	3	4													
July 1955	69	71	95	92	81	70	50	30	20	7	10	1											
Aug. 1955	68	79	43	91	69	74	63	37	53	46	26	26	20	20	4	9	7	3					
Sept. 1955	170	187	194	205	188	147	95	62	40	32	5	7	1	4	1	1							
Oct. 1955	41	34	40	69	93	79	87	47	42	12	26	11	24	17	17	13							
Nov. 1955	28	16	9	19	13	19	15	5	3	3	3												
Dec. 1955	31	33	30	30	27	19	15	8	9	8	1	1	2		1	1							
Jan. 1956	189	163	114	156	130	103	73	64	26	13	4	4	1	1									
Feb. 1956	163	119	86	71	33	43	29	26	13	5	1	2	1										
Mar. 1956	290	257	155	141	107	93	49	34	20	16	8	3	2	2	1	1							
Apr. 1956	98	99	82	72	76	58	40	42	21	26	13	12	3	8	3	3							
May 1956																							
June 1956			2	7	6	17	16	11	15	16	16	14	5	5	3	2							
Sept. 1956																							

TABLE III

H. Pleurostigmoides

Length mm	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146
27-5-55																			1			2	6	6	9	13	12	17	8	8	10	10	7	4	3	4	5	5	2	1	1	1	1	1	1	1	1			
29-7-55																															3	2	14	13	13	17	8	3		1		1		4	1	1				
19-8-55																				3	1	6	5	6	12	11	4																							
																		1		1	2	2	1	3																										
1-10-55																				2	4	2	3	2	5	2	1	1																						
4-10-55																							1	1	1	5	7	5	6	3	3	1	1	4	12	9	15	22	18	15	17	8				1	1			
10- 1-56									1	2	10	15	9	7	5	3																																		
14- 1-56	2	3	1	1	1	2	3	6	15	6	10	6	3										1	2	2	3	5	7	4																					
14- 3-56											1			1				2	1	2			3	1																										
20- 3-56				1		3		2	1	1	2					1	2		4		3	8	7	3	4	6	3	4			1																			
4- 4-56																	2	6	2	3		1	1	2	1		4	7	13	9	6	5																		
17- 4-56				1	3	1	2	3	5	2	5			1	1	1	3	4	4	4	9	21	10	13	8	3	2	1	3							1								1						
18- 4-56															1	1	1		1	2	2	1	2	3	2	2	2																							
1- 5-56																												1	1	2	3		2	2	2	4	5	2		2	3			1			1	2	1	1
9- 5-56								1	1		2	3	6	11	16	5	4	2										1			1	3	1	2	2	4	2		1						1	1				
16- 5-56													3	4	4	11	13	5	3	1	1																													
24-11-56																						3	8	17	20	32	53	50	49	11	2	3																		

TABLE IV

Mloto—Haplochromis Mloto

Length MM.	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
Aug. 1955					4	4	6	3	14	27	54	72	121	119	145	200	171
Sept. 1955										4	17	22	47	72	75	83	91
Oct. 1955		2	2	2	8	7	22	31	31	48	80	102	121	134	139	122	167
Nov. 1955						1	2	1	7	3	1	8	12	18	14	25	21
Dec. 1955							1	3	4	3	2	3	12	15	8	16	15
Jan. 1956												1		1		1	2
Mar. 1956	3	5	5	8	13	18	18	22	11	6	6	2	2		3	1	5
Apr. 1956			2	4	8	18	19	25	17	9	5		5	1	4	4	3

Length MM.	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124
Aug. 1955	179	142	94	69	28	10	10	4	2	4	4	6	2	3	4	2
Sept. 1955	115	97	74	86	42	18	2	3								
Oct. 1955	151	110	70	96	49	27	20	7	8	4	1	4	1	4	5	
Nov. 1955	24	16	8	16	9	7	5	4	2	1		3	2			
Dec. 1955	16	17	11	19	17	20	7	5	2			1		2	2	3
Jan. 1956	3	2	1		1	1				1						
Mar. 1956	6	14	13	13	14	10	7	1	1	2						
Apr. 1956	2	11	14	17	5	5	6	1	4							

CHAPTER FIVE

THE FISHERIES OF THE NORTHERN LAKE

1. THE GILL-NET FISHERY IN THE NORTHERN LAKE

A. Introduction

Preliminary investigation in late 1953 and early 1954 showed that there was a possibility that there existed in the northern parts of the lake a gill fishery which was almost completely unexploited by local fishermen, and an experimental programme was undertaken to determine its extent and potentialities.

The steep-to and often rocky shore line, typical of such a large part of the north of the lake, involved a type of gill-net fishery which differed from any previously carried out on Lake Nyasa, or indeed perhaps in Central Africa as a whole, and in many instances, so called standard methods of procedure were ignored or re-examined. In doing so many facts came to light which are of some general interest, and for this reason some of the fundamental and perhaps to some, simple, facts about gill-netting will be discussed.

The earlier surveys carried out on Lake Nyasa had added to the general body of knowledge of the lake, and recommendations on possible extensions of gill-netting were made.

The 1939 survey (Bertram *et al.*, 1942) had set experimental gill-nets of flax, in mesh sizes of 2″, 3″, 4″ and 5″, usually at the surface, and mostly in the southern parts of the lake at Mpondas, Fort Johnston, Monkey Bay and Kota Kota. Other places visited included Bana, Nkata Bay, Ruarwe, Ngara, Karonga, Mwaya and Deep Bay on the Nyasaland side, Likoma Island, and also places in Tanganyika Territory and Portuguese East Africa. None of these were extensively fished and records for them are not included in detail in the report.

Mainly on the basis of fishing at Kota Kota and Monkey Bay, the following observations and recommendations were made:

1. Gill-nets caught a higher proportion of predatory fish than did seine nets or traps.
2. Gill-netting was not an important fishing method in use at that time.
3. Information as to the catch per unit effort and possible variation of this throughout the year was needed.
4. A comparison of locally-made and manufactured nets was not possible then but was necessary in order to make recommendations as to the most suitable type of net and twine, etc.
5. The open waters of the lake should be investigated at the surface and in deeper waters.

Lowe, in her report (1952), suggested an increase in the African gill-net fishery for *Labeo mesops*. She also stressed the need for the development of a fishery which exploited predators, but again her work was almost entirely confined to the south-east, and was indeed a minor part of the report, which dealt comprehensively with the *Tilapia* fishery. She recommended that *Labeo mesops* be fished with gill-nets not less than 4″ in mesh size, that the predatory fishery might best be fished with 5″ gill-nets, and emphasized the importance of exploiting the predatory fishes to maintain or restore the balance of non-predators to predators.

By 1953 the general situation was that there had been an increase in the number of gill-nets used in the south-east arm and other nearby areas, but that in the northern parts of the lake, gill-netting was an almost insignificant part of the fishing effort, and for these parts little information was available.

The present survey set gill-nets in all parts of the lake from November, 1953, to February, 1957, so that the data discussed covers a period of three years. Most of the experimental fishing was done in the immediate vicinity of Nkata Bay, which is in many ways typical of the conditions to be met with in much of the northern areas of the lake.

However other places were visited, and in particular Likoma Island and Chizumulu Island, and the Ruarwe/Usisya area were investigated. In addition, sets were made at Karonga, and the extreme north, and at Bana, Kota Kota, Domira Bay in the south and the south-east. Unlike the usual method of the 1939 survey, nets were set on the lake bed, and in depths ranging to 250 feet. It was early realized that a deep water gill-net fishery for predators was both feasible and practicable, and most of the subsequent investigations were concentrated on this type of fishery.

Nets of sizes ranging from $2\frac{1}{2}''$ to $10''$ stretched mesh were used, but it was found that of the sizes available those above $5''$ could not be considered as economically justifiable, so after April, 1954, nets of mesh size greater than this were not set. Originally only flax nets were available, but later terylene and nylon nets were used, so that a comparison of the catching power of these nets was made possible. Nets of local twines were obviously inferior to any of these, so that it was not felt necessary to investigate their properties in any detail.

It would seem that in Northern Rhodesia, where a tremendous increase in gill-net fishing has occurred in the last few years, nylon nets have been standard, since the time that detailed records were first kept, and there is surprisingly little detailed information available as to the relative efficiency of natural and artificial fibres in African waters. In particular those qualities of nylon and terylene which make it superior as netting to cotton and linen were not realized until relatively recently.

The main objects of the experimental fishing programme were:

1. To determine the possibility of establishing a gill-net fishery for bottom-living fish in the northern areas of the lake.

2. To collect as much information as possible on the general biology of the exploited fisheries in order to increase our knowledge of the fish and to try to come to some sort of estimate of the extent of the fishery.

These objects were not always compatible. On many occasions, for instance, nets were set in places known to be poor fishing grounds so that gaps in our general knowledge could be filled. Generally speaking, the result of this was that the survey nets were not operated under ideal economic conditions. Later in the survey, however, an attempt was made to fish a fleet of nets under the conditions that had been found to be the best. What was demonstrated most clearly was the fact that maximum fishing efficiency could only be obtained by paying great attention to the small, simple, but nevertheless important details of the mounting, laying, handling and care and maintenance of nets, and these details will be dealt with at some length. Local fishermen were almost completely unused to the type of fishing method which was most promising and when, during the survey, some took up the use of manufactured netting, although generally they were quite succesful, they tended to ignore many of the details of procedure which would have improved their catches.

B. Procedure

I. DESCRIPTION OF A GILL-NET

There are two main kinds of nets in use, the seine or moving net, and the gill or entangling net. To the first belongs all kinds of trawls, draw nets, encircling nets and cast nets which enclose all those fish in the volume of water fished which cannot escape through the meshes. Gill-nets, however, are stationary walls of thin twine netting which catch only fish which attempt to pass through the net and which are too big to pass completely through the mesh, but small enough for the head end to enter a mesh. They are therefore much more selective than seine nets and select fish between certain size limits, and only those which are moving through the water. They are sold as lengths of netting, usually in units of 100 yards, this length being measured when the sides of the meshes are all paralled as indicated in fig. 1.

The mesh size is the sum of the length of two adjacent sides of a mesh, AB and BC. AB and BC are referred to as Bars, and their lengths as Bar-lengths. The net as sold is in the " stretched " position, and the stretched length of a net is the total length AC in this position.

II. SOME THEORETICAL CONSIDERATIONS

The gill-net is fished as a curtain or wall of net, being so mounted that the diagonals of the meshes run vertically and horizontally, and the curtain is maintained in position and shape by fastening the net to a head rope bearing buoyant floats, and to a foot rope to which weights are attached. The methods of attachment to the head and foot rope is described as " mounting " the net, and it is of the greatest importance that this should be done correctly. The simplest method is by lacing the mounting ropes through the top meshes and bottom meshes of the net, and this is the method used normally by African fishermen. It is inefficient, and the correct method known as " stapling " is indicated in fig. 2. A light stapling line is seized to the mounting rope and passed through a number of meshes of the net before being seized again at a distance. This is repeated for the whole length of the net, and the distance and the number of meshes threaded can be varied. Generally speaking the larger the mesh the fewer meshes are reeved into the stapling line. This stapling line secures the net firmly to the mounting ropes, at the same time allowing lateral mobility and conferring " looseness " to the net as it hangs.

When mounted the meshes are opened, and form rhomboids. The length is shortened, so that the mounted length is less than the stretched length. Now the maximum area for a rhomboid is given when it is also a square, so that if a net is to be mounted to give the maximum fishing area then all the meshes should be square. Fig. 3 shows a single mesh in that position.

x = bar length = $\frac{1}{2}$ mesh size

y = $\frac{1}{2}$ horizontal diagonal = $\frac{1}{2}$ length of mesh

z = $\frac{1}{2}$ vertical diagonal = $\frac{1}{2}$ height of mesh.

If in the figure, x is the bar size, then y is half the length of the horizontal and z half the length of the vertical diagonal. The height of the mesh is therefore $2z$ and the length $2y$. When mesh is square, $z = y$, as the diagonals of a square are equal.

Area of mesh $= x^2 = 2zy = 2y^2$

so that $$y = \sqrt{\frac{x^2}{2}} = .707x \qquad \text{———} \qquad (1)$$

This means that when mounted to the maximum given area, the diagonal length of a mesh is equal to .707 of the mesh size (stretched). Since the stretched length of a net is the (mesh size) × (the number of meshes in length), the length of a 100 yards stretched net in this position is 70.7 yards. The general formulae connecting bar size, height, length and area of mesh is given by

$$y = \sqrt{x^2 - z^2} \qquad (2)$$

$$z = \sqrt{x^2 - y^2} \qquad (3)$$

$$\text{Area} = 2y\sqrt{x^2 - y^2} \qquad (4)$$

These allow us to give the height and length of the mesh in terms of the bar size and the area of the mesh in terms of the maximum area, when the net is mounted to different lengths from 0 to 100 yards. The information is contained in Table I, and showed in graph form in fig. 4.

TABLE I

Relation between area of gill-net and method of mounting

Y (diagonal = half length of mesh)	*Z (diagonal = half height of mesh)*	*Area of mesh*	*% Max. area*	*Length of 100 yds. stretched net (yds.)*
1.0x	0	0	0	100
.9x	.436x	$.785x^2$	78.5	90
.8x	.600x	$.960x^2$	96.0	80
.7x	.714x	$.990x^2$	99.0	70
.6x	.800x	$.960x^2$	96.0	60
.5x	.866x	$.866x^2$	86.6	50
.4x	.917x	$.734x^2$	73.4	40
.3x	.954x	$.572x^2$	57.2	30
.2x	.980x	$.392x^2$	39.2	20
.1x	.995x	$.189x^2$	18.9	10
.0x	1.000x	$.002x^2$	0.0	0

III. MOUNTING

It follows from the above that a 100 yards mounted on from between 60 and 80 yards will give more than 96 per cent. of the maximum area of the net. Since the diagonal height of mesh = 2z, length = 2y and mesh size = 2x, directions can be easily given to mount any net to any length and for any method of stapling. Supposing for instance a 5″ mesh 26 mesh deep 100 yards net is to be made up to 70 yards.

The height of the net is given by multiplying the diagonal height (as a proportion of x, the bar size) by the mesh size and by the number of meshes deep. In this case it is .714 × 5 × 26 = 92.8″. The head and foot ropes can therefore be laid out along the ground 93″ apart. If the stapling is seized every 4 meshes, then the distance between seizings will be 4 × 5 × .7 = 14″ and a piece of stick 14″ long can be used as a gauge.

For a 4″ 54 mesh net mounted to 80 yards, the distances between head and foot rope will be .60 × 4″ × 54 = 129.6″, and if seized every 5 meshes the distance would be 5 × 4″ × 8 = 16 inches.

The net is fished as a vertical wall of netting and it is extended and maintained in this position by floats on the head rope and weights or leads on the foot rope. Local nets use, as floats, carved pieces of wood tied to the head ropes at intervals, and the weights are usually either soap stone, or more often merely small stones tied to the bottom of the net with strips of bark or local " chopwa " thread. Although these have the advantage of being inexpensive they lead to increased difficulties in laying and cause appreciable damage to the nets in handling.

On the survey nets the head ropes were threaded with centre-bored cork floats and small centre-bored lead or clay weights were used on the foot rope. The corks were 4″ diameter, 1½″ thickness and were mounted at 6 foot intervals. After use in deep water they became crushed by water pressure and lost much of their buoyancy. It became obvious that this loss of buoyancy led to a fall off in the efficiency of the net, and although foam plastic floats are initially far more expensive, they are recommended in preference. Their resistance to high pressures, and the long life that they have compensates for the high initial cost. The weights were moulded from lead and were generally very satisfactory; however, the small clay weights produced and sold by local firms will be cheaper and more easily obtained. The only essential is that the buoyancy of the corks should be sufficient to extend the net vertically and be less than the weight of the foot, so that the net will remain on the bottom, but it was considered that the amount of buoyancy in the head line on the survey nets was insufficient, and should be increased substantially. A recommended method is to use 6″ oval foam plastic floats at intervals of 4 feet.

The head and foot ropes for the survey nets were usually of hemp or light sisal ropes, about ¼″ in diameter, but later nylon cord became available. This had the advantage of being light, flexible, strong and with a much longer life, and it is recommended as being far more suitable. The type used was ⅛″ nylon and was in fact cheaper per yard than some of the hemp and sisal cords used.

The corks and leads were threaded directly onto the head and foot ropes, and this was considered eventually not to be the best method. It will be seen later that it is advantageous to be able to reverse the net by changing over the leads and floats, and it is recommended therefore that the lead and float lines be separate cords seized at intervals to the nylon mounting line to which the net is stapled, as shown in fig. 5

There is a further advantage in this arrangement. The leads during handling and laying, and particularly when laid in deep water, tend to fall through the net meshes and can sometimes not only cut down on the fishing area of the net, but also lead to a great deal of damage when the net is hauled. If, however, they are mounted on a thicker sisal rope, the extra rigidity prevents this happening to any extent. The suggested method is shown in fig. 5. Such a method is used in many gill-net fisheries. It is, however, stressed here as it is unlikely that it would be followed by local fishermen without demonstration and encouragement. If natural fibre ropes are incorporated into the mounting of the net, it is important that first they be soaked thoroughly and then stretched until they snap, as a new rope when wetted will kink and distort the net considerably, besides leading to possible snagging and damage to adjacent meshes.

It was noticed by the survey that often a new net caught relatively few fish in its first laying or two, and this was also reported by users of gill-nets in the south-east arm of the lake. It is almost certainly the result of not stretching the ropes and when this was done, or when old mounting ropes were used on new nets, this initial poor catch or two was eliminated.

IV. SUITABLE LENGTHS FOR MOUNTING

The length to which a 100 yards stretched net is mounted can be varied. For a so-called standard method, " by the third ", three open meshes take up the distance of two stretched meshes, so that a 100 yards net is mounted to 66 yards. It is by no means certain why this should be considered a standard mounting method as little or no information is available as to the relative catching power of nets mounted to

FIG.1.

DIAGRAM OF A STRETCHED LENGTH OF NETTING

CORRECT METHOD OF MOUNTING A GILL NET

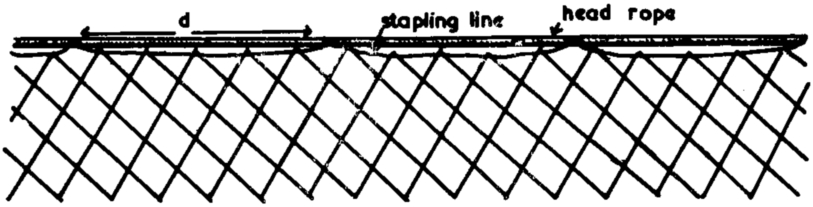


FIG.2.

Instead of being threaded directly on to the head rope, the meshes are threaded on a stapling line which is seized to the head rope at regular intervals 'd'.

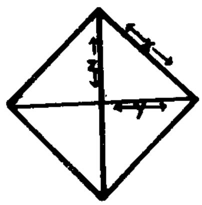
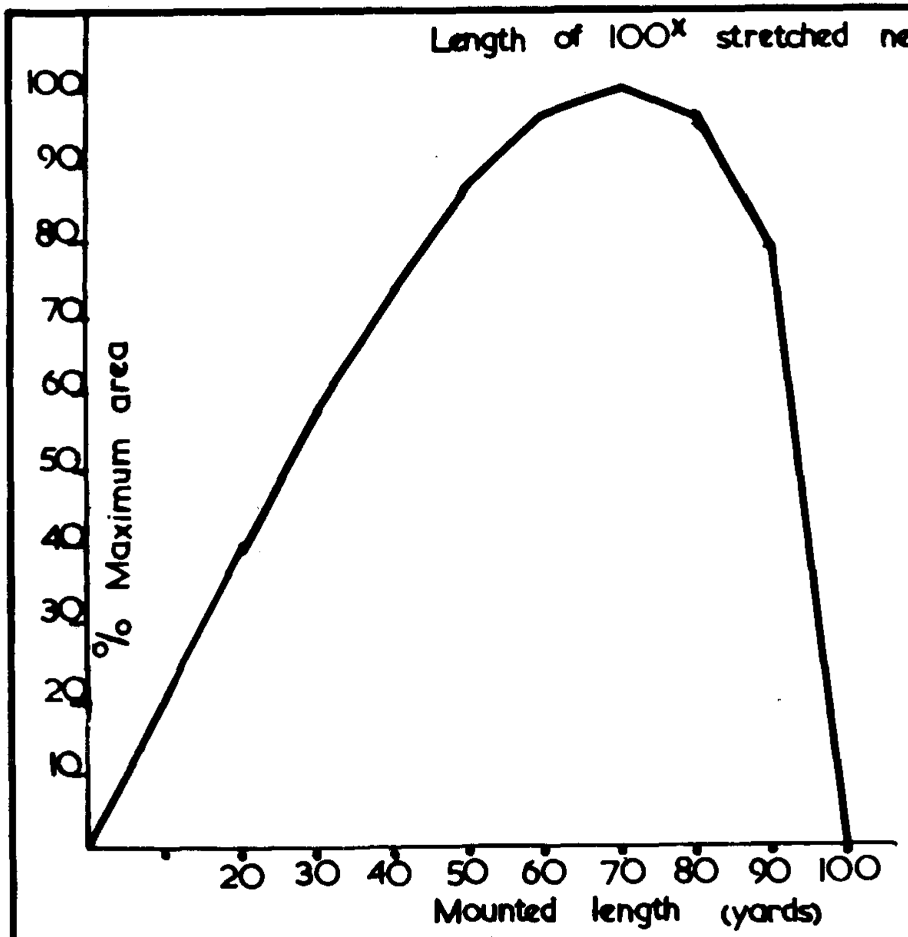


FIG.3.

A SINGLE MESH OF A NET AT ITS MAXIMUM FISHING AREA



RELATION BETWEEN AREA OF GILL NET &
METHOD OF MOUNTING

FIG. 4

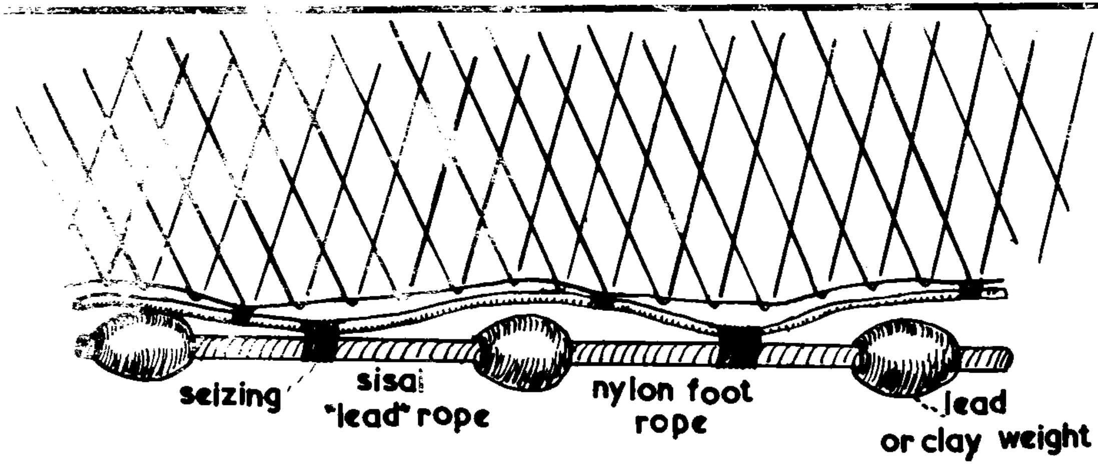


FIG. 5.

METHOD OF MOUNTING WEIGHTS.

different lengths under similar fishing conditions, but it is thought that this, as far as gill-nets are concerned, is a handy rule of thumb that gives in mounting an area which approximates to the maximum area possible. At 66 yards the area of the net is 98.98 per cent. of the maximum.

Apparently it is not usual for nets to be mounted from 100 yards stretched length to more than 66 yards. In Northern Rhodesia, for instance, where extensive gill-netting is carried out, nets are mounted to 60 yards or 50 yards. In fact MacLaren (1956) stated: " the setting of 100 yards of stretched net to 50 yards of rope has been found to be most successful formula for general purposes ". In the Canadian salmon gill-net fishery, setting " by the half " is again standard, but it does not necessarily follow that such a mounting is the best under all conditions.

In view of the number of factors that are involved, which cannot be predicted for any particular type of fishery, an experiment was carried out to obtain data on two methods of mounting.

Two nets were used, both made from 3×100 yards lengths of flax 32/3 twine of 5" mesh and 26 meshes deep. One was mounted 100 yards to 50 yards and the other 100 yards to 70 yards. In each case the stapling was seized every fourth mesh, and over a period of six weeks these nets were fished together, i.e., laid in the same place for the same period. They were laid overnight, and two different types of fishing grounds were chosen, one known to give good catches and the other poor catches. The catches at each laying were strictly comparable and are given in Tables II (*a*) and (*b*), the results from the two stations A and B, being kept separately. The nets are labelled long and short, and the catch is recorded in pounds weight of all species caught at each set.

TABLE II (*a*)

Analyses of catches made from two gill-nets mounted to different lengths. Total weight in pounds per catch

	Station A								*Station B*								
Set No.	1	2	3	4	5	6	7	*Total*	1	2	3	4	5	6	7	8	*Total*
Long net ..	58	21	12	37	40	47	47	262	93	110	116	76	46	93	55	51	640
Short net ..	20	9	10	8	29	38	13	127	17	75	69	21	33	18	12	12	257
	78	30	22	45	69	85	60	389	110	185	185	97	79	11	67	63	897

TABLE II (*b*)

Relative Catches of " Long " and " Short " Nets

Catch of Longest Net / *Catch of Shortest Net*	*Station A*	*Station B*
Ratio per net	2.06	2.49
Ratio per 100 × Length	1.47	1.78

The results are conclusive. At both stations the long net caught more than twice the weight of fish than did the short net. What is more surprising is that the weight caught per unit length of net is 1½ times or more greater for the long net than the short, indicating possibly that the long net is more efficient as a gilling mechanism than the short net, which contradicts the generally accepted impression that " loose " nets are more effective than " tight " nets. This deserves closer examination. It is known, and will be discussed later, that laying nets in deep water may result in one end of the net becoming a " dead space," i.e. ineffective as a fishing mechanism. The length of dead space depends not on the length of the net, but on the depth in which it is laid, and in this case the two nets would be shortened as effective fishing units by the same amount. As the long net catches 2½ times as much fish as the short, it might be that the effective length of this net is 2½ times as great as that of the other, that is, after the "dead space " is deducted, and that the catch per unit fishing length is the same.

The mounted length of this long net is 210 yards and of the short 150 yards, so that assuming this is so and that the " dead space " is x yards we have.

$$(210—x)=2.5\ (150—x)$$
$$x = 110 \text{ yards}$$

The effective length of each net on this assumption would be 100 and 40 yards for the long and the short net respectively, and the dead space 110 yards.

In fact the " dead space " does not exceed 20 yards or so (see Table VI), the dead space being caused by a bunching of the ends in the deep water, and it must be concluded that a 70 yard net is more efficient as a gilling mechanism whether in terms of catch/unit length mounted, or catch per unit length unmounted, for this particular fishery.

V. OPTIMUM HEIGHTS OF NETS

A gill-net laid on the bottom in deep water is catching fish which have a very definite biological association with the substrate, so much so that it is unlikely that their vertical distribution, typically, extends to a great distance above the lake bed. The association is for instance much more marked than is that of pelagic fish to the surface layers of a body of water.

A shoaling plankton feeder which is caught in surface nets might be expected to range for a greater distance below the surface than a bottom feeder would range above the substrate. Herring drift gill-nets, for instance, are usually about 25 feet high and it is unlikely that a bottom feeder or liver would be found in as great a density at this height above the bottom, as at say 5 feet from the substrate. The importance of realizing this is that a high net, i.e. with a large number of meshes between the head and foot rope, will cost proportionally more than a low net. Figures for a recent catalogue show for instance that a 54 mesh 4″ 100 yards 32/9 white cotton costs £4–7s–6d whereas an 18 mesh net of the same type costs £1–10s–0d. The cost is, as would be expected, almost directly proportional to the number of meshes deep. If the higher net extends above the biologically active zone of a bottom-living fish then the top part of the net will catch fewer fish and the catch per 100 yards length would be lower in terms of fish caught for the capital expended, a large part of the net being wasted.

The efficiency of different parts of a 5″ 26 mesh net was determined by recording for each fish caught the mesh above the foot rope in which it was gilled or originally entangled. Over a period of time it was possible to construct a frequency histogram showing the number of fish caught in each mesh, counting from the bottom of the net. Fig. 6 shows the histogram for *Bagrus meridionalis*, and superimposed on it that for all species. Insufficient numbers of the other species were recorded to allow a similar histogram to be constructed for them separately. (The net was mounted 100 yards to 70 yards so that the diagonal height of each mesh was 3.57 inches. This enabled us to convert the mesh number, counted from the bottom, to a height above the bottom). However, it was noted that clariid fishes gave a very similar picture, as also did *Haplochromis heterotaenia*. *Mormyrus longirostris* seemed to be spread more evenly about the net, but the evidence is not conclusive. One interesting point that was observed is that *Bathyclarias foveolatus* seemed to be caught only in the lowest meshes, a fact which fits well with its supposed habit of lurking on tha bottom and dashing out to catch its prey. It is perhaps surprising that *Bagrus meridonalis* and *Bathyclarias* spp. show this distribution, as both are caught also on surface long lines, and the precise reason why *B. meridionalis*, in particular, a predator which in the areas fished by the survey at Nkata Bay feeds largely on a shoaling, plankton feeding fish should be caught so near the bottom is not yet known. In Table III the figures are expressed as cumulative numbers and percentages, the figures for *B. meridionalis*, and all the fish caught in the net being shown separately. For example, of the 523 *B. meridionalis* caught in the 26 mesh net, 332, or 63.1 per cent. were caught in the 13th mesh or below.

TABLE III

Percentage of fishes caught at varying heights from the bottom in a bottom-set 26 mesh gill-net

	Bagrus		All Species		
Mesh number of 26-mesh gill-net	*Total fish caught at and below mesh Number*		*Total fish caught at and below mesh Number*		*Height inches of mesh Number*
	Cum. No.	*Cum. %*	*Cum. No.*	*Cum. %*	
Bottom mesh					
1 ..	2	.4	2	.4	3.57
2 ..	14	2.7	15	2.6	7.14
3 ..	34	6.5	38	6.5	10.71
4 ..	63	12.0	68	11.6	14.28
5 ..	98	18.7	106	18.1	17.85
6 ..	130	24.9	143	24.4	21.42
7 ..	150	28.7	168	28.7	24.92
8 ..	193	36.9	218	37.2	28.56
9 ..	217	41.5	233	39.8	32.13
10 ..	243	46.5	263	44.9	35.70
11 ..	263	50.3	287	49.0	39.27
12 ..	291	55.6	321	54.8	42.84
13 ..	332	63.5	365	62.3	46.41
14 ..	368	70.4	402	68.6	49.98
15 ..	385	73.6	422	72.0	53.55
16 ..	419	80.1	462	78.8	57.12
17 ..	430	82.3	486	82.9	60.69
18 ..	446	85.3	503	85.8	64.26
19 ..	463	88.5	522	89.1	67.83
20 ..	482	92.1	543	92.7	71.40
21 ..	498	95.2	559	95.4	74.97
22 ..	507	96.9	569	97.1	78.54
23 ..	516	98.7	578	98.6	82.11
24 ..	521	99.6	584	99.7	85.68
25 ..	522	99.8	585	99.8	89.25
26 ..	523	100.0	586	100.0	92.82
Top mesh					

The figures in Table III can be taken as a measure of the density of fish in the layer above the bottom, and indicate that the density falls off fairly rapidly above about 5–6 feet. For a net of a given specification it is now possible to indicate the best method of mounting which would ensure that the length is as great as possible, while the height is such that the zone of the maximum density is covered.

For example let us consider a 4″ net 26 meshes deep and mounted to 60 yards. Its height, calculated from the formula given above, is 83.2″, which would include 99 per cent. of the fish caught in the 5″ net for which figures are given above. The product of length and this percentage gives a measure of theoretical fishing power which can be compared with that obtained for the same net when mounted to a different length, and for the net being considered now the comparative figures are 594, when mounted to 60 yards, and 665 when mounted to 70 yards.

It is possible to extend this type of calculation to other types of net, for instance 18 mesh nets, whether 5″ or 4″, and recommendations can be made as to the optimum mounted method for each.

Generally speaking, the best lengths a 100 yards net should be mounted to are on this basis greater than the so called standard mounts, but it has already been shown that this results in a greater catch for the 5″ 26 mesh net and there are other indications that such a mount would be expected to catch more fish.

Thus, the standard method for the Canadian gill-net fishery for salmon is " by half " i.e. 100 to 50 (Peterson, 1954), and the object of this is to mount the nets so that the diagonal height of the mesh is the same as the height of the fish expected to be caught. Since for this fish the height is greater than the width, this amounts to changing the shape of the mesh so that it fits more accurately the shape of the fish. Now *Bagrus* and *Bathyclarias* species are flattened dorso-ventrally; they make up the bulk of the catch in the deep water fishery, and in mounting the net to 70 yards, the mesh is also flattened dorso-ventrally. It is probable that this factor plays a part in the increased efficiency of this method of mounting (fig. 7).

That the maximum density of the fish exploited by deep water fishery in Lake Nyasa does not extend to a great height above the bottom is confirmed by the fact that a 54 mesh 4″ net catches *Bagrus* and clariids mainly in the bottom half of the net, and confirms that for a number of reasons mounting should be to greater lengths.

Recommended mounting methods for different types of nets are given below, but it must be realized that they apply only to the deep water fishery for predators, and do not necessarily apply to say the *Tilapia* fishery in the south-east arm of the lake, or to gill-netting for *Labeo mesops*. It would be necessary in each case to determine the distribution above the botton of these fishes before such recommendations could be made.

(1) The height of mounted nets should be about 6 feet.

(2) This height can be obtained by mounting in the following ways:

5″ 26 mesh 100 to 80
5″ 18 mesh 100 to 70
4″ 26 mesh 100 to 75

(3) It is not recommended that nets be mounted to less than 70 yards.

(4) Nets of depths greater than 26 meshes are not recommended.

VI. OPTIMUM LAYING DEPTH

The gill-net fishery being discussed is characterized by the relatively great depth in which the nets are laid. The best types of fishing grounds were found to be at a short distance from a rocky shoreline in depths between 20 and 70–80 metres, and an attempt was made to determine the relative density of fishes between these limits, to see how it varied, and to find out the depth at which the best catches could be obtained.

(a) *Depth Distribution Method*

The type of net used was of 5″ mesh and was 26 meshes deep, fished as a unit of 300 yards made up to 210 yards. As the floats were attached to the head rope at intervals of six feet, the number for each net was 103, and counting the number from the end hauled first gave a measure of the length of net hauled and could be used to indicate the position of each fish caught.

The nets were set in a number of places of varying depth, so that a range of from 20 to 90 metres was covered. As the net was hauled the position of each fish was recorded by noting the number of the cork adjacent to it. A numbered cardboard tally was placed under the gill cover so that the position of each fish examined in the laboratory could be determined.

The depth was recorded by hand sounding at the end lifted first when the buoy rope was stretched and vertical, and at intervals as the net was hauled. This was usually done as the 25th, 50th and 75th cork were hauled aboard, and finally the depth at the other end of the net was sounded.

The first sounding gave the depth at the end of the net, but reference to fig. 8 shows that subsequent depths do not give the depth at the position in the net represented by the cork counted as the sounding was made. If h was the depth recorded as say the 25th cork was hauled, then it represented the depth at cork number $25+h/d$, where d is the distance between corks. It was possible therefore to draw a graph representing the depth profile of the net and by reference to the number of the cork recorded with it the depth of each fish was determined, and a depth distribution was compiled. A typical graph is shown in Table IV and fig. 9.

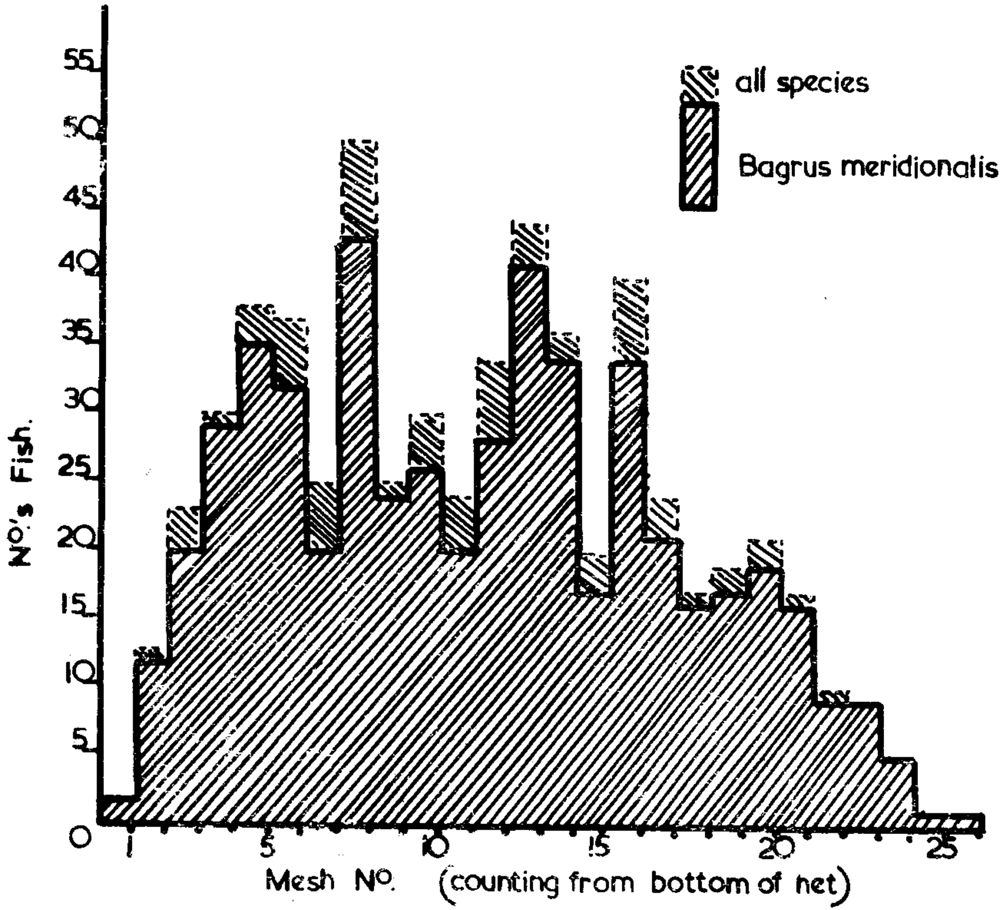
TABLE IV

Data from which depth profile of net is constructed

Depth measured (Metres)	11	27	42	52	53
Cork Number (as counted in boat) $= n$	0	20	45	70	77
Cork Number (at depth recorded) $= n + \frac{Depth}{d}$ ..	0	33	66	96	103

Depth taken at end of net when buoy rope vertical.

It remains to determine the fishing effort at each depth, which was done by dividing the depth range for each set of the net by the length of the net and assuming that each increment of depth was fished by a length of the net represented by the quotient. Summing up for all of the sets gave the fishing effort at each depth and hence the density in terms of fish caught per unit effort could be calculated for different depths. The results are given in intervals of 10 metres, and are shown in Table V.



DISTRIBUTION OF FISH IN 5"26 mesh GILL NET.

FIG.6

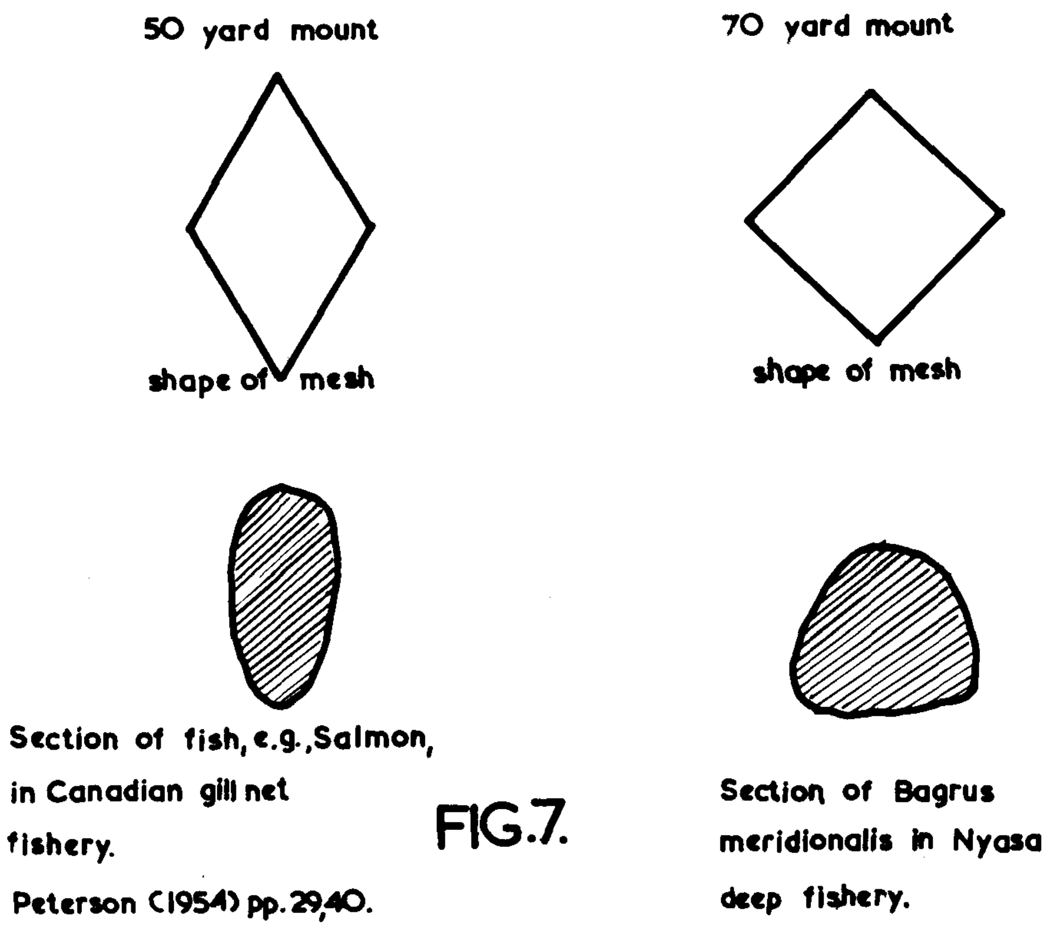
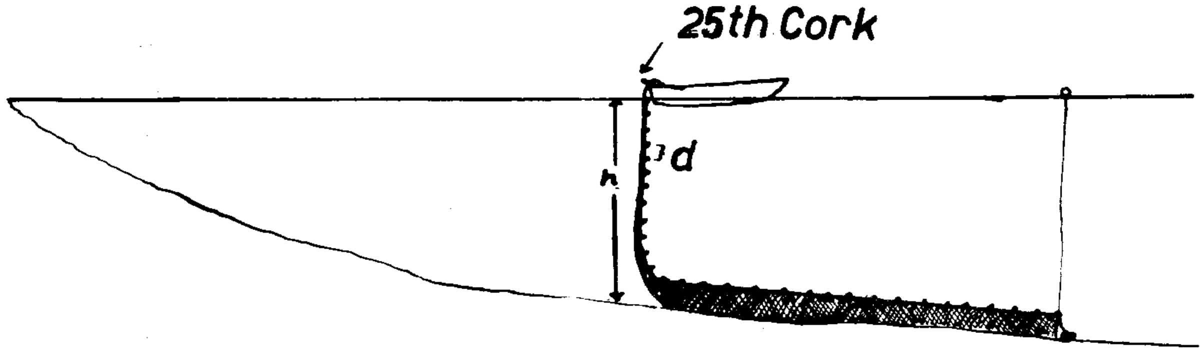


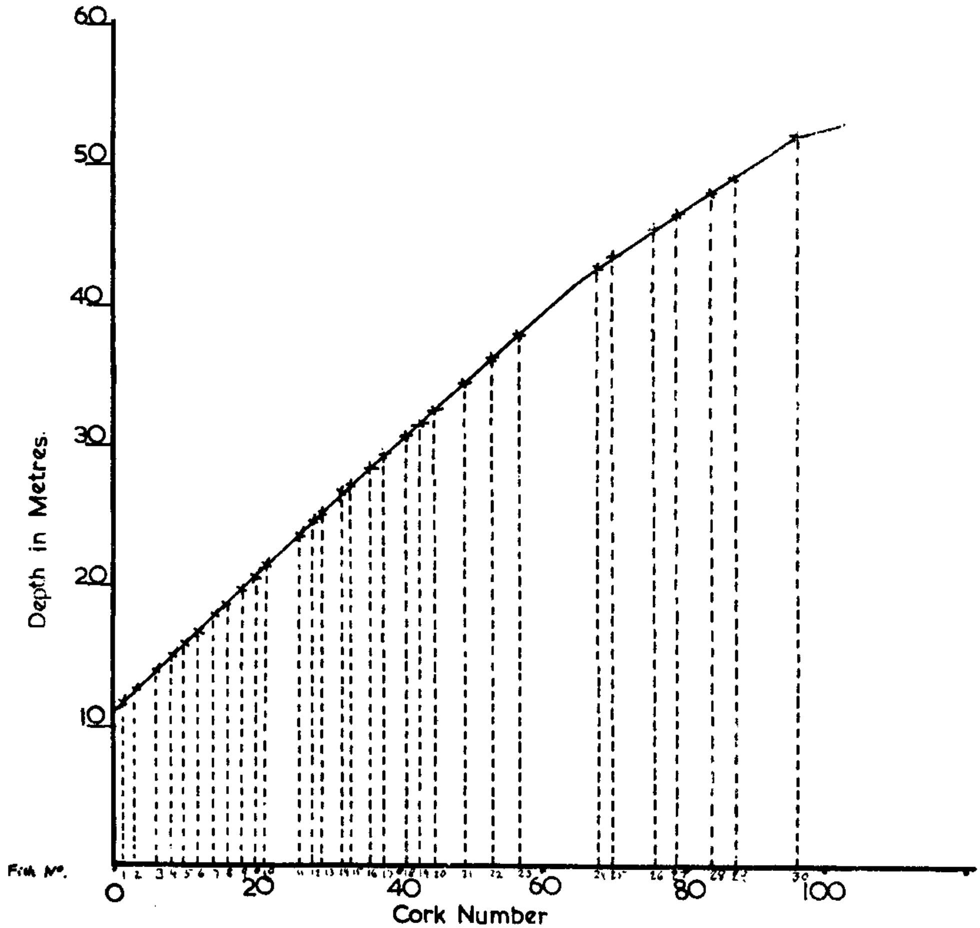
FIG.7.

RELATION BETWEEN FISH AND MESH SHAPE IN TWO TYPES OF GILL NET FISHERY.



To show means of determining depth profile of gill net.

Fig.8.



TYPICAL DEPTH PROFILE.

(Position of individual fish marked by crosses)

FIG.9.

TABLE V

Relative Depth Distribution 5″ Gill Net

	Range of Depth (Metres)							
	10 20′	20 30′	30 40′	40 50′	50 60′	60 70′	70 80′	80 90′
Fishing Effort	73.5	147.3	162.6	162.6	117.7	76.2	77.8	73.5
No. Fish	19	37	39	33	19	15	12	12
No. of Fish/Effort ..	1.9	2.52	2.46	1.87	1.62	1.90	1.56	1.63

(*b*) *Results*

The greatest density was found at between 10 and 40 metres but there was relatively little variation between 20 and 70 metres and this range would appear to be the optimum range. It was not possible to determine the effect of the slope of the bottom on the catch per unit effort, but the impression gained was that too steep a slope led to relatively poor catches. In any case it is advisable that for any area that is to be the subject of development the approximate nature of the contours of the lake bed be examined. It was found that until this knowledge was acquired poor catches often resulted from the nets being laid in very unsuitable places and local fishermen do not have the necessary knowledge to avoid this.

Although the depth distribution has only been investigated for one species, *Bagrus meridionalis*, this species accounts for 65 per cent. of numbers and 75 per cent. of the weight of the fish in the 5″ net, and the information can be accepted as applying to the net as a whole. The 4″ net would give a similar picture, but there is here another factor which can be taken into consideration. The 4″ net during the months of August, September and October, catches larger numbers of the bottom living form *Mormyrus longirostris*, and from observation this fish would appear to have a lower limit of occurrence than *Bagrus meridionalis*. It is caught for instance in water as deep as 80 metres, and it may be profitable for this net and at this time of the year to lay it in deeper water. The recommendations are therefore:

(1) The optimum depth range for the deep water gill-net fishery lies between 20 and 70 metres with the greatest catch occurring at a depth of between 30 and 40 metres approximately.

(2) For 4″ nets it may be possible to extend this range, and fish deeper waters during certain months of the year.

(3) Areas which are being developed should initially be surveyed by sounding so that the most promising grounds in this respect can be indicated.

VII. LAYING OF NETS

The object of laying a net is to ensure that in its fishing position it is stretched to its full length along the bottom, and while this is readily managed in shallow water, it is by no means so easy when laid in deep water. As a result the net is bunched up along the long axis and, beside losing actual fishing length, may also lose fishing efficiency owing to deformation of the meshes.

Some loss of fishing length is unavoidable in deep water, especially if the net is laid from one boat, as is of course usual and most convenient, but this loss is minimized if the net is laid from shallow to deep water, and if it is laid as quickly as possible and kept stretched as tightly as possible during laying. A further advantage is gained if after the net has been completely paid out, the buoy rope is let out slowly while the net is being stretched in the direction of the lay.

It has sometimes been noted that the buoys at the ends of a net 200 yards long are often only about 100 yards apart, indicating poor laying, and almost invariably this has resulted in poor catches.

Rapid laying is probably the most important single factor which can result in a good lay, but this is not possible if the nets are badly mounted and stowed. The small stones commonly used by local fishermen can cause serious snagging in the boat or canoe, and besides giving a bad lay can also cause serious damage to the nets as they are handled. If, however, the suggested method of mounting is followed, and the nets are placed in the boat on a tray near the gunwale level, much better results can be obtained, and efforts should be made to impress the need for such precautions. There still remains an unavoidable loss of the efficiency at one end of the net, the end to be laid last, and a " dead space " results.

The extent of this " dead space " can be determined from data collected for the depth distribution of *Bagrus meridionalis*. Since the position of each fish in the net was recorded, the number of fish caught in each section from the shallow to deep end of the net can be given according to Table VI, compiled from records taken for the depth distribution.

TABLE VI

Number of fish caught in each section of a 210 yard gill-net (distance measured from shallow end)

Distance in yards	20	40	60	80	100	120	140	160	180	210
Number of fish	30	46	29	23	32	34	32	28	25	12

The higher catch recorded in the second 20 yards is accounted for by the fact that this section was often laid in the depth at which the maximum density of *B. meridionalis* was recorded. There is definite evidence that the last thirty yards of net is much less efficient than the rest. Only one end is affected, the other end was the end laid in shallow water and fishes efficiently. It was noticed however that if the net was laid so that both ends came to lie in deep water a relatively dead space was found at both ends of the net, and that the ends of the net fished particularly badly in relation to the middle if the net was also laid badly.

VIII. CARE AND MAINTENANCE OF GEAR

The cost of manufactured gill-nets is high compared to the cost of fishing gear locally made and used at present in the northern parts of the lake. For this reason it is essential that the fullest life be extracted from them so that the return on the capital investment involved in the purchase of gill-nets be as high as possible.

Generally speaking nets used by the survey were not fished to their greatest capacity, and flax nets were rarely in use after 20 layings. Even nylon nets, which have the advantage that they are rot-resisting, did not have as great a life as might be expected. In both cases the limiting factor was not the deterioration of the fibres as a result of immersion. This of course is far more important for natural fibres than it is for nylon which is relatively unaffected by bacterial action, but even for flax nets which showed a great fall in catching power the loss of tensile length of the fibres was not very great, and certainly not enough to account for the decreased efficiency. The nets were, however, very much more affected by physical damage which was caused in a number of ways.

Much of this occurred in the handling of the nets, particularly in the early part of the survey when the fishing staff were inexperienced. Snagging by the weights and corks, particularly during laying, did on occasions result in quite substantial damage, and the importance of minimizing this type of damage cannot be overemphasized. Perhaps the point most to be stressed is that the use of proper weights, floats and mounting ropes, although initially more expensive, is more than repaid in ease of handling and mitigation of damage.

The snagging of nets on the bottom occasionally caused great damage during hauling but it was found that as the fishing grounds became better known this became relatively infrequent.

What was and is the most important single factor which is responsible for the curtailment of the fishing life of the nets is the damage caused by the fresh water crab *Potamonautes lirragensis* Rathbun. This attacks fish caught in the net, becomes very badly entangled, and in its efforts to free itself, cuts the twine of the net. Nylon and especially terylene nets are particularly vulnerable to this type of damage, and in one case, a terylene net was so badly attacked that in a single night one section of twenty yards was almost completely destroyed, and further damage was caused in other parts of the net.

No complete answer to this problem has yet been found, as the crab is apparently most abundant in the type of habitat which is also the one preferred by the fish which are mainly being caught in the northern lake, but simple precautions can help to cut down the damage to the nets.

It was found, for instance, that the crab occurred in greater numbers if hauling of the net was delayed until later in the morning after laying, so that the hauling of the nets should be attempted as soon as possible after day-break. Again, if the crabs were allowed to remain in the nets as they were put into the boats after hauling, they became even more entangled and more destruction of meshes resulted. They should therefore be removed as soon as possible, and removed with care. A number of meshes may be taken up together by the claws which should be prised apart before the twine is removed. Attempting to pull the twine through the closed claw is usually attempted, and invariably results in the twine being severed. Apart from these precautions it is necessary to repair the damage as soon as possible, but this is normal practice with African fishermen. Although deterioration of the fibres is not the main factor which limits the useful life of nets, it is nevertheless important that normal rules of net maintenance be emphasized. The two important points are firstly that neither flax nor nylon fibres maintain their strength if exposed to sunlight, particularly important, of course, in the tropics, and secondly, that the nets should be thoroughly washed after each lay. Although nylon nets are rot-resisting, they become badly discoloured after use, and it is recommended that all nets be not only washed but soaked periodically in a disinfectant.

Most of the damage to the nets is found in the bottom part of the net. Bottom snagging is confined to this part, of course, but it seems also that crab damage is also concentrated here. This is probably the result of (1) that fish are caught in greater numbers here and (2) crabs tend to attack the fish nearest the bottom which are most easily reached. As a result nets which are quite badly damaged can be improved as far as fishing power is concerned by reversing the net. The corks on the head rope can be removed and the lead line taken off and changed. It is for this reason amongst others that the use of a separated lead line is suggested.

C. The Experimental Gill–Net Fishery

I. GENERAL

The area of the lake that can be exploited by deep water gill-netting is confined to a relatively narrow band within the 100 metre mark, and it is unlikely that any attempt to extend this will be successful. Further, our experience has shown that it is unlikely that surface gill-netting will ever be justified either inshore or in open waters of the lake. Nevertheless, the combination of physical, hydrological and biological factors which result in the relative productiveness of the inshore zone provides a sound basis for a substantial fishery with bottom-set nets, which is hardly touched at present. It must be realized, however, that development of such a fishery for the steep rocky northern lake cannot be designed to result in any large scale individual fishing industries on the lines already found in the south-east arm. The area that can be fished from any one spot is usually small, and the fishing unit recommended in this report is a small one of one or a few fishermen, each concerned with a stretch of coast near the fishing base, and not venturing more than a mile or two up and down the coast. Under these conditions the main, almost entire, expense of fishing would be the cost of replacing and maintaining fishing gear. The success of any development scheme will depend as much on the availability of the most suitable gear at a reasonable price as on the introduction and demonstration of the methods themselves. This question of economics is most important, and every effort should be made, by the introduction of buyers' co-operative societies or otherwise, to ensure that gill-nets, rope and other fishing gear is made available for sale at a reasonable price.

At present the supply of gill-nets in the northern part of the lake is maintained by one or two trading firms, and while since operation began in 1953, a number of manufactured gill-nets and gear have been purchased by local fishermen, neither the supply nor the choice is at the moment as efficient as it could be and as it eventually should be. From observation, the best results would be obtained by concentrating on a small variety of types of net which can be relied on to " move " quickly, and it is the object of this section of the report to recommend those types of net which are considered to be the most efficient in the sense that the greatest return is obtained for the capital outlay.

II. SMALL-MESH NETS

The possible types of gill-net that can be marketed is extremely numerous, and the list given in Table VII enumerates those which have been used by the survey.

TABLE VII

Gill-nets used in the J.F.R.O. Survey

Mesh size	*Depth (mesh No.)*	*Twine*	*Twine size*
2½″	54 m	Flax	32/2
3″	54 m 18 m	Flax Nylon	32/2 Mwai No. 3
3½″	54 m 54 m	Flax Nylon	32/2 No. 3
3¾″	54 m	Nylon	No. 3
4″	54 m 54 m 20 m	Flax Nylon Nylon	32/3 No. 6 No. 6
5″	26 m 26 m	Flax Nylon	32/3 No. 6

Generally speaking nylon and terylene nets are more expensive than flax nets. The cost of a net is proportional to the number of meshes deep, and to the weight, and the smaller meshed nets are slightly more expensive than larger ones. It is convenient to discuss each type of net in turn.

(a) 2½″ Net

The only type used was flax, 54 meshes deep and with twine type 32/2. These nets are usually mounted in 200 yard units (3×100× nets made up to 200 ×) and were fished in shallow water, rarely below 30 metres. The reason for this was that preliminary experiments with such a fleet, set deep, indicated a very much lower return than that obtained with a larger mesh net. Such a small mesh would also catch immature specimens of the predatory fish which were the subject of the deep water fishery, and it was thought possible that they could economically be used to fish the smaller species found near the shore. The 2½ and 3″ net were usually laid together and usually near deeper set nets of larger mesh.

Table VIII gives the catch characteristics for the Nkata Bay area for the 2½″ net.

TABLE VIII

Catch characteristics of 2½″ gill-nets at Nkata Bay

No. sets	*No of 100× units*	*Total No. fish*	*Av. No.*	*Tot. wt. lb.*	*Av. wt. lb.*	*Av. wt. fish*		*Wt/100× wt/set*
						oz.	*grs.*	
58	92	1,254	21.6	564.3	9.74	7.2	204g	6.1 lb.

Since the cost of a net of this type is very high, a net of this size cannot be recommended for this type of fishery, and can be discounted as an economic proposition at present. The use of such a net for other types of fishery, particularly that of *Labeo mesops* in the areas where it is found in abundance, cannot be entirely ruled out, but the question will be discussed later.

The biological information gained from this type of net is nevertheless of value and interest, and Table IX indicates the species caught during its use.

TABLE IX

Main species caught in 2½″ gill-nets

Analysis of fishes caught in 2½″ gill-nets

Species	*Total Number caught*	*Percentage occurrence*	*Number per set*
Haplochromis spp.	561	46.7	6.10
Labeo cylindricus	422	33.7	4.60
Labeo mesops	82	6.5	0.89
Barbus spp.	67	5.3	0.73
Bagrus meridionalis	59	4.7	0.64
Rhamphochromis spp.	12	1.0	0.13
Lethrinops spp.	11	0.9	0.12
Bathyclarias worthingtoni	9	0.7	0.10
Mormyrus longirostris	5	0.4	0.03
Tilapia spp.	5	0.4	0.05
Mormyrops deliciosus	7	0.6	0.07
Barilius spp.	4	0.3	0.04
Others	10	0.9	0.11

The variation in catch throughout the year was considerable. In the early months of the year the catch/unit effort was higher in weight of fish, and in May, June and July higher in numbers of fish. These conditions were the result of larger numbers of *Labeo cylindricus* being caught in December, January and February and of *Haplochromis quadrimaculatus* during the latter months.

Labeo cylindricus is the commonest species caught by this net under these conditions, and the increase in numbers found during the early months of the year is associated with the breeding season, which for this species is relatively short and well marked.

It would appear that the increase is the result of an increased activity of the fish rather than a migration from deeper waters during the breeding season, the phenomenon of increased catches at such a time without an increased density of fish on the fishing ground being a common occurrence in this type of gill-netting.

There is a very marked selectivity of the males by the 2½" gill-net, and the overall sex ratio is 64 per cent., which is, however, probably accounted for by a marked selection of males during the breeding season, which weights the overall ratio. This will be discussed further in the list of fishes at the end of the report.

Labeo mesops was not caught unless the net was set away from the rocky substrate and appeared in the catch early in the breeding season in the early months of the year. *Bagrus meridionalis* is caught all the year round and no seasonal variation is obvious.

The relatively small numbers of *Mormyrus longirostris* indicates that it does not normally extend to the biological range fished by the net. It represents only 0.7 per cent. of the catch whereas in deeper-set nets it may form 40 per cent. of the catch in numbers in the 4" gill-net.

The percentage numbers of *Mormyrops deliciosus* is very low, but is not markedly different from that of the larger mesh nets set in deeper waters and it is likely that its distribution along steep to, rocky shores is fairly uniform both for depth of water and size of individuals. It cannot, however, be considered a normal inhabitant of this zone.

The species of *Barbus* include *B. johnstoni*, a very common fish of shallow sandy shores, and *B. eurystomus*, which prefers more rocky habitats, but most of the 67 specimens are accounted for by individuals of *B. rhoadesii*, a mild predator of other fishes, caught in January and February, 1956. At this time *B. rhoadesii* appeared in numbers in long line and chilimila catches; many were in breeding condition, both males and females occurring together, and it is likely that the fish shoals in reasonable numbers at this time of the year for breeding purposes.

The species of *Haplochromis* caught include *H. trimaculatus*, *H. woodi*, *H. macrostoma*, *H. tetrastigma*, *H. kiwinge*, *H. euchilus* and *H. serenus*, and it was noticeable that a large proportion of the specimens were at or near breeding condition. It would thus appear that many of the fishes, especially Haplochromids, are caught during the period of breeding, either by reason of their increased activity and range of movement at this time, or because they move close inshore, especially to this rocky habitat, for the purpose of spawning. During May, June and July, for example, a very large proportion of the Haplochromids caught was represented by *H. quadrimaculatus* (mbarule) which come inshore to breed at this time.

For this species the 2½" net catches a very high proportion of breeding males while the 3" catches a large proportion of breeding females. This is another example of the selectivity of gill-nets. It was at one time thought that the small-mesh nets at this time of the year might be used to exploit this species, but the average weight of the fish caught in the 2½" net is low (3 oz.) and the numbers caught per 100× do not justify its recommendation.

(*b*) *The* 3″ *net*

These nets, nearly always of flax 32/2 ply and 54 meshes deep, were set with the 2½″ nets. Whilst they also did not appear to be of any real economic use under these conditions, they nevertheless afforded interesting comparisons with the 2½″ nets.

The catch characteristics for the Nkata Bay area are given in Table X

TABLE X

Catch characteristics of 3″ nets at Nkata Bay

No. sets	*No. of 100× units*	*Tot. No. fish*	*Av. No. set*	*Tot. wt.*	*Av. wt. set*	*Av. wt.*	*Av. wt. set per 100× lay net*
90 ..	175	1,090	12.1	899 lb.	10.1 lb.	13.2	5.14 lb.

The catch /100× per set is a little below that for the 2½″, and well below that economically justified.

The catch in numbers of each species is given in Table XI

TABLE XI

Analysis of fishes caught in 3″ gill-nets, with the numbers per set of the 2½″ nets included for comparison

Species	*Total number caught*	*Percentage occurrence*	*Number per set*	*Number per set for 2½″ (Table IX)*
Labeo cylindricus	529	48.5	3.02	4.6
Haplochromis spp.	221	20.3	1.26	6.1
Bagrus meridionalis	92	8.4	0.52	0.64
Labeo mesops	90	8.3	0.51	0.89
Rhamphochromis spp.	28	2.6	0.16	0.13
Clarias spp.	21	1.93	0.12	0.10
Mormyrops deliciosus	21	1.93	0.12	0.07
Barbus spp.	18	1.7	0.09	0.73
Mormyrus longirostris	13	1.2	0.08	0.05
Barilius spp.	7	0.65	0.04	0.04
Others	50	4.6	0.29	0.29

The comparisons between the numbers caught per set in the 2½″ and 3″ nets are interesting. 2½ inches is clearly the optimum size for the shallow-living *Haplochromis*, and the difference in numbers is particularly attributable to the fall-off in numbers of *Haplochromis quadrimaculatus* in the larger net. While none of these nets were set in the true habitat of *Labeo mesops*, the fact that nearly twice the number were caught in the 3″ net is indicative that the larger size is the more useful one for this species. The Mormyrid figures are consistently low for both nets indicating that these fishes do not inhabit the shallow rocky localities fished by these nets to any great extent. The depth preference of *Mormyrus longirostris* can be seen in that in these shallow set nets it is less abundant than *Mormyrops deliciosus*, while the reverse is true in the deepset large-mesh nets (cf. Tables XVIII-XX).

Although the small-mesh nets were usually set inshore in shallow water, some were set in deeper water, with the 4″ and 5″ mesh nets. The catch/unit effort was below what is considered economically practical but the figures representing the proportion of each species caught are of interest and are shown in Table XII. The nets were 3″, 3¼″ or 3½″, and will be treated together.

TABLE XII

Numbers and percentages of fishes caught in 3″, 3¼″, and 3½ gill-nets set deep

Species	*Number Caught*	*Percentage of Catch*
Labeo cylindricus	94	27.3
Bagrus meridionalis	88	25.6
Haplochromis spp.	54	15.7
Mormyrus longirostris	37	10.7
Bathyclarias spp.	24	7.0
Mormyrops deliciosus	11	3.2
Labeo mesops	11	3.2
Rhamphochromis spp.	10	2.9
Barbus spp.	8	2.3
Barilius spp.	3	0.9
Others	11	3.2
TOTAL ..	341	100.0

The average weight of fish caught in one of these nets of 3½″ mesh was 16.6 oz., and the average number of fish caught per set for all these was 7.5. It was quite clear that on economic grounds no net smaller than 4″ mesh would be recommended, in the northern lake, for the rocky shore type of fishery (although they may be of use in the *Labeo mesops* fishery), and most of the experimental fishing programme was carried out using nets of larger size.

III. LARGE-MESH NETS

(*a*) *General*

At first, nets of mesh sizes from 5″ to 10″ were used, but it soon became obvious that of these only the 5″, and possibly the 6″ nets, could be fished economically. Later it was found that the 6″ mesh was probably too large, and only 5″ nets were used in deep water until June, 1954, when 4″ nets became available. These 4″ nets were 54 meshes deep, whereas the 5″ and larger sizes were in all cases 26 meshes deep.

Table XIII lists the results obtained for the three main types of nets when used to exploit the predatory and bottom living population, and refer mainly to the Nkata Bay area. Records for the flax and nylon nets are combined, a comparison of the relative efficiency of natural and artificial fibres being dealt with later.

The unit of fishing effort is a single set of a net 100 yards stretched length. Although it has been suggested that the standard unit for catch comparison be a set of nets 100 yards when mounted, the use of the stretched length relates catch more directly to the cost of net, which is the most important factor to be considered. Thus, if there is any advantage in mounting the net to 75 yards instead of the more " usual " 66 yards, this will give a greater catch per 100 yards stretched net, but would not necessarily be reflected in the catch per 100 yards mounted net.

TABLE XIII

Results for the three sizes of large-mesh net used

Net	*No. of sets of unit*	*Total No. fish*	*Total weight lb.*	*Average No./unit*	*Av. wt. fish*	*Av/wt/set lb.*
4″ 54m	308	2,746	5,880	8.92	2.14 lb.	19.09
5″ 26m	711	3,018	12,376	4.25	4.10 lb.	17.41
6″ 26m	50	68	456	1.36	6.71 lb.	9.12

While the catch per unit effort is highest for the 4" net, it must be remembered that this net has twice the number of meshes and is twice as expensive, so that if the return on the cost of the net per unit effort is considered, the 26 mesh 5" net is more satisfactory. Other points of interest are that the number of fish caught per unit effort falls off as mesh size is increased, but that there is a marked increase in average weight. This increase follows closely the assumption that the average weight is proportional to the cube of the mesh size, and the constant for each net is given in Table XIV.

TABLE XIV

Relation of average weight of fish (lb.) to mesh size (ins.)

$$K = \frac{\textit{average Wt. of fish in pounds} \times 100}{(\textit{mesh size in inches})^3}$$

Mesh size	*K*
4"	3,344
5"	3,280
6"	3,106

Direct comparison of the catch per unit effort with those recorded for other parts of Africa is not easy, because there is so much variation from place to place in method of mounting, size of mesh, depth of net, method of laying, and other factors, all of which can influence the catch per unit effort, but Table XV (after Maclaren, 1956), for different places in Northern Rhodesia gives some indication of the relative productivity of this deep water gill-netting, when compared to areas which are already being fished commercially.

TABLE XV

Relative productivity of gill netting from various parts of Central Africa

Locality	*Mounting*	*No. meshes*	*Mesh size ins*	*Catch/100 × (mounted) lb.*	*Catch/100 × (stretched) lb.*
Kafue River	100/50	24	4	98.8	49
Zambesi	100/50	24	4	61.1	30
Lake Bangweulu	100/60	20	5	30.7	15
	100/60	24	4	9.0	4.5
Lake Chisi	100/60	24	4	92	46
Lake Mweru	100/60	24	4	31	18.6
Nkata Bay	100/70	54	4	27.3	19.0
	100/70	26	5	24.9	17.41

The Northern Rhodesia records refer in every case to nylon nets, whereas the Nkata Bay records include both flax and nylon nets, and bearing in mind the greater efficiency of nylon nets, the deep water fishery being discussed appears at first sight to compare favourably with the gill-net fishery of Lake Mweru, which is fished heavily by about 800,000 yards of gill-nets over nine months of the year. However, conditions in the two areas are very different; the fishery at Lake Mweru takes place over a wide area of shallow fertile water, while in northern Lake Nyasa it is limited to a narrow strip of inshore, steeply shelving coast which rapidly becomes too deep for exploitation. Furthermore, damage to gear by snagging on rocks and especially by crabs is a negligible factor in Lake Mweru, while in northern Lake Nyasa both assume very serious proportions and may severely hamper an economic fishery.

(b) *Characteristics of large-mesh gill-nets*

(i) *Average weight of fish*

Table XVI shows the average weight (in oz.) of fish for each species caught in the three nets under consideration.

TABLE XVI

Average weight of fish (in ounces) caught in three large-mesh gill-nets set deep

Species	*4″ Net*	*5″ Net*	*6″ Net*
Bathyclarias spp.	46.97	85.87	107.36
Bagrus meridionalis	44.36	66.20	87.00
Barilius microlepis	34.70	79.08	—
Barbus spp.	32.33	72.00	—
Mormyrops deliciosus	32.12	56.27	—
Rhamphochromis spp.	24.83	26.16	—
Mormyrus deliciosus	22.43	34.39	—
Labeo mesops	28.93	24.22	—
Haplochromis heterotaenia	18.50	27.53	—
Labeo cylindricus	13.64	16.50	—

While the average weight of all the fishes caught in a net of particular mesh size follows closely the rule that the average weight of all fish is proportional to the cube of the mesh size, this rule does obviously not apply to those species, such as *Labeo cylindricus* and *L mesops*, which do not attain the size at which true net selection is effective.

The relation between mesh size and size of fish is, however, relatively simple and will be dealt with in a separate paper to be published later.

(ii) *Relative Occurrence of Species*

Table XVII gives the percentage numbers of each species caught in the 4″, 5″, and 6″ nets over the whole period of the survey.

TABLE XVII

Percentage numbers of species caught in deepset large-mesh gill-nets

Species	*4″ Net*	*5″ Net*	*6″ Net*
Bagrus meridionalis	48.72	59.76	36.76
Mormyrus longirostris	29.06	16.98	—
Bathyclarias spp.	5.54	15.39	61.76
Haplochromis heterotaenia	1.57	3.95	—
Rhamphochromis spp.	4.41	1.03	—
Labeo mesops	4.30	0.37	—
Mormyrops deliciosus	—	0.30	—
Others	6.40	2.22	1.48

Of greatest interest are the members of the three genera which make up most of the catch, *Bagrus meridionalis, Bathyclarias* spp. and *Mormyrus longirostris.* While the shape in section of *Mormyrus* is different from *Bagrus* and *Clariids* and may well be an influencing factor, the lower percentage of *Mormyrus* caught in the larger nets probably indicates that the size selectivity of these nets comes outside the normal size range for the species. As the size of mesh increase the larger species make up more and more of the catch, which therefore becomes more and more homogenous. None of the representatives of the family Cichlidae appear in the 6″ catch, and the bulk of the catch is represented by *Bathyclarias* species. The increase in percentage of these larger fish does not of course mean that greater numbers are caught per unit effort and Table XVIII gives this information. The unit is again a single set of a net of 100 yards stretched length.

TABLE XVIII

Numbers of fish caught per unit effort in the large-mesh deep set nets

(Unit of 100 yards stretched length per set)

Species	*4″ Net*	*5″ Net*	*6″ Net*
Bagrus meridionalis	4.34	2.54	0.50
Mormyrus longirostris	2.59	0.71	0.02
Bathyclarias spp.	0.93	0.65	0.84
Haplochromis heterotaenia	0.13	0.17	—
Rhamphochromis spp.	0.39	0.04	—
Labeo mesops	0.38	0.01	—
Mormyrops deliciosus	—	0.01	—
Others	0.57	0.09	—

The only species which do not show a progressive fall off in catch per unit effort with increase in mesh size belong to the genus *Bathyclarias*, and perhaps *H. heterotaenia*. Each case will be discussed separately under the species heading in the list given at the end of the report, but it is obvious that a compromise will have to be made, and that the best catch per unit effort in terms of weight of fish, will not necessarily give also the best utilization of all the species available. However, at this stage, the overriding consideration is the weight of fish caught per unit effort.

(iii) *Variation in catch throughout the year*

The figures given above are for the whole of the survey period, and it is to be expected that a certain amount of variation be shown from month to month. This is indicated in Tables XIX and XX and the combined records for the three years 1954, 1955 and 1956 are given. The records for each separate year are given in the Appendix, and there is no evidence to show that there is a marked variation from year to year. For convenience, the 4″ and 5″ nets are treated separately; for the 6″ net sufficient data is not available to be able to give a reasonably accurate picture.

TABLE XIX

Variation in catch of 4″ mesh net, set deep throughout the year. Figures for the years 1954, 1955, 1956

(Numbers of fish per unit effort)

Date	*B. meridionalis*	*Bathyclarias* spp.	*H. heterotaenia*	*M. longirostris*	*L. mesops*	*Rhamphochromis*	Others	Total
January ..	4.7	.59	.10	4.80	.67	—	1.00	11.96
February ..	6.7	.52	.13	2.30	.49	.01	.68	10.81
March ..	3.3	.33	.16	2.25	.38	—	.58	6.91
April	2.7	.33	.33	1.45	—	1.11	.55	6.91
May	No record							
June	4.55	.53	.21	1.45	.33	.67	.50	8.30
July	2.65	.52	.10	1.71	.81	.29	.52	6.58
August ..	2.63	.51	.20	2.69	.56	1.43	.51	8.00
September ..	1.62	1.00	—	5.31	.16	.16	.32	8.54
October ..	1.33	.33	—	.66	—	—	.33	—
November ..	2.00	.50	.16	—	.67	—	—	—
December ..	8.43	.24	—	3.95	.19	.19	.33	13.33

TABLE XX

Variation in Catch (Number of fish) per unit effort throughout year for 5″ Net

Date	*B. Meridionalis*	*Bathyclarias* spp.	*H. heterotaenia*	*M. longirostris*	*L. mesops*	*Rhamphochromis*	Others	Total
January ..	3.17	.64	.29	.06	.07	.04	.14	5.21
February ..	3.46	.56	.12	.83	—	.13	.83	5.93
March ..	3.49	.99	.22	.39	.06	.06	1.33	6.50
April	2.10	.67	.03	.13	—	—	.20	3.13
May	2.86	.44	.32	.25	—	.13	.11	4.11
June	2.25	.48	.25	.33	—	—	.06	3.37
July	2.18	.30	.07	.26	—	.03	.15	2.99
August ..	1.81	.65	.17	.72	.01	.07	.07	3.50
September ..	1.63	.70	.07	1.41	.04	.03	.03	2.91
October ..	2.33	.95	.08	1.31	—	—	.10	3.67
November ..	2.35	.81	.09	1.02	—	.08	.04	4.39
December ..	2.27	.62	.11	.99	—	.04	.02	4.06

Figures for the three most important types, *Bagrus meridionalis*, *Bathyclarias* spp. and *Mormyrus longirostris* are shown in fig. 10 in graph form. For both nets the *Bathyclarias* spp. show little variation in numbers caught per unit effort throughout the year, although it is possible that there may be variation in the individual species concerned. Both *B. meridionalis* and *M. longirostris* show considerable variation, and in each case the highest catches are recorded during the peak of the breeding season. *B. meridionalis* is known to breed in the early months of the year. All the evidence goes to show that it breeds in shallow waters, and away from the fishing grounds, and yet at the onset of the breeding season there is a marked increase in catch per unit effort. It would seem that we have here a good example of how an increase in general activity, associated in this instance with breeding, and also involving an increase in " cruising range ", is reflected in higher catches. The breeding of *B. meridionalis* is discussed in Part IV, but it must be mentioned that the increased catch at this time of the year involves mainly females as there is a marked increase in the proportion of females caught. *M. longirostris* apparently breeds throughout the year and in fact it is a feature of the larger size nets that almost all of the fish caught are sexually active. However there does seem to be a season during which the breeding is intensified and this coincides with the period of increased catch. Here, however, the evidence points to the conclusion that the fish are caught on the breeding ground which is in deep water, and that possibly a breeding migration brings these into the orbit of the gill-nets.

The fall-off in catch during the cold months is very considerable, and for nets, like those of flax, whose life is affected markedly by immersion in water, this period might be considered one in which fishing would be uneconomical. For nylon nets, however, the position is different. Although the life of nylon nets is restricted as a result of damage by fresh-water crabs the amount of damage is roughly proportional to the number of fish caught, as the crabs are only found in nets when fish have been caught, and during the relatively poor season the lower catch per unit effort may be compensated for to some extent, by an increased life expectancy. Fig. 10 shows the variation for the three major species throughout the year for the 4″ and 5″ nets respectively. Fishing with nylon nets is therefore possible throughout the year, whereas the months from April to October could be considered an uneconomical period for flax nets.

(iv) *Length of Fishing Unit.*

The larger mesh size nets were fished in units of 100, 200 and 300 yards, made up to about 70 yards to the hundred. Of these lengths the 300 yards made up to about

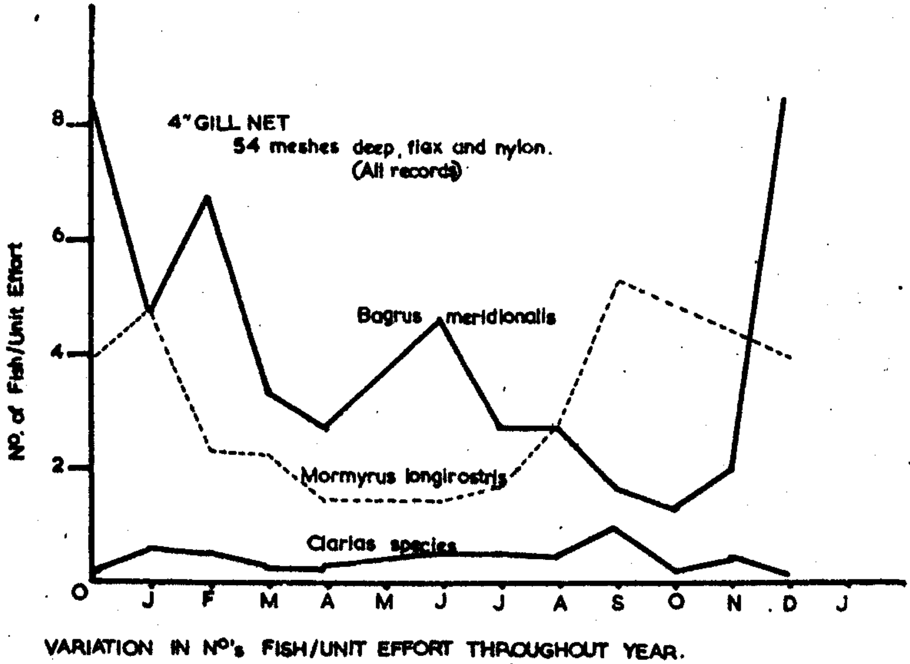


FIG. 10a

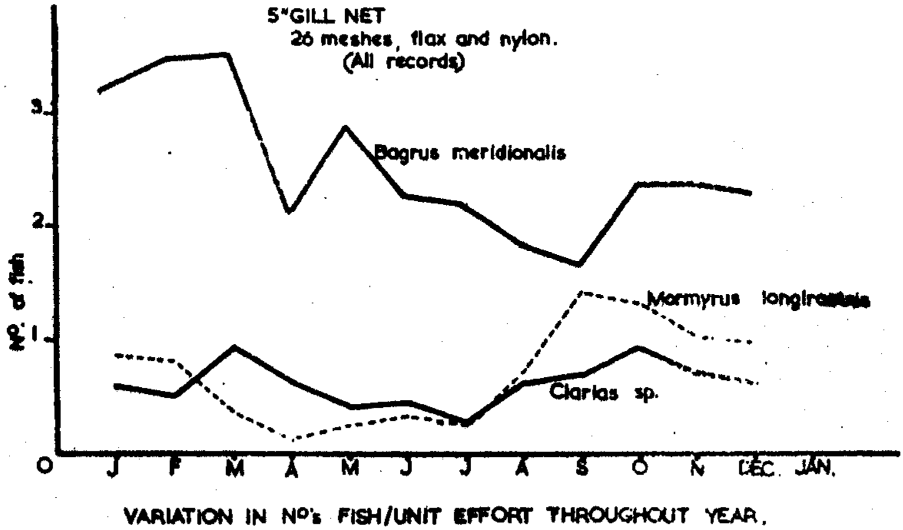


FIG. 10b

210 yards was found to be the most convenient. It has already been shown that if a net is laid in deep water the one end fishes less efficiently than the rest of the net, it has in fact what could be called a dead space. The extent of this " dead space " is determined by the depth of water in which it is laid and is independent of the length of the net, and in a depth of about 50 metres may be the equivalent of about 15 yards. The longer the net the less is the percentage loss that this represents. On the other hand, too long a net is difficult to lay so that its length lies in the optimum depth zone for the fishes being exploited and is, moreover, unwieldy to handle as a single unit. Where the shore is particularly steep to, as it is in the Ruarwe and Usisya district, it might be of advantage to use nets of two 100 units made up to 140 yards, so that the whole of the net can be laid between about 30 and 70 metres.

(v) *Depth of Net*

It has already been pointed out that the 4″ nets used by the survey were almost always 54 meshes deep. While these nets are twice as expensive as 26 mesh nets, they do not necessarily last longer, and are not recommended on the grounds that the return, during the life of the net, in terms of total fish caught and in relation to the initial cost of the net, is lower than for the 5″ nets which were always 26 meshes deep. However, it was noticeable that the fish caught in the 54 meshes net tended to be caught in the bottom part of the net, and this was particularly evident for *Bagrus meridionalis*, and many of the *Bathyclarias* spp. The exception was that certain species of *Rhamphochromis* were caught mainly in the top part, but the average weight and numbers per set is low for this group, and they can be discounted as economic species for this type of fishing. The fact that *Bagrus* sp. and *Bathyclarias* spp. are caught low down fits in with the hypothesis already put forward that these fishes have a restricted vertical zone above the substrate, and it raises the question as to whether a 4″ 26 mesh nylon net would catch a larger proportion of those fish than would be caught by a 54 mesh net. There are no observations which would give a positive answer to this and the information must be obtained indirectly.

During the months of March and April, 1957, both 26 mesh 5″ and 26 mesh 4″ nets were used at Nkata Bay as part of fishing operations of the Model Fishery started here by the Department of Game, Fish and Tsetse Control of Nyasaland. The catch data from these nets were not recorded separately, but the number of sets of each type of net is known. From figures of catch per unit effort for these months for 5″ nets fished by the survey it is possible to calculate the numbers caught by each net, and to estimate the catch per unit effort of the 4″ 26 mesh net. The data is set out in Table XXI.

TABLE XXI

Estimated catch of 4″ 26-mesh gill-nets

	March 1957	*April* 1957
Total number of units fished	49	80
Number 5″ units	23	26
Number 4″ units	34	46
Estimated No. fish, 5″	122	107
Estimated No. fish, 4″	177	335
Estimated catch/unit effort 4″	6.8	6.0
Comparable catch from 4″ 54 mesh nets set by survey	6.91	6.44

For the survey nets of 5″ mesh the catch per unit effort for March and April are 5.32 and 3.15 respectively giving estimated catches shown. This leaves a total of 177 and 335 as being caught by the 4″ net, and the final estimate of catch by the 4″ 26 mesh are 6.8 and 6.44 for the 4″ 26 mesh net for March and April respectively. This is nearly as much as was recorded for the 54 mesh net during the survey, and although the figures cannot be accepted as being of high accuracy they do indicate that a 26 mesh net will be more suitable net than the 54 mesh net, and it is recommended in preference to the deeper net.

(vi) *Twine type and thickness*

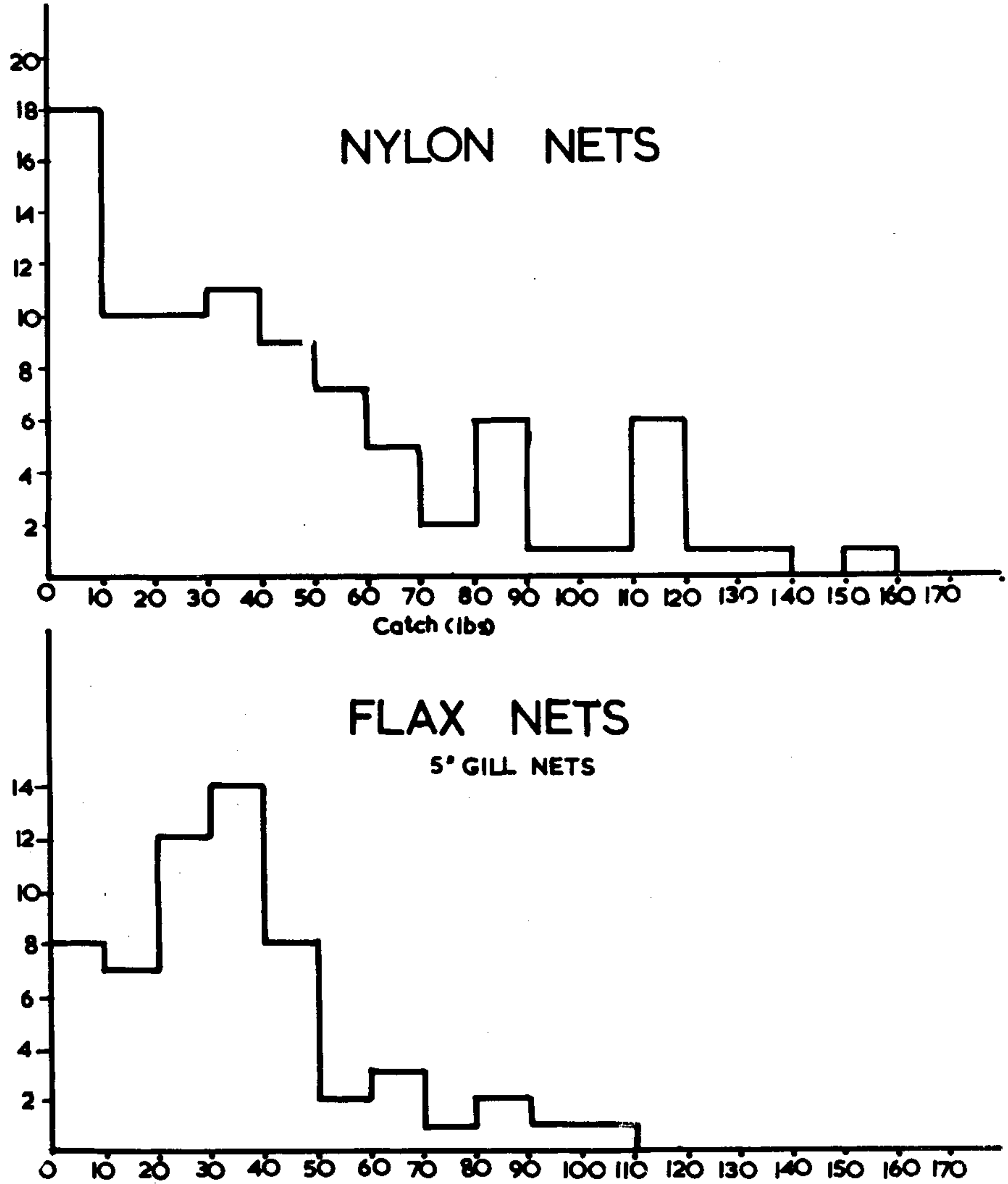
Flax, nylon and terylene nets were used by the survey, but they were not always available at the same time, and nets of the same mesh size but different twine type were not often fished together so that a direct comparison of the types of net cannot be made.

A comparison of natural and artificial fibre nets can be made in two ways. Either the total amount of fish caught in each type throughout its life can be compared, of the catch per unit effort under the best conditions. The second method discounts the effect of damage, and measures a difference in real catching power, which is a property of the twine as a gilling mechanism. The comparison discussed below refers to the 5″ nets only, for which sufficient records over the whole of the year are available to enable a good comparison to be made. A period has been chosen in which they were most often fished together. Frequency histograms of catches (in lb. weight of fish per unit effort) are given for flax and nylon nets in fig. 11. The average catch for nylon nets is 54.44 lb. for a three unit fleet and for flax nets 44.5 lb. over the given period. As nylon nets were used much more in the period under consideration, and were more often than flax nets laid in places known to give poor catches, to collect biological rather than economic data, the figures for these nets are biassed and are lower than would be expected. This bias is to some extent allowed for if catches below 20 lb. per set are ignored for each type of net, and the figures then to be compared are 64.3 lb. for nylon and 49.2 lb. for flax nets, which gives an indication of their relative fishing power under normal fishing conditions. An estimate of the real comparative efficiency is given by taking the highest catches for each type of net, representing the catches obtained at the best times of year when the nets are in new condition.

Taking the 12 highest catches we find for nylon the average is 125.8 lb. per set and for flax is 80 lb. per lay.

Other figures available for the relative catching power of natural and artificial fibres compare in most cases cotton and nylon, and the ratio that seems to represent an average value is 3 to 1 in favour of nylon. Cotton nets are less effective than flax nets, but even so the best comparison of 1½ to 1 obtained from survey nets, seems low. The reason why this should be so is not clear, but may be related to the depth at which this fishing is carried out. These other records refer mainly to surface nets. If, as is reported, nylon nets owe some of their high efficiency to the fact that they are less conspicuous in the water than flax nets, this factor would not operate to the same extent in the depths at which the nets are used. For the south-east arm, figures kindly placed at our disposal by Mr. A. D. Sanson, Fisheries Officer, Fort Johnston, and referring to a much shallower fishery for *Tilapia* species, show that there is a marked fall-off of catch at the full moon period which is obviously related to the visibility of the nets at night at this time. No such variation in catch has been recorded by the survey, and it therefore appears that the visibility of the nets in deep water is not an important factor, and any advantage that nylon nets would give a result of this is probably not acting.

The estimated 50 per cent. increase in efficiency of nylon over flax nets under ideal conditions cannot be explained wholly by the fact that nylon nets catch larger fish. For *Bagrus meridionalis* the figures are given below and show that the average weight is larger for nylon nets, but the difference is not great enough to account for the 50 per cent. increase. It cannot be accounted for by the greater strength of the nylon nets, which prevents the larger fish from breaking through the nets. Although flax nets lose tensile strength after use, over the period of life on which the figures are based there is



FREQUENCY HISTOGRAM OF CATCHES WITH NYLON & FLAX GILL NETS RESPECTIVELY.

FIG 11

no fall off in the average weight of fish caught in the flax nets; this indicates that strength of twine is not a factor operating under these conditions. It must be assumed, therefore, that nylon nets catch a larger proportion of fish which attempt to pass the net, although exactly how this is managed is not clear. It seems clear however that the elasticity of nylon twine, which is much greater than that of flax twine, is of importance. A fish swimming into a net is stopped by the net and its momentum would be taken up by the stretching of the twine. An " elastic " twine, that is, one which would return to nearly its original length when the momentum had all been taken up, would exert a greater force on the fish than a relatively inelastic twine such as flax. If the fish was not " gilled ", i.e. if the twine had not been forced beyond a portion of the fish which would prevent it simply slipping off, then the fish could extricate itself by backing out of the net. However such a movement would not be as powerful as the normal forward swimming movements of the fish, and would be prevented in an elastic twine by the " gripping " force. For *Bagrus meridionalis* for instance, and comparing nylon and flax nets, there is a greater proportion of large fish caught in the nylon nets, and these large ones are often, as has been observed, not " gilled " but " gripped " by the twine. This is only a superficial treatment of the question, but does indicate what is thought to be a reasonable explanation.

Although nylon is more efficient than flax as far as catching power is concerned there are other factors which have to be taken into account. The nylon nets used by the survey were of No. 6 Mwai brand twine and the flax nets of 32/3 ply. The nylon nets cost about twice as much as flax nets of the same dimensions, and for them to be considered a better proposition we have to consider the total catch during the lifetime of the net in relation to the initial cost. A nylon net of this type must therefore catch at least twice as much fish as a flax net. The greatest theoretical advantage of nylon is that it has a much longer life, but under the conditions met with in deep water fishery in the northern parts of Lake Nyasa this advantage does not operate fully. The main reason for this is the damage caused by the freshwater crabs, and the survey nets were seldom in use after more than 20 layings, whereas flax nets usually were set about 15 times.

It has, however, been pointed out earlier in this report that the survey nets were not fished on a commercial basis, and, in particular, mending was neither as thorough nor as frequent as would be expected under the best conditions. Again, the causes of damage were not immediately realized, and ways of obviating them were not investigated until later in the survey. As a result the initially very high catches of new nylon nets fell off quite markedly, and in fact tended to fall below those of flax after about ten sets.

In order to get an indication whether it is possible by strict regard to the simple rules of net care and maintenance, to improve the fishing capacity of these nylon nets and to maintain the high catches over a long period, one net was fished on what would be a commercial basis. The net was of three 100 yards units, 5″ 26 mesh and the twine size was No. 6 Mwai brand which runs about 2,000 yards to the pound:

No. lays	*No. units*	*Total No. Fish*	*Tot. Wt. lb.*	*Av. Wt./Lay/unit*	*Av. Wt. Fish lb.*
36 ..	108	502	2,236	20.7	4.454

There is a fall off in catch over the fishing period of this net, and the average catch per unit set for successive periods of six sets is given below, showing how catches drop to below economic level after about 30 sets:

Period:	1	2	3	4	5	6
Av. Wt/set:	50	34.4	38.0	25.3	15.3	4.3

It is clear that the life of nets can be extended very considerably if strict care is maintained and even in the conditions met with in deep water fishery, a life expectancy of from about 30 to 40 layings can be expected. At least one case is known of an African fisherman who has used a nylon net successfully for more than 40 layings, by dint of careful and continuous mending.

The other type of artificial fibre nets used by the survey was terylene, of similar twine size and strength to the nylon, but for some reason they appeared to be even more vulnerable to attack and damage by crabs than nylon. The reason for this is not clear, neither is it known why flax should be less vulnerable than either nylon or terylene. It seems that flax is less easily cut, although of course it is not as strong and is more easily snapped, and certainly the examination of crab damage indicates that the fibres are sheared and the ends are very cleanly cut.

One advantage that terylene has over nylon is that its strength when wet is greater than the strength when dry, whereas nylon loses about 20 per cent. of its strength in water (Messrs. Linen Thread Co., Kilbirnie, Scotland, Catalogue, 1957). While terylene cannot be recommended in preference to nylon on the facts available, the question cannot be regarded as definitely settled. In areas where crabs are not found to be an important pest, terylene may be preferred.

The twine size of nylon nets was in almost every case such that a 100 yards net 26 meshes deep weighed 2 lb. 3 oz. The breaking strain of the twine (dry) was 26 lb., but this is more than ample for the type and size of fish caught. This is made obvious by the fact that for both flax and nylon nets, although the catch per unit effort fell off after use, the average weight did not fall, even when in the case of flax the breaking strain was as low as 13 lb. A lighter and therefore cheaper twine than the above could thus be used without necessarily sacrificing catching efficiency, and since the cost of nets of the same dimensions is proportional to the weight, a saving could be made which would be very considerable. Nets of half the weight and therefore price have been fished, and the indications are that in fact they are as efficient as heavier nets. Such nets would bring the price of the nylon nets into line with those of flax nets, which is obviously desirable.

Although such lighter nets would not be as strong, this does not mean that they would necessarily be more easily damaged. A great deal of the damage caused by handling can be avoided, and it is not by any means certain that crab damage would be any greater with a lighter twine. Much of this damage is caused by the crabs becoming so entangled that a number of meshes are caught between the claw and severed as a tight roll, and it is possible that thinner twine would be less vulnerable to this. Lighter nylon nets are therefore strongly recommended and it is suggested that a twine of breaking strain about 18 lb. be considered as the best standard.

(vii) *Mesh size*

The relation of catch to mesh size indicates that the 5″ net is to be considered the best for exploitation of the deep water gill-net fishery. It is also the minimum size that was suggested by an earlier survey, but for all the important species this net will catch fish larger than the minimum breeding size, and nets smaller than this would not necessarily exploit immature fish and could be recommended if they gave as good fishing results.

Gill-net selectivity is so marked that a slight difference in mesh size may lead to a significant difference in the catch, and in the Canadian gill-net fishery for salmon, for example, gill-nets in size increments of 1/16″ are commonly used. Thus although the 5″ net is to be considered most generally suitable on the facts available, it may be possible that nets of mesh size $4\frac{3}{4}$″, $4\frac{1}{2}$″, and $5\frac{1}{4}$″ may be as effective as or even more effective than the 5″ net and would have the advantage of spreading the fishing effort over a wider size range of the various species exploited. It is recommended therefore that nets of such sizes be introduced, although it is recognized that such nets are not at the moment considered " standard " manufactured nets.

2. THE UTAKA FISHERY IN THE NORTHERN LAKE

A. Introduction

The Utaka group of the genus *Haplochromis* is a complex one, including a number of forms which are distinguished biologically by their plankton feeding habits. Six species were recognized by Trewavas (1935) who distinguished them on the presence of a small protrusible mouth, which forms a short sucking tube when the lower jaw is depressed. Little was then known of the general biology of this group. Bertram *et al.* (1942) stated that they were abundant near rocky shores where the bottom slopes sharply away, and also at some large sandy beaches visited by the 1939 survey. It was also suggested that their distribution extended over the whole of the lake, and that the fact that they were zooplankton feeders confirmed the idea that " they may well be present in the surface waters all over the lake." Vigorous fisheries were reported at Nkata Bay, Deep Bay, Likoma Island and at other places, and the chilimila net, an open water seine, and its method of use were simply described, in this paper.

Lowe (1952) dealt mainly with the Utaka of the south-east arm of the lake, and stated that they probably come inshore into shallow water when spawning and brooding young, generally being caught there by fine meshed shore seines, but she mentioned also the use at night of the chilimila net north of Boadzulu Island. She also indicated the importance of the Utaka fishery in the Northern Province where there were few *Tilapia* species and *Labeo mesops* (Nchila) and stated that here the chilimila was the usual method of fishing for Utaka. The need for research on the distribution of the various species of Utaka, and the systematics of the group was stressed, it being recognized that several forms could not, at that time, be assigned to any one species, and it was also stressed that information on the general biology, and particularly the life histories and the rates of growth and multiplication was needed. Miss Lowe thought it highly probable that the development of a large scale Utaka fishery would be proved possible in the north of the lake, and that by analogy with other lakes, at least 6,000 tons per year might be realized at full development. A type of ring-net was thought to be the most promising new method that might be tried, and might be used in the central waters of the lake.

The main objects of the present survey, therefore, were to investigate the systematics and biology of this group of potentially important fish, to investigate the possibilities of improving and extending the fisheries at present undertaken in the north, and to try new methods which might prove to be more successful in increasing the amount of fish caught. In 1954 a small experimental ring net was made and tried, without a great deal of success, and it was not until 1955 that a more suitable method, based on the open water seine already in use by local fishermen, enabled fairly regular samples of Utaka to be obtained and examined. It was soon recognized that the Utaka group was indeed very complex, and that it was unlikely that any thing like a reasonably complete account of its systematics and biology could be given except over a very long period. However, a great deal of information was collected and the general picture was clear enough to indicate the possibilities of the extension of the present fisheries. Systematic work carried on at the same time increased the number of species to 16 (Iles, 1960).

Perhaps the most important point that has emerged, and one which does not fit in with the generally accepted idea of the Utaka as a group of plankton feeding pelagic fish, is that their distribution is almost certainly restricted, and that the open water of the lake, i.e. the areas at any distance from the shore, do not support as large a population as might be expected. The indications are in fact that this group, although plankton feeding, is bound much more closely to the shore than had been thought. Thus there is little likelihood of a fishery being developed in the open water of the lake and the Utaka fishery must be considered to be an inshore one. Any extension of this inshore fishery would be the result of the introduction of better methods than at present exist, of the improvement of those that already are used and the discovery of new sites for fisheries. Another important finding has been that the distribution inshore of the shoals of Utaka is localized and associated with particular types of habitat. In any area in which Utaka are fished, the exact position of these habitats is known with surprising accuracy. The knowledge of the general topographical features and of the distribution and habits of Utaka in their area shown by local fishermen, is quite detailed in some respects, and represents a sound basis on which development could be built up.

B. The Present Fishery for Utaka in the North

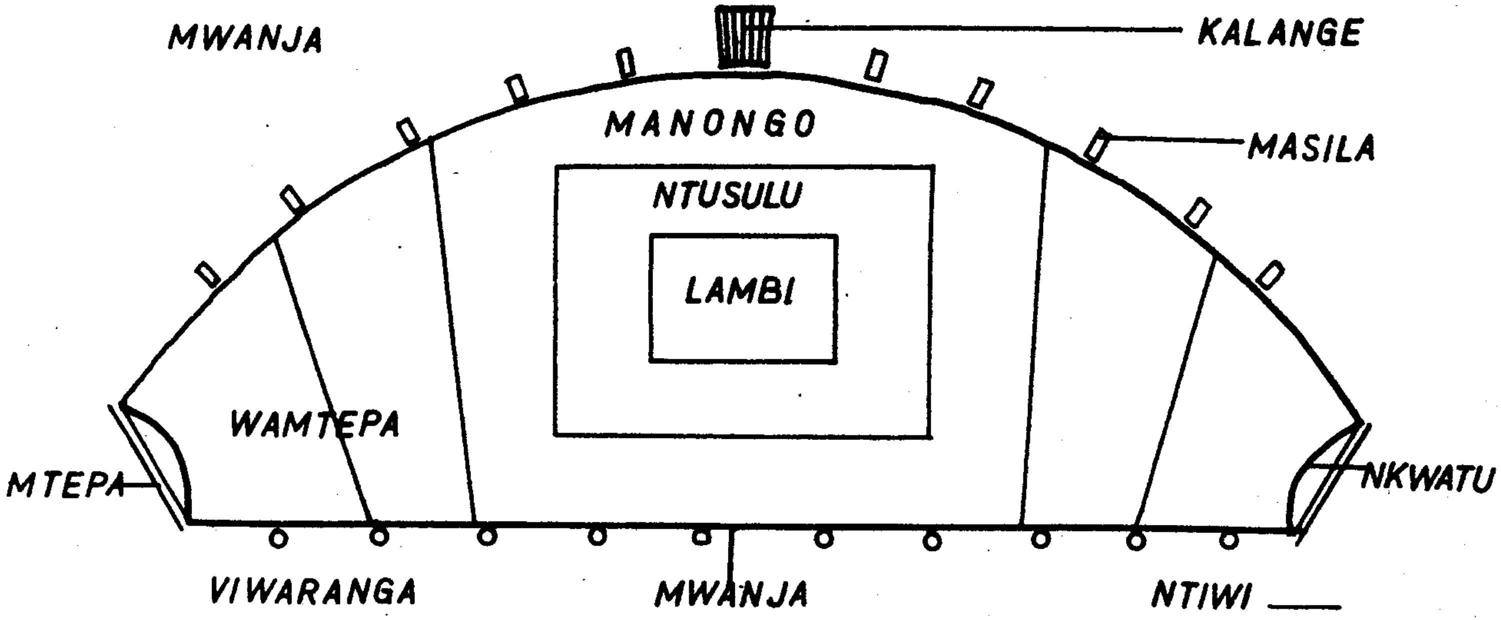
1. METHODS

(a) The Chilimila Net

The use of the open water seine, known as the " Chilimila " net, is by far the most important method of catching Utaka in the northern part of the lake, and it is unlikely that it will ever be completely superseded by other methods. The best opportunity for the improvement of the Utaka fishery seems to lie in the modification of this method, to overcome certain of its limitations, and in the development of methods based on its use. It certainly represents one of the most refined indigenous methods of fishing on Lake Nyasa and great skill is needed, both in the manufacture of the net, and its use.

The Chilimila net is often seen laid out flat to dry or for repair and fig. 1 shows it in this position. The general construction is of a number of strips of netting running from top to the bottom of the net, and known collectively as " Vilepa " (singular " Chilepa "). Different kinds of vilepa are recognized according to the mesh size, and the arrangement of these various strips and the way in which they are joined gives the net its shape and fishing properties. The construction of the net is a matter of considerable skill, and although most fishermen can use, and even repair a chilimila, very few can make and shape one. All the netting is made of " Chopwa " thread which is obtained from a shrub (*Poulzolzia hypoleuca*) very common along the lake shore. The central part of the net, the bag, is called the " Lambi ", and is of small mesh, not more than ½″ measure stretched. It is about four yards from top to bottom and five yards long, being made of a number of vilepa each from 400 to 500 meshes in length and joined together one to one, throughout their lengths. Surrounding the lambi is the " Ntusulu ", of a larger mesh, about ¾″ to 1″ size, which may be 600 meshes from top to bottom and which extend about 200 meshes from the side of the lambi. The next section is called the " Manyongo ", which name is derived from an old Tonga word meaning roughly " to make less " and it is this section of the net that the first " shaping " occurs, designed to allow the net to bag while it is being fished. The mesh size of the manyongo is about 1½″ and it completes the centre of the net. The wings of the net are of still larger mesh and may be in two sections, one of about 2″ size next to the manyongo, referred to sometimes as the " Masughanchila ", and it is here apparently that " Nchila " or *Labeo mesops* may sometimes be gilled. The last section is called " Masughavyambo " being of such a mesh size that " Chambo " or *Tilapia* spp. may occasionally be gilled. The wings are also called the " Wamptepa ".

FIG. 1.



The CHILIMILA Net (not to scale)

The number of meshes from head rope to foot rope is decreased along the wings by joining at intervals, two meshes of one chilepa to one of an adjacent and outer one. Through the edge of the last strip is threaded a short cord, the " Nkwatu," and the 100 meshes reeved on this short cord gives a large degree of bagging in the wings of the net as it is fished. The head rope and the foot rope are called the " Mwanja," and are made either of thicker chopwa cord, or of twisted bark rope. Both are small in diameter and flexible but the foot rope is usually rather thicker than the head rope. At the ends, the foot rope and the head rope are separated by a short stick of fairly stout bamboo called the Mtepa and the hauling rope or " Ntiwi " is tied at the end of the mtepa nearest the foot rope. The head rope is buoyed by carved pieces of light wood tied into small bundles and called " Msila," and in the middle of the head rope is a much larger bundle called the " Kalanje," which serves both to mark the centre of the net, and to give extra buoyancy at this point. The foot rope is weighted by soap-stone weights or by small stones tied on with strips of bark, and the net is reeved at head rope and foot rope, no slip cord or osselling being used. Nets vary in size, but an average size is about 50 yards long by 15 yards in maximum height when laid flat.

The chilimila is used from two canoes and the net is placed in the bottom of one, together with the hauling ropes which are, however, not attached to the net until later. At least three men are needed to handle each canoe and haul the net, but more often as many as six or even eight may be found in each canoe. On arrival at the place at which fishing is to be carried out, half the net is placed in each canoe, with the canoes about four feet apart. The foot rope is laid in the direction in which the net will be fished. The canoes are paddled apart at right angles to this direction and the net paid out until the manyongo is reached, after which they turn slightly towards the direction of fishing and the rest of the net is paid out. The warps are then attached to the mtepa and the canoes paddled almost parallel to each other and in the fishing direction, but no strain is put on the warps, which are thrown out freely. The net is so weighted and buoyed that it just sinks at a slow rate, and it is this that gives the net its name which can be translated as " the thing that drowns ". The net is allowed to sink to a certain depth, depending on the particular place at which fishing is carried out, and this depth is determined by the amount of warps paid out and the distance the canoe is paddled in the fishing direction, and is recognized when the weight of the net can be felt on the warps. When this depth is reached, the canoes are paddled energetically towards the fishing area, which has the effect of pulling the wings of the net forward so that the net is in plan **C** shaped.

Since the warps are attached near the foot rope, and the head rope is longer than the foot rope, the foot rope is in advance of the head rope, and lower in the water of course, and in vertical section the net is **L** shaped, so that in this fishing position the net forms an enclosure open at the top and in the direction of movement. Any fish or shoals of fish are collected as the net moves forward, and when it has reached a certain position, the warps are hauled. The canoes are pulled back towards the net as the warps are hauled, and at the same time the foot rope is raised so that the net gradually forms a U-shaped bag open at the top. The floats on the head rope are so arranged as to maintain this shape, and as the ropes are hauled the canoes are pulled together to within a few yards of each other. The first part of the net to reach the surface are the wings, and the net is folded into the canoe as they are hauled. The head rope and the foot rope are hauled at the same time but they are kept within a few feet of each other so that the net forms a deep narrow bag in the water. When the large central float breaks the surface, the foot rope is hauled in as quickly as possible, particularly if there are signs that the catch is good, but when it breaks surface and the bag is completed, the net is pulled more leisurely until the lambi is reached and the fish caught are then transferred to one of the canoes. At this stage, the net is ready to be fished again, the canoes are paddled to their original position and the operation repeated.

The size of fish caught by this type of chilimila may be quite small. Juveniles of about 70 mm. have been seen in catches of such a net, even though much of the area of netting is of a size through which these fish can pass fairly easily. Fishing operations with a small meshed chilimila net have been studied under water as the net neared the surface, and it has been observed on many occasions that the Utaka avoid the netting itself, thus tending to congregate in the most effective part of the net in the lambi region. It is only when the net is near the surface, and the bag is being hauled in, that fish attempt to swim through the meshes. Occasionally a small shoal of Utaka has been seen in the net as the foot rope is being raised and before it completes the bag at the surface and have failed to escape the net. It would seem that the angle at which the fish can swim upward to pass over the foot rope is relatively small, emphasizing the need for a rapid haul on the leads as the net nears the surface.

Although the type of chilimila in common use does catch smaller fish, it is most effective for the larger species of Utaka, and particularly for *H. quadrimaculatus*. This species breeds at about 160–200 mm., and breeding fish called "Mbarule" appear in March or April near the shore. The fishing carried on in the north is therefore, at present, largely seasonal and probably about half of the total weight of fish caught by chilimila nets is made up by this one species, and is caught during the months April to July. Fishing does however go on throughout the year and occasionally large catches of other species are made.

Fishing in the way just described is, in all places visited by the survey, restricted to certain very definite areas. These fishing grounds are known as virundu (singular—chirundu) and they correspond to certain underwater features of the lake bed. Map 5 shows two well known and important virundu at Likoma Island, rocky prominences rising above the lake bed, and at these virundu, shoals of Utaka have often beeen recorded on the echo sounder. Some were estimated as being 50 or more yards across, and about 4 fathoms from top to bottom of the shoal. Map 5 shows the Nkata Bay area, and on it are marked several of these fishing grounds. No. 3 is the continuation of the rocky " Boma " point, No. 1 is an underwater rocky mound, No. 2 is the edge of a rocky shallow shelf extending from Mayoka point and suddenly shelving into deep water giving in one place an almost vertical face. No. 4 is nearer the shore, but essentially similar to No. 2. No. 8 is inside the South Bay where the rocky shore line gives way to deeper water over a sandy substrate not far from the shore. Each of these and others, is well known, often fished, and each is fished in its own particular way. The general features of each are known, and, for instance, the depth and extent of the two at Likoma Island were given with surprising accuracy by a local expert, although they do not reach within 80 feet of the surface. When a chirundu is being fished, its position, and the direction of approach of the net, is accurately gauged by reference to land marks. At Bandawe for instance, one chirundu exists as a small mound rising some 60 feet from an almost flat lake bed at 20 fathoms or so, and over a mile from the shore. Its position is difficult to locate accurately, and it could not be fished by anyone without the detailed local knowledge which the Bandawe fishermen possess. At Sanga, just south of Nkata Bay, the chirundu seems to be at a particular spot at the shelf between the shallow sandy inshore region and the deeper water beyond.

The position and general shape of these virundu determine the way in which each is fished, but there is one factor which is overriding and which determines the value and importance of any particular fishing ground. Although in the fishing operations described above, the canoes are paddled vigorously, they cannot exert enough force to haul the net through the water. The net can only move if it is swept along bodily by a water current. Paddling and the force exerted thus only serve to pull the wings and the foot rope in advance of the main body of the net and, as such, is solely concerned with maintaining an efficient fishing shape as described above. If there is no current at the depth at which the net is used, the net will not travel through the water. Consequently the speed of the net varies as the strength of the current varies and on occasions when no current is found, fishing is discontinued by the local fishermen after the first or second attempt. On one occasion a fairly large shoal was located near chirundu No. 2 at Nkata Bay, in what seemed to be an ideal fishing position. The position and the depth of the shoal were recorded accurately but despite this, fishing was entirely unsuccessful because no current was flowing and the net did not move through the water.

The currents themselves are known collectively as "Mweza", and they are quite common near the shore and at particular places. At Bandawe on one occasion it was estimated from the distance travelled by the net during one haul, that the speed of the current was of the order of 1 knot at a depth of 10 fathoms. They are probably the result of the larger scale seiche movements generated by the wind's action, and may be looked upon as compensatory currents which would be expected at the margin of a lake the shape and size of Lake Nyasa. They usually appear to run more or less parallel to the long axis of the lake at the shore and are often given specific names. At Nkata Bay a current from the south is known as "Mkachi", and from the north "Nkonde", the latter name being derived from the fact that the current comes from the area of the Wankonde tribe which lives in the Karonga area. These two currents are much more common than the "Mpaulu" which comes from the east, and they are apparently associated with the "Mwera", the south-east trade wind, and the north-east wind, the "Mpungu".

While it is fact that the chilimila is fished only at the virundu and that it can only be used as described above when a current is flowing, this does not necessarily mean that the Utaka occur only at these places and under those conditions, as there is evidence that there exists a definite association between the chirundu, the current and the position of the Utaka shoals. Echo sounder traces have shown that the position of the shoal is almost always on one side of a chirundu, and whenever this has been so, always on the current side. It has in fact been possible to predict the direction of the current by such traces and to verify it by using the chilimila. The shoals apparently maintain this position for long periods while the current is flowing. At Bandawe, for instance, on the occasion when a particularly strong current was found, a shoal was observed over a period of eight hours and it was always found on the same side of the chirundu, the south, from which the current was flowing, and always in the same position and depth. The possibility exists, therefore, that under certain circumstances, Utaka shoals have definite biological associations with particular underwater features of the lake, and that the association may determine the detailed distribution of the Utaka in a given locality. The obvious inference, and the one put forward by the fishermen at Likoma Island, is that the fish are feeding on plankton brought to them by the current, so that under these circumstances a plankton feeding existence does not necessarily also entail a ranging pelagic existence in search of food. This does not mean of course, that all species are at all times so related to chirundu and current, but it is in general probable that Utaka are not open water species in the strict sense of the word, and that their natural habitat is an inshore one. Currents are only found at certain of the virundu, and on the map of Nkata Bay (Map 5), Nos. 1, 2, 3 and 4 are such. These are often referred to as "real virundu" although sometimes the term is restricted even further to those places, which, like No. 2, are isolated from the land. It is only therefore at these places that large catches of Utaka are recorded.

Many of the best grounds at present fished have been discovered within living memory. The one at Bandawe is reported to have been found by accident about twenty years ago when a fishermen caught a long line in offshore water much shallower than was expected, and this and other evidence indicates that the chilimila method is a relatively new one in Lake Nyasa. It is believed to have been introduced by the Arabs in about the 1870's at Likoma and Chizumulu Islands. Here, certainly, the most expert fishermen, and the most flourishing fishery, exist at present. It is purported to have been introduced to the mainland at Bandawe at about the turn of the century, and the first net was introduced from here to Nkata Bay soon afterwards. In this century the use of the net has spread northwards on the Nyasaland side, and both north and south of the eastern side of the lake. Bertram *et al.* (1942) (Appendix IX) report no chilimila in use south of Nkata Bay on the Nyasaland side and south of Chilowelo on the eastern side of the lake. The coast line south of Bandawe is more sandy and exposed, generally speaking, as far as Domira Bay, and the likelihood of there being obviously suitable grounds where the chilimila would be successful in these areas would not have been great. In the extreme south of the lake, off the islands in the south-east arm, near Cape Maclear, at Boadzulu Island and at many other places, however, suitable conditions appear to exist, and yet at these places it is a method rarely used, and where it is, it seems to have been introduced within the last few years by fishermen from the north. Such a distribution of the use of the chilimila as a common method for fishing Utaka fits in well with the suggestion that it has been relatively recently introduced into the lake, and at such a place as Likoma. It also suggests that in the north, there is a possibility that places which might be suitable grounds have not yet been discovered and that in the south of the lake quite extensive fisheries may be discovered and could be exploited by this method. The survey of likely places is one which is recommended strongly, as is the mapping with the help of an echo sounder, of the present areas fished.

The chilimila is usually used at the " real chirundu " in the manner described above, but it is also used at places at which no current is found. At these places, although the net is laid in the same way, the warps are taken ashore, or to rocks at or very near the surface, and the net is hauled by hand. When the net nears the shore, in all cases a precipitious one, the warps are hauled from the canoe, and the net pulled in as described above. Sometime, and particularly at No. 4 at Nkata Bay, one warp is hauled from a rock near the surface while the other canoe paddles as usual, but this can only be done while a current is flowing in the right direction.

The chilimila is never used in open water successfully. In the North Bay of Nkata Bay shoals of *H. chrysonotus* are often found about 60 yards or more from the shore where the survey launch is moored. Many attempts have been made to fish these with the chilimila both in the normal way and by hauling from the launch itself. Underwater studies have shown that the fish swim away from the net as it is hauled and easily escape in the direction of the shore. The presence of a precipitous face would seem to be essential for the successful working of the net, completing, so to speak, the fourth side of an enclosure, the other three sides being formed by the wings and bag of the net.

The chilimila is also used at night, but then never at the " real virundu ". It must not be caught on the rocks and the difficulty of locating the position of the chirundu as accurately as this at night, even if there is a moon, is too great. At night it is hauled from the shore as described above at places like No. 8 and No. 5, but then it is used only in moonlight so that the distance from the shore can be gauged fairly accurately and the warps marked accordingly to indicate when it is time to haul from the canoes. When it is dark, the chilimila is used with a light, the method being known as " Kuthopole " in the Nkata Bay area. The net is laid in fairly deep water as before and allowed to sink. A third canoe bearing a flare is paddled slowly towards the position of the net while it is hauled from the shore, and it then remains over the spot where the net is expected to break surface while the net is hauled from the canoes in the normal way. At night, whether by moonlight or when the flare method is used, *Mormyrus* sp. and species of *Bathyclarias*, besides an occasional *Bagrus meridionalis* are caught along with various kinds of Utaka.

(b) The Kawelekete Net

Night fishing for Utaka is, however, more usually carried out using a different type of net, known as the Kawelekete net. Its relationship to the chilimila is obvious and it is almost certainly a development of it. It is, however, smaller, the twine is somewhat thinner, and it is so constructed that it " bags " less while being fished. It has an ntusulu and lambi and as such is a type of open water seine, but it also works partly as a gilling net, the wings being of mesh size up to $2\frac{1}{2}''$. It is used in much the same way as the chilimila when this is used at night. Two canoes are needed and the net is laid in fairly deep water off a sandy or rocky shelf. One such place occurs well inside the south bay at Nkata Bay, where, at the mouth of a small stream, a shallow sandy shelf gives way to deep water suddenly. The warps are hauled from the shore until marks are reached which indicate it is in the correct position to be hauled, when it is pulled in the same way as is the chilimila. It is used whether there is moonlight or darkness, and many species of Utaka are recorded in the catch besides occasional specimens of *B. meridionalis* especially at the breeding season of this species, and other cichlids, and much of the catch is gilled in the wings of the net.

(*c*) *The Ngongongo Net*

This third type of net is also commonly used at night, and it is in effect a combination of shore seine and gill-net. It is a long net, almost uniform in mesh size and height, and the meshes are about 2" stretched and it is usually 42 meshes deep. On moonlight nights it is used as a beach seine, off sandy beaches, or off beaches which give way to rocks near the shore. In the first case it is hauled up to the beach and the gilled fish and others which have been seined, are removed, but if the shoreline itself is rocky, the nearest position to the shore at which it can be pulled is indicated by marks on the warps. At this point hauling from the shore ceases and one canoe goes out to lift the net from one end to the other, and returns with the net and catch to the shore where the catch is removed and the net made ready for use again. Here of course, it acts as a special type of gill-net only, as hauling it from one end from fairly deep water would allow any seined fish to escape.

When it is dark, the ngongongo net is used in conjunction with a light. It is weighted and buoyed at each end and laid on the bottom in a straight line as a gill-net. Starting from the shore, a canoe with a grass flare is paddled backwards and forwards across the line of the net, and at the same time the sides of the canoe are beaten with a paddle. The name ngongongo is onomatopoeic and represents the sound made in this way—one which most of the inhabitants of Nkata Bay will recognize easily. The object of this is to cause the fish, attracted by the light, to sound, so that following the light they move over the bottom and are gilled. The net is taken up as a gill-net after the operation has been carried on as long as it takes for the grass flare to burn, the fish are removed and the operation is repeated. The best results are apparently obtained in the dry season and the net is then laid near sandy beaches and in fairly shallow water. The species most commonly caught at this time is *H. nkatae* and " Ukongole " (*H. prostoma* ?).

(*d*) *Beach Seines*

There appear to be no large beach seines used mainly for catching Utaka as there are in the south-east arm. Even at places where large sandy beaches exist, such as at Sanga, the beach seine used here is designed specially for Usipa. One section of this seine, towards the wings, is however called the Utaka, and here at certain times of the year from about May to September, Utaka and particularly *H. nkatae* are sometimes gilled in considerable numbers. Often too, some of the other sand-loving species are seined, including *H. eucinostomus*, but apparently never in large numbers.

The methods described above account for nearly all the Utaka caught in the north of the Lake, and of these, the chilimila net catches by far the largest quantities, mostly at virundu when a current is flowing, and during the day. The chilimila net is in fact, the basic method for catching Utaka, is designed as such, and is particularly well adapted to fishing under the conditions met with in the north.

C. Experimental Fishing

1. RING NETTING

While the chilimila net is, within its limitations, a good method for catching Utaka, it had been suggested by Lowe (*op. cit.*) that ring netting might prove a suitable method for developing and extending the fishery, and in 1954 a small experimental net was made. The netting was of cotton, the mesh size $\frac{13}{16}''$ stretched measure, and a net 60 yards long and 7 yards deep was constructed. The rings were improvized from the nodes of bamboo poles and the weights cast from the lead from car batteries. $3\frac{1}{2}'' \times 1\frac{1}{2}''$ centre bored corks were used on the head ropes. This net was used from two small boats and was tried both in the day and at night. It did not at any time prove successful and was eventually used only to collect samples of *H. chrysonotus*, *H. nkatae* and other species which shoal in small numbers near moored boats and other similar places. While the failure of this method could possibly be attributed to the small size of the net and its improvised nature, it has become more and more clear that in the north, ring-netting for Utaka can never be so successful as to replace the type of method represented by the chilimila net, and it is extremely unlikely that it could prove economic even on a small scale.

The reasons for this are many, both practical and biological. Utaka are small fish, the largest species reaches a maximum length of only 200 mm. and most species are much smaller, about 120 mm. The mesh size would have to be correspondingly small, and a large net therefore would be very expensive. The use of such a ring-net also presupposes accurate locating of the shoals of fish, and there seems to be only one type of location at which the fish can be located with reasonable and regular accuracy, i.e. at the virundu. This does not mean that fish are never found elsewhere. Occasionally Utaka shoals have been seen near the surface and fairly near the shore, but they have never been large shoals and have been seen only a few times. Nor have there been reports of regular sightings of such shoals at particular times of the year or at particular places along the shore. Occasionally also shoals have been sighted near the surface and some distance from the shore. In September, 1956, small shoals and individual Utaka were seen near Sanga off shore at a distance of about one and a half miles. They were feeding on a carpet of dead "Nkungu" flies and individuals of *B. meridionalis* and *Bathyclarias loweae* were also seen, but the sighting of even such small concentrations of fish is rare at any distance from the shore and the small possibility of being able to find them would not justify any expensive method requiring large sea-worthy boats. The largest concentration of Utaka have always been found at, or associated with, virundu, and fishing at these places is neither practicable nor economically feasible with ring nets. The depth at which the larger shoals seem to occur is from about six fathoms to about twenty fathoms from the surface and the height of such shoals from top to bottom of the shore would be in the region of five fathoms. It is not often that such shoals have been found to extend any great distance from the virundu and the difficulties of setting a small meshed ring-net so close to the rocks and so accurately that the shoals can be fished without catching the net on the substrate are extremely great.

The species of Utaka which are found in places near the shore which could be fished by a ring-net, such as *H. chrysonotus* which prefers a rather more "open water" habitat, or *H. prostoma* and *H. eucinostomus* which prefer a more sandy habitat, are not found in large numbers. *H. chrysonotus*, for instance, shoals near the launch mooring in the north bay at Nkata Bay in small numbers and is also seen near the floating dock at Monkey Bay. However, the populations are small, apparently rather isolated and could be fished out in a very short time by any efficient ring net method, and even then would not give high catches. Species such as *H. eucinostomus* and *H. nkatae* which are found on sandy beaches either occur in small numbers or occur there mainly in the breeding season and are then associated with the bottom, and could best be fished with the beach seine. The fact that beach seines are not used for Utaka to any extent in the north even where seine beaches occur, and where small meshed seines are used, indicates that the population of such sand-loving forms are small.

There remains the possibility that large Utaka shoals could be fished by any net in the open waters of the lake. The detailed distribution of Utaka species will be discussed briefly below, but what has become clear is that of the many species included in this group, most have an association with an inshore habitat which prevents them effectively from being open water species. *H. pleurostigmoides* and *H. borleyi*, for instance, appear to be rock living forms, seldom found at any stage of their life histories at any distance from this type of habitat. *H. virginalis*, a small species but perhaps the most abundant member of the Utaka group, is found inshore at all stages of its life history. It has apparently a rather wider range of movement than the other two species mentioned, but has never been caught in quantity at any distance from a rocky habitat. Other species have some sort of connection with other types of inshore habitat, for part of their life history at least, and in fact the only species which might be an open water form in the true sense of the term is *H. quadrimaculatus*, which is found at most places in the north of the lake. Even this species spends much of its life history inshore, and only for a part of its life span is it possible that it occurs in the open water of the lake. Even so, of course large populations of *H. quadrimaculatus* and possibly other, as yet unknown species of Utaka could be found in the open waters of the lake but even if, as has been suggested, Lake Nyasa could support in the open waters a population of plankton feeding fish which could yield 6,000 tons per annum, a population of this size would have a density of fish of the order of 1/50th or less of that found in the south-east arm. This part of the lake yields about 3,000 tons in a year, has an area of less than 1 per cent. of the whole lake so that the return per unit of fishing effort in the north under the assumptions made above, even under the best conditions would probably never exceed 1/50th of that obtained in the fishery for *Tilapia* spp. of the south-east arm. Fishing in the stormier waters of the centre of the north of the lake (or indeed any other type of open water fishery) is unlikely in the extreme on economic grounds. The Utaka fishery and its development and extension should be concerned only with inshore waters, and in particular with the habitats which are known to be sites of concentrations of shoals of this type of fish.

II. FLOATING TRAWL

It was thought possible, however, that another type of fishing method, at present unknown on Lake Nyasa, might be used to exploit the Utaka inshore. A floating trawl or mid-water trawl has the advantage that it can be made to fish any reasonable depth, and experiments were carried out with one from the launch *Gigipat*, and with the aid of echo sounding equipment. It was possible to relate the speed of the vessel and the length of the warp to the depth of the net and the height of the opening of the net so that, a shoal being located, the net could be fished at the appropriate depth. Some few trials carried out with this net at Nkata Bay and at Bana were unsuccessful and did not encourage the pursuance of the endeavour. The main difficulty is again, that the association of the large shoals with the virundu is so close that it is extremely difficult to fish the shoal and avoid snagging the rock. It was found that large properly designed fishing vessels with hauling gear would be necessary, and the cost of purchasing and operating such vessels is unlikely to be justified by the return in fish caught.

III. HIGH-SPEED SELF-OPENING TRAWL

A small high-speed self-opening trawl, pulled by one warp and similar to one used in surface waters in the study of pelagic fisheries in the North Sea, was also used at Nkata Bay, but never successfully.

IV. SMALL MESH CHILIMILA

The type of chilimila at present used by local fishermen is, in many ways admirably adapted for catching Utaka but it would appear to have been designed mainly to exploit *Mbarule*, the breeding adults of *H. quadrimaculatus*. These are larger than the other species which also occur in large numbers, and although sometimes the chilimila will record good catches of smaller species such as *H. virginalis*, such occasions are rare, and it is likely that the mesh size at the wings of the net is such that a large proportion of small fish which are enclosed can escape with relative ease.

It was thought therefore that a net of the same general design as the chilimila but of smaller, and for convenience, uniform mesh size might exploit these smaller species to a greater degree. In early 1955 a net was made by a local expert to specifications laid down with this in mind. The netting was made of cotton, the mesh size was 13/16ths inch stretched measure and the twine type a little thicker than gill twine but thinner than that normally used. It was rather smaller than the normal type of chilimila but was shaped in the same way. Manufactured ropes were used as foot rope and head rope but these on the insistence of the expert were thin and flexible. Centre bored corks were used as floats and lead weights as sinkers, and the net, after being barked, was fished in exactly the same way and in the same places as is the local type of net. It was intended at first to be used mainly to collect samples of the smaller species and individuals but it was soon apparent that it represented a very considerably improved type of net, and consistently gave better results at Nkata Bay, in terms of the weight of fish caught, than did the local nets. The reasons for this were first, as had been expected, the small mesh prevented the escape of the smaller fish, particularly those belonging to the common species *H. virginalis*, but it became more apparent also that such a small mesh, by offering more resistance to the current was moved along at a sufficient speed by currents not strong enough to move the larger meshed nets, so that it could be fished under current conditions which would be limiting for the local type of net. It was later found, too, that it had another advantage. The small mesh made it less easy to snag on the rocks, if as sometimes happens, the chirundu is approached too closely, and when snagged would, because of the thinner twine, receive less damage. This is quite an important point because the local nets, if caught, are freed with great difficulty and often serious damage has been caused, sufficient to keep them out of action for many weeks. As a result they are often hauled rather further from the chirundu than is most efficient so that the danger of snagging is minimized, and it was noticeable that the survey fishing team, after a while, did approach the chirundu rather closer than did local fishermen.

(a) *Catch Data*

The catch data for the small meshed net is summarized in Table I for fishing operations spread over a period of two years from February, 1955, to March, 1957. Catches varied during a series of hauls extending over a morning or evening, or over part of a morning or evening, from less than 30 pounds to 900 pounds; but on more than half the occasions only small amounts were caught. This is partly because on many occasions the net was fished in places where catches were expected to be low but from which biological information might be obtained, but on many occasions too, very small catches were recorded at the chirundu because current conditions were bad and the net therefore fished inefficiently.

TABLE I

Chilimila Catches

Catch	(lb.)	No.
0	30	77
30	60	20
60	90	9
90	120	10
120	150	6
150	180	6
180	210	1
210	240	4
240	270	3
270	300	—
300	330	2
330	360	1
400	500	1
600	700	3
900+	—	1
TOTAL WEIGHT	13,000 lb.	

It was only at virundu that the large catches were recorded, and only there when current conditions were favourable, and when the net was pulled from the shore or at places like No. 5 on the map it was not often that more than 30 pounds were caught. The largest catch was recorded during a morning's fishing in February, 1955, when 900 pounds was taken, but other catches of over 600 pounds were also recoreded. More usually the catch was of the order of 200 pounds when conditions were good.

While at Likoma Island and Chizimulu Island, and in the Mbarule season, larger catches are recorded with the local type of net, frequent reports of catches of about a ton have been made. During the period fished by the survey at Nkata Bay, the small meshed net consistently out-fished, by a factor of two or more, the local nets. Whether this superiority would be maintained under the conditions obtaining at Likoma and Chizimulu, recognized as the best areas for Utaka in the north, and during the Mbarule season, is not known. At Nkata Bay, 1955 and 1956 were bad years for this species so that all that can be said as yet is that the small meshed net is undoubtedly superior to the normal type for the smaller species and under more limiting conditions, but it is likely that during the Mbarule season, and when the current conditions are not ideal for the local type of chilimila, that higher catches would be obtained.

The distribution of catch throughout the year is irregular. In a period of one month in January and February, 1955, 25 cwt. were caught, and in a little over a week in July, 1955, nearly 30 cwt. were landed, whereas in many months the catch per unit effort was low, less than 10 pounds. This does not however indicate that the species being exploited necessarily vary in abundance throughout the year. The deciding factors are the presence of suitable current conditions at the virundu, and reasonably calm lake conditions at the time when the currents do exist, and the uneven distribution of catch is probably a reflection of these factors more than any others.

Whenever larger catches were made, the bulk of the catch was made up of relatively few species. *H. virginalis* always accounted for more than 50 per cent. of catches of over 60 pounds and sometimes as much as 90 per cent. was represented by this one species. *H. mloto* was often the most abundant of the remaining species and sometimes made up to 30 per cent. of the total catch.

Juvenile *H. quadrimaculatis* (Mbaba) were not often caught in great quantities and the remainder of the larger catches were made up of small quantities of *H. trimaculatus*, *H. pleurostigmoides* and *H. borleyi*. Only rarely were *H. nkatae*, *H.*

verdi, *H. eucinostomus* and *H. flavimanus* caught at the virundu, and *H. chrysonotus* was recorded only once or twice in deep water near these habitats. As has already been indicated, during the two year period over which fishing was carried out, the Mbarule seasons at Nkata Bay were poor and relatively few were caught. Whether this was because fewer fish came inshore than normally do or because during the season the current conditions were for long periods unsatisfactory, is not certain, but numbers of breeding fish were caught in gill-nets set inshore indicating that a fairly large breeding population was located in the Nkata Bay areas and possibly that the low catches in the chilimila nets were the result of poor fishing conditions.

The total amount of fish caught by the small meshed net in the two years was 6 long tons, and of this about one half was caught at one chirundu, No. 2 on map 5. Of this total most was made up of *H. virginalis* and other species which are found, and at all stages of growth throughout the year and within a very short distance of the shore. These species do not exploit directly the plankton of the open waters of the lake; their distribution is almost certainly limited to the inshore regions and to what extent the catch would be supplemented by the breeding *H. quadrimaculatus* in a reasonable year is not known. It could, however, be expected to at least equal that of the other species, so that an estimate of what could be caught in a reasonable year in Nkata Bay area might be of the order of 5 tons. This is probably a rather conservative estimate.

Chilimila Catch Data (See Map 5)

Number of chirundu	Total times fished	*H. virginalis*	*H. mloto*	*H. trimaculatus*	*H. pleurostigmoides*	*H. borleyi*	*H. quadrimaculatus*	*H. flavimanus*	*H. jacksoni*	*H. chrysonotus*	*H. nkatae*	*H. eucinostomous*	*Rhamphochromis* sp.	*Lethrinops* sp.	*Pseudotropheus* sp.	Number sp. recorded	Average No. sp./haul
% 1	% 7	% 5	% 3	% 2	% 5	% 5	% 6	%	%	%	% —	%	% 1	%	% 1	% 8	% 4.0
2	15	15	10	1	10	10	2		1		2	1	3		1	11	3.7
3	6	6	3	4	3	2	2						3			7	3.8
4	5	3	1	1	2	4	1		1	1			3		1	10	3.6
5	20	13	5	5	12	12	10		1	3		7	10	6	3	12	4.4
6	—		—	—													
7	—		—	—													
8	20	15	4	6	12	15	6	2	3		3	3	3	3	10	13	4.3
9	5	4	2	1	4	4	1		1	2	2		2		1	11	4.8
10	5	3	1	3	3	5	2		1		—		3	3		9	4.8
11	7	7	2	4	4	4	4	1			2	3	5	4		11	5.7
12	3	3			2	3					1	1			3	6	4.3
Total	93	74	31	27	57	64	34	3	8	6	10	15	33	16	20		

3. DAMBO FISHING

An appreciable amount of fishing goes on in the dambo (marsh) system of the Limphasa and Banga rivers near Nkata Bay, and is probably repeated in other areas where similar conditions prevail. These dambos consist of wide flat-bottomed valleys through which fairly slow-flowing rivers follow a meandering course. Because of the flatness of the valley floors and, in the Nkata Bay area, the heaviness of the rain during the rainy season, extensive annual flooding is usual. During the dry season shallow pools of various sizes are isolated from the river, and those often contain large numbers of immature fishes of various species.

The fishing methods employed on the dambo are largely designed to exploit this annual fluctuation in level. The rising or falling water often passes from the river to the pools and vice versa through relatively narrow channels. Across these channels reed fences or weirs, spoken of in Chitonga as " Beyu ", are constructed. Here and there in these fences gaps are left, and in them are placed basket traps based on the " catch-'em alive " rat trap principle, which are called "Mono" and which trap fishes passing along these channels.

When the level of the river is low, the juvenile fishes are left stranded in the isolated pools in which many of them were doubtless born during the rainy season, and are caught by another method. For this another type of basket trap known as the "Visako" is used. Each such trap is in essentials a deep but narrow reed basket perhaps 4 or 5 feet long and 2½ to 3 ft. deep with a relatively narrow mouth, say 18 inches wide. Such traps are operated in " fleets " by women who advance for a few feet from the bank into the water and lay their traps in a row with their mouths facing the shore. The result is a wall of open traps perhaps 30 feet long. The women then begin to tread water, advancing slowly from the bank to their traps and driving the small fishes before them into the gaping mouths of the traps. Each trap is then lifted. Sometimes several dozen small fishes are caught in a single trap as a result of one setting and, after a few hours on the dambo, women sometimes return to their villages with a considerable weight of fish.

Apart from this method the only other method observed is simple line fishing with worm-baited hooks which is indulged in largely by young boys.

The species recorded from the dambo region are listed below, those which appear to be most abundant in catches examined being denoted by an asterisk.

* *Clarias mossambicus*
* *Clarias theodorae*
Clarias mellandi
* *Tilapia sparrmanii*
Tilapia shirana
Serranochromis robustus
Mastacembelus shiranus
* *Marcusenius discorhynchus*
* *Gnathonemus macrolepidotus*
Barbus spp.
Alestes imberi.

While at first glance the methods employed, and particularly that using "visaka" traps, might appear wasteful and destructive, a more careful consideration of the facts seems to indicate that dambo fishing as practised at present is not seriously harmful, so far as is at present known. It is in any case probable that a large proportion of the juvenile fishes caught in isolated pools by women are already doomed at the time of their capture, for some of their habitats would dry out during the hot season when extremely high temperatures prevail in the unshaded dambo. Again the "Mono" traps must capture only a very small proportion of the fishes moving up or down from the river, for the number set in relation to the area of the dambo is very small.

Incidentally the juvenile fishes caught appear always to be cooked whole, and thus the valuable mineral content of the bones (other than the bony casques and sharp spines of small specimens of *Clarias* which are rejected) is ingested as well as the protein of the flesh.

4. RIVERS AND THE BARILIUS FISHERY

A. General

Two species of the genus *Barilius* Hamilton Buchanan occur in Lake Nyasa ; they are far and away the largest species of the genus in Africa and are both endemic to Lake Nyasa and the rivers that flow into it. The two species are *B. microlepis* (Gunther), " Mpasa ", with a largest recorded length of 660 mm., and *B. microcephalus* (Gunther), " Sanjika ", with a largest recorded length of 370 mm. Both these lengths are recorded by Bertram *et al.* (1942) from 1939 figures ; the present survey records are at least 100 mm. smaller in both cases.

There is an African fishery for these two fish of very great importance.

Both species are predators upon other fishes and both, to a large extent, ascend rivers to spawn. It is possible that not all the lake fishes of this genus are river spawned as there is some little indication that certain stocks spawn in the lake and do not enter rivers, and some further indication that there are dwarf river-living races which do not enter the lake. These indications may apply to both species or may apply only to the Sanjika.

In view of their great importance as a protein supply to Africans and in further view of the fact that they are exploited for food when they are on their spawning migration, a most critical stage of a fish's life, the study of the biology of these fishes is of major importance. During the survey these fishes were not studied in any very great detail, as to do so would have taken up too much of the limited time available, and would have involved frequent visits to the various rivers, which are far apart from each other and very inaccessible, and the keeping of detailed records at such places, as well as detailed work during their lake living phase. Even had it been possible to devote more time to these two species, several year's figures are necessary to determine any trend to growth or reduction in average size of the populations, and some long-term tagging work is also very desirable.

Nevertheless the necessity for study of these fishes is very real, because of their importance in the diet of inland and lakeshore Africans and because the very special method of exploitation in rivers lends itself more than in the case of any other lake fish to a very considerable danger of overfishing and consequent destruction of the stock, which would cause a good deal of hardship to Africans particularly in the Northern Province.

Both are relatively large silvery fishes, actively predatory in the open waters of the lake, and, though belonging to an entirely different family, bear a striking resemblance both in habits and in body form, to members of the family Salmondae (e.g., *Salmo*, *Oncorhynchus*). Juveniles feed on insects, crustacea, etc., as is usual with the young of predatory fishes ; the food of larger fishes in the lake would appear to be largely Utaka (*Haprochromis* species) and Usipa, *E. sardella*, when these are available.

They are a well-known angling fish in Lake Nyasa, and will readily take a spoon or spinner if it is bright silvery in colour ; they are known to European anglers as the " Lake Nyasa salmon ". The amount taken by sporting anglers is, however, negligible.

At Nkata Bay in the lake they were not found to be abundant at all (see table on gill-net fishing) and they are not caught in very large numbers by trolling, one or two only being the average catch for an afternoon's fishing. Similarly, Bertram *et al.* (1942) saw only 97 Mpasa and 27 Sanjika, although the authors state (p. 51), that the small numbers of Sanjika recorded by the native clerks are due to the fact that they were not being fished for deliberately, and does not mean that the fish were scarce in the lake. Notwithstanding this, indications seem that the fishes are not as abundant as they should be, for a fish of this type, and that they used to be more abundant in previous years. If this is true, it is regrettable, as the Mpasa is the one species in Lake Nyasa with any pretensions at all of being a game fish, and as such has definite attractions for the tourist industry and thus for the economic welfare of the country. The importance of these species as food for Africans in inland northern areas, however, far overshadows all other considerations, and scarcity is particularly regrettable here.

Lowe (1952), from data collected by her at Karonga, gives the following as a tentative estimate of the growth rate of the Mpasa :

1st year to about 10 cm.
2nd year possibly to 21 cm.
3rd year possibly to about 31 cm.
4th year possibly to about 38 cm.
5th year possibly to about 44 cm.
6th year possibly to about 49 cm.
7th year possibly to about 53 cm.

B. The Spawning Migration and African River Fishery

Both species live for most of the year in the lake and ascend rivers in order to spawn. As mentioned above there is a possibility firstly that some Sanjika and perhaps Mpasa as well stay in the lake all the year round and breed there, and secondly that Sanjika and perhaps Mpasa remain in rivers indefinitely. Evidence for the first possibility is based on the fact that young *Barilius* have been caught by this survey in the lake, miles away from the nearest river, of such a small size as to make it seem improbable that they have descended any river after hatching and proceeded to the point of capture, and also on statements by native fishermen and lakeshore dwellers, who are confident that some Sanjika spawn in the lake. Lowe (1952) is followed for the second asseveration from her account (p. 73) of dwarf and probably fluviatile Sanjika in the Lilongwe River.

These two possibilities must be borne in mind in any future study of this genus in Nyasaland in case confusion between these fishes and the anadromous populations should arise, but no further mention will be made of them here, and only the anadromous populations will be considered.

The actual date of spawning run is not constant but varies from river to river. In the Luweya River the migration upstream usually commences about the middle of August but is dependent upon the temperature of the water, and the run is later if there has been a long cold winter. The run lasts until September or October, being thus from about 7 to about 11 or 12 weeks in this river.

In no other river does the run start as early in the year as this, in the height of the dry season, and in the other major rivers the spawning run takes place during the rains, commencing usually in January and being at its height in February. Thus " at Chipoka in January (1939) the water in the Lintippe River was said to be boiling with Mpasa." (Bertram *et al.*, 1942). In the North Rukuru River near Karonga a number of large specimens of Mpasa were taken by this survey on 14th February, by gill-net set near the mouth. Lowe (1952) suggests that there is a large lake-living population of Sanjika which ascends the Lilongwe River during the rains which is distinct from the fluviatile race of small fish which were caught there ripe in early September. Reports from the Dwambazi River state that the spawning run there occurs during the rainy months.

C. African Fisheries for Barilius during the spawning migration

The major part of the fishing effort for these two species takes place at the mouth of or in rivers during the spawning run, and it has long been realized that this state of affairs is not a very healthy one. Bertram *et al.* (1942) state: " In most large rivers fences and traps are put up which almost block the river, and these must catch a high proportion of fish. Since at these times the fish are just about to spawn, it is clear that there is a great deal of waste in the fishery." (p. 50.) This type of fishery has, however, gone on for a very long time.

I. THE SPAWNING FISHERY IN THE LUWEYA RIVER

The Luweya River in the Nkata Bay District presents several distinctive and interesting features, one of which, the unusual date of the spawning run, has already been mentioned.

Another unique character concerns the Chiwandama Falls, a series of cataracts about 14 miles upstream from the mouth, which forms a bottleneck through which the Sanjika must pass to reach their spawning grounds upstream and where they have for a long time been caught in very large quantities indeed. This fishery is entirely in the gift of the Chief Ngombo and this is another particularly interesting feature, a primitive and ancient tribal right still being of very real value and prestige to a chief even in these sophisticated days with its monetary values and trends towards western urbanization.

An excellent account of this fishery was written by Mr. Hoole, District Commissioner, Nkata Bay, in the Appendix to the D.C.'s Annual Report of 1934. This is still substantially accurate, so much so that parts of it are given verbatim here:

" In conclusion, Chiwandama, the falls on the Luweya River already mentioned, deserve a special note.

" At Chiwandama the river runs through a deep rocky gorge between the Mbara hills on the north and the Ukali hills on the south.

" At this point it has worn a passage through the rocks and boils down in steps through a narrow gap about 20 feet or so wide, widening out again and passing over rapids into a long deep pool called Chambesi. The Chiwandama proper only extend for a short distance. Rocky ledges project into the main fall, and in the pockets and eddies at the foot of these, the fish, chiefly Sanjika, rest either after having failed in an attempt to jump the falls, or whilst pausing before proceeding to negotiate the next step up. On the rocky projections over these pockets there are certain precarious stands known in the vernacular as " Vuu " where during the season (August to early October) when the fish are running up the river to spawn, the natives stand armed with their Khombe nets.

" There are Vuu or stands on the north side and six on the south side, each with its own name. The fishing rights at Chiwandama are strictly preserved and hereditary in the family of Chief Ngombo . . . . Chief Ngombo controls the fishing.

" Although as I have stated Chiwandama itself is a strict preserve, above and below the falls is free to all except for two small pools known as " Mkwache " and " Chitenche " . . . .

" In the greater part of the year this gorge is deserted, but during the season it is the scene of intense activity. Amongst the large boulders and rocks on the steep sides of the gorge the natives build themselves green booths in which they live, every available shelter or cranny among the boulders being occupied.

" Round these booths the women, smoking their pipes and surrounded by their children, work busily all day opening up the fish caught by their men folk and drying them over small fires.

" It is an unforgettable experience to stand in that scene of animation, with the roar of the falls in one's ears, and to watch the constant streams of fish leap up and out from the water below into the sunlit falls."

Over twenty years later the scene at the falls remains much the same. The Sanjika, driven by their intense and overwhelming urge to get past this barrier to their spawning ground, attempt to force a passage with the utmost determination, leaping high into the air, swimming with all their strength, and being washed back time and again by the torrent, until eventually they succeed in surmounting the first cataract. There they congregate to rest and gather their strength for the next onslaught against the current, in the few little areas of slack water available, and there they are scooped up by the ceaseless wielders of the longhandled Khombe nets (Plate V, A, B).

Fishes migrating from the lake up to this point are all cyprinids. They are " Mpasa ", *Barilius microlepis*, " Sanjika ", *B. microcephalus*, " Kuyu ", *Barbus eurystomus*, and " Chikasu ", *Barbus johnstoni*. The Mpasa does not go any further up the river than the deep pool Chambesi about 400 yards below the main falls. This pool is fished with nets, but Chief Ngombo has no exclusive rights over this area. The pool is a noted breeding ground for this species and it should be relatively easy to observe spawning habits there. The fishes, according to local information, spawn in a manner somewhat similar to salmon, lying on their side with bellies touching. There is no clear evidence that any sort of scrape or nest is made, and it may be that there is no previous preparation of the ground by either the hen or cock fish.

Barbus eurystomus also never attempts to proceed up the Luweya past the falls, but nothing otherwise is known of its breeding except that its upper limit of spawning is probably also the Chambesi pool. *Barbus johnstoni* are said to attempt to negotiate the falls, but in very much smaller numbers than the Sanjika, and none were seen caught there.

It can thus be seen that the very great majority of fishes which attempt to ascend the falls are Sanjika, and these are caught by the fishing in very large numbers. A certain proportion succeed in evading the nets, but this number is probably small. There is, however, yet another unique feature of this fishery, and that is that deliberate steps appear to be taken to allow some fishes to escape upstream, apparently for the purpose of allowing them to breed. This is done by starting the fishery a little later than is strictly possible, and thus there are some clear days when the run is first starting and the number of fishes is small, where there is no fishing and these fishes at the beginning are allowed a clear run with only natural hazards to overcome. Then the fishing effort also is slackened at times later on, particularly, again, on days when the fish are not running strongly.

These measures directed towards voluntary conservation of the breeding stock are most creditable, the more so for being unusual among African fisheries, and, together with the fishes which escape the fishing effort, these preserved fishes form a stock which breed and migrate further upstream until finally stopped by the weir near Mzonga of which mention will be made below.

On 1st October, 1955, alevins of Sanjika were taken immediately above the Chiwandama Falls. These ranged from 8–16 mm. in length and were grouped in little shoals, from 8–20 individuals only, in pools and very shallow slack waters. Several of these little bunches of fishes were seen but the impression gained was that these fry were relatively not abundant. In addition fingerlings of 20–40 mm. were seen and a few taken.

About four miles above the falls there is a large weir built for the purpose of trapping Sanjika. At this weir there is no evidence that any fish are allowed to pass. It is constructed by the village of one Pasu, who although not an Administration Village Headman and who does not hold a census book, nevertheless has a position of some authority in tribal matters. The job of building the one is a traditional service to the Kabunduli, and Pasu takes a share of the fish caught for this service. This weir is built every year as soon as the water and weather becomes warm enough for the workers to stand in the river with comfort; and is generally completed by the end of August or beginning of September.

The weir is large and exceptionally well constructed of logs, its construction having apparently been sanctioned by Government many years ago as a tribal prerogative of the Kabunduli. Every effort is made to make it as efficient as possible, and, to prevent Sanjika jumping over it a screen of reeds is built above it. Baskets are attached to the screen in such a way that fish after jumping up and striking the screen will fall back into the baskets. There are four of the usual valved basket-work traps in the weir, of which the one nearest the southern bank is particularly large, and all fish taken in it are the sole property of the Kabanduli. Mr. J. van Velsen, an anthropologist of the Rhodes-Livingstone Institute, saw 400 Sanjika taken out of this trap at one emptying in September, 1954.

Between the Chiwandama Falls and this trap is a fairly quiet reach of river extending for some four miles and it is probable that, in these circumstances, this forms the breeding ground of the Sanjika, a negligible proportion being able to pass the limit set by the weir into the upper reaches and tributaries of the Luweya River, as the weir appears to be extremely efficient and it is unlikely (though not known for certain) that any deliberate measures are taken to allow any Sanjika to pass it.

Some Sanjika may breed below the falls; again no work has been done to ascertain whether any do, and if so, what proportion of the whole these form. Judging by the determination of the migration past the falls, however, it would appear to be probable that the very great majority, if not all, of the Sanjika which enter the river do not shed their reproductive products until they are at least so far up the river as to have passed the Chiwandama Falls. It is thus likely that, under these circumstances, the breeding of all Sanjika in the Luweya is largely restricted to the stretch of river between the Chiwandama Falls and the Pasu weir.

Breeding of the Mpasa is certainly restricted to that part of the river which lies below the falls. The Luweya River, traced backwards from its mouth, pursues a winding course through large areas of marsh and swamp for about ten miles as the crow flies and for about twice that distance if the exceedingly tortuous and winding career of the river is followed, as a fish must do, opening out into many lagoons and swamps of all sizes. From here the river's course is down more sloping ground, and the flow is swifter in a well-marked valley. There is, working upstream, about two miles of flow through such country before the falls are reached, and the breeding grounds of the Mpasa are probably restricted to this portion of the river, unless they breed in the marshy area, which is unlikely because of the lack of gravel in such areas, which are more likely to have a muddy bottom.

Thus it would seem, in the present state of our knowledge, that in the Luweya River the Mpasa breed only in the two miles between the Chiwandama Falls and the commencement of the slow flowing muddy swamp reaches, and the Sanjika in the three or four miles between Pasu's weir and the falls, together, in each case with any suitable tributaries which flow into the Luweya.

The Chiwandama Falls, in the 1955 season, did not yield nearly as many fishes as it usually does, and the Sanjika, which varied from 210–252 mm. in size, on 1st October, and 4 oz. to 7 oz. in weight, were very small and undersized compared with the run of previous years. In spite of this, the numbers being caught were very large, and, when the spot was visited on 1st October, it was possible to obtain from the Ngombo some figures from which a first tentative guess of the actual numbers caught can be hazarded. These figures were totals of daily catches from each of three stands, or VUU, on the northern bank, which the Chief allows relatives and other favoured people to fish from, on the condition that the major part of the catch, about 60 per cent. to 70 per cent. of the total, goes to the Chief, the rest the visitors being allowed to keep. In order that the Chief may claim his tribute, watchers are set over these three stands, and a record, which may be considered to be fairly accurate, is kept of the numbers of fish lifted from these three stands. The daily figures for the month of September were:

Fishes caught from three northern stands during September, 1955:

September	..	2nd:	..	57
,,	..	3rd:	..	72
,,	..	8th:	..	127
,,	..	9th:	..	132
,,	..	10th:	..	136
,,	..	11th:	..	275
,,	..	12th:	..	884
,,	..	13th:	..	103
,,	..	14th:	..	123
,,	..	15th:	..	175
,,	..	16th:	..	100
,,	..	17th:	..	154
,,	..	18th:	..	89
,,	..	22nd:	..	172
,,	..	23rd:	..	263
,,	..	24th:	..	280
,,	..	25th:	..	367
,,	..	26th:	..	284
,,	..	27th:	..	122
,,	..	28th:	..	83
,,	..	29th:	..	142
,,	..	30th:	..	150
				4,290

These figures are very far from presenting an accurate idea of the total taken during the month, being as they are records from only three stands. They take no account of the substantial numbers of Sanjika and larger fish taken below the falls by nets and by angling. They take no account of fishes caught at night, and, above all, catches from the southern stands are not included. The southern stands catch collectively more than the northern, for the primary reason that the very best of all, the stand from which all catches go to the Chief, is situated there. This stand is over a deep cleft or gully in the rocks, which forms much the largest area of slack water along the cataracts, and the resting fishes accordingly congregate there in large numbers. Where the nets from the other stands take out fishes singly, the net over this stand scooped them out in twos, threes and fives, and, when the Sanjika are running strongly, two nets work there in relay, as one has not time to scoop all the resting fishes. It can therefore be assumed that the catch from the southern stands is probably more than that from the northern, and certainly not less.

To these figures must also be added catches from the falls at night (where fishing is asserted to go on for most of it) and catches by nets and angling in the parts below the falls. Angling is done using a species of termite (?) called Ngumbi, which are dug up with hoes from a few inches below the ground in hard dry sunbaked earth, and together with nets catch a substantial quantity of fish. In spite of what the locals say it is unlikely that as many fish are caught by the scoop nets at night as by day, and 1,000 a month for both sides may be taken as a conservative estimate. Netting and angling below the falls account for a quantity of Mpasa and *Barbus* species as well as Sanjika and this quantity may be estimated at 2,000 per month, although this may be a little on the low side.

One may thus arrive at a total of 10,000 fishes caught in the Chiwandama area of the river in September, 1955. 1955 was from all accounts an exceptionally bad year, with all catches well below average in number and size, so that, to be conservative again, one may consider 12,000 fish per month, or 3,000 per week during the season, to be a normal catch. If a season lasts eight weeks, this means that 24,000 fishes, all ripe and ready to spawn, are taken out per annum at Chiwandama. It is even more difficult to arrive at any conclusion as to the weight of fish involved or to the value of them. All that can be said in this connection is that about 75–80 per cent. of the total catch is Sanjika, that their average weight in 1955 was well under half a pound, and that they were being sold on the spot at 2d or 3d each according to size. Only two Mpasa were seen and they both weighed over 4 lb. and would have sold at 3s–6d to 4s, each on the spot. The average weight of Mpasa is probably rather lower, but no Mpasa sell for less than about 2s–6d. Using this information as a basis, conservative figures as to poundage and price for an average year would be 14,000 lb. and £400, for an eight week season, or 10,500 lb. and £300 for a six week season, but there is little to go on to indicate that these are accurate and again are probably too low. They serve, however, to indicate how large and generally valuable the Luweya River fishing industry is, especially as its duration is so short. Dried and smoked fish from the Luweya find their way far and wide over the country and some are even brought back to the lake-shore at Chinteche for sale there.

II. OTHER BARILIUS FISHERIES

Not even figures as scanty as these are available for other rivers, although some, being larger, must be quite as valuable.

Observers on other rivers have all been struck by the determined efforts made to catch the ascending fishes and the equally determined efforts not to allow any to escape to perform their function of reproduction and carrying on the stock. Almost equally workers have been surprised that in spite of all this, stocks of Sanjika and Mpasa still persist, although probably not now in the quantities in which they used to occur. Lowe (1952) quotes David Livingstone (1865) who described fish weirs with basket traps to catch the Mpasa or Sanjika running up the rivers to spawn in August or September. Livingstone commented that "It seemed a marvel how the most sagacious Sanjika could get up at all without being taken," but suggested that possibly a passage up the river was found at night.

Lowe goes on to state that at Karonga in March, 1946, despite a local Native Authority rule that seines should not be used near the Rukuru mouth during the Mpasa season, many seines were catching Mpasa, together with Sanjika and other fish. She comments: "A Mpasa desirous of ascending the North Rukuru River to spawn was faced with (*a*) numerous crocodiles lying off the delta of the river, (*b*) a number of seines, (*c*) fishermen with scoop-net in each hand chasing Mpasa in the shallow water of the delta, and, once in the river proper, (*d*) fishermen with large scoop-nets fishing from platforms built every 50 yards or so along the banks of several miles of the river, (*e*) eight complete barriers of traps spread out over about 13 miles of river, and (*f*) fish netting parties, in which all the men of a village were seen to form a line across the river each with a scoop-net in his hand.".

D. Discussion and Recommendations

It can be seen from the foregoing that exploiting populations of migrating fishes in rivers is a popular and valuable method of fishing. Both its popularity and its value may be ascribed to the fact that, acting under the spawning urge, the fishes congregate themselves into places exceptionally adverse to their own survival, which firstly renders them easily taken, i.e., that a relatively small fishing effort results in a relatively large catch, and which secondly enables them to be caught in places at a distance from the lake-shore where fish and other forms of protein are not otherwise readily obtainable by a hungry native population.

But this method of fishing has the great disadvantage, made much greater by its value, that it is at present almost completely uncontrolled and there is a great danger of overfishing. Indeed in the circumstances obtaining it would appear to be inevitable that overfishing must eventually take place unless some sort of control is imposed. Nothing very drastic has happened to the stocks as yet, and while it is probable that these fish are not as abundant as they used to be, this is difficult to prove. Catches were not abundant at the Chiwandama in 1955, and the Sanjika caught were all of very small size, though this was ascribed by the Africans to a very cold winter and a lack of Usipa in the lake. More settled conditions and an increase of human populations have probably resulted in fiercer exploitation of the breeding stocks of recent years, and the present day escapement is probably not as great as it used to be in previous years.

Thus while the present day position is not gravely serious the fate of the stocks is still much more precarious than it should be. Many cases are known of a valuable fishery disappearing as the result of overfishing combined with one or two bad years, and in the present state of our knowledge there is no evidence for supposing that the same may not happen to the *Barilius* fishery at any time.

The main reason for this undesirable state of affairs are the weirs. Methods of fishing which involve constant labour, such as scoop netting, must perforce let some of the stocks pass, and the Chiwandama Falls fishery, where conditions are most adverse to the fish by virtue of the terrain, has also the virtue of voluntarily allowing some fish to escape. Weirs, however, are a most primitive method of fishing, and cause great harm. Their use has long not been tolerated in countries with any pretence towards being civilized. Apart from allowing very little escapement of fish, and virtually none in bad years when the water is low, they cause damming of streams which result in flooding and washing of banks with consequent silting up of the stream bed on the one hand and soil erosion on the other, and they are a constant hindrance to navigation by canoe or boat.

These short-coming of weirs are well known and legislation to the effect that a gap must be left in weirs has long been in force. It is hardly ever observed, and enforcement of it is extremely difficult due to non-co-operation of the local population and the extreme inaccessibility of many of the sites, which can ordinarily be visited only once every three months or even less often. It is bad logic, however, to shelve a problem because it is difficult to enforce laws designed to alleviate it ; not to enforce a law because it is difficult to do so does not *ipso facto* remove the cause for which the law was made. The problem is still extant, and must be tackled afresh.

The primary cause of weirs being built is to supply fish to a protein-hungry people who have difficulty in obtaining it otherwise. In other words, the incentive is primarily, but not entirely, that of subsistence and not of a cash product. Much can be done to diminish this incentive by efforts to provide more meat in the form of sheep, cattle and goats and, in so far as fish are concerned, by efforts to increase the catch of fish from the lake where fishing is not so deleterious to the breeding stock and to have this fish distributed to inland areas, and, what will be of particular benefit to inland people, the encouraging of village fish ponds which will provide a permanent supply of fresh fish to villages remote from the lake. It is to be hoped that in future years efforts now being made in this direction will alleviate much of the present incentive to build weirs and reduce antipathy towards leaving a portion of the river open to fish and boats when they are built.

It is further suggested that weirs and other river problems may advantageously be tackled through the local authorities by encouraging them to take an interest in these problems, which are their own, a manner fitting to the spirit of modern day local government. It is suggested that as an experiment, Conservancy Boards be erected for some of the more important rivers, such as the Luweya and the North Rukuru. These would be on the same lines as the present British River Conservancy Boards, for instance, would represent all those who have rights and interests on the rivers and their primary purpose would be to ensure that all interested would have a fair share of the benefits conferred by the river, and be a means of ensuring that these benefits be continued in perpetuity. At present the benefits at first may be limited to fishing and transport, but may in future, as the country develops, include other things, such as water for irrigation, paddies for rice, and even, in the not yet foreseeable future, such things as hydro-electric schemes for light and power for secondary industries, with consequent problems of pollution, etc. Such things will probably come one day, though it may not be in the power of the present generation to visualize them.

For the Luweya River, for instance, among those on the board would be the Chiefs Ngombo and Kabunduli, both of whom have traditional fishing rights, and all those who have rights and interests further down, and on tributaries such as the Limpasa. It would include representatives of Government departments such as Agriculture, Game, Fish and Tsetse Control and Forestry. Ideally the board should have certain powers and responsibilities. Its powers should include the enforcement of laws with relation to gaps in weirs, illegal methods of fishing and activities which are liable to cause undue diversion of water, flooding, damage to rivers through planting in the " eyes " of streams, soil erosion, pollution of water, etc., and bailiffs should be employed to enforce this. Its responsibility should include ensuring that a reasonable proportion of spawning fish be allowed to fulfil their function in a wider area than is at present possible, that a fair share of the river's produce goes to all entitled to it by right and custom, the keeping of records for both these purposes, the right of anyone to navigate without let or hindrance, and a recommendation of schemes and measures for the public good, such as the building of fish ponds, irrigation and hydro-electric schemes, rice projects, etc., etc.

5. THE FISHERY FOR USIPA

A. Introduction

Engraulicypris sardella, known all over the lake as Usipa, is a fish of considerable importance in the north of the lake, more so probably than it is in the south, but little is known of its biology. It is the only species that could be considered to be a truly pelagic fish, for other plankton feeders, such as the Utaka group of *Haplochromis*, are tied biologically to the inshore regions by their breeding characteristics and are mostly not open water species at all in the true sense of the term.

The Usipa, however, produces large numbers of floating eggs, and larvae have been recorded occasionally from plankton hauls, so that it is possible for it to spend its whole life history in the surface waters of the lake. In September, 1954, for instance, a shoal of juveniles was seen at the surface in the extreme north of the lake and far from land, and reports of large shoals in the centre of the lake have been received on other occasions. Even so, the existing fisheries for Usipa are all inshore fisheries and an account of the three most important ones in the north of the lake is now given. Usipa is a small fish, the largest seen by the survey being a little over 120 mm. so that the nets used are all of small mesh. Two of the methods described have probably been in use for some time, those involving the beach seine and the scoop net, while the third in which a mosquito net is used is probably relatively new. In all cases considerable skill is shown, together with knowledge of water conditions and of the habits of the fish.

B. The Chiwu Method

The Chiwu net is a scoop net consisting of small mesh netting mounted between two short poles as in the figure (Plate VD).

The netting is made of chopwa thread and the mesh size is about ½″ stretched. The net is tied to the poles at intervals along the margin, but the poles are not tied together at the fork. A seasonal and localized fishery exists at Chizi, south of Nkata Bay, and the account given here is based on observation and information gained mainly from this place. Fishing is carried on at night from canoes, each usually with three men who form a well organized team. At the front of the canoe is the one responsible for handling a flare called the " mwenje ",which is a long bundle of short twigs, each about 1″ in diameter, and bound firmly together so that the whole is about 10 feet long and 1 foot in diameter. The second man in the canoe handles the net and is considered to be the most skilful member of the team, while the third at the back paddles and handles the canoe according to the instructions from the scooper.

The shore at the site of the fishery is sandy and at a short distance from land gives way abruptly to deeper water. The shelf at the junction of deep and shallow water is called the " chinu " and fish are located in deep water and fished when they have passed over the chinu into the shallows or " chiyeziyezi ". The canoe is paddled out to a definite area about half a mile off shore and half a square mile in extent, the flare lying smouldering in the bottom of the canoe. At a place in which fish are believed to be shoaling it is lifted out and it bursts into flame, giving a bright light. As many as forty flares have been seen at the same time, a very spectacular sight. The flare is held over the left side of the canoe and balanced so that it can be moved easily. To begin with it is kept steady at a little distance from the surface of the water and if Usipa are present in the immediate area they are attracted by the light, and often first indicated by a stream of tiny bubbles rising to the surface. These bubbles are probably the result of discharging air bladders and indicate that the fish may be rising from a considerable depth. When a large enough shoal has been attracted to the area of light, the fish being easily visible from the canoe by now, the canoe is paddled slowly and carefully to the shore, the man handling the light adjusting its position so that the shoal is kept together until the chinu is crossed. The fishing is done in shallow water, not more than 12 feet deep, and close to the shore. Here on occasions the shoal may be so dense as to occupy the whole of this depth. The scooper dips the net in front of and above the light, draws it through the shoal, the light being moved away as the net passes it, and empties it behind him into the canoe, this operation being repeated as often as possible. Meanwhile the canoe may approach very close inshore, in which case it is turned, always to the right, so that the shoal is between the canoe and the shore, and fishing continues while the canoe moves parallel to the shore. As the density of the shoal decreases, the flare is controlled by sprinkling water on it so that the area illuminated decreases and the fish tend to congregate again. Eventually the shoal disperses or is fished out, and the whole operation is repeated. The shoals are sometimes so concentrated that it is with difficulty that the net can be forced through, and the net handler may require assistance. At such times catches are very high. On 2nd August, 1956, for instance, four canoes were seen, each well loaded with an estimated half ton of fish at least. Each canoe was filled during one trip, two nets only were involved, and the whole operation carried out twice for each net. Sometimes fish may be attracted to the surface in deep water but the fishermen fail to bring them to the shallow water, or, not as often, none may be located. As a result such catches, although not rare, are not common.

Fishing operations are restricted to certain periods of the moon's cycle when its light is not strong enough to interfere with the flare. This period is called " chisi ", and the rest of the month " balawala ". The chisi period lasts about two weeks, over the first and last quarters of the lunar cycle. The last quarter is distinguished as " chisi cha ku nyanja " or " lake chisi ", the moon rising after midnight and therefore being to east, or lake side, as fishing goes on, and the first quarter when the moon rises earlier and is overhead, or in the west, is known as " chisi cha kunena "or the " land chisi ". Fishing is carried out between two and five a.m., but apparently, some years ago, fishing used to be carried on before midnight but as the fish is usually boiled and sun-dried, it was found that by the time it could be prepared in this way, the catch had become bad and was wasted.

Although fishing is attempted over a large part of the year, it is concentrated and most successful in the months from June to about November, the best months being August and September. This longer period probably includes a period of breeding for the species, as the fish seen in September, 1956, were ripe running, and during March and April, fish caught inshore at Nkata Bay were at earlier stages of the development of the gonads. Lake conditions have to be reasonably calm for fishing to be possible, a rough sea or a high wind making the handling of the boat or the control of the flare difficult.

In the same Chisi area there exists another type of fishery which may be associated with Usipa indirectly. This is a long line fishery for certain species of *Rhamphochromis* " Batala ", a predatory Cichlid. The area fished is larger and further offshore where the depth is about 100 fathoms. A weighted frame bearing two hooks is left down as much as 70 metres. The hooks are baited with Usipa, which are considered to be very much more effective than Utaka. The main species of *Rhamphochromis* caught, although it cannot be identified with certainty, does not occur, except very rarely, with Utaka caught in the chilimila net, and does not apparently prey on these fish. The same species does however occur in gill-net catches, but seasonally. They are caught in the 54 mesh, 4" net, during the months of August and September, particularly, and the places where many have been caught are near the Chizi chiwu grounds and near the light-house north of Nkata Bay where the chiwu method is also used.

The long line fishery is most successful from October to January, and large numbers may then be caught. As many as 70 canoes have been seen over an area of several square miles, and catches of 30 fish are not uncommon from a morning's fishing, indicating a high density of population. It is possible that a specific predator/prey relationship exists between Usipa and this, and other species of *Rhamphochromis*, which may determine the distribution of the predator as does the distribution of Utaka condition that of Bagrus (see page 107). The occurrence of *Rhamphochromis* nearer the shore in August may be related to the fact that the chiwu fishery exists there at that time, and the wider distribution of *Rhamphochromis* in December and the early part of the year may have a similar explanation. Although this is only an assumption, the seasonal and regular appearance of Usipa at the chiwu grounds, and possibly at the breeding phase, does indicate that the distribution of Usipa is not as random as might be expected for a pelagic fish, and that for a period of its life history at least, it is associated with a definite type of shore or nearshore habitat.

C. The Beach Seine

At Sanga, a few miles south of Nkata Bay, the shore line consists of a long shallow sandy beach, and this is a site for the other large scale Usipa fishery found in the north.

The net used is a beach seine, the " mkwau wa Usipa ", and it is made and fished almost entirely for this species of fish. One of these nets was found to be about 300 yards long, of an almost uniform height of about 12 feet, and made of strips of netting manufactured locally from chopwa thread. The wings or " wamtepa " are of mesh size about 2", but the central portion about 30 yards long, called the " lambi ", is of very small mesh about $\frac{1}{2}''$ or less, and is made of very thick twine so that the lumen is very small. Between these sections the net is divided into paired pieces, the " ntusulu " of a little less than 1" mesh, and the " mtaka " of larger mesh size, and so called because here, individuals of the Utaka group are often gilled. The head ropes and foot ropes are of twisted bark, and the floats and weights of carved pieces of wood and small stones respectively. The handling of such a net requires a large number of helpers, although the laying is carried out from a single large canoe containing about eight people. Lake conditions must be calm, and at such times about forty people can be seen sitting on the beach watching for signs of Usipa, with the net ready folded for use in the canoe. The shoals are sighted at the surface and are fished with this seine only when within a short distance of the shore. Both the position and the direction of movement of the shoal have to be judged accurately, and the net is then laid in an arc beginning some distance in front of the shoal and in the direction of movement. Laying is then continued, so that the net comes to lie outside and then behind the shoal, finally enclosing it on three sides. The whole operation is carried out as quickly as possible, and no one is allowed in, or even near the lake, until the net is laid. Recently in this area, the use of the mosquito net to dive for Usipa has been forbidden by the local Native Authority, for the reason that the shoals are dispersed and driven off in this way, opportunities for the use of the beach seine thereby being lost.

The net is laid so that the wings are quite near the shore in shallow water, and men are stationed along the warps both to haul and to drive usipa towards the centre of the enclosing net. At this stage of the proceedings the shoal acts as a single unit, and although it may pass around the wings of the net, individuals do not normally attempt to pass through even those meshes which are big enough to allow escape. There is a definite tendency on the part of Usipa to sound, so that escape over the top of the net, which, because the net bags considerably, is less than its full 12 feet from the bottom, is not common. The hauling is rapid until the wings and the ntaka comes ashore after which it proceeds more leisurely. At this time the net forms a long and narrow enclosure and the outside is patrolled by men reporting the position of any fish enclosed, and attempting to drive them towards the lambi. At this stage too, other are ready with mosquito nets to catch any fish which may escape, as by now the original shoal is usually fragmented, and individual groups, or individuals attempt to pass over or through the net. The catch when hauled is placed in the large canoe and the operation is repeated when another shoal is spotted.

On one occasion about 4 cwt. were seen to be caught, which was considered to be a small catch for this method. In 1954 several canoes, well filled with Usipa, were seen on the beach, each containing what was estimated to be of the order of one ton of fish, the canoes being very large, so that catches can be very high. However, fishing with this seine is not carried out regularly, as it is limited by rough lake surface conditions which make the sighting of the shoals difficult. As the beach itself is well exposed, the number of days on which fishing can be practicable is relatively few but the distribution of the fishing effort throughout the year is not known.

Although shoals can be sighted about 300 yards from the shore they cannot be fished with the seine unless they are seen much closer inshore. They are usually reported to be moving parallel to the shore and it is alleged that the direction of the shore currents is related to the direction of movement of the shoal. Fishing is usually carried out in the afternoon, the sun being behind the observers, making spotting more easy, and in the morning, if conditions seem promising, wooden floats are anchored in shallow water, so that they can indicate the current flow.

There is a long, almost unbroken sandy beach extending from Sanga almost to Bandawe some twenty miles away, and it is reported that when conditions are suitable, good catches are often recorded at one end of the stretch while very few Usipa are caught at the other, indicating possibly that such a stretch contains one or a few populations of Usipa which move up and down fairly near the shore. Although small stretches of similar beach are found in the Nkata Bay area, no large shoals of the order of size of those sometimes fished at Sanga have been seen or recorded, although small groups often appear at certain times of the year. The Usipa seine is unknown at Nkata Bay, as it is between there and Usisya about 20 miles to the north; the sandy beaches are smaller between these places, and it is possible therefore that the size of the shoals of Usipa seen inshore depends to a large extent on the length of sandy beach available.

D. The "Usikite" Net

The third type of fishing method for Usipa is one with the widest distribution of use, and wherever a stretch of sandy beach is available, the rather picturesque diving with mosquito nets can be observed at certain times. It is common at Nkata Bay where it is known as the "Kabuliya Usipa" fishery, using an "Usikite" net and where neither the chiwu nor the beach seine is used, and it is also used at places where these larger scale methods are important. The net is an ordinary mosquito net with an oblong opening of about 7 ft. by 3 ft. 6 inches. Along the short sides are fixed sticks to hold the net open and whenever the lake is calm, canoes may be seen with two or three people, one of whom will be paddling and the others standing on the gunwale. When a shoal is sighted inshore, usually in water less than two fathoms deep, it is approached carefully until within range. As it is reached one man dives in with a net, to be followed immediately by the other, and each takes one of the pieces of wood. Separating, they swim through the shoal or on both sides of it, and direct the fish into the opening of the net. The stick held by one is then passed to the other who remains in the water until he can pass the net into the boat. If the shoal is fairly large this may be repeated. At certain places where the beach seine is also used, this method can give high catches, a small canoe being filled in a morning's fishing, but at Nkata Bay and places similar to it where sandy beaches are not large, a morning's fishing which yields a hundredweight of fish is considered exceptional.

E. Discussion

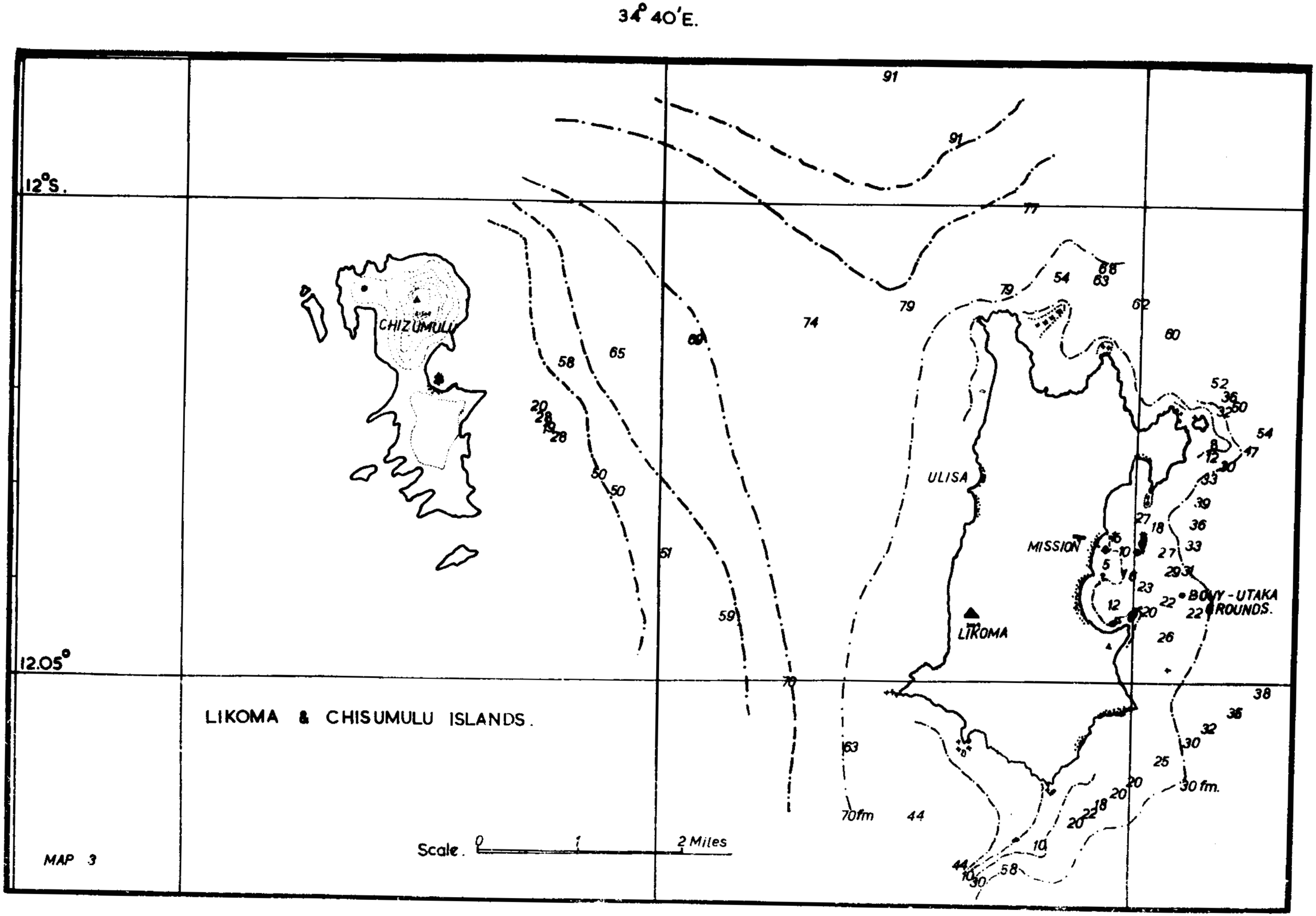
The biology of Usipa forms a major part of the continuing research programme for Lake Nyasa and detailed discussion of the data at present available is not appropriate here.

The basic problems concern the distribution, movements and breeding behaviour of this species. It has been suggested that Usipa is a fish which goes through its whole life history in one year, and that like certain insects which do this, the population size is subject to great fluctuations depending on whether conditions of life are good or bad. While this theory cannot be wholly discounted, it cannot be held if, at the same time, the fish has a single fairly well defined breeding season, as does seem possible. The appearance at the same time, in March and April, of active fish of about 60 mm. length and below the apparent breeding size, of planktonic larvae and of occasional large specimens of over 100 mm. cannot be explained on these grounds, and it is almost certain therefore that the biology is more complex. Nor is it likely that its distribution and migratory movements are, at all times of the year, random. The existence at Chizi of a seasonal fishery for Usipa indicates that at certain times of the year, Usipa may have a definite biological association with certain types of near shore or inshore waters. It is extremely unlikely that *Eugralicypris* will ever be exploited during its "open water" stage, i.e. while it moves randomly in the pelagic zone of the lake as the problems of locating randomly moving shoals in the centre of the lake, or at any distance from the land, and the practical difficulties of fishing any shoals located, which would require expensive gear and large fishing craft, could only be solved economically if the population of Usipa was much larger than can be reasonably expected. As with the Utaka group of *Haplochromis*, therefore, Usipa can only be exploited when it appears inshore, and the study of factors which decide this association with inshore water is therefore of prime importance.

NORTHERN NYASALAND
LAKE CONTOURS AND SAMPLING STATIONS

SCALE 1:500,000 OR 15·782 MILES TO 2 INCHES


CHART OF NORTHERN SECTION OF LAKE NYASA
showing soundings after Commander
E · Rhoades with additions from
cruises by J·F·R·O
SCALE 1·279 INCHES TO 5 MILES
MILES 5 4 3 2 1 0 5 10 15 20 MILES
34°E
35°E
10°S
11°S
WISSMAN BAY
KAPORO
KAPORO BAY
MWENETETE
KARONGA
LAKE CHIWONDO
MLALI LAGOON
NGARA
VUA MISSION
UJKWE 6297
MBIRI DEEP BAY ASTRO FIX
YOUNGS BAY
LION POINT
FLORENCE BAY
NKALAMBWE 8103
CHOMBE 4618
CHIWETA
MWENEMBE 8030
MLOWE
UZUMORO 6467
ASTRO FIX
CINDER CONE
'HOLE'
LUPINGO MISSION
CAPE KAISER
ST THOMAS MISSION
MANDA
ILELA
LITUHI MISSION
NDUMBI BAY
LIUNDO
PAPIA ISLAND ANCHORAGE
LIULI
SPHINX HAVEN
BAMBA
MAP 2


34° 40′E.
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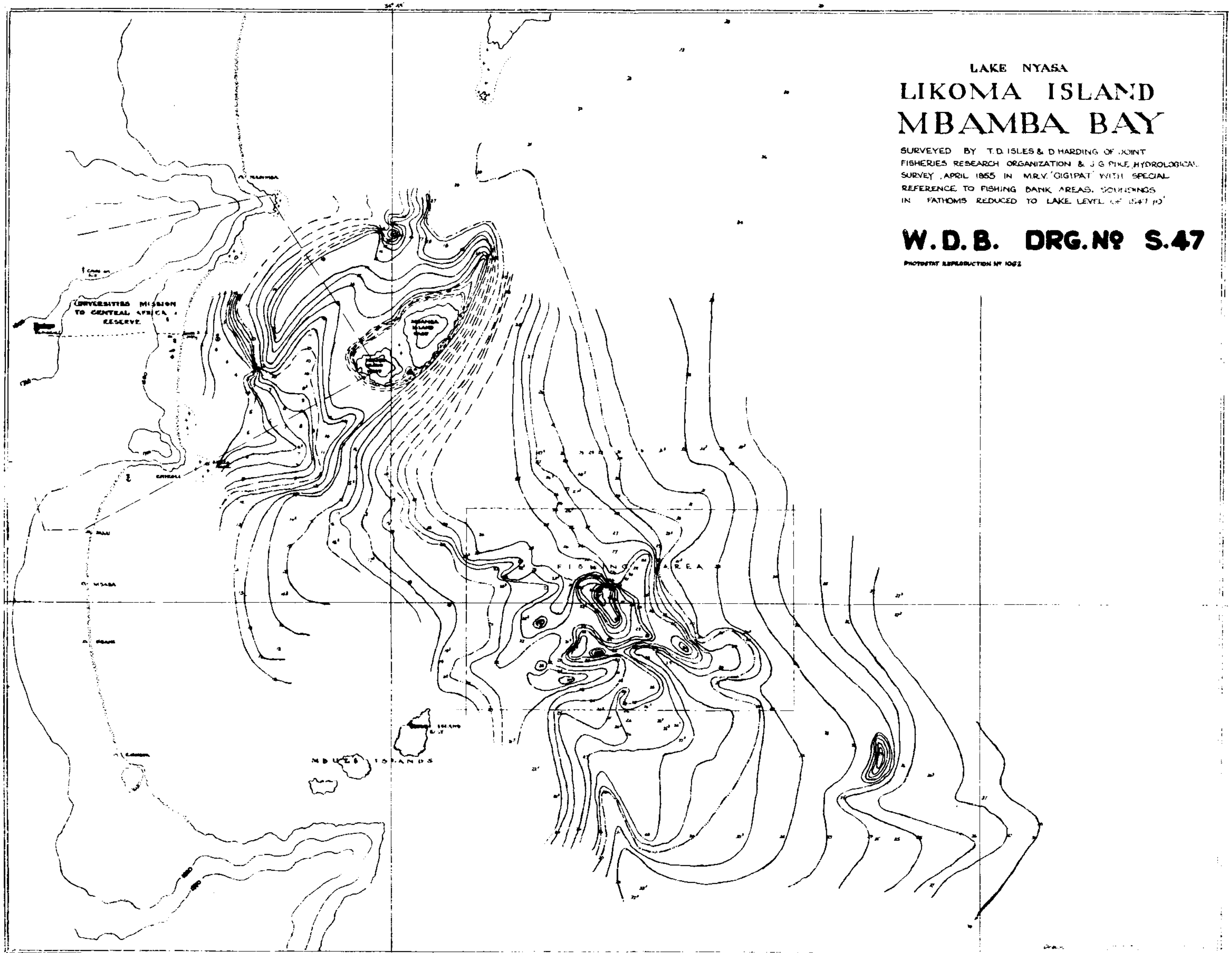
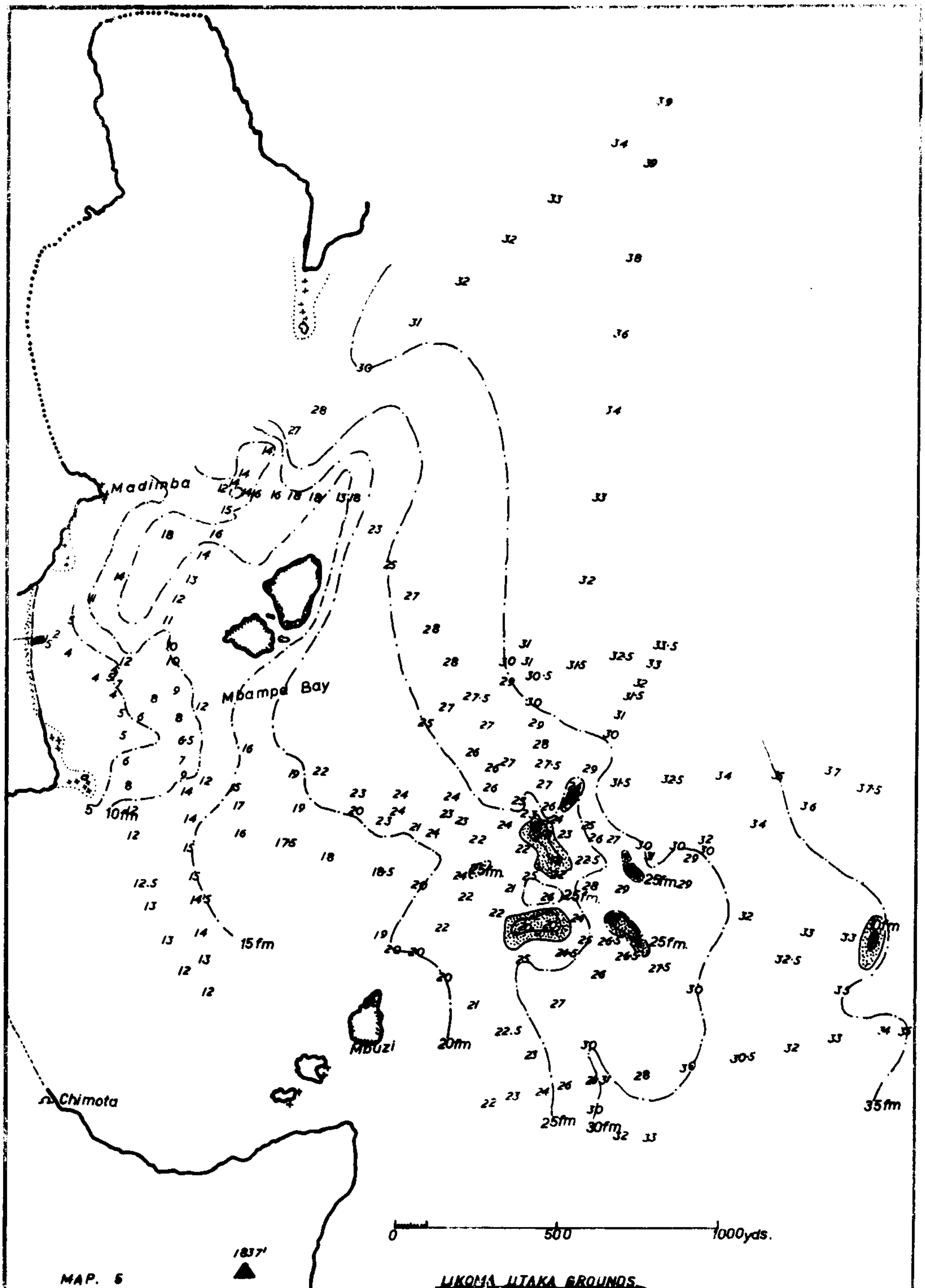
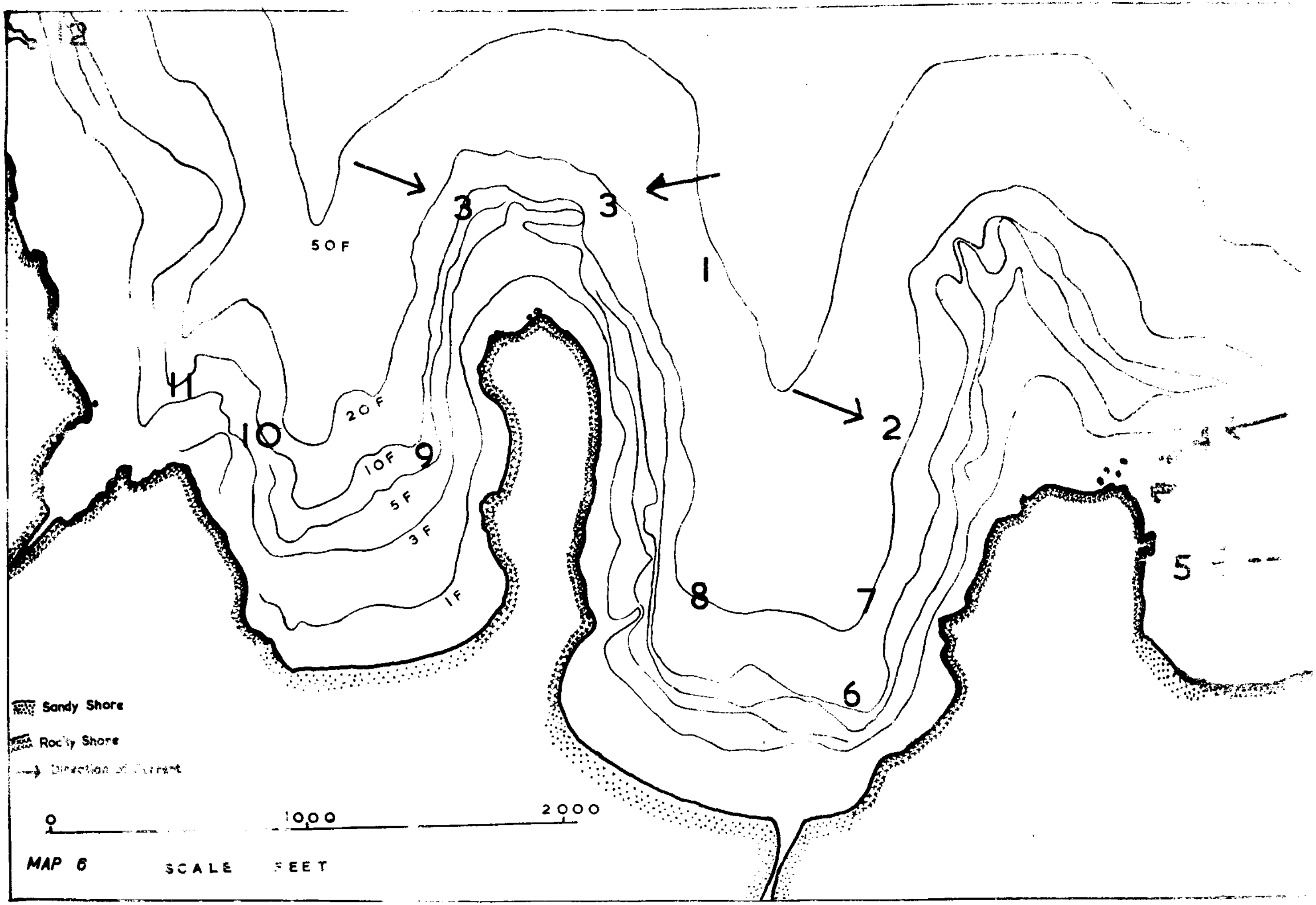
12.05°
LIKOMA & CHISUMULU ISLANDS.
CHIZUMULU
LIKOMA
ULISA
MISSION
BOVY-UTAKA GROUNDS.
70fm
30 fm.
Scale. 0 1 2 Miles
MAP 3


LAKE NYASA
LIKOMA ISLAND
MBAMBA BAY
SURVEYED BY T.D. ISLES & D HARDING OF JOINT FISHERIES RESEARCH ORGANIZATION & J G PIKE, HYDROLOGICAL SURVEY, APRIL 1955 IN M.R.V. 'CIGIPAT' WITH SPECIAL REFERENCE TO FISHING BANK AREAS. SOUNDINGS IN FATHOMS REDUCED TO LAKE LEVEL OF 1547.10'
W.D.B. DRG.Nº S.47
PHOTOSTAT REPRODUCTION Nº 1062
UNIVERSITIES MISSION TO CENTRAL AFRICA RESERVE
FISHING AREA
MBUZI ISLANDS



LIKOMA UTAKA GROUNDS



SITES OF UTAKA GROUNDS NKATA BAY

A

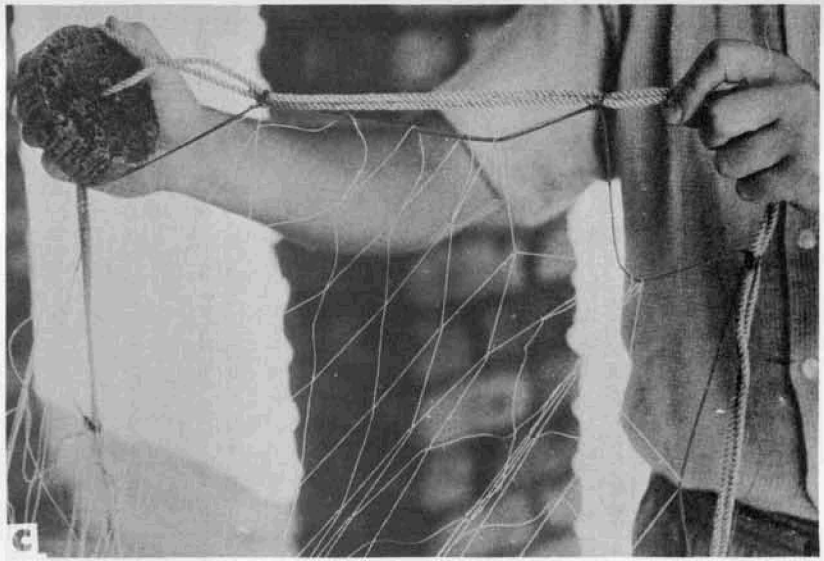


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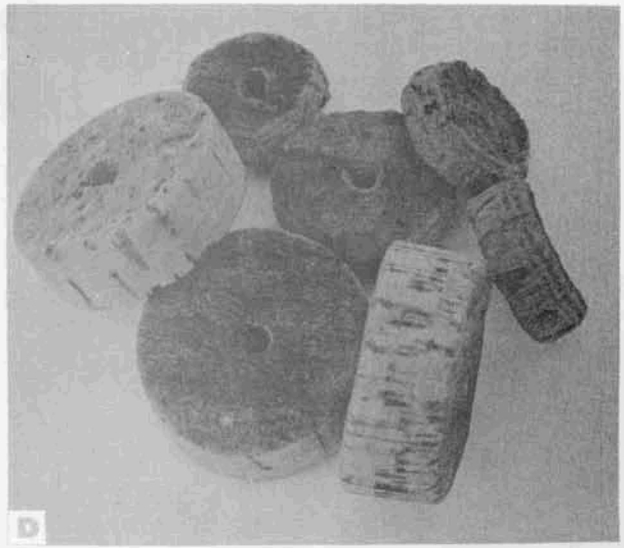
Plate I

B



D

A. The laboratory, Nkata Bay.

B. The research launch moored at Nkata Bay.

C. Method of mounting gill-nets to head rope.

D. Floats crushed by pressure in the deep gill-gill-net fishery. The three on the left are unu e unused.

Plate II MAJOR ECOLOGICAL ZONES

A. A sandy sheltered bay in the northern lake; habitat for zone V fishes at Nkata Bay.

B. A small sandy beach on the open northern lake, sharply adjacent to the more usual rocky shore; habitats for fishes of zones V and VI respectively near Nkata Bay.

C. A rocky shore with some intermediate rock/sand area in the foreground; habitats for fishes of zones VI and VII respectively near Nkata Bay.

D. Rock/sand zone; habitat for zone VII fishes near Nkata Bay.

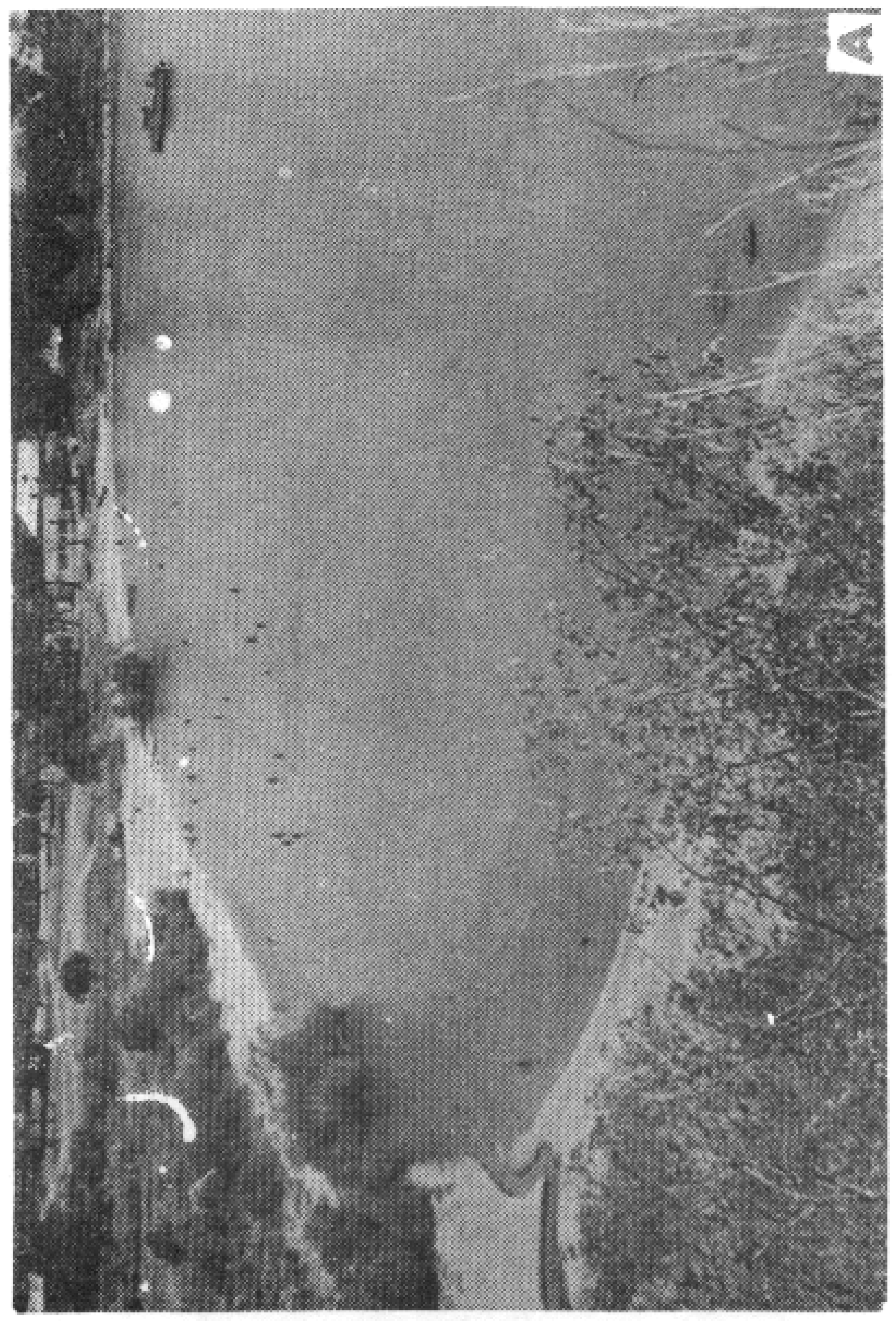
E. Dhows and dug-outs at Fort Maguire; the weedy stagnant gutway in the foreground provides a typical habitat for zone III fishes in the southern lake, while sheltered zone IV conditions are beyond.

F. A sheltered bay in the southern lake; zones V and VI at Monkey Bay.

G. Sheltered zone V conditions in the northern lake; the anchorage at Bana.

H. A slow-flowing reedy river in its lower reaches, habitat for zone III fishes; the Limpasa River ten miles inland from Nkata Bay.

Plate II



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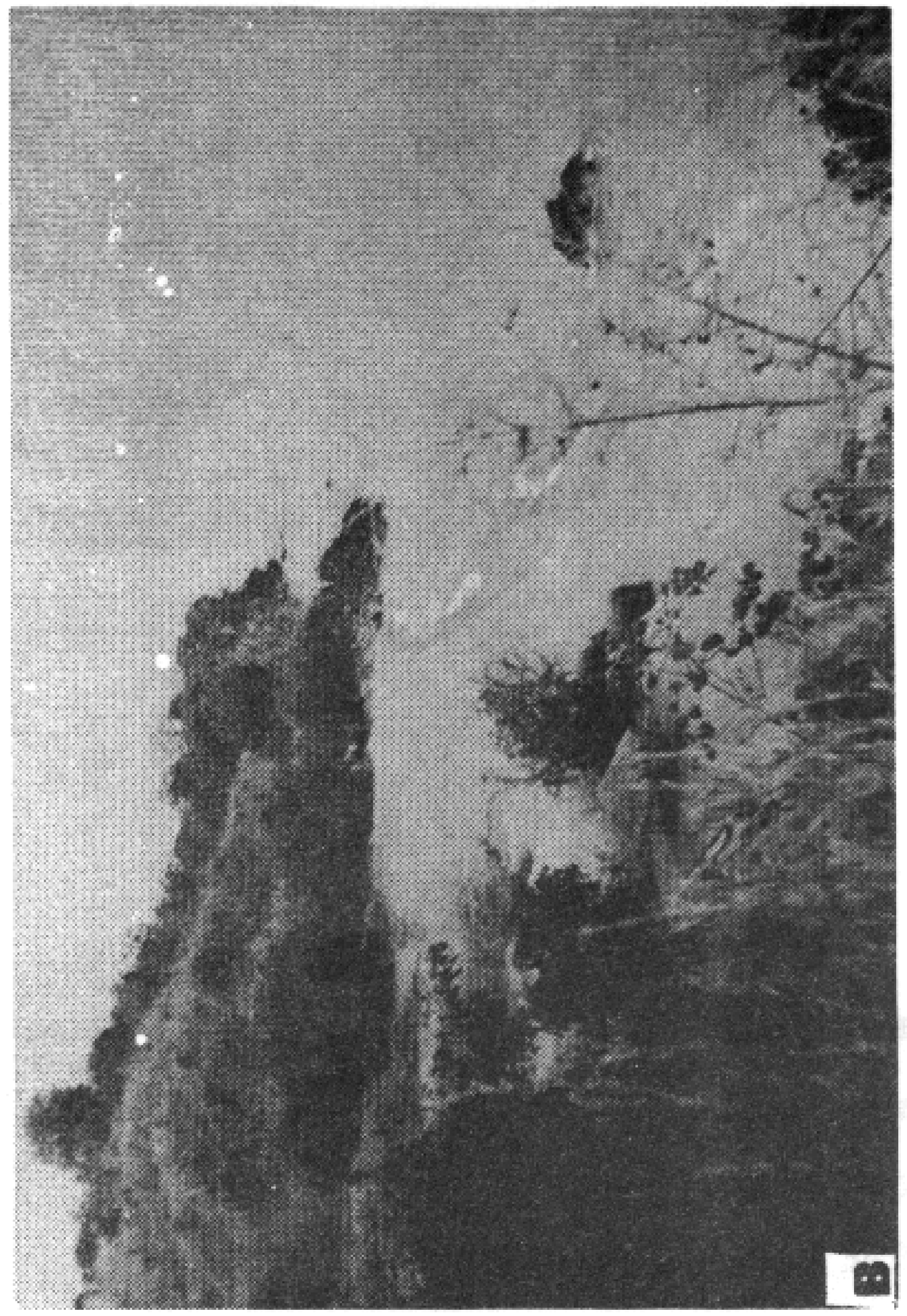

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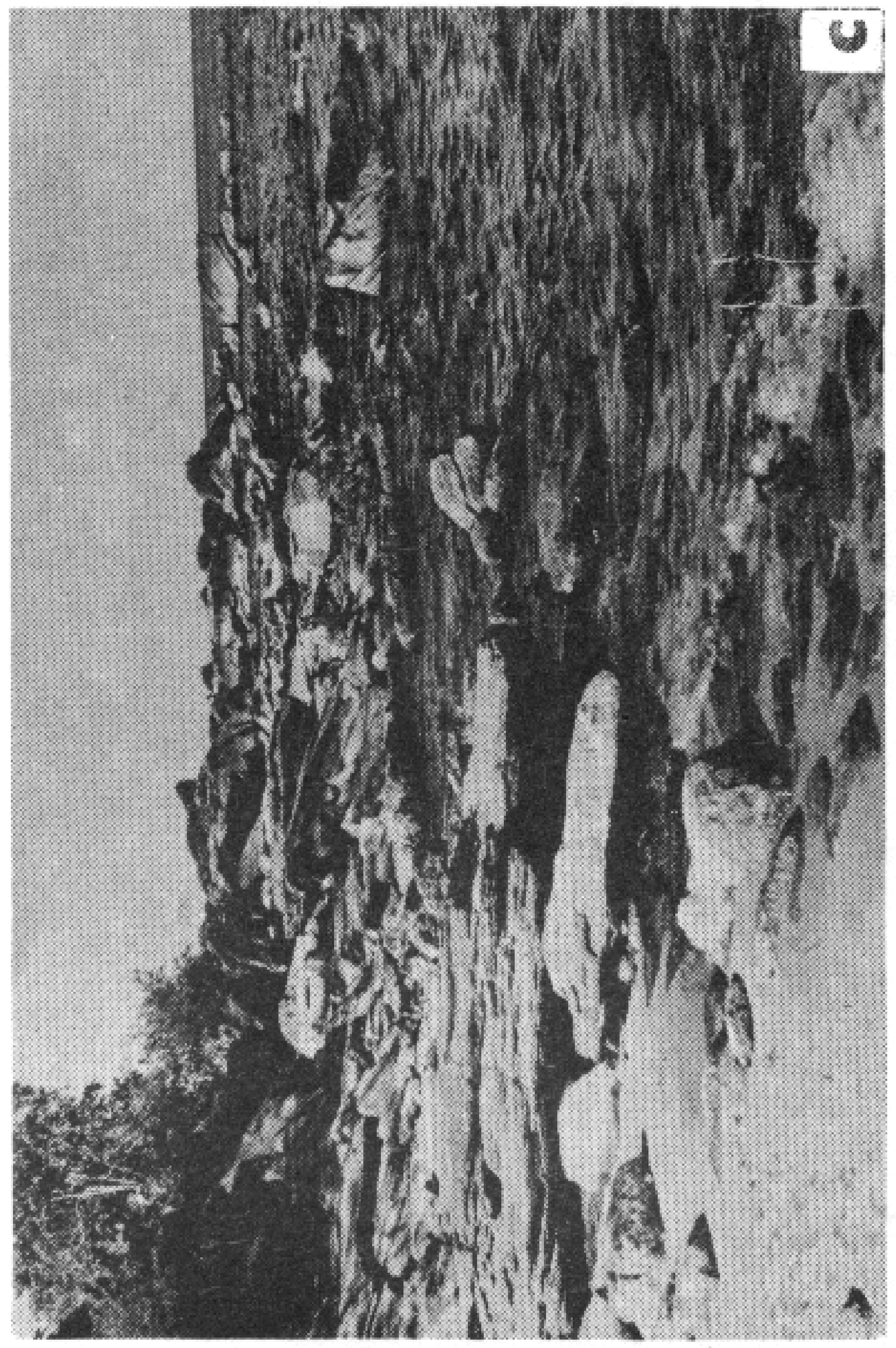

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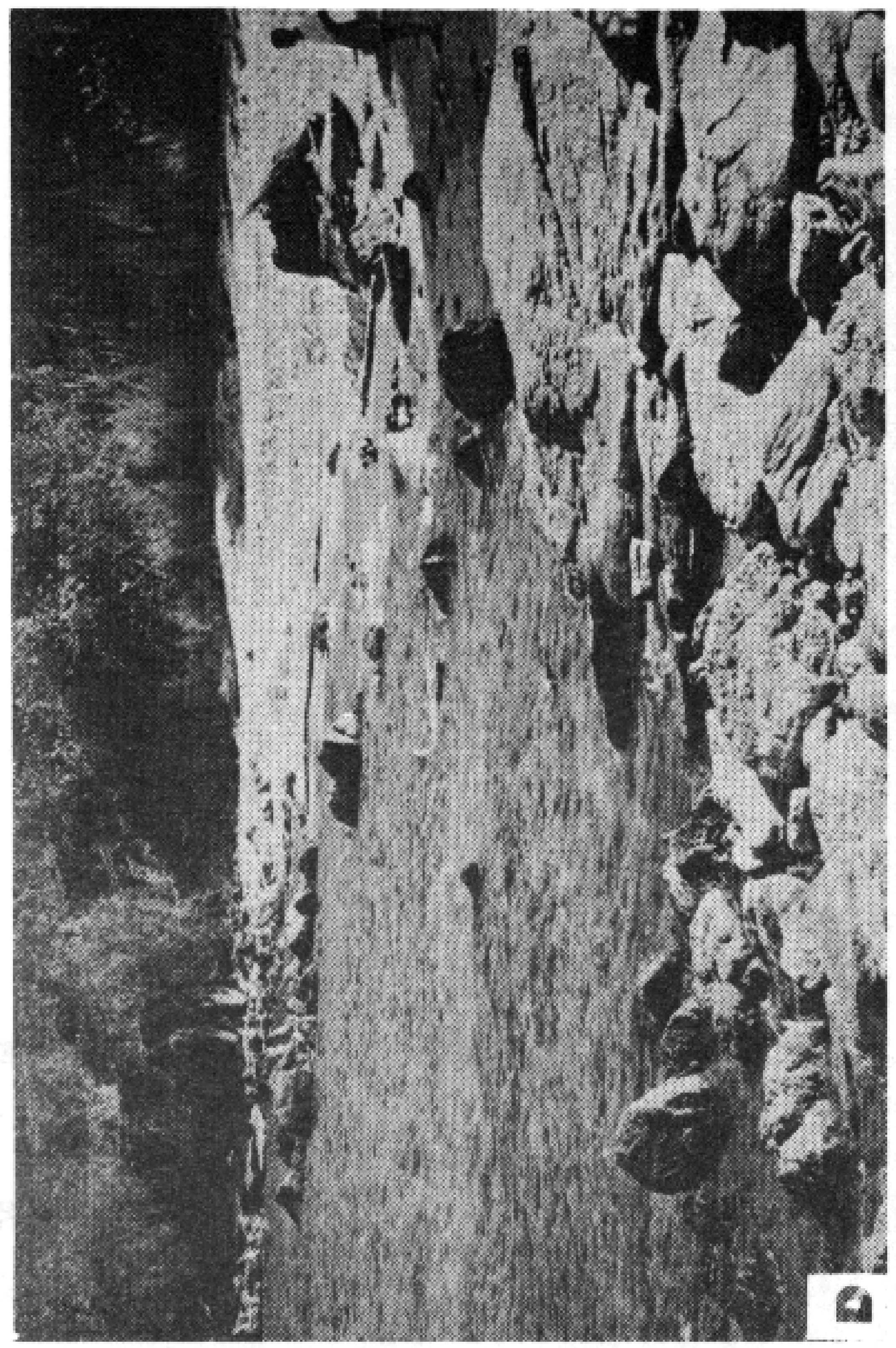

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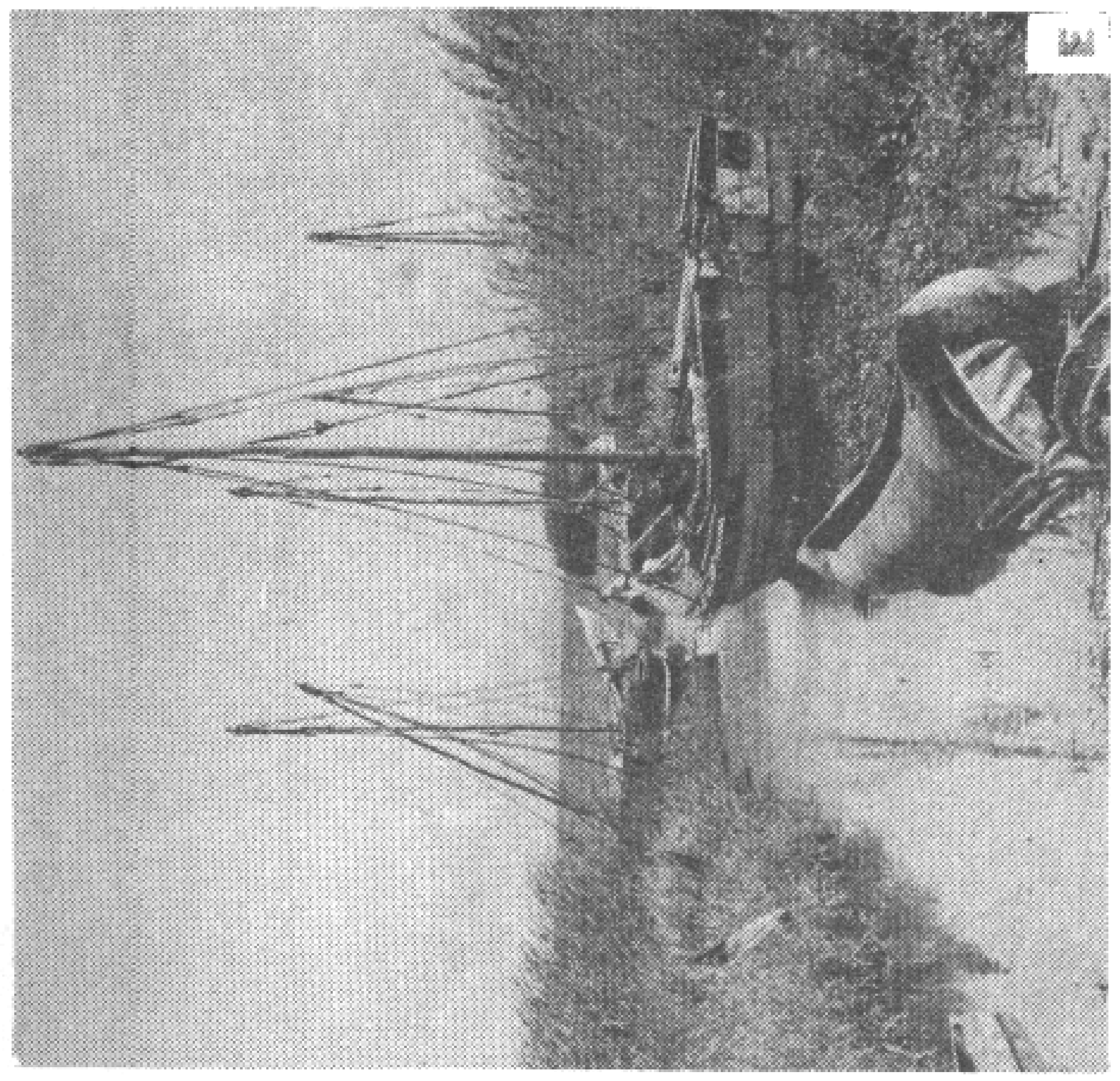

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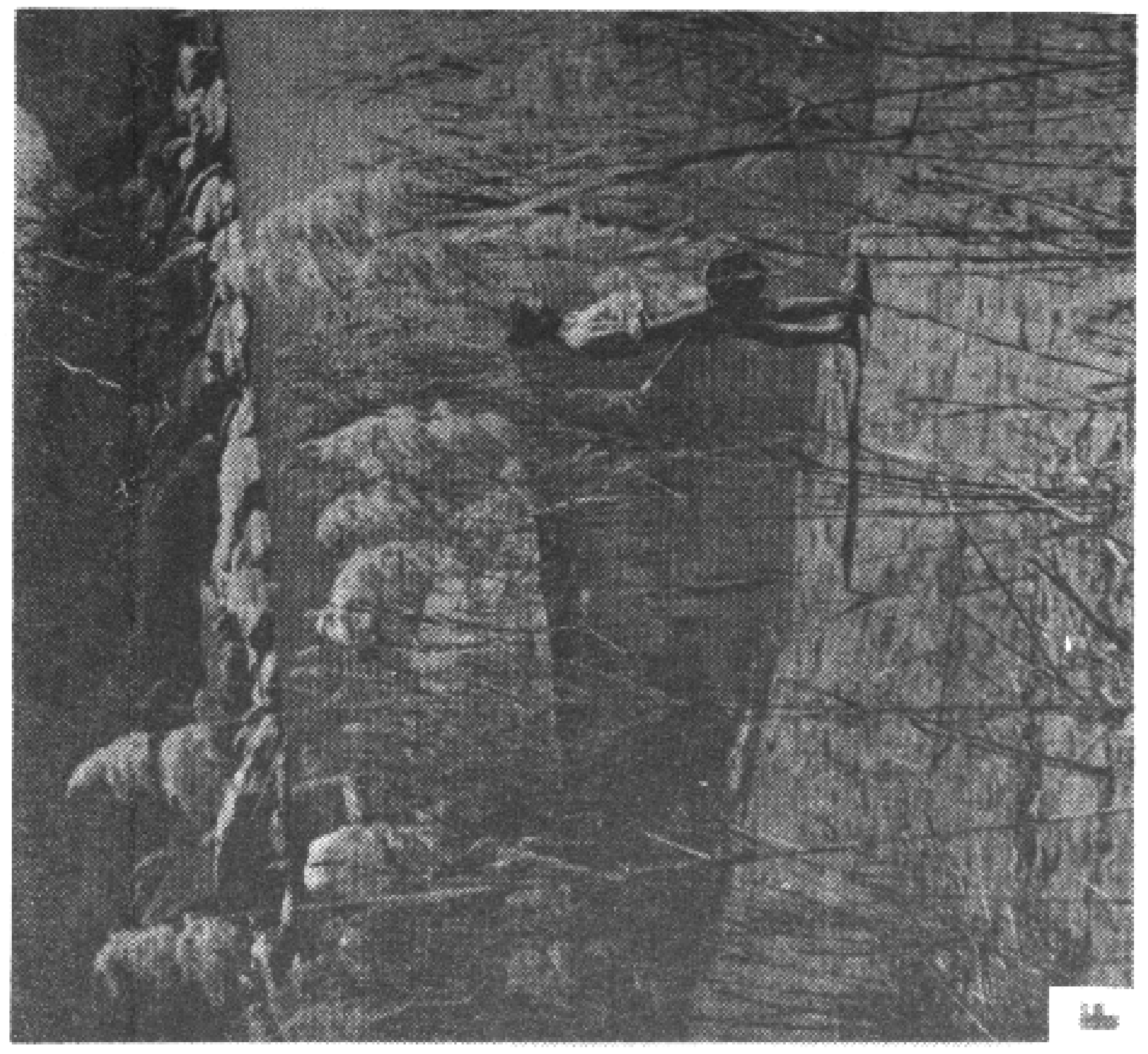

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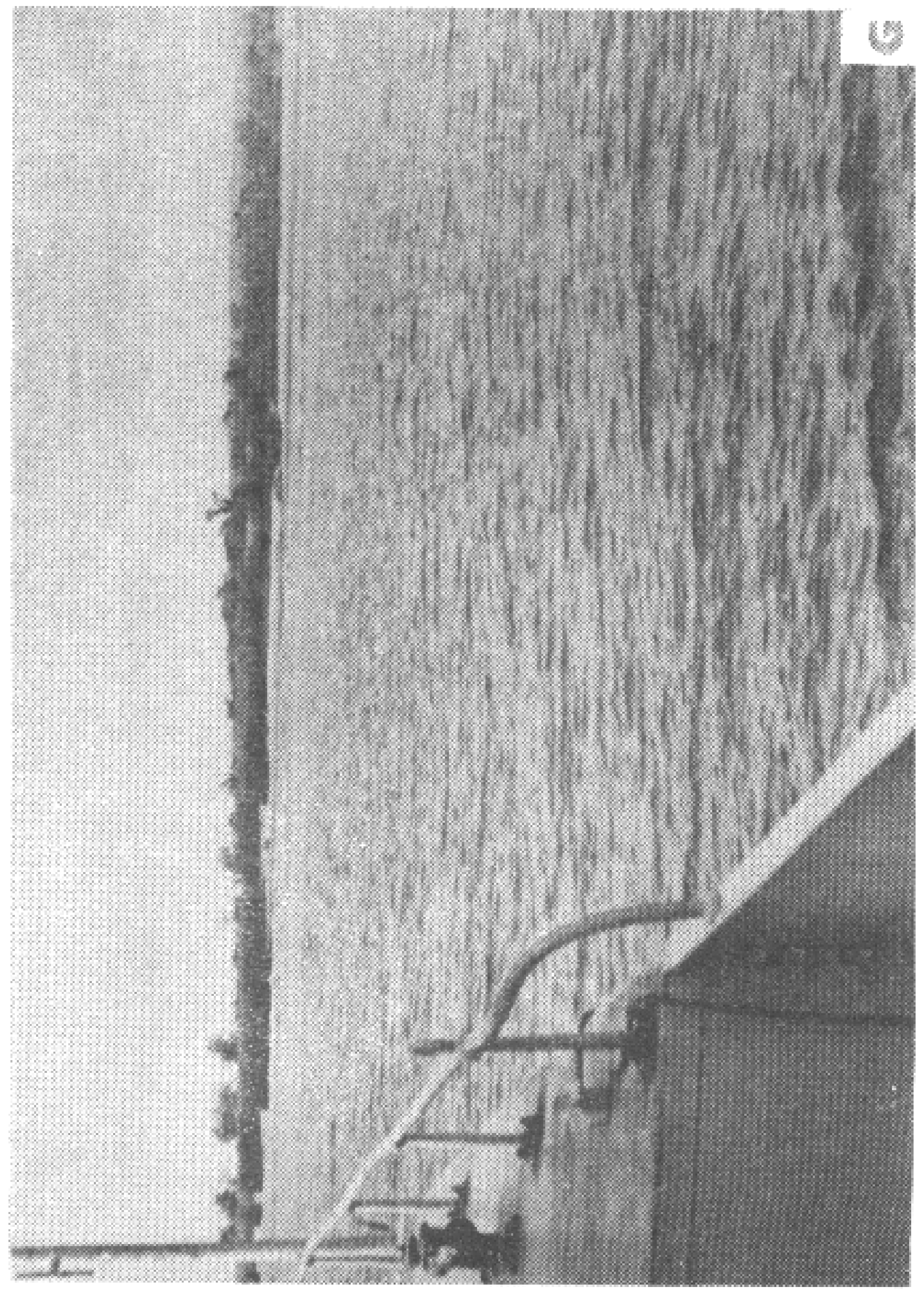


G

H

Plate III THE DEEP GILL-NET FISHERY

A. A large haul of Tilapia and Clariids; south-west arm.

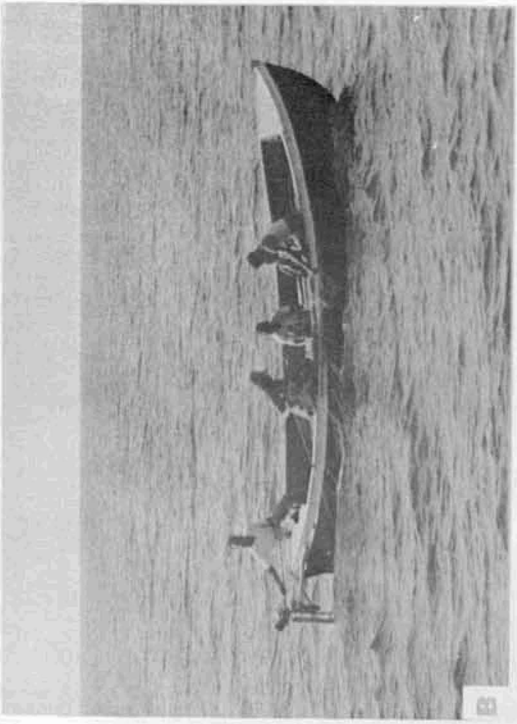
B. Setting a deep gill-net, Nkata Bay.

C. Gill-nets and fish after hauling from 60–70 metres, Nkata Bay.

D. *Bathyclarias nyasensis*, *B. longibarbis* and *Bagrus meridionalis* in gill-nets hauled from 60–70 metres, Nkata Bay. Note the distended abdomen of the *Bagrus* caused by the rapid change in pressure.

Plate III

A



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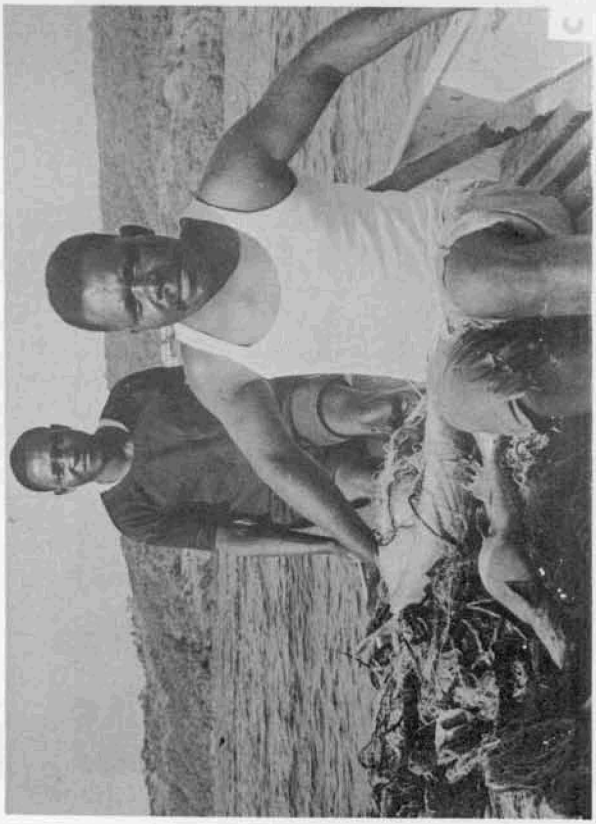


C

D

Plate IV Four species of Utaka from a chirimila at Nkata Bay. From top to bottom:

A. *Haplochromis* H, H, H,

B. *Bathyclarias gigas*, Nkata Bay.

C. *Bathyclarias filicibarbis*, Nkata Bay.

D. *Haplochromis heterotaenia* Nkata Bay

Plate IV

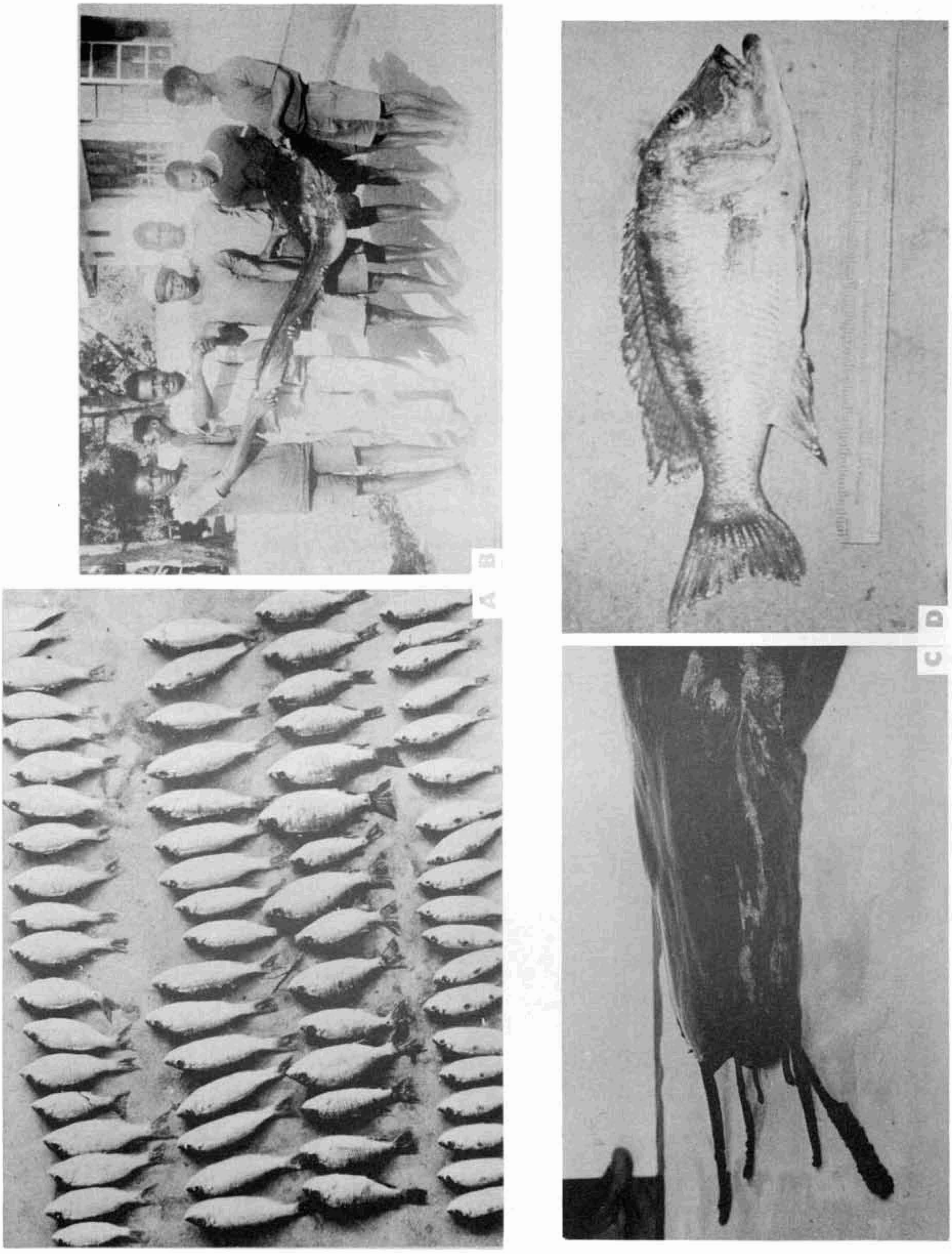


Plate V

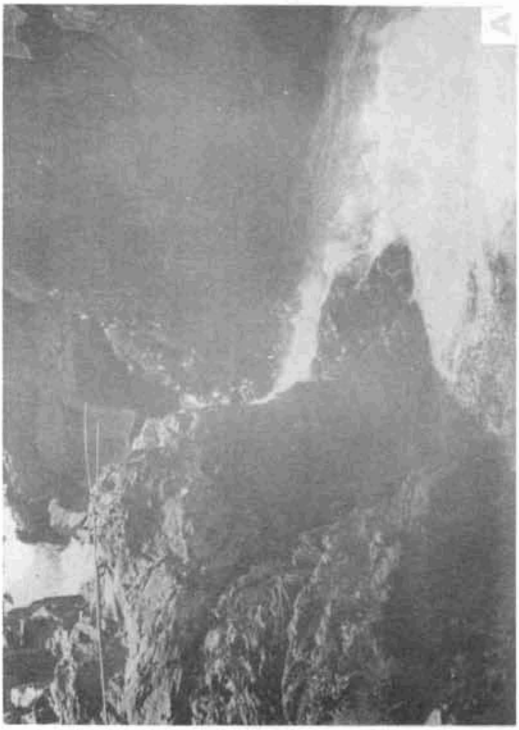
A. The gorge at Chiwandama, Luweya river, where Sanjika (*Barilius microcephalus*) are caught on their upstream breeding migration.

B. Breeding Sanjika being lifted from slack water in crevice of the rock, where they rest before attempting to move further up the rapids. Note the construction of the " Khombe " net.

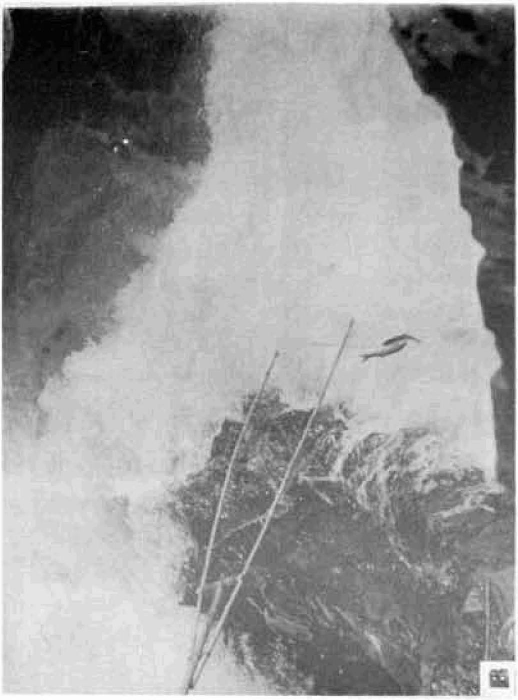
C. " Mono " basket set in deep water to catch *Synodontis njassae.* Usually baited with dough as fish bait attracts crabs. Near Nkata Bay.

D. Arrangement of canoe for Usipa fishing. The torch-bearer is forward with the netsman close to him, while the paddler sits astern.

Plate V



A



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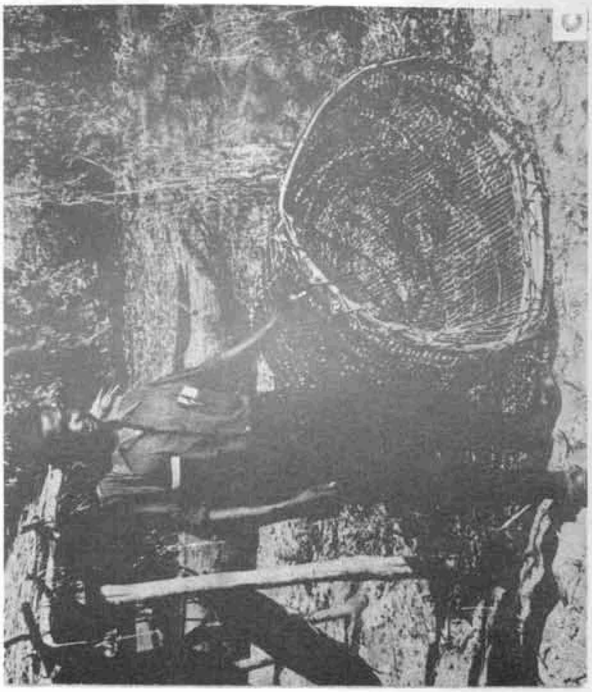


C

D

Plate VI

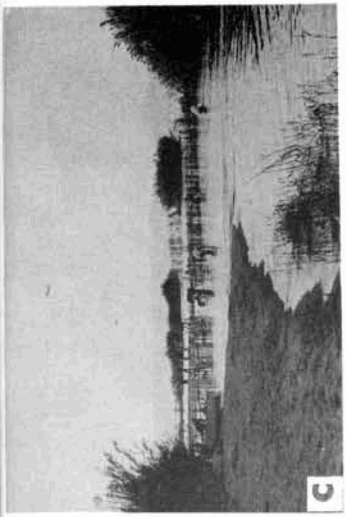
A, B, C. A seasonal fishery for breeding *Rhamphochromis* (probably *R. longiceps*) at Bana near the entrance to the lagoon (obstructed by weir, C). Small seines are hauled by the two men.

D. A large beach seine being hauled in the south-west arm.

E, F. Fishing in Kambwe lagoon near Karonga with scoop nets, and baskets are stabbed vertically downwards, trapped fish being removed through an aperture halfway up.

G. A " Mono " basket trap filled with crabs, the result of baiting with fish bait, Nkata Bav

Plate VI



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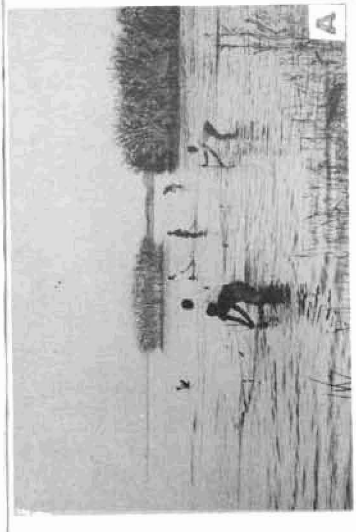
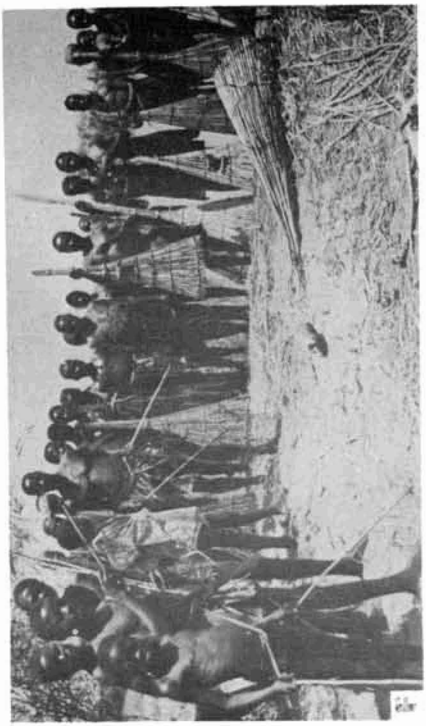


A



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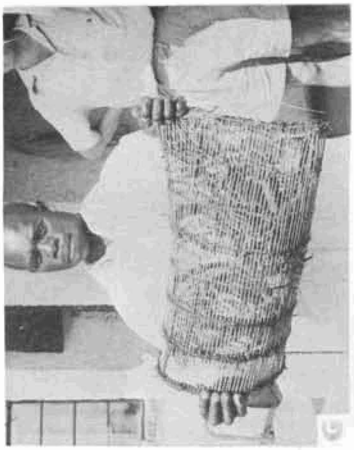

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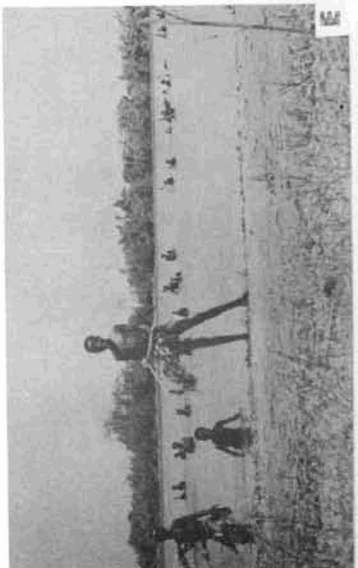

E