Michael K. Oliver

Northern Rhodesia

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P.O. BOX 48,
SAMFYA,
NORTHERN RHODESIA.

NOTE.—This report was edited by Mr. Jackson; he also wrote Sections 1, 2A, 2C and 5. Section 2B was written by Mr. Coulter, Section 2D by Mr. Harding, Section 3A and 3B III–V by Mr. Iles, and 3B I–II by Mr. Eccles.

STAFF AND COMMITTEES, 1960

Scientific Advisory Committee:

H. J. H. Borley	Director, Department of Game, Fish and Tsetse Control, Blantyre, Nyasaland.
F. I. Parnell, M.B.E.	Director, Department of Game and Fisheries, Chilanga, Northern Rhodesia.
P. B. N. Jackson	Chief Fisheries Research Officer, Joint Fisheries Research Organisation, Samfya, Northern Rhodesia.
Dr. V. D. van Someren, M.B.E. ...	Director, East African Freshwater Fisheries Research Organisation, Jinja, Uganda.
T. D. Iles	Officer in Charge, Joint Fisheries Research Organisation, Nkata Bay, Nyasaland.

Samfya Laboratory (Headquarters):

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Research Officer	A. P. Bowmaker, B.SC. (Scientific Officer, Her Majesty's Overseas Research Service).
Senior Technical Assistant ...	M. P. Gilbert.
Clerk	Mrs. M. B. G. Sandwith.
Senior Fish Guard	L. Phiri.

Chilanga (Kariba Substation):

Research Officer	D. Harding, B.SC. (Senior Scientific Officer, Her Majesty's Overseas Research Service).
Research Assistant	F. Chibuye.

Abercorn (Lake Tanganyika Substation):

Research Officer	G. W. Coulter, B.SC. (Scientific Officer, Her Majesty's Overseas Research Service).
Research Assistant	J. Chela.

Nchelenge (Lake Mweru Substation):

Research Officer	T. G. Carey, B.SC. (Temporary Zoologist).

Fiyongole Fish Farm:

Supervisor	W. Gay.

Nkata Bay Laboratory:

Research Officer in Charge ...	T. D. Iles, B.SC. (Senior Scientific Officer, Her Majesty's Overseas Research Service).
Research Officer	D. H. Eccles, B.SC. (Scientific Officer, Her Majesty's Overseas Research Service).
Senior Research Assistant ...	A. J. P. Mzumara.

Joint Fisheries Research Organisation

Annual Report No. 10, 1960

1. INTRODUCTION

This year has been an extremely busy one for the Joint Fisheries Research Organisation, and the calls on the Organisation's services have increased. A number of results have been obtained and some new work started. The trend, which started several years ago, of the Organisation forming itself into a series of stations on many of the important or potentially important fisheries, has become very marked. By the end of the year there were five such stations, with a scientist permanently at Mpulungu, Southern Lake Tanganyika, at Kariba, at Nchelenge, Lake Mweru, and at what is still the headquarters of J.F.R.O, Samfya on Lake Bangweulu. The fifth station is the Fish Farm at Fiyongole, near Fort Rosebery. The erection of these stations was essential in order to obtain quickly the information urgently required on these important fisheries, which are, however, so widely separated from each other; it has proved to be much more efficient than any system of frequent long tours from a central headquarters, which are prohibitively expensive, tiring and preclude any possibility of continuous effort. It has, however, often posed many administrative problems, such as the provision of housing for scientists and other staff, the provision of launches, scientific apparatus, etc., at each station, on a limited budget. Most of these have now been overcome, and in this respect we are indebted to the Development Commission of the Northern Province of Northern Rhodesia for the financial help, over the past few years, in getting the research station for the important fishery on the Lake Tanganyika established, including the provision of a twenty-nine-foot research launch.

Close liaison was maintained during the year with the Joint Fisheries Research Organisation in Nyasaland, and a meeting was arranged at Nkata Bay of all scientists from both countries in October, just before the Advisory Committee meeting. This was successful and indeed such meetings, as well as frequent visits to the headquarters and its library, are essential to combat the scientific isolation which is a real factor in the life of scientists working usually alone and far from any kindred activities.

During the year Mr. T. D. Iles, Senior Scientific Officer and Officer in Charge, J.F.R.O., Nyasaland, gave notice of resignation, and left early in the new year to take up an appointment at the Fisheries Laboratory, Lowestoft. Mr. Iles joined the J.F.R.O. in early 1954 during the Nyasa survey and remained in Nyasaland after the survey was over to form the first of the J.F.R.O. stations away from headquarters, which he did with success. Mr. Iles's especial interest was the mathematical treatment of gill-net catches to improve catches and estimate fish populations. Some of his early work in 1954, which will appear in the J.F.R.O. Nyasa Survey Report, was indeed pioneering in this now very important field, and others of his studies have appeared in J.F.R.O. annual reports such as the present issue.

The year 1960 is the last full year in which a proportion of the costs of J.F.R.O. in Northern Rhodesia will be paid by the British Government's Colonial Development and Welfare Scheme, and from the 1st July, 1961, the Organisation will be financed from Northern Rhodesia's territorial budget.

2. ACTIVITIES OF THE ORGANISATION IN NORTHERN RHODESIA

A.—Report for the year ended 31st December, 1960

Staff

The permanent establishment remained at full strength throughout the year. In pursuance of the policy of posting scientists as near as possible to the area on which they work, by the end of the year Mr. Harding was assigned to Chilanga in order to work full time on Lake Kariba, Mr. Coulter to Abercorn for work on Lake Tanganyika, while Mr. Bowmaker remained at Samfya to work on Lake Bangweulu.

Mr. W. Gay, Fish Farm Supervisor, was on vacation leave for a large part of the year, being replaced by Mr. D. Pretorious, and, on the resignation of this replacement, by Mr. P. Wright.

As mentioned in last year's report, the agreement by the Development Commission to finance a Temporary Zoologist enabled an appointment to this post to be made in 1960. This was Mr. T. G. Carey, who was posted to Nchelenge, Lake Mweru. Soon after appointment, however, Mr. Carey was called up for National Service, and spent four months in the second half of the year in camp. As a result he was not able to start serious work on Lake Mweru until November, 1960, but by the end of the year a research programme on the lake was well under way.

In January and February, 1960, Miss Phillida M. Grieveson, a student of zoology at the University of Cape Town, worked for the Organisation at Samfya during her long vacation. She was able to undertake long-needed work on the sorting and labelling of the Organisation's collection of fish specimens from Northern Rhodesia and Nyasaland. Mr. R. Chisupa, a chemistry student from the University College of Rhodesia and Nyasaland, worked at Mpulungu in December, 1960, and January, 1961. He was engaged chiefly in the estimation of oxygen in water samples and the analysis of fish records.

During the year Mr. Langley Phiri, Fish Guard, was promoted to Senior Fish Guard. Mr. Francis Chibuye and Mr. John Chela joined the Organisation as Laboratory Assistants.

Mr. R. D. Weatherdon was employed by the Development Commissioner to work with J.F.R.O. in the development of the Chirimila net. He worked at Mpulungu from September, 1960, to January, 1961.

Housing and Facilities

Housing remained adequate at Samfya throughout the year. The departure of Mr. Coulter to Abercorn was slightly delayed while the house built for him at Abercorn by the Development Commission was being completed. The District Commissioner, Abercorn, however, at all times made a rest-house on the shore of Lake Tanganyika available for his use during his frequent tours from Samfya. A house at Nchelenge was immediately available for Mr. Carey on his appointment.

In July, 1960, a launch with a Kelvin 20 h.p. engine was completed by Mr. R. G. Heath at the Government Boat-building School at Nchelenge. The launch, which is named *Limnothrissa* has a twenty-nine-foot wooden hull, has a small cabin forward, and good working space aft covered by a hard top. It was taken to Lake Tanganyika on the J.F.R.O. trailer, the electrical installation and echo-sounder fitted by Mr. Gilbert, and was in service from August, greatly extending Mr. Coulter's activities, making research a great deal easier and more productive. The lack of a launch has hampered research activities on Lake Mweru. The Department of Game and Fisheries' launch *Mpumbu* has been made available for research use, but unfortunately has remained out of commission for virtually the whole year. It is anticipated that the 1961 position will be better.

A prefabricated shed was made available as a laboratory on the Commercial Fisheries premises at Mpulungu. This was converted into a useful little laboratory by J.F.R.O.; benches, plumbing and shelf space were constructed and fitted, and a storeroom made. On Kariba a little storage space became available in the building allocated to the Co-ordinating Committee's Fish Ranger, but the position at the end of the year was still far from satisfactory, with no laboratory facilities whatever. On Lake Mweru both storage space and laboratory facilities were adequately provided in the building on the lake shore belonging to the Department of Game and Fisheries.

The Research Programme

A very wide range of research was undertaken by the Organisation during the year; this ran the gamut of, on the one hand, research aimed at the exploiting as rapidly and efficiently as possible of new fisheries with a large potential, through more basic research to provide knowledge necessary for development and management of fisheries in general, to, on the other hand, work on overfished and declining fisheries in the hope of ascertaining the causes and recommending conservation measures, legislation and extension work to remedy the decline.

These varied obligations of the Organisation were provided for in the research programme approved at the tenth meeting of the Advisory Committee, held at Jinja on the 12th December, 1959. This provided for Mr. Harding, as a first priority, to continue with the Bangweulu work until it was ready for publication, and then to continue with Kariba, where research was becoming steadily more complex and difficult, assisted where possible by Messrs. Jackson and Bowmaker, but at any event at a rate additional to the two tours a year which had hitherto been undertaken since 1956. Mr. Jackson was to spend most of his time available on research on fish systematics, Mr. Coulter to continue with his research work on Lake Tanganyika, and Mr. Bowmaker to continue with his survey of the Bangweulu swamp fauna especially at the Luaka lagoon. In addition, the new temporary zoologist, which it was hoped to appoint with Development Commission funds, should at once be assigned to the problem of migration and biology of *Tilapia macrochir*, the commercially valuable green-headed bream or "Mpale", which was a most important problem that J.F.R.O. has in past years been forced to neglect.

It is interesting and important, before reporting on the work done, to consider how this programme has changed, to meet changing conditions and present exigencies, from one that would have been approved in the early days of J.F.R.O., say at the second or third meeting of the Advisory Committee. Then, the emphasis was on team work; the scientists would have been considered as a team, each specialising in a certain branch of science, and they would have been assigned to one lake to undertake an inter-related survey, with each man specialising in a branch such as hydrology, vertebrate zoology, plankton, etc. It is a measure of the speed with which the fisheries have developed over the country as a whole that this kind of team survey is no longer possible. In the present case new and promising fisheries were in the offing as a result of the construction of Kariba and the development of Tanganyika, while other fisheries, such as Mweru and Kafue, though fished with nets made of the latest and most modern nylon, perlon and terylene twines, and served with modern lorries, trucks, outboard motors, etc., were not served with modern management and control measures, so that a possible decline in their productivity could be foreseen. These problems were as urgent as any that could be imagined in an industry worth over £2m. a year, the largest rural industry in the country, intimately affecting the welfare of hundreds of thousands of rural people, and had to be met at once. With the resources available the team survey was not practicable; the needs of the moment had to be met by the single scientist, who, with a staff of African assistants, deals as an all-rounder with the problems of a single area. This policy is justifying itself in the results being achieved, that the broad overall knowledge of life histories and other biological problems relating to the fish and its habitat, necessary in order to devise new or more efficient methods of catching, or of conservation and management policy where necessary, is being obtained. The policy loses, of course, in the basic research which is so necessary over the long term, and it is very necessary that universities, museums and other institutions should undertake the basic hydrobiological research so necessary for this Territory but which the J.F.R.O., with its emphasis on applied research, cannot undertake.

The Bangweulu swamp and lake survey was wound up during the year, and the data is being written up by Mr. Harding. The policy mentioned in last year's annual report, of writing the work in two parts, is being followed. The first, in a form suitable for a scientific journal, contains biological and hydrobiological data of general scientific interest, while the second, containing information and statistics of the swamp fishing industry, is being written in collaboration with Mr. E. G. R. Pike of the Department of Game and Fisheries. Work on the first part was under way by the end of the year, while the second part was well on its way to completion.

Six visits were made to the Kariba area during the year, while by the end of the year Mr. Harding was permanently posted to Chilanga in order to be nearer Kariba and devote his full time to it. A good deal of research there has been carried out. The multiplication and relative abundance of the various fish species continues to be assessed, and regular hydrological work was and is being done. Early in the year the existence of stratified conditions, with a thermocline below which is reduced, deoxygenated water and anaerobic conditions, was confirmed. The progress of the thermocline has been watched; stratification was that year found to break down in July, with overturn of water, and to re-establish in September. The 1960–61 rainy season should be important and analyses of data during this period will be of interest. Two species of fish, not previously found in Lake Kariba, though known to the watershed, have been discovered. Progress in the life history study of fish species has been made, a series of young of the commercially important Mozambique Bream (*Tilapia mossambica*) from the fertilised egg upwards has been collected, and in February, 1960, the young of the well-known tiger-fish were discovered down to a length of 1.3 c.m. ($\frac{1}{2}$ inch), the youngest of this species which have ever been collected anywhere. A more detailed account of Kariba work, with tables, especially on the commercial fisheries aspect, is given in section 2D of this report. There is every hope that a large and thriving fishery will soon develop on Lake Kariba. Because of the lack of any research on Kariba except what J.F.R.O. was able to manage out of its limited resources, it is regrettably the case that no work on the invertebrate fauna of Kariba was done.

During the year alarm and concern continued to be felt through the exponential growth of the water fern *Salvinia auriculata*, and a number of meetings on this subject were attended by Mr. Harding and Mr. Jackson. An initial air survey undertaken by Mr. Harding, Mr. Phipps of the Department of Plant Pathology and Dr. Schelpe, a Botanist from Cape Town University, in April, 1960, indicated that some 200 square miles of lake surface were covered. By the end of the year indications were that the early rapid growth was not being maintained, especially in the open lake areas, although the shore line was steadily being encroached upon. A technical sub-committee of the Kariba Lake Co-ordinating Committee was set up during the year, to advise on the study and control of *Salvinia*, of which Mr. Harding is a member.

During the year three papers on various aspects of the work on Kariba, written by Messrs. Harding and Jackson, were accepted for publication.

Mr. Bowmaker has continued with his intensive survey of the Luaka Lagoon, Bangweulu Swamps, as a detailed study of a certain area following up the general survey of the Bangweulu area as a whole, and made good progress during the year. As can be expected of a detailed study, special attention was paid to the invertebrate fauna, which has been very little studied in the past. A number of taxonomic experts in the various groups have been contacted, and by the end of the year the satisfying total of eight experts had been found willing to classify the invertebrate collection. Of insects alone, some 15,000 have been collected, examined and preserved. A light trap was in operation during the year, which traps many adults of insects, the larval form of which are taken by the other methods at Luaka. Some 400,000 insects, of over 115 different species, have been trapped, and this gives data also on the periodicity of emergence of aquatic insects of the area. About 5,000 fish have been collected and examined, and the hydrology and seasonal variation of water composition is being examined in detail.

Mr. Bowmaker also commenced field studies on the impact of predation by cormorant on the fishes of Luaka and Bangweulu in general, and data has been obtained from a large number of birds. Data is also being collected on the life-history of the catfish *Auchenoglanis occidentalis*, concern over the status of which has for many years been felt. Mr. Bowmaker will commence winding up his field studies in the first half of 1961, and have his various papers ready for publication by the time he goes on leave.

After his recruitment Mr. Carey spent a period of training at the Samfya headquarters and was then posted to Nchelenge after having been called up for four months' military service. A brief account of the preliminary Mweru work appears in section 2C, and it is anticipated that a comprehensive report of his results will be published in next year's annual report. By the end of the year the decline of the Mweru fishery had reached serious proportions, so that it is anticipated that work on this area will consist of research into the rehabilitation of a declining fishery, leading to recommendations for management and conservation measures.

Work on Lake Tanganyika, on the other hand, does not fall into this category, and J.F.R.O. have been able to contribute to an expansion in this fishery. The report on Mr. Coulter's work in this area is here given in some detail, in section 2B I–VII. Some very interesting research results are reported by Mr. Coulter. One of the most interesting is the successful development in its modified form of the Nyasan Chirimila net, a kind of Lampara net, and the great promise that it holds out for the catching of the Tanganyika sardine in bulk by small groups of African fishermen. Scarcely less important in the development of this, as yet, little fished of our fishery areas, are the very promising results, with very high catch per unit of effort in the season, of deep-set gill-nets operated by African fishermen. These gill-nets catch mainly Nile perch, which are very largely predators on the sardine, and the close correlation between the life-histories of the Nile perch and the sardine is shown several times in this section. It is very necessary therefore, since both man and perch prey on the sardine, and in order to keep the balance of nature in equilibrium, to balance large catches of sardine with large catches of Nile perch by means of gill-nets, which fishery is particularly well suited to African fishermen. However, the sardine forms an easily dried and handled product, which because of its oiliness and tastiness is unique, without any competitors, and consequently sells very easily. There is therefore a very strong profit motive to concentrate entirely on the capture and sale of sardine, with the danger of neglecting by comparison the interconnected Nile perch, which in both dried and fresh filleted form has many competitors, such as the bream of most of our other fisheries, and fresh fillets of marine fish, such as of hake, which are imported into the Federation in large quantity from South Africa. Thus the development of a market for Nile perch is not nearly such an easy matter; many vested interests may be involved; but it is nevertheless desirable that it should not be lost sight of for many good reasons, such as the necessity for maintaining a biological balance in the fishery, the desirability of encouraging African gill-net fishing, and the economic advantage that accrues to the Federation in the use at least to some extent of a local product rather than one which has to be imported from another country.

The necessity for extension work among African fishermen is shown in section 2B VI, in order to stimulate the desire for large and profitable catches; it is here for example that the influence of the European fisherman is so beneficial. The European makes large catches; he benefits the African at once by providing employment and at the same time instruction in good fishery technique, which can be turned to good advantage later, and overall acts as a pace-maker, showing the local fisherman what can be done, and the size of catches that can be achieved.

Among other interesting results the Tanganyika research has indicated, though not yet fully proven, the probability that the sardine has a very short life for a vertebrate animal, of the order only of a year or two, with exceptionally large annual recruitments to the stock by means of immensely fecund and frequently repeated spawnings in the spawning season. Echo-sounding work has demonstrated the daily vertical migrations and shoaling behaviour in the life of these fish, which knowledge is important in the study of fishery techniques, while a very marked impact of predation by the Nile perch on the sardine appears to be probable.

The J.F.R.O. appears to be on the way to the establishment of a " school of predation study ", as, besides Mr. Coulter, both Mr. Bowmaker and Mr. Jackson are interested in predator-prey relationships in aquatic animals.

Progress in the growing of local food at the Fiyongole Fish Farm, the necessity for which was described in last year's annual report, continued to be good, though retarded a little by the absence of Mr. Gay on leave. Mr. Gay succeeded in producing strikingly successful stands of Rhodes grass, *Paspalum* and *Phalaris*, at the farm, without irrigation and with no mineral fertiliser, showing the practicability of these pasture grasses in the Luapula Province, where they are virtually unknown. Before the end of the year the newly purchased hammer mill had arrived and it is hoped to feed milled grasses to the ponds next year. Further progress with cleaning and ploughing had been made. An ensilage tank was made and it is hoped by the end of next rains there will be sufficient feed for all ponds throughout the year. A new series of brick and concrete breeding ponds was completed, and these will be used for experiments on the number of young produced by single pairs of various fish species, especially *Tilapia*. The series of growth-rate and productivity experiments under different rates of feeding with cassava and the use of ducks ranging over a pond have been completed, and it is hoped to write these up for publication in the near future.

For the future, it is hoped that aid in the form of a grant from the United Nations Special Fund will be obtained for Kariba, and possibly for Northern Rhodesia, as a result of applications made by the Federal and Territorial Governments. This, if forthcoming, should provide greatly needed additional research on Kariba in which Mr. Harding will co-operate fully. J.F.R.O. will also assist to the best of its ability in any fundamental, basic research which is started by a university or other body. For the rest, the only new research which can be foreseen in the reasonably near future is on the Kafue when the Bangweulu work is finally written up next year and the scientist working here is available. The Kafue is highest on the list of priorities, as the fisheries, according to the annual reports of the Department of Game and Fisheries, from being one of our largest fisheries has shown a regrettable decline from a total production of 11,300 tons in 1958 to 2,700 tons in 1960. No research on this area, however, has yet been possible.

Publications and Meetings

A list of the papers published or in Press at the end of the year is given in section 5.

Mr. Jackson continued with his systematic work as well as writing a number of other papers. He attended a meeting of the National Publications Trust in May, 1960, at which the decision was taken that the next book published by the Trust should be the book on the fishes of Southern Africa published jointly by himself and Mr. Jubb. Work on this is proceeding. The check-list of the fishes of Northern Rhodesia was virtually complete by the end of the year and it is hoped to submit it to the Government Printer early in the new year. A revised check-list of the fishes of Nyasaland has been accepted for publication. Notwithstanding the fact that several names have been removed from the faunal list of the area and that several other names have gone into synonymy, the total of species from Nyasaland has increased to 244. The check-list also contains for the first time a key to all species in Nyasaland. Following the recommendation of the Committee at its tenth meeting, Mr. Jackson wrote an article on Kariba for the *New Scientist*.

Mr. Harding collaborated with Mr. J. A. Gulland in writing a paper on mesh selectivity in the catfish *Clarias mossambicus*. Another paper by Mr. Harding was accepted, on the hydrological trends in Lake Kariba. Mr. Harding and Mr. Jackson attended the Federal Science Congress in Salisbury in July, 1960, where Mr. Jackson read a paper on the ecological effects of flooding on the fishes of the Kariba area. Messrs. Harding, Coulter, Bowmaker, Eccles and Jackson attended the C.S.A./C.C.T.A. Hydrobiological and Inland Fish Symposium in August, where five papers were read by Northern Rhodesian and Nyasaland J.F.R.O. staff.

Mr. Jackson attended the annual meeting of the East Africa High Commission's Fisheries Research Co-ordinating Committee at Zanzibar in October, 1960, while the meeting of the J.F.R.O. Advisory Committee was held at Nkata Bay, also in October. A number of meetings with Southern Rhodesian personnel and the Kariba Lake Co-ordinating Committee were attended by Mr. Harding and Mr. Jackson.

Visiting Scientists

Dr. Dan Livingstone of Duke University, Durham, United States of America, visited the Lake Tanganyika station in the course of his work on the composition of the substrata of large lakes. Using the J.F.R.O. launch *Limnothrissa*, Dr. Livingstone succeeded in raising a core twelve meters in length from the bottom of Lake Tanganyika. Publication of his results is awaited with interest.

Mr. J. A. Gulland, of the Fisheries Laboratory, Lowestoft, visited all Northern Rhodesia fisheries to assess and advise upon methods of collecting accurately statistics of the commercial fisheries of the Territory, and was based at Samfya for some time working up his data. Mr. Mr. Gulland collaborated with Mr. Harding in the writing of a paper on mesh selectivity.

Dr. David Mettrick and Dr. Mary Mettrick of the University College of Rhodesia and Nyasaland visited Samfya for three weeks to collect helminth (worm) parasites from fishes and other vertebrate animals of the Bangweulu area. A large quantity of material was collected which is being worked upon at present. This was the first time that any study of the helminth parasites of the fishes of the area had been made, and the two parasitologists report that at at least ten new species are represented in the material.

B.—Research Results, Lake Tanganyika

I.—Hydrology and Plankton

Since the arrival of the launch in late July a regular routine of temperature measurements has been possible—before this measurements were irregular. Early in 1960 two sampling stations were chosen which it was hoped would be representative of the two environments which Kufferath (1952) mentioned, that of the deep-water open lake and that of the " bays ". This latter in the south-eastern arm of the lake seems to consist of the extensive bay areas near Mpulungu and Kalambo where the depth is not greater than 140 metres. The inshore station which for convenience I have termed " mid-Mwela " is midway on the line between Nkumbula Island and Mwela Village, depth 120 metres, and the offshore station termed " outer-Mwela " is beyond Mwela Village on a west-north-west course, depth 170 metres (map 2 B 1). For true open water conditions it may be necessary to sample much further out, but this has not always been convenient and quite clear differences have been noted between these two stations.

Temperatures were recorded generally with a thermistor thermometer and on a few occasions with a reversing thermometer. Figure No. 2 B 1 indicates by a representative group of temperature gradients the general scheme of thermal changes in mid-Mwela station throughout the year. Starting in January a clear discontinuity exists between about 15 and 35 metres, with a surface temperature of about 27.5°C. By April the thermocline is deeper and less well defined although surface temperatures in the upper twenty metres remain above 27°C. (not illustrated in figure). At the end of May, however, the surface temperature has dropped to about 25°C. and there is no sharp discontinuity between the upper and lower temperatures. By July temperatures were almost homothermal. (Discounting diurnal fluctuation at the surface.) A gradual increase in surface temperatures followed through August, September and October and the formation of a deep discontinuity layer which in November could be defined between about 40 and 65 metres. In December the layer was between 20 and 60 metres and by January a sharp discontinuity between 18 and 28 metres, where the temperature fell from 27°C., was established. Since then in the first few months of 1961 the pattern of temperature changes has been about the same as in early 1960.

In short, the surface temperature decreased during the rainy season from its peak in December/January at the beginning of the major rains; after the rains finished in April/May the temperature continued to decrease until July to a homothermal or nearly homothermal condition, and thereafter thermal stratification was gradually built up again with increase of surface temperatures until December. It may be supposed that reduced sunshine and falls of cold rain together with wind caused the reduction of surface temperature and dispersion of the discontinuity layer. The sharpest temperature decrease occurred, however, after the rains in May and June. In May the offshore night wind or " kapata " assumes the regularity with which it blows throughout the dry season, but in May, June and July particularly, this offshore wind can have considerable violence. Apart from the turbulence it causes in the surface layers of the lake the wind brings colder air which is of a much lower temperature than that at the lake during the day, since it blows down the steep escarpment from the plateau where night temperatures were between 10°C. and 13°C. Increase in dry-season temperatures, especially from September, were followed by a heat gain in the lake and the formation of a well-defined thermocline.

Coinciding with the brief period when homothermal or near homothermal conditions were recorded at the mid-Mwela station, there occurred a dense phytoplankton bloom. For some months previous to this, as far as could be observed in the brief tours from Samfya, the water was clear with little apparent phytoplankton. At the beginning of this first bloom which lasted for about two weeks or less there was a considerable fish mortality in inshore waters; the floating fish were quickly harvested by the local people. Only inshore fish it seemed were affected since (*a*) no dead fish were observed on the surface more than half a mile from shore and (*b*) those identified were characteristically inshore fish, for example *Boulengerochromis microlepis* (Blgr.), *Cyathopharynx furcifer* (Blgr.) and *Limnotilapia dardennei* (Blgr.). An explanation of this mass mortality might be that it was due to oxygen deficiency caused by the oxygen demand of the phytoplankton. Many newly dead fish were to be observed at daybreak which is when the concentration of dissolved oxygen would be lowest because of the respiratory uptake of the plants and lack of photosynthesis throughout the night. There is also the possibility that water from the depths, which had come to the surface in " the turnover " bringing mineral salts which initiated the bloom, being of low oxygen content had lowered the oxygen concentration in inshore water to a lethal level. The former appears to be the most probable since in deep water where fish could remain well below the euphotic layer there was no evidence of mortality.

In section II it is described how a concentration of phytoplankton acted to exclude sardines from the surface at night and impeded or stopped fishing. The series of blooms were in this way clearly marked out by their practical effect on the pelagic fishery. It has been the experience of some workers that, particularly in the sea, direct experimental evidence of horizontal or vertical excluding effects of phytoplankton has been generally difficult to obtain. Here, whether the inhibitor is a substantial lowering of the oxygen concentration, or the effect of external metabolites or something else, a distinct vertical exclusion effect could be related to the presence of concentrated phytoplankton at the surface. The relation was made clear in several ways through this peculiar type of fishery where light-attracted fish come to the surface. For example, immediately before and after each bloom sardines could be gathered at the fishing lamps, but few or none during the blooms, and the denser the concentration of phytoplankton the fewer were the sardines; echo-sounder traces would indicate shoals of sardines rising towards the surface while none appeared under the lamps; when, as occasionally happened, the phytoplankton was " patchy ", a shoal of sardines might be attracted to the lamps where the density had lessened only to disappear as the lamp-boat drifted into thick phytoplankton, and similarly at the edge of the bloom area several miles from land, good catches were made when it had been impossible earlier to find fish in the phytoplankton.

Five main phytoplankton outbursts were noted, in July, August, October, November and December/January, and the visual impression was that the duration of each was between one and two weeks, each bloom lessening in intensity in relation to the previous one, with the exception of the final outburst in December/January which seemed more dense and unusual in its distribution. As mentioned above, the blooms were always limited to the large " bay areas " in the south-eastern arm of the lake, and whenever one sailed out towards the lake middle, often six or more miles from land, the phytoplankton which had been dense became sparer and sometimes hardly noticeable. It would have been interesting, but time did not permit, to investigate the variations of this boundary in deep water. The final bloom was densest very close to the coast and did not extend as far out into the lake as the others. It was most noticeable near the mouth of the Lufubu River and along the coast on either side of the river which was in its first spate. As this bloom followed shortly after the first heavy rains and was limited largely to the margins of the lake it may possibly have resulted from the addition of salts brought by the run-off into the lake. No detailed examination has yet been made of the compositions of the phytoplankton samples over this July–December period, but from brief inspections it appeared that *Ahabaena* spp. and *Nitschia* spp. were especially common in the early part and *Microcystis* spp. very common later.

These phytoplankton blooms as described, commenced at the time when the temperature (at mid-Mwela) approached nearest to a homothermal gradient and seemingly arose from the supply of nutrient salts brought to a large area of the surface by convection currents. The subsequent re-establishment of the thermocline would indicate that this supply caused by instability and movement of water masses only took place within a limited period. However, although the first bloom was the most intense, successive ones occurred. This may be because the thermocline forms a density barrier which therefore slows up the sinking rate of phytoplankton—dead and living—so that much of what would otherwise be lost by sinking to the depths is held up at the thermocline to be remineralised and recirculated in the epilimnion. This would maintain the supply of minerals even though vertical mixing had ceased and support fresh blooms of phytoplankton, which however would diminish each time in intensity. The recycling process (assimilation, death or consumption and regeneration) would run down so that it is not surprising that in the following January to May there was little phytoplankton in the euphotic zone.

The situation offers scope for interesting research particularly, if the above explanation is correct, into the important question of which little is known of the speed at which this cycle of breakdown of organic material and its regeneration may proceed in tropical waters. For in this phenomenon may be the mechanism by which a considerable level of organic production is maintained on what may be a relatively small budget of nutrient salts.

Another interesting idea which invites further investigation is the possible prediction of the size of a following year's stock of sardines from knowledge of the relative amount of available planktonic food. Local African fishermen say that the abundance of sardines varies—some years are " good years " others are " bad years ". As explained in section III it seems that the life of the sardines *Limnothrissa miodon* (Blgr.) and *Stolothrissa tanganicae* Regan may be regarded for commercial purposes as being about one year. From the observations of Poll (1953) and my own observations at Mpulungu it appears that *Stolothrissa* is almost completely a plankton feeder and *Limnothrissa* feeds in part on plankton and insects, and preys on younger *Stolothrissa* and its own juveniles. Thus any one year's stock of sardines may depend very largely upon the quantity of plankton which was available to it in the previous year. If this in turn depends chiefly upon the initial supply of nutrients obtained through vertical mixing in the short period when the stability of thermal stratification was broken down, a measure of this mineral supply or indirectly a measure of the intensity of the organic outburst to which it gave rise may, within certain limits, be a measure of the size of the following year's sardine stock. If reliable prediction could be made on this basis it would have considerable commercial value, since the method of prediction used with some success with herring, based on a knowledge of strengths of year classes, is impossible because of the short life-history of the sardines.

II.—The Sardine (Ndagaa) Fishery on Southern Lake Tanganyika, with Notes on the Introduction of the Chirimila Net

Most Northern Rhodesians and many people in Southern Rhodesia, particularly farmers and other employers of labour, are familiar with the dried sardine known widely as " Nshembe " or " Kapenta ". On Lake Tanganyika where it is caught it is known in the southern part as " Ndagaa " and further north as " Ndakala ". In this sundried form it will keep for at least six months without noticeable deterioration, and probably for much longer if stored properly. Those keeping qualities, together with its herring-like tastiness and use as a relish as well as its nutrient value, have made it increasingly sought after where concentrations of African labour especially in cities and towns cannot obtain or afford fresh fish. In addition, dried Ndagaa has been used as a protein supplement in pig and poultry food.

The production of this useful commodity has been retarded by two main factors. The first is that the fishery is an indigenous one with primitive methods and a poor yield for man-power effort. It has been until lately merely a subsistence fishery for the local population and in its present form barely touches upon the possibly great resources of the lake. The second factor is that of unorganised buying, distribution and marketing. The result of this has been an irregular supply to the consumers of a product of variable quality at an inconsistently high price in relation to that paid to the fishermen. The need for price stabilisation and a grading of the dried fish according to quality is obvious; it would lead to a greater demand from the market and give the fisherman more incentive to increase his catches. This paper, however, is concerned only with an examination of the fishery in its present state, and its suggested improvement by the adoption of a different catching method—the Chirimila net.

The Present Fishery

There are two closely related species of sardine known together as Ndagaa, *Stolothrissa tanganicae* and *Limnothrissa miodon*. (*L. miodon* is sometimes recognised separately by the name of " Lumbu "). They are true members of the herring family the Clupeidae, and the only fresh-water herring of economic importance in Africa. As with certain other clupeids in many other parts of the world they have a strong attraction to a bright light at night and immense, closely packed shoals may be aggregated. The fishery is based upon this behaviour.

Light was at first provided by a burning bundle of thin sticks which was held out over the bow of the canoe, but this has gradually been replaced within the last eight years by paraffin and petrolmax pressure lamps. An excellent description of the history of this fishery in the north of the lake has been given by Collart (1954). European-operated ring-net boats work from the Congo at Albertville and more particularly further north in the Urundi-Kivu area, but up to date there have been no privately operated ring-nets in Northern Rhodesia waters. The fishery here is wholly a peasant industry based on a simple scoop-net, the " Lusenga " net, made of mosquito netting fastened to a wooden frame (Plate 1). When sardines are gathered in sufficient quantities under a lamp the net is simply dipped in rapidly and some are scooped out. The advantages of this net are that it is cheap to construct, it can be used from a canoe, and when sardines are plentiful and come up near the surface it is quite effective.

In Northern Rhodesia waters fishing takes place from two main centres with their associated villages, Mpulungu on the east side and Sumbu on the west. No Ndagaa are caught on the precipitous coast between these two extremes which is almost devoid of settlement and about half of which is game reserve (Map 1). Thus all this coastline as well as all open water more than two miles at most from shore are unexploited, although there is reason to believe that sardines occur sometimes in great abundance in these areas also. Fishing is seasonal from June to October largely because, it would seem, that there is no rain in this period and fish can be spread for drying immediately after being caught. Two or three days in the sun is generally sufficient for drying. In addition even this short season is influenced, one might say bedevilled, by other limiting factors with the result that no routine pattern of fishing is possible; the most successful fisherman is here an opportunist ready to take advantage of suitable conditions as they present themselves.

The three chief limiting factors are (i) moonlight, (ii) wind and (iii) the fish exclusion effect of concentrated plant plankton (phytoplankton).

(i) For three days before each full moon and two days after, fishing is abandoned. Thus at least one week each month is lost. Many theories have been advanced as to why some fish (as well as birds and insects) are attracted to light at night, and although none of these ideas may be regarded yet as proven or universally accepted, one fact is common to all such attraction behaviour. That is, attraction is strongest to a localised intense light source, and the more this light is diluted or diffused by other light in the same background, the less effective is its attractive power. Thus on moonlit nights fish do not come up to the lamps.

(ii) Moderately strong wind which ruffles the surface and causes waves disrupts fishing. The sardine shoals may still be held by the lamps but move further below surface out of range, and in a pitching canoe manipulation of the net is difficult. The night wind or " kapata " is an offshore wind, and though often only a gentle breeze it may capriciously, within minutes, blow up strongly and maintain its force for several hours. From this comes the fisherman's habit of anchoring his canoe to prevent being blown out into deep water, and his tendency to remain inshore under the lee of the mountains which in most places rise steeply from the lake. Here the water often remains calm, and on a rough night clusters of lamps may often still be seen close inshore.

(iii) In the 1960 season it was estimated that at least a quarter of fishing time when conditions were otherwise suitable was lost because of the occurrence of successive phytoplankton " blooms ". The accelerated metabolic activity resulting in these dense algal concentrations is due to successive releases in surface waters of nutrient salts initially brought from below by water currents. Thermal stratification so typical at other times of the year was broken down by July, 1960, to an almost homothermal condition in 120 metres, and was not built up again until October (coinciding precisely with the fishing season). At some time during this period it was therefore to be expected that a mixing of the upper and lower layers of water would occur. As far as the fishing is concerned, although phytoplankton can be said to provide the basic food by nourishing zooplankton on which the sardines are maintained, concentrations at the surface have also in this case a definite inhibiting effect on fish. During any of these periods one could float quietly on the lake undisturbed by any wind on dark, moonless nights, and not see a single sardine under the lamp.

Apart from these chief limiting factors there are occasions when visible shoals do not for some reason come close enough to the lamp to be within catching range of the Lusenga-net, and again when shoals of the predatory fish *Luciolates stappersii* (Blgr. " Mvolo ") are hunting; this latter may be seen in the excited behaviour of Ndagaa which, instead of passively swimming up around the lamp, flit hurriedly at greater depths passing in and out of sight. This latter behaviour was particularly common in November and December, 1960. Strangely enough the presence of Nile perch does not seem to cause such alarm and big perch can often be seen in the midst of a shoal consuming individual sardines.

In spite of these conditions the fishery remains a very productive one having regard to its primitive state, but there is immense scope for improvement and increase in quantity of sardines landed. The most effective fishing device so far used is of course the ring-net, but leaving this method aside with its relatively great capital cost, upkeep and complication in operation, what is needed as a first step in the improvement of a peasant industry is a fishing device whose catching power is greater than the one at present used but which can utilise if possible the existing tradition of fishing at night from canoes in shoals of sardines aggregated by the light of simple pressure lamps.

With this in mind a suggestion of the Chief Fisheries Research Officer was followed, and a net known as the " Chirimila ", native to Lake Nyasa, was used experimentally on Lake Tanganyika. This net had been improved and used very successfully by the J.F.R.O. on Lake Nyasa (*see* Jackson, *et al.* (1961)). After some further alteration in form and using a new technique of employment, this net seemed to provide an answer to the problem of improving the peasant fishing. The essential difference in the employment of the net on Lakes Nyasa and Tanganyika is that on Lake Nyasa the action of the current sweeps the net to a submerged bank, while on Tanganyika it is used in the open water at night, the place of the bank or " chirundu " being taken by a light, round which the fish congregate. No use is here made of a current as the boat on which the light is mounted can manoeuvre by means of oars, and the attraction of the light draws the fish along with it. The following is a description of this net and an account of experiments made with it. The description of the net in Lake Nyasa is taken from Jackson *et al.* (1961).

Chirimila Net

The Chirimila is believed to have been introduced by the Arabs in Lake Nyasa in about the 1870s at Likoma and Chizimulu Islands where the most expert fishermen and a flourishing fishery exist at present. The average dimensions of a net in yards and the names of the chief parts are shown in figure 2 B 2 A. It can be seen that in essence the Chirimila is a type of Lampara-net. All netting was made of " Chopwa " thread obtained from a shrub (*Poulzolzia hypoleuca*) very common along the Nyasa shore, though nowadays nets are being made of cotton.

The fishery is chiefly for the " Utaka " group of fish and particularly for *Haplochromis quadrimaculatus* Regan, and is restricted to very definite areas known as " virundu " which correspond to certain underwater features of the lake bed. These virundu are rocky prominences or shelves which are characterised by a steep slope from shallow to deeper water and also by water currents which flow towards the slope. The movement of the Chirimila net is very dependent upon these currents which sweep the submerged net along. Echo-sounding traces have shown that Utaka shoals are almost always massed on the current side of a virundu.

Thus in action the net is shot from two canoes in places determined by local knowledge, being weighted and buoyed so that it sinks slowly. (It is this that gives the net its name which may be translated as " the thing that drowns ".) The depth of the net is controlled by the amount of warp paid out, and its shape maintained by paddling the canoes energetically towards the fishing area. Any fish are collected as the net is moved forward by the current, and when it has reached a precise position the warps are hauled and the fish trapped in a deep narrow bag formed by the net.

The Lake Nyasa Chirimila is never used successfully in open water whereas it is for open water fishing that it has been adapted in Lake Tanganyika (figure 2 B 2 B). It should here be noted that neither figure shows a most important feature of the Chirimila, viz. it is not a flat semicircle, but by its construction from strips it is bagged out over the whole centre portion.

A cotton net shown in figure 2 B 2 A, identical in every way (except in having several more floats) to that used on Lake Nyasa, was first tried in October, 1959, in Cameron Bay, Sumbu. A shoal of sardines was attracted to a lamp and the net somewhat inexpertly drawn around them. After five hauls, each taking about fifteen minutes and one of which was faulty, 500 lb. of fish were caught. The surprising thing was, however, that nearly 400 lb. consisted of Nile perch of 8 lb. average weight (*Lates angustifrons* Blgr.), most of the sardines having escaped through the much too large meshes of the net. This first catch was considered promising enough to justify the construction of another more suitable net this time made completely of nylon, since even in one evening the powerful perch had torn several holes in the cotton. In addition all meshes should be about ½-inch or at least six millimetres (square mesh). Such netting was eventually obtained and a net constructed by July, 1960.

Trials with this net resulted in a number of modifications being made to it; figure 2 B 2 B illustrates its modified form. The trials also indicated the type of canoes required from which to shoot the net and building of one such canoe was then commenced locally and another canoe was hired and modified. Thus it was not until mid-September, towards the end of the season, that the unit was ready. Catches obtained by a Government operated ring-net boat which worked experimentally from Mpulungu in the 1959–60 rainy season had indicated that in the period October to December poor catches might be expected. Nevertheless it was decided to commence a fishing programme of at least twelve nights per month in the moonless periods, until the end of the year. The criteria of the value of the net were not taken as the total quantities it could catch over a season but firstly the quantity it could catch when conditions of wind, moon, etc., were good, and secondly the proportion caught of any shoal collected under the lamp.

Mr. R. C. Weatherdon, an employee of the Development Commission, was assigned this task and had trained his own crew by the end of September. The following is an analysis of his results.

There were thirty-one nights on which fishing was carried out. On another eleven nights, fishing was prevented by impossible weather on six occasions, dense phytoplankton on two occasions, sea-sickness among the crew on two occasions and once by engine trouble in Mr. Weatherdon's launch. In the thirty-one nights an average catch of 512 lb. was taken. In twenty-three of these there was an average of 245 lb. (the best catch being 633 lb. and the lowest 17 lb.) because of the varying influence of one or more of the above limiting factors. In addition the excited behaviour of the sardines associated with attacks of *Luciolates* occurred on several nights, and it was also considered that in November and December the great shoals typical of the period July–October were simply not there. However, in this period there was never any difficulty in finding great masses of juveniles (up to five centimetres) in inshore waters less than forty metres deep, and among these large *Limnothrissa* of ten to fifteen centimetres. The six-millimetre mesh size allowed the juveniles to pass through the net.

On eight of the thirty-one occasions, however, conditions resembled those in the conventional fishing season—fairly dense shoals coming up to the lamps and the weather remaining calm. Each time all storage space on the boats was rapidly filled, bringing home the lack of storage space and fish boxes or baskets. On 23rd September 1,800 lb. of Ndagaa were taken in 1½ hours in four hauls, and there were at least as many fish present under the lamp at the conclusion as at the commencement of fishing but there was no more storage space. Again, on 13th December 970 lb. were taken in one haul, but the interesting thing is that Mr. Weatherdon estimates that in this haul this was only about one third of the fish captured by the net. The other two thirds escaped before the net could be hauled in owing to the difficulty in handling the great weight of fish. Of the eight occasions catch figures ranged from 703 lb. when there were no storage facilities, to 2,011 lb. when there were. Some indication of the abundance of fish may be gained by the fact that as one shoal was taken by the net it was generally replaced within minutes by another, equally dense.

It was considered that the net fulfilled its promise according to the criteria mentioned above. The quantity it could catch when conditions of wind, moon, etc., were good was only limited by storage space, and the proportion of any shoal caught if the net was properly operated included all that was visible.

In terms of cash, the average catch of 512 lb. over the thirty-one nights' fishing would realise, at the current price of 2½*d*. per lb. fresh, a little over £5 per night, normally to be shared among a crew of seven. A catch of one ton would be worth about £21.

The following is a description of a Chirimila unit and the fishing method which was found to give best results.

Net:

The modified net (figure 2 B 2 B) differs from the Lake Nyasa net in that it (i) is constructed of nylon, (ii) is of $\frac{1}{2}$-inch mesh throughout, (iii) has a greater number of corks so that unlike the Nyasa net it will not sink (the large central float, the " Mamayake ", is painted white for better location at night), (iv) is more heavily weighted around the centre of footrope, (v) has a hauling footrope attached at intervals along the footrope, and (vi) has hauling warps marked off in ten-yard intervals.

Canoes:

These must be of a size which can readily be propelled by three men, say of about sixteen feet in length, and three feet in beam at the gunwhales. The gunwhales should be broad and rounded to facilitate shooting and hauling the net. A floor space of at least six feet is required between fore and aft seats to contain the net. The outer surface of the sides and bottom must be absolutely free of such projections as nails and wood splinters which would snag the net.

Lamp-boat:

This may be another canoe bearing a lamp either fore or aft, and controlled by one man.

Figure 2 B 3 illustrates the operation of shooting and hauling the net in five stages. Stage 1.—The lamp-boat at anchor or floating free collects a shoal under the lamp while the two working canoes bearing the net, half in each canoe, lie off. Stage 2.—Canoes quietly come thirty yards to windward and start laying the net, parting at first in opposite directions. Stage 3.—When the net is laid in the form of a broad semicircle the hauling warps are paid out in ten-yard intervals, both canoes keeping abreast on either side of the lamp-boat. After paying out about forty yards they meet and are promptly linked bow to bow. Stage 4.—Lamp-boat paddles gently towards the central float of the net, taking the shoal with it until it lies a few yards from the central float. The fish should then be in the bosom of the net but not so close to it as to alarm them. Meanwhile the hauling warps are pulled in until each canoe has an end of the net. This point is the most critical of the operation for now the footrope must be hauled up as rapidly as possible to trap the fish, while the lamp-boat is carefully handled so as to keep the shoal undisturbed and in the right place. Stage 5.—Footrope is up, canoes are unlinked, the cork rope is being drawn in and the fish trapped in the net between the two canoes ready to be scooped out and stored in boxes. The lamp-boat moves off to aggregate another shoal.

Three points are worth emphasis. A satisfactory haul depends upon the skill of the lamp-boat operator and the speed with which the footrope is hauled up. The lamp-boat operator should be the one in charge. The net should be stowed carefully on hauling and shot cleanly without snagging.

A Chirimila has the following advantages over the existing Lusenga net:

(*a*) It has a much greater catching power, the whole visible shoal being surrounded on each haul. Perch and mvolo often form part of the catch and so there is a more balanced exploitation.

(*b*) Juvenile Ndagaa are not taken with a mesh size of six millimetres.

(*c*) On occasions when shoals are out of range of the Lusenga net they may still be caught. Indeed, good hauls have been made when no fish were visible but only bubbles to indicate their presence. (The occurrence of such bubbles is, incidentally, an excellent indicator of the fish, and is caused by the release of gas from their swim bladders on rising from depths to maintain hyrostatic equilibrium.)

(*d*) A Chirimila unit with its greater value and potential should be able to afford more seaworthy craft and thus exploit areas further from shore where Ndagaa are often greater in quantity and of larger average size.

Its disadvantages are:

(*a*) The capital cost of a net. An all-nylon net costs in the region of £250 to £300. However, this cost may be greatly reduced by the netting being of cotton with a nylon centre. Although the trial net was of nylon, there is no apparent reason why a cotton one should not work equally well. A nylon centre piece of about seven by eight yards is necessary, however, since perch when caught are quickly isolated in the centre section of the net and are still very full of life.

(*b*) Lusenga fishermen are generally two or three to a canoe, whereas a Chirimila requires seven men amongst whom the catch has to be shared.

It is worth while to point out the extremely destructive effect of the Lusenga net on young Ndagaa stock. As mentioned above, no difficulty was experienced at any time during the trial in finding masses of juvenile Ndagaa close inshore. While six-millimetre mesh size will not take these, mosquito netting of the Lusenga-net certainly will above a length of fifteen millimetres. It is a common sight to see big quantities of tiny immature sardines landed whose bulk would be several times increased even three months later. Belgian authorities, aware of the danger to the fishery, at one time imposed restrictions on the sale of such fry in major markets in the Congo.

Potentialities

It might not be out of place here to quote the opinions of other workers on the potential productivity of this fishery. Kufferath (1952) assumed a minimum stock of fifty kilogrammes of Ndagaa per hectare, and a rational exploitation of 20 per cent. of this per annum. Over a surface area of lake of 3,000,000 hectares this would result in an annual production of 30,000 tons of Ndagaa, or 7,500 tons in its dried form. (Assuming a reduction of four to one on thorough drying out.)

Collart (1958) gives the total catch figures from both ring-nets and native methods for the north of the lake (Urundi-Kivu area) from 1954 to 1957 as—

	1954 (*estimated*)	1955 (*estimated*)	1956 (*precise*)	1957 (*precise*)
Ndagaa	7,200	9,000	8,132	12,413 tons fresh
Predators (*Lates and Luciolates*) ...	800	1,000	1,360	2,064 tons fresh
TOTALS	8,000	10,000	9,492	14,477

This was without any apparent sign of overfishing. The value of the total catch in 1957 was estimated at 62,590 francs.

An estimate of the 1960 production in Northern Rhodesia waters caught by the native method may be obtained from the activities of firms and individuals receiving it. About 230 short tons of dried Ndagaa were taken up by one large concern and an estimated equal amount spread over many smaller traders.

The production from Northern Rhodesia waters, however, accounted for only about one-fifth of the total weight of dried fish which passed through the port of Mpulungu in 1960. An estimated 2,000 short tons, mostly brought by the lake steamer, came from the Congo and Tanganyika coasts, all of this caught either by the Lusenga-net or, on the Congo coast, by daylight-operated seine-nets.

It is difficult, since so little of the biology and movements of Ndagaa are known, to hazard a guess at the potential of Northern Rhodesia waters; one can only yet state that, from the evidence of echo-sounding and fishing trials, masses of sardines occur over much of the year in offshore waters, as yet completely unexploited. Both ends of the axis of the lake should theoretically be the most productive parts, and the north end has already been proved to be very productive. It is a pity that such a small fraction brought into the country was actually caught in Northern Rhodesia waters since the present undeveloped state of the markets in the other two territories may not continue to be so indefinitely. The assumption of a continued delivery of dried fish to Northern Rhodesia ports may not be a secure foundation on which to build the trade here.

Suggestions for Development

Much remains to be done to place marketing and distribution on a sound and stable footing, but there is also great scope for the expansion and development of the fishery itself even if it were to remain a peasant industry. The author would like to suggest that development of the native fishery should proceed on the following lines:

(1) The adoption of an improved but uncomplicated method such as the Chirimila net, which has greater catching power and is more economical of manpower effort. It is encouraging that so far the Chirimila has met with enthusiasm from local fishermen.

(2) The introduction of more suitable fishing craft for open water conditions so as to take advantage of a greater exploitable area. One possibility here is a catamaran of the type already used for gill-net fishing on the lake by a European, and thoroughly tested. The advantages of this craft are that it (*a*) can be cheaply constructed locally, (*b*) is seaworthy, (*c*) can be driven by a light outboard engine at an adequate speed, and (*d*) has a load-carrying capacity of a ton, even when of small size.

(3) Artificial drying facilities are a prerequisite of out-of-season fishing. Until this is introduced by either commercial interests or Government, fishing will quite definitely be limited to about four months of the year.

(4) As important as anything else, continuous long-term and short-term research into the biology and movements, etc., of Ndagaa and *Lates* spp., greater knowledge of which is the only dependable basis for the direction of the fishery.

Table 2 B 1

NUMBERS OF ALL SPECIES CAUGHT BY THE LARGE SEINE-NET ON CHOSEN BEACHES

Distinction is made between day (D) and night (N) catches

		Lates mariae	*Lates angustifrons*	*Lates microlepis*	*Alestes macropthalmus*	*Alestes rhodopleura*	*Hydrocyon lineatus*	*Dinotopterus cunningtoni*	*Auchenoglanis occidentalis*	*Heterobranchus longifilis*	*Chrysichthys brachynema*	*Chrysichthys stappersii*	*Chrysichthys sianenna*	*Phyllonemus typus*	*Synodontis multipunctatus*	*Synodontis lacustricolis*
3-6-60	D		0	0		0	0		1				0		1	
Nyika	N		7	1		7	1		12				8		11	
15-6-60	D		0	0	35	0	0		0		0	0			0	
Nyika	N		13	56	131	1	16		15		7	25			52	
9-6-60	D	20	14	6		0	3		79						0	
Liemba Jetty	N	16	1	0		1	0		4						2	
22-6-60	D	0	2				2	0	1		0				0	
Croc. Island	N	8	1				0	1	0		8				20	
29-6-60	D	55	18	0		0	1		12			0				
Liemba Jetty	N	0	3	2		1	0		1			1				
8-7-60	D		0		11		1				0				1	
Nyika	N		3		0		1				10				27	
14-7-60	D	46	11	4	0	0			45	0					5	
Liemba Jetty	N	0	0	0	6	9			13	1					0	
21-7-60	D		0	0	71	3	0		0						9	
Nyika	N		2	9	0	0	1		8						36	
27-7-60	D		0					1	0		0				0	
Croc. Island	N		2					0	1		3				22	
18-8-60	D	0	1	0	0		0		0						4	
Nyika	N	3	4	26	21		3		20						26	
1-9-60	D		8					0			0				0	
Croc. Island	N		0					15			2				12	
20-9-60	D	0	0	0	1				0		0		0	0	0	0
Nyika	N	1	6	14	0				12		8		2	3	9	1
29-9-60	D		2	6	483			1			0					
Musumba	N		2	1	0			0			2					
5-10-60	D		2					1			0				0	
Croc. Island	N		0					0			3				16	
10-10-60	D	0	0	0	0			0	1		0				0	
Nyika	N	1	8	27	1			1	5		2				3	
17-10-60	D	0	1			0			0							
Musumba	N	2	0			2			1							
31-10-60	D		0	1					5						148	
Croc. Island	N		2	1					1						5	
7-11-60	D	0	0		3	0			0		0			0	0	
Nyika	N	11	2		20	1			2		1			3	12	
14-11-60	D	0	2	0			1		0		0				0	
Musumba	N	6	2	2			0		2		4				29	
21-11-60	D										0				0	
Croc. Island	N										4				31	
30-12-60	D	0							0		0					
Nyika	N	2							19		4					

TABLE 2 B 1—*continued*

NUMBERS OF ALL SPECIES CAUGHT BY THE LARGE SEINE-NET ON CHOSEN BEACHES

Distinction is made between day (D) and night (N) catches

		Malapterurus electricus	*Mastacembelus* spp.	*Barbus tropidolepis*	*Varicorhinus tanganicae*	*Tilapia tanganicae*	*Lobochilotes labiatus*	*Plecodus paradoxus*	*Limnotilapia dardennei*	*Grammatotria lemairei*	*Haplotaxodon microlepis*	*Petrochromis polyodon*	*Cyathopharynx furcifer*	*Simochromis diagramma*	*Haplochromis horei*
3–6–60	D	0		0	0	10	0	0	7				174	7	0
Nyika	N	1		1	5	7	13	1	136				407	3	118
15–6–60	D	0		0	2	0	2	1	2			1	4		
Nyika	N	3		4	27	2	0	2	369			2	465		
9–6–60	D	0				260	0		0		0	0	38	5	6
Liemba Jetty	N	1				32	14		17		1	1	88	1	5
22–6–60	D		0	6		0	0	0	0		0		0	1	
Croc. Island	N		1	24		1	2	3	33		8		6	0	
29–6–60	D		1	1		12	7		27		0	8	138		
Liemba Jetty	N		0	1		1	2		9		1	0	2		
8–7–60	D	0			1	30			2		0	0	23		
Nyika	N	2			0	0			272		2	39	305		
14–7–60	D			0		8	2	2	55		1	3	162		10
Liemba Jetty	N			1		27	1	1	70		2	0	13		13
21–7–60	D			0		0	0		1		0	15	82		
Nyika	N			4		4	1		218		1	5	147		
27–7–60	D	0				3	1	0	0		0		0		
Croc. Island	N	1				0	13	3	64		4		14		
18–8–60	D			0	0	0			0		0	13	18	0	
Nyika	N			27	3	1			574		3	0	185	2	
1–9–60	D	0	0	188		1	3	0	0		0	0	0		
Croc. Island	N	1	3	0		1	124	19	618		7	2	3		
20–9–60	D			0	1		0	0	6		0	0	11	9	
Nyika	N			6	2		1	2	257		4	1	223	0	
29–9–60	D	0			8	4	0	1	9		0	6	0	0	
Musumba	N	1			0	3	5	1	19		3	10	45	14	
5–10–60	D	0		1		0	0	0	1		0		0	0	0
Croc. Island	N	2		1		1	86	8	151		31		1	19	2
10–10–60	D			12	0	11	4	0	0		0		23		
Nyika	N			3	1	0	0	2	175		3		159		
17–10–60	D			0		0	2		2		0	0	0	1	
Musumba	N			1		149	2		64		3	10	29	0	
31–10–60	D	0		1			0	0	1		0	2	4		
Croc. Island	N	5		0			120	23	597		5	7	11		
7–11–60	D	0		0	2	0	0	0	7		0		1	0	0
Nyika	N	2		7	0	41	2	1	59		5		9	2	3
14–11–60	D	0				3	3	1	0		0	0	0	2	
Musumba	N	3				3	2	7	13		3	10	23	8	
21–11–60	D	1				1		0	10		0	0			
Croc. Island	N	13				0		2	19		19	22			
30–12–60	D	0			0		0		24	0		1	0	7	
Nyika	N	1			2		1		108	10		2	438	5	

TABLE 2 B 1—*continued*

NUMBERS OF ALL SPECIES CAUGHT BY THE LARGE SEINE-NET ON CHOSEN BEACHES

Distinction is made between day (D) and night (N) catches

		Xenotilapia spp.	*Callochromis macrops macrops*	*Aulenocranus dewindti*	*Lamprologus* spp.	*Boulengerochromis microlepis*	*Tylochromis polylepis*	*Simochromis curvifrons*	*Bathybates fasciatus*	*Bathybates ferox*	*Bathybates vittatus*	*Bathybates horni*	*Bathybates graueri*	*Tilapia karomo*	*Tropheus moorei*
3–6–60	D	3	4	1	3	4	4		0	0					
Nyika	N	10	5	5	4	0	39		3	2					
15–6–60	D	0	0	0	1	17	24		0	0	0	0		0	
Nyika	N	87	15	9	2	3	111		11	8	2	1		1	
9–6–60	D		102	11	8	13	63		2		0				
Liemba Jetty	N		40	22	15	1	3		4		4				
22–6–60	D			0	0	9	5		0						
Croc. Island	N			3	4	0	2		1						
29–6–60	D	0	44	134	19	3	7	20	1	7					
Liemba Jetty	N	30	10	11	0	3	6	0	0	0					
8–7–60	D	2	0	0	1	0	1	0						0	
Nyika	N	152	11	1	14	2	31	4						1	
14–7–60	D	3	108	38	17	0	8	14						8	
Liemba Jetty	N	4	55	48	1	4	1	3						1	
21–7–60	D	4	0	0	0	4	3	0							
Nyika	N	88	1	2	4	3	28	6							
27–7–60	N	1			83	6	3				0				
Croc. Island	N	1			7	0	1				2				
18–8–60	D	1	0		2	10	4	1							
Nyika	N	62	12		40	2	57	0							
1–9–60	D	1		0	0	2	9								
Croc. Island	N	1		1	6	6	0								
20–9–60	D	1	0	0	8	7	51								
Nyika	N	70	1	6	25	1	56								
29–9–60	D			0	1	6	5								0
Musumba	N			3	6	0	1								2
5–10–60	D			0	0	1	21		0		0				
Croc. Island	N			2	7	1	8		1		2				
10–10–60	D	2	5			8	62		0	0					
Nyika	N	11	4			0	15		1	1					
17–10–60	D			0	0	2	0		0	0					
Musumba	N			2	3	5	2		1	1					
31–10–60	D				11	11	3			0	0	0	0		
Croc. Island	N				23	6	0			3	3	1	1		
7–11–60	D	0	1	0	4	27	14			0					
Nyika	N	4	22	45	9	2	4			3					
14–11–60	D	0			0	8	3		0	3					
Musumba	N	4			5	1	0		10	7					
21–11–60	D					22	2		0	0					
Croc. Island	N					0	0		6	5					
30–12–60	D	0	1		1	2	14			0					
Nyika	N	40	11		6	9	26			4					

TABLE 2 B 2

SPECIES COMMONLY TAKEN IN BEDS OF WEED (? *CERATOPHYLLUM*) IN LAKE TANGANYIKA

	Maximum recorded length cm.	*Maximum length taken by the seine-net cm.*	*Maximum length taken in quantity in weed cm.*	*Length first recruited in weed cm.*	*Occurrence in seine catches* during day. *Localities without weed*
Tilapia tanganicae (Gthr.)	38	43	23	9	Rarely less than 24 cm.
Lobochilotes labiatus Blgr.	37	36	23	6	Rarely taken.
Plecodus paradoxus Blgr.	29	24	15	6	Rarely taken.
Limnotilapia dardennei (Blgr.) ...	26	27	23	6	All sizes up to 27 cm.
Grammatotria lemairei Blgr.	26	24	18	6	Rarely less than 20 cm.
Haplotaxodon microlepis Blgr. ...	26	24	22	6	Rarely taken.
Petrochromis polyodon Blgr.	21	22	20	6	Taken occasionally, 9 cm. to 22 cm.
Petrochromis fasciolatus Blgr. ...	14	18	15	5	Rarely taken.
Cyathopharynx furcifer (Blgr.) ...	21	15	13	6	Taken occasionally between 6 and 15 cm.
Simochromis diagramma (Gthr.) ...	19	15	12	6	Taken occasionally, from 7 to 15 cm.
Haplochromis horei (Gthr.)	18	18	16	6	Rarely taken.
Xenotilapia sima Blgr.	16	17	16	6	Rarely taken.
Xenotilapia melanogenys (Blgr.) ...	14	17	14	8	Rarely taken.
Callochromis macrons macrons (Blgr.)	16	14	12	7	Taken occasionally.
Aulonocranus dewindti (Blgr.) ...	12	12	11	6	Rarely taken.
Lestradea perspicax perspicax Poll. ...	12	12	11	7	Taken only in weed so far.
Lamprologus spp.	—	25	—	6	All sizes between 9 to 25 cm.
Boulengerochromis microlepis (Blgr.)	65	—	20	5	Above 22 cm.
Lates microlepis Blgr.	83	—	18	6	Above 25 cm.
Lates angustifrons Blgr.	132	—	18	6	Above 25 cm.
Lates mariae Stdr.	64	—	18	5	Not taken during day.

III.—Limnothrissa Miodon (Blgr.) and Stolothrissa Tanganicae Regan

Regular samples of sardines were obtained from the catches of a ring-net which operated near Mpulungu from October, 1959, to April, 1960. The samples were readily obtainable from October to December but thereafter fishing was not consistent and there were large gaps—on one occasion of a month—between samples. In early May, 1960, the ring-net unit operated by the Commercial Fisheries Organisation of the Development Commission was unfortunately withdrawn from use and samples from deep water were unobtainable. One sample was, however, obtained in June by means of a stocking-net of the type used in the north of the lake. In August and September as described in section II, trials were being made with a small-meshed nylon Chirimila-net with which some samples were taken, and from October onwards this provided a regular means of sampling. Thus although the ideal was not achieved of examining a regular supply of sardines of both species in order to follow changes in the size composition of the population throughout the year, and so perhaps obtain some information on the life-history of the sardines, some degree of continuity was maintained.

In the earlier samples a random group of about 100 sardines was measured, but as this often consisted of more than 80 per cent. of one or other of the species, the number measured had to be expanded to at least 200. At present, because it has been found that the size range, especially in *Limnothrissa*, generally includes several significant size modes which were not being brought out clearly enough, a sample consists of about 500 fish. Further it was noted that the size composition of a catch often varied according to the depth of water where it had been made. Juveniles of *Limnothrissa* and to some extent of *Stolothrissa* also live inshore, and as they increase in size move out into deeper water. Hence in order to obtain a picture of the whole population it is necessary to fish in water of different depths. This fact was clearly apparent when, ultimately, it was possible to obtain the samples with the Chirimila-net operated by J.F.R.O. staff, and by means of an echo-sounder to know precisely the depth where one was fishing. A third complication arises from the fact that spawning is not limited to one or two brief periods in the year, but seems from the number of apparent broods to be spread out over about a six-month period when several spawnings take place. Thus a sample often shows the modes of several of such spawnings.

In practice it is not as difficult as it might seem to obtain a comprehensive picture of the size structure of the population at any one time providing the above factors are taken into account. A good deal of overlapping occurs, so that if large samples are taken from known depths (say, twenty, seventy and 110 metres) on the one occasion in one distinct area, e.g. Mbete Bay, the size structure becomes clear, and growth progression with time can be followed. The present sampling technique is operated accordingly, accent being placed on the measurement of larger numbers on fewer occasions rather than the reverse as was done earlier.

The Chirimila-net fishes to a depth of about eighteen metres and because of this and the fact that its inch-mesh will not retain very small sardines, it is used mainly to take sardines in water deeper than twenty-five metres. In shallow water, where at times many juveniles occur, the African " Lusenga " scoop-net made of mosquito gauze is used.

Juveniles

Figures Nos. 2 B 4 A and 2 B 4 B are scatter graphs of the length modes of *Limnothrissa* and *Stolothrissa*. A tentative interpretation is made in the lines A and A1 and B and B1, indicating the growth-rate of a few of the successive broods. This in the case of *Limnothrissa* is about eight millimetres per month and in *Stolothrissa* about seven millimetres per month. Early in July a great mass of juvenile sardines of lengths between fourteen millimetres and eighteen millimetres appeared close to the edge of the lake at Mpulungu in daylight, and similar though lesser masses appeared in August and January, 1961. Identification of these juveniles was attempted on the features given by Poll (1956), which mainly concerned the disposition and order of appearance of chromatophores. According to these descriptions most of the juveniles were undoubtedly *Limnothrissa*, but in a minority there was some confusion since the description, especially of the size at which pre-dorsal chromatophores appeared, fitted that of *Stolothrissa*. Further doubt of the identity of these young " *Stolothrissa* " was raised by the fact that subsequent samples taken at night in shallow water yielded *Limnothrissa* between fifteen millimetres and sixty-seven millimetres and *Stolothrissa* between thirty-eight millimetres and seventy millimetres, but no clearly identifiable *Stolothrissa* between twenty-two millimetres and thirty-eight millimetres. Indeed from all samples both in deep and shallow water no *Stolothrissa* of this size range have been found. It seems likely therefore that these masses of tiny filamentous young were *Limnothrissa* and that this stage in the life of *Stolothrissa* is not spent inshore. Poll (1956) has found juvenile *Stolothrissa* from two millimetres to twenty-six millimetres in plankton samples from deep pelagic waters, and further investigation may show a sharp difference in the ecology of these two sardines, which are so closely associated as adults, below a length of forty millimetres.

The scatter-graphs show the main recruitment in successive broods of juvenile *Limnothrissa* to have been from July to early January. Young *Stolothrissa* above thirty-eight millimetres were found inshore mostly between November and early January. What the graphs do not show is that the greatest abundance of juveniles occurred in these periods and, although some juveniles were to be found at other times, the impression gained was that they were relatively very few in number.

It may be in order to mention an idea for theoretical consideration; that is, that the spawning of the sardines is closely connected with the occurrence of phytoplankton outbursts. Lucas, in Graham (1956), says, " Evidence is accumulating, however, to show that spawning, at least in some forms, may normally be linked with a local phytoplankton outburst (perhaps mediated by some metabolite) ". Certainly the great mass of juveniles which appeared in July coincided exactly with the first and biggest phytoplankton bloom. This was also particularly noticeable in the blooms of August and December/January. Much more precise observation would have been needed to establish such a link, if it exists, between each bloom and the first appearance of another juvenile mass, but the idea is merely put forward that such a situation may obtain here.

Older and Mature Sardines

The large spawning which gave rise to the mass of juveniles in early July was preceded by several months in which few juveniles were produced. This should have been apparent later in samples taken from deep water as a big recruitment to the stocks of older fish. Figure 2 B 5 shows in fact a major recruitment of fish of about fifty-five millimetres in December, 1959, and December, 1960. This is some confirmation that the interpretation of the graphs in figure 2 B 4 and of a monthly growth increment of seven–eight millimetres is correct, since the fifteen-millimetre juveniles of July would at this rate be about fifty-five millimetres in December. In the histograms in figure 2 B 5 differentiation of the successive broods has been attempted, but because earlier sampling techniques did not represent the full size composition of the population (for the reasons discussed above) the fate of each brood and its successor is not fully shown. Moreover sampling was irregular, especially between May and October, 1960. The larger number of fish dealt with in each sample from December, 1960, onwards is reflected in the broader size ranges containing a greater number of modes.

It will be noted that *Stolothrissa* occurs in the samples over a much smaller length range than does *Limnothrissa*, a range of thirty-five millimetres as compared with eighty millimetres. The largest *Limnothrissa* represented here is 130 millimetres although specimens are from time to time taken up to 150 millimetres. In the histograms seven broods of *Limnothrissa* and seven of *Stolothrissa* are represented between the main recruitment in December, 1959, and in December, 1960.

It should be emphasised that the histograms are only a tentative explanation of the length frequencies, which, however, in spite of the imperfection arising from inadequate sampling do on close inspection show a regular pattern. It is hoped that the fuller sampling in 1961 will make the pattern clearer.

Discussion

The maximum lengths which *Limnothrissa* and *Stolothrissa* have been known to attain are 170 and ninety-eight millimetres respectively (Poll 1956), yet it will be seen from the histograms that the bulk of both species disappear or are greatly reduced in number well before reaching their maximum natural size. The most obvious explanations are that the sardines are either reduced by predation or that they migrate much further out into the lake. Sardines have been caught in quantity fifteen miles out from Mpulungu towards the middle of the lake by the ring-net when it operated, but *Stolothrissa* in these catches did not substantially differ in their size from shoals of adults much closer inshore. Between December and April, 1960, the majority of catches far from land were composed of big *Limnothrissa* between eighty-five and 145 millimetres, and in this period *Limnothrissa* of this size formed much of the inshore catch also. There was thus no striking evidence that the sardines continued to migrate *en masse* towards the middle of the lake on reaching maturity. It seems rather from the following evidence that predation was the main factor responsible for their reduction:

(*a*) Adult sardines are most abundant between approximately March and October, and according to the histograms have a shorter life expectancy in this period. *Lates* spp. are most abundant in the same area in which the adult sardines occur between June and October, as catches from many gill-nets and the ring-net have shown, and are known to feed then copiously and perhaps almost exclusively on sardines (c.f. section V).

(*b*) Between October and March practical fishing experience both in 1959–60 and 1960–61 showed a very great reduction in the amount of fish caught and in the size of sardine shoals which could be aggregated, in spite of diligent search both well out into the lake and inshore. Echo-sounding records showed only small shoals of adults, and in December and January it was often impossible to find fish on the sounder, except, of course, for the masses of juvenile sardine in shallow water.

(c) Most sardine catches in November, December and January, 1960–61 (except those taken far from shore), were composed of two distinct size groups, small *Stolothrissa* and *Limnothrissa* between forty-five millimetres and fifty-five millimteres, and large

Limnothrissa about ninety millimetres to 140 millimetres. The large sardines were found to be feeding heavily on the small, of both species. Relatively few fish between these size groups were taken.

(*d*) Finally, the histograms show a gradual decrease in numbers with increase in size. If the decrease were due to a mass migration away from the fishing grounds, it might be expected to take place more rapidly.

An outline of the life history of the sardines therefore, from our present knowledge, seems to be as follows: There is a major spawning period with successive broods between June and October, and a minor spawning in December/January. This general period coincides with the time when planktonic food is most abundant. *Limnothrissa* fry first appear in shoals at about fourteen millimetres close to shore, *Stolothrissa* at about thirty-eight millimetres. The first of the broods, assuming a growth-rate of seven or eight millimetres per month, forms a striking recruitment to the surviving stocks of older fish at about fifty-five millimetres in December. The build-up of mature stocks takes place from January to April, and with increase in size they become more abundant in deep water. These adults are ready to spawn in May or June (ripe ova have been found in *Stolothrissa* and *Limnothrissa* of about seventy millimetres; the frequent presence of three or four very distinct modes in the diameters of ova in an ovary may indicate that individuals can spawn several times). Spawning takes place from June to October, and in this period adult sardines are most abundant. At the same time, they suffer heavy mortality from predators, chiefly *Lates* spp., *Luciolates stappersii* and *Bathybates* spp., which could perhaps be described as catastrophic, since relatively few survive to natural old age. This mortality is probably density-dependent, the seasonal abundance of *Lates* coinciding with the abundance of adult sardines. In November, December and January the surviving *Limnothrissa* which are now large (between about ninety and 140 millimetres) form a striking contrast in size with the current years' broods, between forty-five millimetres and fifty-five millimetres, on which they actively prey.

If the above conclusions are in general correct, four implications arise of importance to the commercial fishery:

(1) The sardine, for commercial purposes, has a life cycle of about one year. The fishery is not one in which earlier and later year classes than the commercial class have to be closely considered.

(2) The fishing season is probably a natural biological season, which fortunately coincides with the dry season when sardines can so easily be preserved by sun drying. Fishing at other times of the year has not in 1959 and 1960 been very productive.

(3) In this season a heavy toll is taken of adult sardines by *Lates* spp., providing a further argument in favour of fishing methods which take Nile perch as well as sardines, and thus achieve a balanced exploitation. The perch form a strong natural competitor to the commercial sardine fisherman.

(4) Problems of overfishing and the fecundity of a commercial species are generally closely linked. Here, adult sardines are decimated by predation during their prolonged spawning period; nevertheless their fecundity is evidently balanced against this loss so that the following year's stock is maintained.

IV.—Shoaling and Vertical Migration Behaviour of the Sardines, as Recorded by Echo-sounding

There is a marked diurnal vertical movement of zooplankton and certain fishes away from the surface waters at daybreak, and towards the surface at dusk. This phenomenon may be observed both in the open-water pelagic environment and close to the shore, and abundant evidence of it was collected by Belgian workers in the Exploration Hydrobiologique du Lac Tanganika, conducted by the Institut Royal des Sciences Naturelles de Belgique in 1946–47. Vertical migrations of marine fish, notably the herring, have been traced by echo-sounding, and the following is an account of preliminary observations by echo-sounding of the shoaling and vertical migratory behaviour of the sardines *Stolothrissa tanganicae* and *Limnothrissa miodon*.

The echo-sounder in use is a Kelvin-Hughes type M.S.30., with a maximum recording depth of 290 metres. This was only fitted to the launch in late August, 1960, before which it had been occasionally used in a dinghy, the transducer being bolted to a temporary support fastened to the gunwhale.

It was quickly apparent, even from the earliest recordings, that the main activity as recorded by the sounder occurred at two short periods in twenty-four hours, that is, for about half an hour at dusk as the fish were rising, and for about the same length of time at dawn as they descended again. Further, it was found that shoaling and vertical migration behaviour varied, and that these variations were characteristic of (*a*) the age of the sardines, and (*b*) the depth of the water. With regard to (*a*), it is known from other work (section III) that juveniles of *Limnothrissa miodon* from about fourteen millimetres and juveniles of *Stolothrissa tanganicae* from about forty millimetres are taken in shallow water of five metres or less, and samples from increasing depths show a general increase in size. Samples from any area of the lake, particularly of older sardines, show a high degree of homogenity of size in both species. As yet no attempt has been made to find whether a close correlation between size up to maturity and depth is discernible, but it is likely that the correlation, though definite, will be a general one.

The picture shown in plates II and III, of 28th and 29th November respectively, was common from August to December. Plate II shows recordings made in an approach to the shore from deep water at dusk when the evening vertical migration had just been completed. On the top right of the plate from a depth of twenty-five metres to about ten metres a dense mass of juveniles extending from the bottom to within about eight metres of the surface may be seen. A sample netted at this precise place two hours after the recording yielded a great abundance of juvenile *Limnothrissa miodon* with modal lengths of nineteen millimetres and twenty-three millimetres, and *Stolothrissa tanganicae* with a mode of forty millimetres. The following morning starting at 9 a.m., the recording shown on plate III was made over a course which was as close as possible the reverse of that taken on the previous evening. During daytime the juveniles appeared to spread out close to the bottom or pack into dense shoals a little way off the bottom.

A second type of behaviour as the sardines increase in size and move gradually into deeper water may be seen in plates IV and V. The recordings shown in plate IV were made about midday and show the typical daytime juvenile behaviour on the top left; then in deeper water the larger fish lie packed in dense shoals, mostly clear of the bottom down to a depth of about ninety metres. This is a typical daylight recording of behaviour on the relatively steep slope between about thirty and ninety metres. Plate V recorded over the same course at dusk on the same day shows the evening rise to the surface.

A third variation in behaviour, illustrated in plate VI, is characteristic of the extensive "shelf" area near Mpulungu and between Mpulungu and Kalambo, where, after the initial fairly steep slope to 100 metres, the slope becomes gentler over a fairly even bottom. During daylight relatively few signs of fish are seen on the echo-sounder, but at the approach of dusk shoals form, commonly at about seventy metres, and rise to the surface in a period of about half an hour. After this behaviour was first observed, the experiment was undertaken on a number of occasions of passing over an area in the afternoon just before dusk, and then over exactly the same course during dusk. The course generally taken was from Nkumbula Island to Mwela Village, a distance of about seven and a half miles across Mbete Bay. For over three-quarters of this distance the depth is greater than 100 metres, and the maximum depth 125 metres. Before dusk on the first run across the bay the echo-sounder paper would be almost devoid of markings, but as dusk approached light markings would indicate the appearance of shoals (point X, plate VI) which gradually became more dense as the shoals formed and started to ascend.

Further experience may show a slightly different type of behaviour to exist in the really deep water where depth is measured in hundreds of metres and which comprises so much of the lake. Few recordings have been made of sardine shoals in these depths largely because of the short time that the sounder has been installed in the launch, and perhaps also because the sardines were not abundant in deep water in the period October to March, 1961, when most attempts were made. Plate VII shows the vertical migration from sixty metres to near the surface at dusk off Cameron Bay on 5th July, 1960. Earlier isolated fish traces had been seen, for example points P and G in depths of seventy and 100 metres respectively, where the bottom was between 210 and 250 metres. Long markings on the lower half of the plate which indicate echoes from the bottom as the sounder was switched occasionally to phase three (180–290 metres), in order to find the depth, are easily differentiated from the shorter and more irregular fish markings. At the approach of dusk shoals compacted and rose towards the surface.

Plate VIII is a record of the downward migration at dawn. During darkness scattered irregular markings near the surface probably indicate small groups of fish. With the increase in light, shoals rapidly form and descend slowly to disappear at seventy metres at a point where the bottom is 100 metres deep. The irregular nature of the bottom of some areas is, incidentally, clearly brought out in this recording.

Discussion

The earliest observations made with the echo-sounder in 1959 showed traces indicating a vertical migration made by some organisms, but apart from the Belgian work mentioned above, which referred to a diurnal vertical migration of zooplankton, sardines and predators, the identity of the organisms causing the traces was unknown. However, it was noted that, nearly always after the trace had disappeared on the sounder at between ten and fifteen metres at the end of the vertical migration, sardines were seen in small groups leaping from the surface. This activity, when seen, always coincided with the end of the vertical migration and was of short duration. Simultaneously gulls, which during dusk are generally to be seen flying anxiously to and fro, commenced diving vigorously on the water surface. Further evidence that the echo-traces were caused by shoaling sardines came from the results of experimental fishing. Good sardine catches were generally made if other fishing conditions were suitable when strong traces were recorded at dusk, conversely when light traces or no traces were recorded, particularly during December, January and February, 1960–61, catches were negligible and sometimes not a single sardine could be seen under the fishing lamps. Finally, echo-traces of the vertical migration present a very similar shape to the traces of herring and sprat shoals as observed by workers in the fisheries of the North Sea. For example the traces obtained by Richardson (1952) of herring and sprats, and in particular the "comet-shaped" traces of sprat shoals described by Hodgson (1950), are very close in appearance to what is believed to be the sardine shoal traces here. Moreover, the only other species likely to be in abundance in the same neighbourhood at the same time, *Lates* spp., are not usually from other evidence shoaling fish, and these traces are of shoals, not of individual fish.

Dealing with the above behavioural variations in greater detail: Mention is made in section III of the masses of very young *Limnothrissa*, from fourteen millimetres to about twenty-two millimetres, which may be seen in daylight at certain times near the surface. Shoals with modal lengths less than nineteen millimetres are much commoner than those with modes between nineteen and twenty-two millimetres. Seemingly as they grow they shoal a little deeper. They appear at this size to have little inhibition to strong light. With a slight increase in size above twenty millimetres, however, a move into deeper water between about five and thirty-five metres takes place, as witness the abundance of juveniles which can be aggregated around a lamp in these depths on any dark night during certain months. The daylight behaviour of these juveniles of lying very close to the bottom (plates II and III) suggests a greater sensivity to light, which as soon as it falls below a certain level of intensity coincides with a spreading out of the fish between the bottom and sub-surface in a diffuse mass (plate III) or in small shoals or groups (plate V). It is well known that the young of herring in the " whitebait " stage are often seen on the surface in shallow water during daylight, and only move into deeper water and avoid the surface as they increase in size.

In correlating length frequencies of sardines between about forty and sixty millimetres and the localities and depths in which they were caught, it was clearly brought out that this size range is commonest in both species in depths between about thirty-five and ninety metres; that is on the steep slope down to the wide 100–140-metre " shelf ". Thus with increase in size the fish clearly move out, and if their tendency to avoid light were to increase with growth, this movement is what would be expected. Although it is apparently no longer necessary to spread out close to the bottom, the fish remain in closely packed shoals, presumably as a protection mechanism. Plate IV shows such close, typical " comet-shaped " shoals between about forty metres and ninety metres. The breakup into smaller shoals and ascent to the surface again coincides with the evening diminution of light.

The third variation, over the shelf area, consisting of lack of fish echoes during the day and the formation of rising shoals at dusk, is very reminiscent of certain herring behaviour recorded by echo-sounding in the North Sea (Balls, 1951). Here also in what is called the medium zone (thirty to seventy fathoms), herring were seldom echoed during the day even when great quantities were known to be present, but they rose in compact groups at dusk. Balls assumes that the daylight absence of fish echoes is due to their abandonment of shoal formation for some kind of flat formation at the bottom, in which position they were not echoable and in which there was the least illumination. A measure of protection from attack would be afforded by close proximity to the bottom.

There is not enough evidence yet to show what happens to the sardines when they disappear at dawn and reappear at dusk generally at depths near seventy metres, but the fact that shoals have not been seen to descend to the bottom and rise off the bottom (Balls observed the latter with herring) seems to indicate that their disappearance as an echo-trace may be the result of the breakup of shoals into small groups or individuals as the optimum light intensity is reached. It seems most probable that this is the reason for the disappearance of shoal traces near the surface at the end of the evening migration. The usual pattern followed is for the separate shoals to break up into smaller units which gradually become more scattered and diffuse until they almost disappear. It seems a reasonable conclusion that optimum light intensity being attained the fish separate out in the layer above the depth of disappearance of the separate shoals (generally ten to fifteen metres, the depth at which shoals break up at dusk and form at dawn is usually very constant). It has several times been observed, however, on bright moonlit nights, that after the shoals break up near the surface they remain as a diffuse trace on the sounder for much longer, as though they had reached a limit and were reluctant to spread out further as on darker nights. It has also often been the experience that on such moonlit nights relatively few sardines can be attracted and held by the fishing lamps and do not appear to be present in quantity in the surface waters. This may indicate that the threshold of acceptable illumination for the sardines would be exceeded if they spread out into the moonlit surface waters, and is further evidence that these migrations are controlled by the degree of light.

Shoaling behaviour in very deep water may exhibit the same difference from the behaviour in moderate (100–140 metres) depths as Balls found to exist between his " medium zone " and " deep zone " behaviour. In the deep zone, for example in the Norwegian Deep, he states that herring masses can be found lying at a constant level at any time during the day and infers that the depth had been reached in which the light penetration of the Norwegian winter daylight was not strong enough to produce any further downward movement of the fish. Such soundings as have been done in deep water in Lake Tanganyika indicate that isolated fish shoals are sometimes echoable in daylight at varying depths between seventy and 100 metres, but whether this corresponds to Balls's deep zone behaviour and that if the fish were there in quantity they would be seen as a continuous layer, or whether these are just isolated shoals which do not reflect the much more numerous but diffuse and not echoable sardines present, there is not enough evidence to judge. However, recordings such as the one shown in plate

VII suggest that a much greater number of fish are present at depth than are recorded, since at dusk the occasional light traces are replaced by heavy continuous traces indicating the formation into shoals prior to their ascent. More echo-sounding records from deep water are necessary.

Very occasionally adult-size sardines have been seen near the surface in daylight far from the shore. In each case when this has been observed large predators, generally identifiable as *Lates microlepis*, were seen breaking surface all around. Often the surface over areas of several acres would be in a flurry with the disturbances of large fish. The sardine shoals when sighted would be tightly packed and moving rapidly as though in flight. From these observations it is surmised that such appearances of adult-size sardines in daylight are due to the shoals, formed as a protective measure against severe attack by predators, being forced up near to the surface by the attacks. Occasional echo-traces such as at point Z on plate VI, which are not characteristic of the dispositions of other shoals observed at the time, may be phenomena of this sort.

Of common occurrence on the rocording paper is an echo-trace from a shallow scattering layer, usually extending between fifteen to thirty metres. This layer generally appears when sailing out from shore in deepening water and disappears on returning close to shore. Plates II, III and IV show it clearly. This trace is similar in appearance to that often recorded in the sea where it sometimes extends for many miles. There it has been found usually to consist of a layer of small organisms, often including very young fish. (Lucas in Graham (1956).)

It is hoped to publish the above investigation of the behaviour and migration of the sardines elsewhere in greater detail after further work and experience in echo-sounding, particularly in the months of the year when the adult sardines are most abundant. In the meanwhile it has been shown that shoals of sardines lend themselves to echo-sounding observation, and that the echo-sounder should prove a useful tool in the elucidation of the complex shoaling behaviour, which it is thought is governed by a need for light avoidance as an important reaction to the heavy predation pressure from voracious *Lates* spp.

V.—Diurnal Vertical and Lateral Migrations of Fish, an Effect of Predation

In the notes made by Poll (1953, 1956) on what had been observed of the biology and life histories of Lake Tanganyika fishes, he frequently makes the statement that certain fish may be caught close to the shore in greater numbers at night, indicating a nightly migration inshore from deep water. This statement seems to have been made most often in descriptions of cichlid fish. It was decided therefore in early June, 1960, to commence a routine of fishing chosen beaches in turn with a large seine-net by day and at night in order to obtain experimental proof of this diurnal " laternal " migration. A description of the diurnal vertical migration in deep water, particularly of the sardines *Limnothrissa miodon* (Blgr.) and *Stolothrissa tanganicae* Regan, as recorded by echo-sounding has been made in section IV. Its significance in the context of these notes is dealt with below.

Method

The seine-net used was 300 yards along the headrope, consisted mostly of two-inch and one-and-a-half-inch mesh (stretched) with a large bag of one-inch mesh (stretched) and had a fishing depth of about eight yards. Hauling ropes were 100 yards long and were always paid out the full length from the shore. Such a large net if properly balanced and skilfully operated is a very effective method of sampling an inshore fish population. It was found possible also to use it over a rocky bottom provided that the obstacles were not too large or angular. The actual operation of the net was observed several times in the clear inshore waters by following close behind it as it was hauled.

Of the three seining beaches selected, two were on Nkumbula Island; one with a shingle and sandy-mud bottom facing the open lake (Nyika), and one with a rocky bottom facing across Mbete Bay (Msumba). The third on Crocodile Island has a bottom of coarse grit, broken gastropod shells and pebbles, and is in a sheltered position facing the mainland. Another beach at the lake steamer jetty was rejected after three trials because, as explained in detail below, of its peculiar characteristic of heavy weed growth. The beaches seined and the dates are listed in table 2 B 1 which also gives the number of each species caught in the daytime and at night. The routine adopted was to make two consecutive hauls in approximately the same area between 10 a.m. and midday. On the *same* evening between 8 p.m. and 10 p.m. another two hauls were made. The intention was to net three beaches weekly, in turn, but in practice seining was carried out on twenty-two days over the period of seven months instead of about twenty-eight.

An examination of the abundant data gathered from the seining routine clearly showed a very marked shoreward migration of fish at night. One effect of the technique used was that if a stable population were to exist in the area seined, the morning catch would probably take most of that population. Thus if there were to be no shoreward migration at night, the night catch should be much less than the day; but as figure 2 B 6 and table 2 B 1 shows the night catch was very much greater. The composition of day catches are of significance, and it appears that fish living in inshore waters during the day can be placed in either of five categories, i.e.:

(1) Large active predators.
(2) Shoaling anadromous fish.
(3) Species which shelter in dense growths of weed.
(4) Rock lurkers.
(5) Nesting cichlids.

These will be discussed in turn:

Large active predators

Most striking of these is *Boulengerochromis microlepis* (Blgr.) or " Nkupi ", the large and active predatory cichlid (indeed the largest species of the family Cichlidae), which was caught in greater numbers by the seine during the day than at night. Nearly 80 per cent. of all specimens caught were in day catches. This seems to imply that its habitat is largely an inshore one and that if its numbers were depleted or wiped out in the seined area during the day, they were not replenished by others migrating inshore at night. Local African fishermen when seining in daylight do so almost solely for *Boulengerochromis* which is a choice eating fish. *Boulengerochromis*, generally large specimens, can however be caught by gill-nets in depths down to sixty metres.

Lates angustifrons and *Lates microlepis* both were taken inshore during the day, but occurred in larger numbers at night. On occasions when juvenile sardines are gathered in great shoals in certain shallow inshore bays, perhaps driven there from deeper water by predators or strong wind action, concentrations of these " swift " predators may be seen. One's attention is drawn by the vigorous surface disturbances. These circumstances are common in the months of December to March, and angling in these concentrations is always most rewarding. *Lates microlepis, Lates angustifrons, Boulengerochromis* and often *Hydrocyon vittatus* and *Alestes macropthalmus* are taken; rarely any other predator.

Less active predators, for example, *Chrysichthys* spp., *Auchenoglanis occidentalis, Dinotopterus cunningtoni, Heterobrachus longifilis* and *Malapterurus electricus*, were rarely or never taken by the seine by day, but appeared to move in with the mass of other fish at night.

Shoaling anadromous fish

Two species with markedly anadromous habits, *Barbus tropidolepis* and *Alestes macropthalmus*, may sometimes be encountered inshore in large shoals in daylight. Indications that another anadromous species, *Citharinus gibbosus*, behaves similarly have been obtained from gill-net catches. On two occasions a large number have been taken immediately the nets were laid, but no shoals of *Citharinus* were encountered in this experiment. On 29th September 483 *Alestes macropthalmus* were landed in a single haul in daylight (range, twenty-one to forty-eight centimetres; mode, between thirty and thirty-six centimetres), making this the sole occasion when the seine-net catches of the day exceeded those of the night. Catches of seventy-one and thirty-five fish were made in daylight on two other occasions. In the case of *Barvus tropidolepis*, 188 fish (range, twenty-five to ninety centimetres; wide mode, between fifty and seventy centimetres) were seined from very shallow water on 1st September. Such shoals as these are probably of irregular occurrence and may be connected with reproductive activity.

Species which shelter in dense growths of weed

As described in section VII, a seine-net when drawn through dense growths of *Ceratophyllum* will yield many small fish, and a weekly daylight seining with a small-meshed, thirty-yard seine-net is carried out in such a weed growth at the lake steamer jetty for juvenile *Lates* spp. As well as juvenile *Lates* other juvenile and small fish are taken in abundance. This clearly is peculiar habitat and is not typical of most of the rest of the coast. Therefore after three occasions the large seine-net was not used there again. Table 2 B 1 shows the composition of the catches on these occasions, the day catch being greater in numbers than the night each time.

Table 2 B 2 lists species taken commonly in the weed (not in order of abundance) and as may be seen from table 2 B 1 some of these were also caught in large numbers by the big seine-net on the other beaches. The maximum recorded lengths (from Poll 1953, 1956) are compared with the maximum lengths of specimens taken by the seine-nets. It will be seen that most of these are fish which are small as adults, the majority being under twenty-five centimetres long. In the weed, however, fish generally do not exceed twenty-three centimetres and the majority at all times sampled are much less than this, even though some as adults are large—notably the *Lates* spp., *Boulengerochromis microlepis, Tilapia tanganicae* and *Lobochilotes labiatus*. Greatest numbers have been examined of the juvenile *Lates* spp., the bulk of which were found to leave the weed before reaching eighteen centimetres (section VII).

The frequency of occurrence is also given of these species in daylight seine-net catches from the three chosen beaches—which are without weed. Those species marked with an asterisk are of rare occurrence (or rare under about twenty-four centimetres) outside the weed during daylight.

Finally, the length at which these fish are first found in the weed is in most cases about six centimetres. This figure is constant enough to imply that fairly rigid requirements govern the size at which shelter must be taken in the weed. Jackson (1961 in Press) mentions the use of shallow water by small fish as an evasive reaction to predation. Certainly it is a common sight in Lake Tanganyika to see shoals of tiny fish less than six centimetres long in marginal shallow water. One of the commonest of these is *Limnotilapia dardennei*. The collection and identification of these tiny shallow-water forms has yet to be done, but it is here suggested that this may be the early habitat of those fish which at about six centimetres find refuge in the weed.

Rock lurkers

Much of the inshore bottom of Lake Tanganyika, at least in the south, is rocky and presents extensive scope for a rock-lurking habitat. From personal observation and the comments of Poll (1956) it seems that this is the environment of *Limnotilapia dardennei*, *Petrochromis polyodon*, *P. fasciolatus*, *Cyathopharynx furcifer*, *Simochromis diagramma* and the *Lamproloous* spp.—the remainder of the fish listed in table 2 B 2. The fact that all these are small when adult*, and yet may be caught over most of their size ranges during daylight inshore, is significant, and implies that some means of refuge from predation must be available to them. Several other small rock-lurking cichlids appear to live in water a little deeper, just beyond the 100-yard reach of the large seine-net. For example, *Haplotaxodon microlepis*, *Cyphotilapia frontosa* and *Tropheus moorei* are frequently caught in gill-nets set in twenty to thirty metres on a rocky bottom, and are occasionally taken by the seine-net at night.

Nesting cichlids

At certain times of the year some cichlids may come much closer to the shore, perhaps to take advantage of the relative safety of very shallow water in which to build their nests. Nests of *Cyathopharynx furcifer* are common in patches of sand or sandy-mud between rock, and in even shallower water *Grammatotria lemairei* builds numerous nests on a sandy bottom.

It should be repeated that the above five categories are of fish which occur inshore during the day. Night catches include many other species both adults and juveniles, particularly from the non-cichlid group, indicating that unless refuge is taken in the protective environment of dense weed, or adaptation to a rock-lurking habitat has been evolved, some powerful factor prevents small fish under twenty-three centimetres and juveniles from living on the rocky shore during daylight. This inhibitor is postulated as being the presence of predators, in particular *Lates angustifrons*, *Lates microlepis* and *Boulengerochromis microlepis*, and to a lesser extent *Hydrocyon vittatus*. These predators cannot be described as mild, their speed and voracity being remarkable by any standards, and in the clear inshore waters small prey fish would stand little chance of escape.

The Vertical Migration

In section IV the vertical migratory behaviour of the sardines *Stolothrissa tanganicae* and *Limnothrissa miodon* as recorded by echo-sounding is discussed. A clear diurnal vertical migration of the sardines exists, and from observation and evidence of catches of ring-nets which operate on the surface in the open lake at night, the sardines are accompanied in their migration by their predators. These predators are chiefly the three *Lates* species which have shown differential trends in their proportions of ring-net catches throughout the year: *Luciolates stappersii*, *Bathybates* species, notably *Bathybates fasciatus*, minor, and *Dinotopterus cunningtoni*. Occasionally in shallow water *Boulengerochromis microlepis* and *Alestes macropthalmus* have been caught with the sardines. The sardines have thus to contend with heavy predation pressure and as discussed in section III it would appear from preliminary work that the predatory impact on the sardine population is, at a certain period of the year, almost catastrophic. This predator-prey relationship, which is probably density-dependent and thus involves heavy mortality to the sardines, has resulted in two obvious protection mechanisms, i.e. a diurnal vertical migration, and the adoption during these migrations of tight shoal formation. The diurnal vertical migration of course follows the diurnal migration of the zooplankton upon which *Stolothrissa* particularly feeds. Again, from stomach content examinations it seems that a large component of the diet of *Limnothrissa* is aquatic insect larvae and adult insects on which it must feed near the surface. Nevertheless it is postulated that the maintenance of a twilight or dark environment which affords greater protection for the sardines is at least as important a motive for vertical migration as remaining close to their food. During the phytoplankton blooms between July and December, 1960, echo-sounding recorded the usual daylight descent of the sardines when frequently large quantities of zooplankton, especially *Diaptomous*, were grazing on the phytoplankton much nearer the surface in the euphotic zone.

Preliminary echo-sounding work tends to show that the shoal formation is always adopted before any concerted movement up or down is commenced. In between these movements, that is for most of the day and night, adult pelagic sardines record relatively little trace on the sounder. The most reasonable explanation of this at present seems to be that having reached the end of their migration in either direction the protective shoaling and probably none-feeding phase is abandoned for a more free-swimming and feeding phase in which, because of their diffusion over a wider area, the sardines are not echoable. Their immediate reaction to a major change in illumination of the surface waters at dawn and at dusk is significant.

Of the predators the *Lates* spp. are the most important, both in numbers and feeding capacity. Some idea of the degree of their voracity may be obtained from an examination of stomach contents shortly after landing the catch. Admittedly their feeding prior to capture is in an

*The exceptions are the three *Lates* spp. under twenty-four centimetres, *Boulengerochromis* juveniles and *Lestradea perspicax perspicax*. These have not so far been caught in areas free of weed.

artificial situation where a mass of sardines are gathered under a bright light, and with their prey concentrated and clearly apparent the perch can feed *ad lib.* In perch of all three species between, say, sixty centimetres and eighty centimetres, it is common to find in these circumstances twenty to thirty sardines (6.5 to eight centimetres length) and sometimes as many as forty, all generally at the same early stage of digestion, and packed in the stomach literally like canned sardines.

Discussion

Worthington's theory (1937, 1940 and 1954) that the presence of predators of the genera *Lates* and *Hydrocyon* has reduced speciation wherever they have occurred in the Great Lakes has provoked considerable interest and some controversy. Speciation has in fact proceeded further where these genera are absent, with the notable exception of Lake Tanganyika. Here, 233 species of which 100 belong to the family Cichlidae have so far been recorded, though the relative number of genera to species is high when compared to some of the other Great Lakes, for example Lake Nyasa. This has been quoted in refutation of the predation theory; the considerable number and diversity of fish occurring in the same water as *Lates* spp. and *Hydrocyon* has seemed a contradiction of Worthington's theory and has made the case less clear. This study of the extensive diurnal lateral and vertical migrations in Lake Tanganyika may indicate the chief mechanism which renders possible the co-existence of such extremely voracious predators and their prey, allowing at the same time of wide scope for the evolutionary variation of the prey species.

Jackson (1961) in his broad study of the impact of predation on African freshwater fishes, and in particular the effect of *Hydrocyon vittatus* on small and juvenile fish, says that " a length of what may be broadly reckoned as between fourteen to twenty centimetres, considering all species of fish together, seems to be critical in the life-history of many African freshwater species not endemic to the Great Lakes, and it crops up often in such ecological studies as have been done ". Data for this work was collected largely from the Zambezi River and Lakes Bangweulu and Mweru. Many of his findings, however, in particular the existence of a critical size limit of about twenty centimetres below which almost the full impact of predation is felt, seem to apply to Lake Tanganyika also. For example, the use of the cover of Cevatophyllum made by juveniles and small fish up to a length, for the majority, of eighteen to twenty centimetres is closely paralleled by the behaviour of *Tilapia macrochir* the abundant commercial cichlid of Lake Mweru. Juveniles of *Tilapia macrochir* are to be found only among dense banks of " hippo grass " (*Vossia cuspidata*), but at lengths of about eighteen to twenty centimetres enter the open water. Similarly, in comparing the Upper and Middle Zambezi and Kafue areas, Jackson points out that the Upper Zambezi and Kafue have considerable vegetation throughout the year and have both the total number of fish species and the number of those which are small (eighteen to twenty centimetres) when adult more numerous than is the case in the Middle Zambezi which is relatively bare of vegetation. Regarding the Middle Zambezi, he continues: " The very low percentage of species which are small when adult is probably a measure of the impact of predation by the tiger-fish, and it is perhaps significant also that the Kafue, which alone of the three has no *Hydrocyon* population, has the largest percentage of species which are small when adult."

In Lake Nyasa, Jackson points out that of the thirty-one species listed by Fryer (1959a) as occurring habitually on a rocky shore the majority are small in size when adult (less than eighteen to twenty centimetres) and are exposted to predation, but not however by *Hydrocyon* or *Lates* spp. which do not occur there. This situation is very different from that of Lake Tanganyika. It would be interesting to know whether similar diurnal migrations to those described above occur in Lake Nyasa.

Further evidence that shelter of some sort is necessary below about twenty centimetres is given by preliminary observation of the anadromous species in Lake Tanganyika (section VIII). Again, where it has been possible to obtain large numbers of specimens, the same critical extreme of twenty-four centimetres and a modal limit of eighteen to twenty centimetres is met with. Of the anadromous species, so far *Citharinus gibbosus*, *Hydrocyon vittatus*, *Alestes macropthalmus* and *Alestes imberi* have been taken in large numbers. Above these size limits the juveniles disappear from the creeks and rivers and it seems that they must then migrate downstream, probably during the rains when the river is swollen, into the lake. The *Lates* spp. do not occur in the river and *Hydrocyon* only during its spawning run, so that these juveniles have much less to fear from predators than if they were in the lake.

One is led to the conclusion that the same early size range which in the lacustrine species is spent either in the refuge of weed or rocks or of deeper less illuminated water, is spent by the juvenile anodromous species in the abundant vegetation of the creeks and river sides for the same purpose, i.e. to hide from predators. This again is in accord with Jackson's view (*loc. cit.*) that one of the main purposes of spawning migrations in African freshwaters is to place young fish out of reach of such predators as *Hydrocyon* when they are of vulnerable size.

To sum up, it is proposed that the reason that speciation has proceeded in Lake Tanganyika in the presence of *Lates* spp., *Boulengerochromis* and *Hydrocyon* is due to a number of special evasive mechanisms, most marked of which are widespread daily migrations into deeper, darker waters, shelter in dense growths of weed or shelter in the rocky bottom, and in the case of anodromous species, in the river and creeks. The inshore environment of the lake and the surface waters presents during the day an appearance so naked of life that it is easy to understand why earlier workers classified it as oligotrophic. Further work may show that a very high proportion of the fish population lives in deep water from over 100 metres up to about forty metres. The marked development of the abundant *Lates mariae* as a deep-water predator may be significant in this connection. Although this fish feeds voraciously on adult sardines and may even be caught near the surface feeding upon them at certain times of the year when the sardines are most abundant, at other times *Lates mariae* (which forms the basis of the deep gill-net fishery) is found to feed on a variety of other prey, chiefly of the family Cichlidae.

Jackson (1961) regards the impact of predation by the *Lates* spp. in Lake Tanganyika to have been limited by their concentration upon the pelagic clupeids, and their adoption of an open-water life. It is true that the *Lates* do feed largely upon the clupeids, but the suggestion is made in section III that this concentration is seasonal, coinciding with the period when adult clupeids are most abundant; even during this period *Lates angustifrons* and *Lates microlepis* occur inshore. At other times of the year it seems that *Lates angustifrons* and *Lates mariae* at least can change over to a diet or benthic fish, mostly Cichlidae. *Lates microlepis* is commonest inshore and in deep water near the shore from October to February (c.f. figure 2 B 1, J.F.R.O. annual report, 1959) when the juvenile clupeids occur in quantity, and it is probable—although no detailed work has been done on its stomach contents—that this species adheres more closely to a clupeid diet than the other two. The effect of predation from the *Lates* spp. must be very much greater than from the rarer *Hydrocyon vittatus*, at least in the south of the lake. *Boulengerochromis microlepis* also is almost certainly a more important predator than *Hydrocyon* and this is probably due (as mentioned in section VIII) to misdirected human effort as well as the shortage of suitable rivers in which spawning can take place.

Evidence of the impact of predation on small fish has in this study been largely derived from observations of the frequency of occurrence of prey fishes in areas exposed to predation, and their evasive responses, and to a lesser extent from examination of predator stomach contents. Further investigation of stomach contents and the ecology of some of the inshore species of small fish is being undertaken.

VI.—The Gill-net Fishery for the Nile Perch "Lates Mariae"

Since May, 1960, a loan system has been in operation at Mpulungu for the purpose of enabling African fishermen to purchase gill-nets, canoes and outboard engines, and to establish a gill-net fishery. The catches have been bought by the Development Commission's Commercial Fisheries Manager, who administers repayment of the loans, at a fixed price of 3*d*. per lb. for the whole fish. Five gill-net crews had already organised themselves and were fishing before January, 1960. It was known that worthwhile catches consisting largely of *Lates mariae* could be caught in deep water (generally seventy to 140 metres deep) but it was not known (*a*) whether this was a seasonal fishery, and (*b*) how much a commercial gill-netter could expect to catch. An advantage possessed by gill-nets is that the two species of *Lates* (Nile perch) caught are of high commercial quality, unlike the catches taken previously with a ring-net which operates near the surface, and which caught a high proportion of the less acceptable *Lates microlepis* (J.F.R.O. annual report, 1959). The Commercial Fisheries Manager has kindly supplied the total catch figures and details concerning the gear loaned to owners, etc., used in the following analysis.

From July onwards frequent examinations of the catches were carried out by J.F.R.O. staff. Fish were measured, weighed, and gonads and stomach contents examined. Some 1,480 *Lates mariae* were examined in this way between July and December. This number is obviously insufficient to give a reliable picture of the biological activity and other desirable data concerning *Lates mariae* in this period, nevertheless certain interesting trends appeared which it is thought are clear enough to merit preliminary notice.

An analysis of the gill-net production is given in table 2 B 3. Two interesting facts are brought out, which are illustrated in figure 2 B 7. Firstly, that production rose sharply in June, reached a peak in September and thereafter fell sharply, thus marking out a period of higher production of about five months. Secondly, catching effort rose in April and remained fairly steady until the end of September, thereafter it rose to a peak in November and fell sharply. The index of catching effort is expressed in the graph as the number of owners multiplied by the average number of net-settings per owner. It will be seen from table 2 B 3 that, whereas the number of owners working rose until the end of October, the number of times that individual owners set their nets each month declined after April; thus the effort did not rise in proportion to the number of owners, and the peak production of late September was not due to an increase in effort. This is a human factor which tends to make large-scale development of the Tanganyika fishery difficult at present. That is, fishermen are sufficiently unambitious to be content with the money brought in by a small catch. If this catch is attained in a few settings, they are satisfied with this. It seems that it will take some time to develop a gill-netting tradition; at present the fishermen have not even organised their fishery on the necessary seasonal basis.

Bearing in mind that 1960 was the first full year in which gill-netting on a commercial scale was attempted, the problems which arose may be divided into two main groups: those concerned with the efficiency of the fishermen, and those concerned with the creation and supplying of a market to keep pace with fish production.

1. The efficiency problems are characteristic of a fishery where many new methods are being quickly introduced to unskilled fishermen, with the further complication in this case of lack of adequate instruction. The nets supplied are of two main types—nylon No. 9 and No. 12 ply and heavy Perlon No. 1 twine both of four-inch mesh (stretched) by twenty-four meshes deep. A strong preference is growing for the Perlon-type nets, probably because they require less repairing. An examination from time to time of the nets showed many of them to be badly mounted, being stretched too tightly to the head and footropes. A result of this was that there was considerable variation in the length of net when mounted and this introduced a variation in catch per net and thus in averaging the catch per net (*see* figure 2 B 7). Few repairs were apparently carried out, certainly much less than were necessary. Only about twelve nets were used by an owner, whereas a crew of five or six should be able to handle twice the number, several of which should always be on shore for repair. The number of times that nets were set each month were too few, for example in September when the catch per net-setting was highest the nets were set only an average of nine times. Since during most of the season, a distance of eight miles from Mpulungu was the greatest that it was generally necessary to travel, a greater number of net-settings per month, say eighteen, should not be considered unreasonable. A certain amont of fishing-time and profit was lost by the unskilled use of outboard engines; this is a difficulty which will increase with the age of the engines unless skill is learned, or a repair system organised, and the choice of the simpler, robust type of outboard engine is to be encouraged. Finally the efficient laying of nets in such deep water demands care and some skill.

In view of these considerations it is likely that, during a season of four or five months at least, greater fishing effort with more skill in the mounting, repair and handling of nets would result in much larger catches than were landed in 1960.

2. The local market on and near the lake shore is much too small for the potential or even the present production, and it is necessary to think in terms of the main market several hundred miles distant. Connected with this is the problem of the freshness of fish, characteristic of a tropical gill-net fishery where much of the catch may have been in the nets hours before they are hauled, and then exposed to the sun in small boats for one or two hours before landing. Thus rapid handling on shore and quick freezing are essential. If the fishery is a seasonal one, as it appears to be, and marketing arranged in accordance with this, it may be desirable to discourage the continuation of gill-netting when production falls below an economical level. It should be possible to find two points on the graph of the average catch per net-setting when this level was reached (perhaps in June and in December); that is, when the overhead costs of labour, engine fuel and depreciation of gear were higher than the profit realised from the catch. If the future fishery were planned on this seasonal basis, it is likely that, apart from a saving in costs, the response from the local fishermen would be to exert their greatest effort at the time when this effort would be most productive.

Unfortunately the gill-net season coincides with the sardine season, so that marketing arrangements must fit the requirements of both fisheries, which are somewhat different, at the same time.

Figure 2 B 8 shows what may be the selectivity curve of *Lates mariae* taken in four-inch mesh (stretched) gill-nets. In our ignorance, however, of the size composition of the *Lates mariae* population on the fishing grounds, it is impossible to know whether the curve is concerned only with mesh selection. It would also be desirable to know the mesh selection factors characteristic of the morphology of *Lates mariae* and also the differences, if any, introduced by the use of nylon No. 9 and 12 ply nets and Perlon No. 1 twine nets. With greater knowledge of these factors it may well appear that larger mesh nets, or at least the inclusion of larger mesh nets in the fleets of four-inch mesh nets, would be advisable. From the data examined it seems that males of *Lates mariae* spawn for the first time at a minimum length of forty-four centimetres and females at a minimum length of fifty centimetres. Generally, however, first spawning occurs at lengths several centimetres in excess of these minima.

Examination of the gonad activity of 1,480 *Lates mariae* from July to December showed, in the females, a trend from a majority of spent or inactive ovaries to a majority of ripe running ovaries. All ovaries examined in each fortnight over the period were classified according to their condition of activity, and the arbitrary classifications used are indicated in figure 2 B 9 by the following symbols:

> I—Immature. IA—Beginning to develop. A—Actively developing. AR—Approaching ripeness. R—Ripe. RR—Ripe running. Sp. I—Spent and inactive. Sp. IA—Spent, but beginning to re-develop.

It should be emphasised that much more comprehensive sampling dealing with many more specimens will be required before this trend can reliably be established, meanwhile since the progression as indicated in the graph shows a clear sequence it is worthwhile expressing. Throughout the same period the majority of the males of *Lates mariae* were ripe, ripe running or spent.

Figure 2 B 10 shows the preponderance in the number of males over the number of females in the catches sampled.

Lates angustifrons occurred in much smaller numbers, its proportion of the samples examined over the whole period July to December being 9 per cent.

TABLE 2 B 3

ANALYSIS OF THE PRODUCTION OF THE GILL-NETS USED IN THE LOAN SCHEME, LAKE TANGANYIKA, JANUARY–DECEMBER, 1960

	January	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
Total catch, in lb. wt.	6,590	4,583	1,846	9,082	7,646	15,693	33,140	29,934	54,261	44,406	33,544	8,427
Number of owners	5	6	7	8	8	9	9	10	15	22	21	17
Number of times nets were set	62	34	30	129	114	134	133	144	133	161	182	84
Average catch per owner, lb. wt.	1,318	764	264	1,135	950	1,744	3,682	2,993	3,617	2,018	1,597	496
Average number of net-setting per owner	12	6	4	16	14	15	15	14	9	7	9	5
Average catch per net-setting of twelve nets, in lb. wt. ...	106	132	62	70	67	117	250	208	408	276	184	100
Average catch per net in lb. wt.	9	11	5	6	6	10	21	17	34	23	15	8

VII.—OBSERVATIONS ON GROWTH IN JUVENILE "LATES" (NILE PERCH) SPECIES

It was discovered in April, 1960, that a small-mesh seine-net ($\frac{1}{2}$-inch mesh by thirty yards long) when drawn through dense growths of a weed (which is very prolific in certain littoral areas and is at present being identified, but which seems close to the genus *Ceratophyllum*) generally yielded juvenile *Lates; Lates mariae*, *Lates microlepis* and *Lates angustifrons*, sometimes in large numbers. One can fish in vain when searching for these juveniles in areas devoid of weed growth. The most prolific areas found so far are at the lake steamer jetty (" Liemba Jetty "), Mpulungu, and at a place in Kamba Bay in the game reserve. The seine-net is usually laid in about six metres depth and drawn towards the shore to where the *Ceratophyllum*-like weed finishes, generally in one metre close to the water's edge. Commencing in April a routine of seine-netting at frequent intervals at the Liemba Jetty was commenced. The number of *Lates* juveniles taken in two hauls of the net usually exceeded 200 and was often close to 1,000. Thus it was possible to obtain length-frequency data of a reliable nature. Length-frequency curves for each sample were drawn and the modal points calculated. These modes are plotted as a scatter graph in figure 2 B 11. If the interpretation indicated of the scattered modes is correct, the following information can be derived:

(*a*) Growth, at least between five and twenty centimetres approximately, can be expressed linearly.

(*b*) The rate of growth is a little over one centimetre per month. After entering the weed at approximately five centimetres, the young *Lates* spend about one year there and leave generally before reaching eighteen centimetres in length. (Individuals up to twenty centimetres are common and some may be found up to twenty-four centimetres.)

Although seine-net samples nearly always contained juveniles of all three *Lates* species, *Lates mariae* was almost invariably in much greater numbers, but *Lates microlepis* was in the majority on several occasions. The numbers of *Lates microlepis* and *Lates angustifrons* taken over the whole period, however, are insufficient for the construction of reliable growth curves, and all that can be said at the moment is that these two species appear to remain in the weed over the same length range as does *Lates mariae*. The relative proportions of the three species calculated from the total numbers caught between May, 1960, and March, 1961, were in the case of *Lates microlepis* about one quarter of the number of *Lates mariae* when they were present together, and in the case of *Lates angustifrons* about one tenth of the number of *Lates mariae* when they were present together. These proportions may also perhaps represent the relative proportions of adult *Lates*, but this would be more difficult to ascertain because of the very different habitat preferences of the adults.

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Plate I
The " Lusenga " scoop-net, traditional method of fishing for sardine, in a modern plank-built canoe with pressure lamp. Note the very small size of mesh

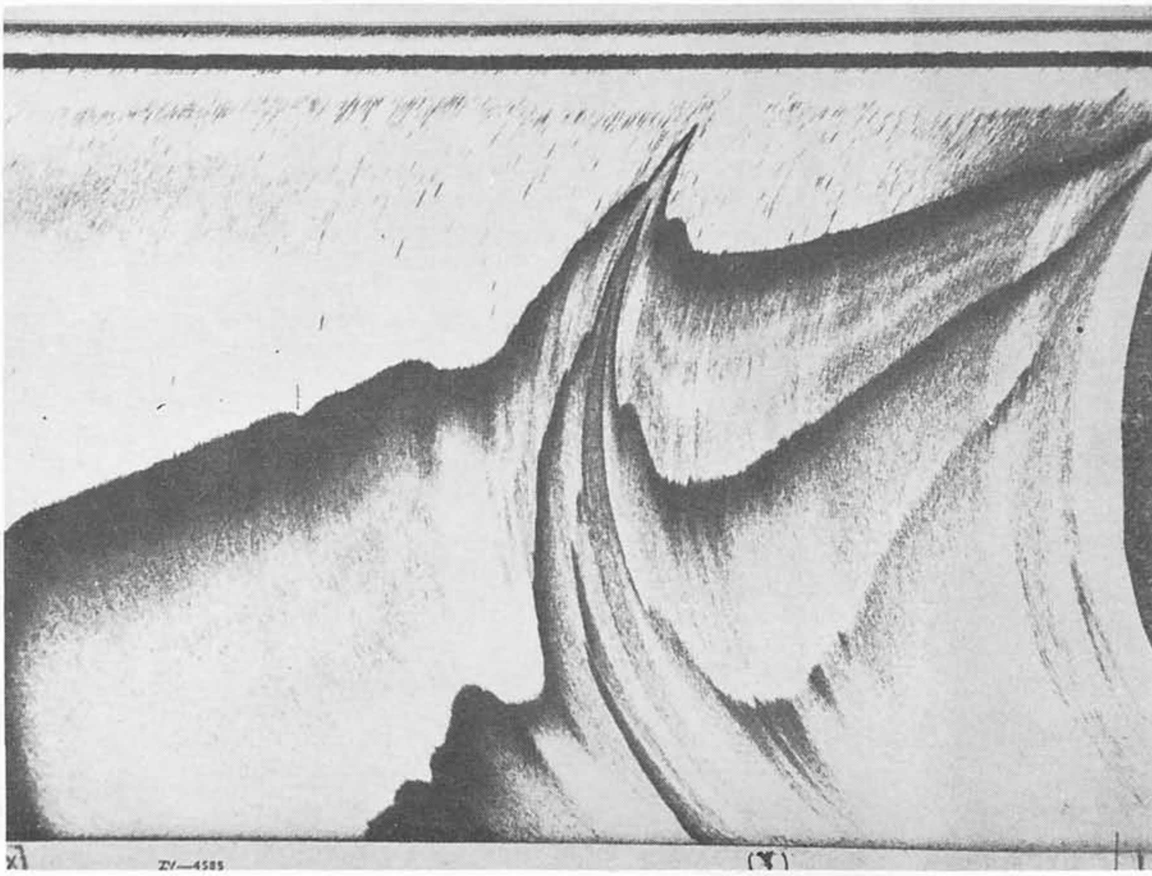


Plate II

Dusk. Sardines at the surface, Lake Tanganyika, at dusk just after the evening vertical migration had been completed. A dense mass of juveniles can be seen in the shallow water on the right

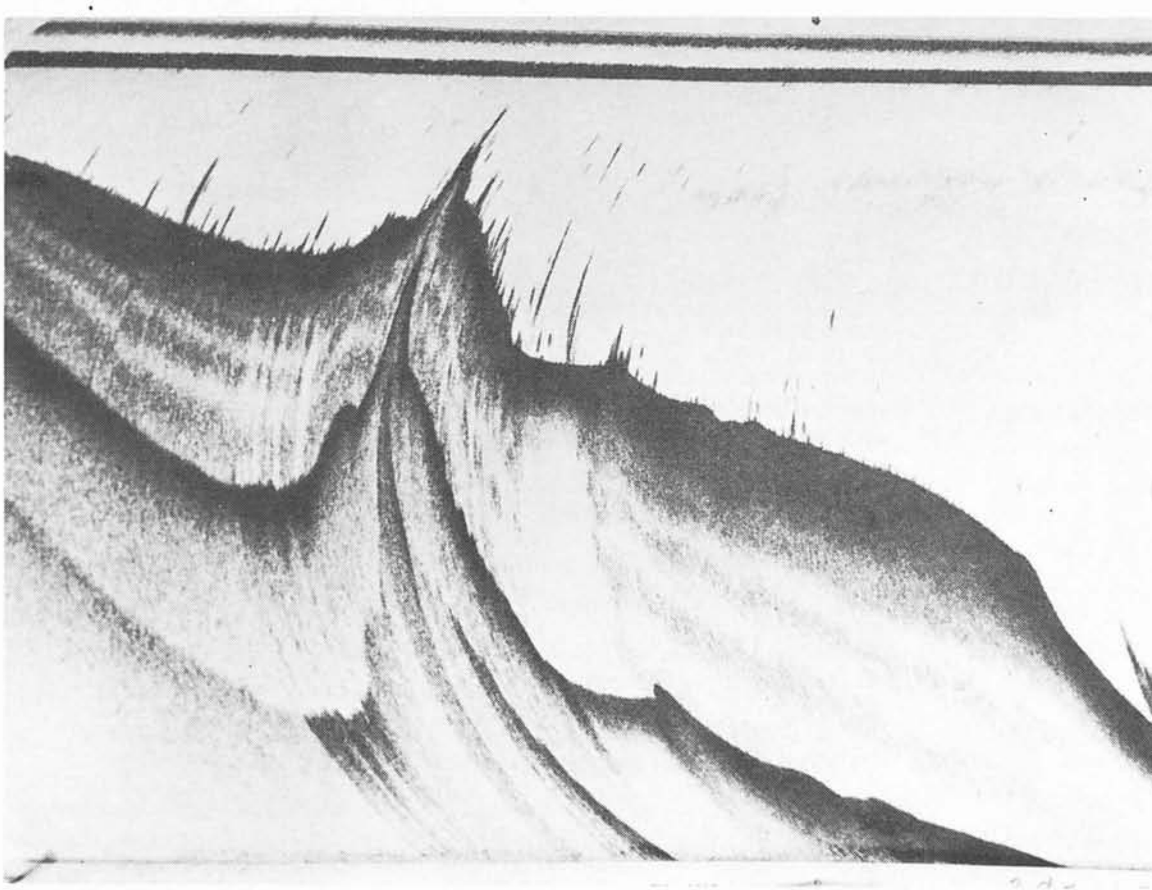


Plate III

Morning. The picture the following morning, steaming over the same ground as in Plate II but on a reciprocal course. Shoals, typically " Comet-shaped ", at or near the bottom

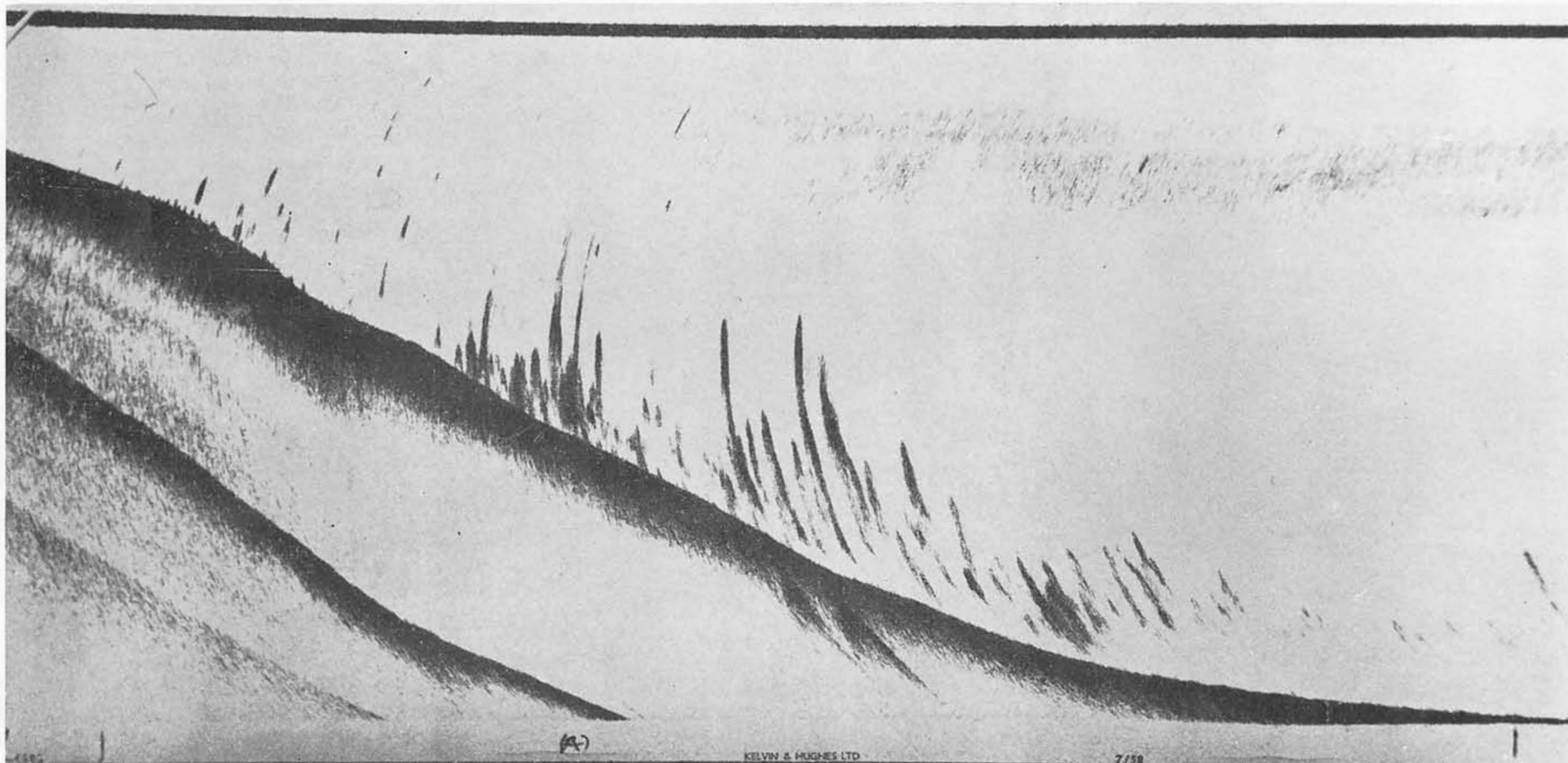


Plate IV

Midday. On the left, juvenile fish in tightly packed shoals near the bottom, and similarly tightly packed shoals of larger fish in deep water at or near the bottom further out

Plate V
Evening. The same ground as in Plate IV, showing the evening vertical migration to the surface

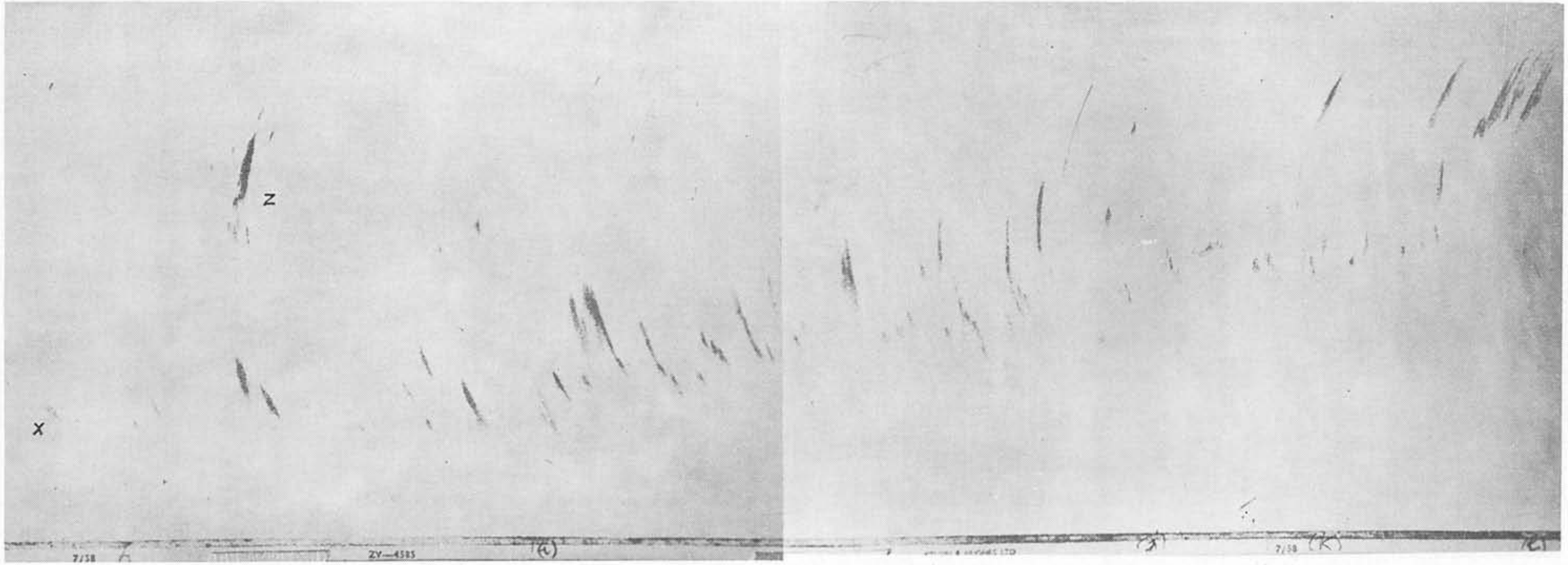


Plate VI

Dusk. This echo-sounding shows the aggregation of fish into shoals which then rise to the surface. The sounding covers a period of about half an hour

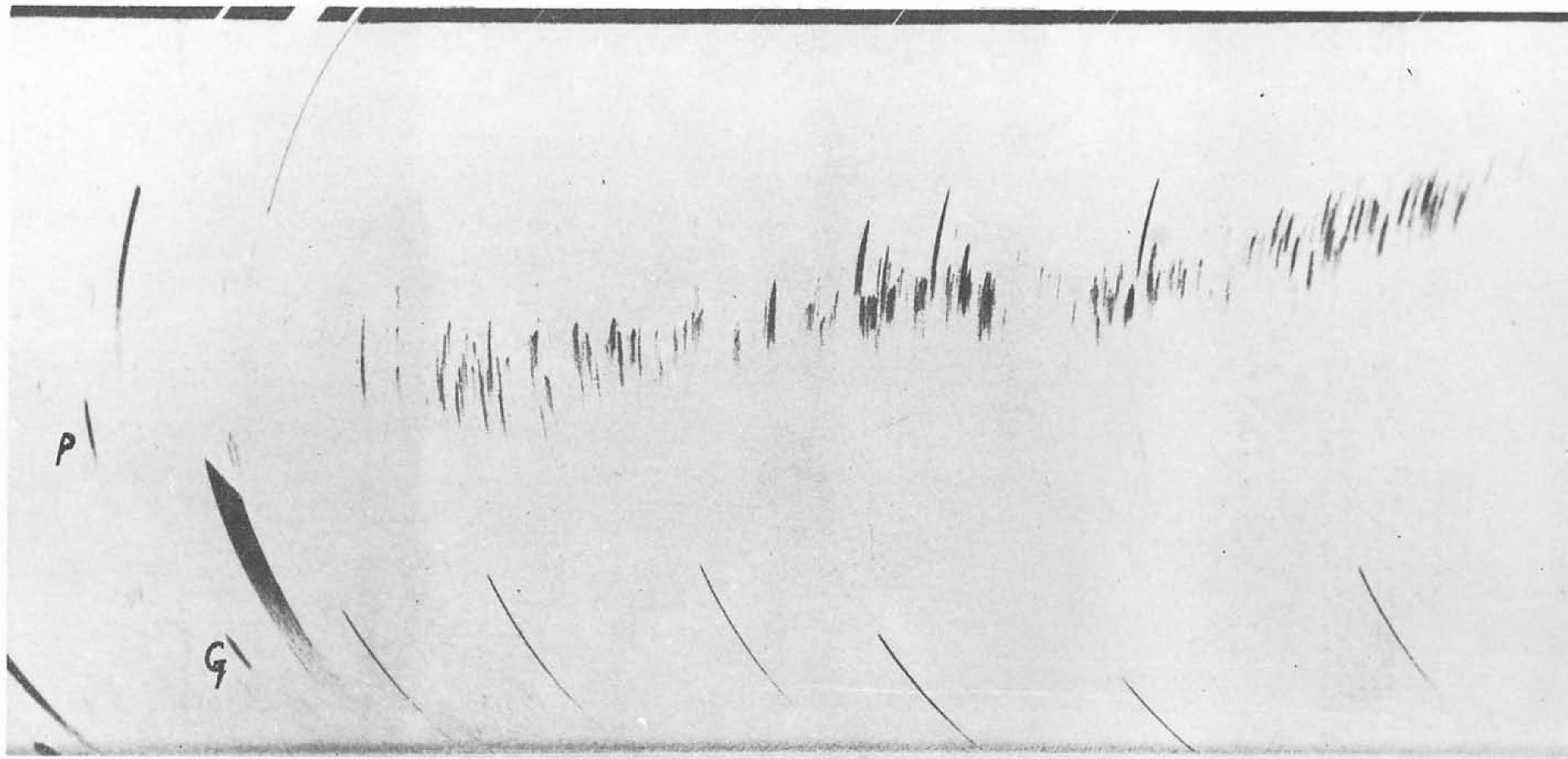


Plate VII
Dusk. The evening vertical migration in deep water. Cameron Bay

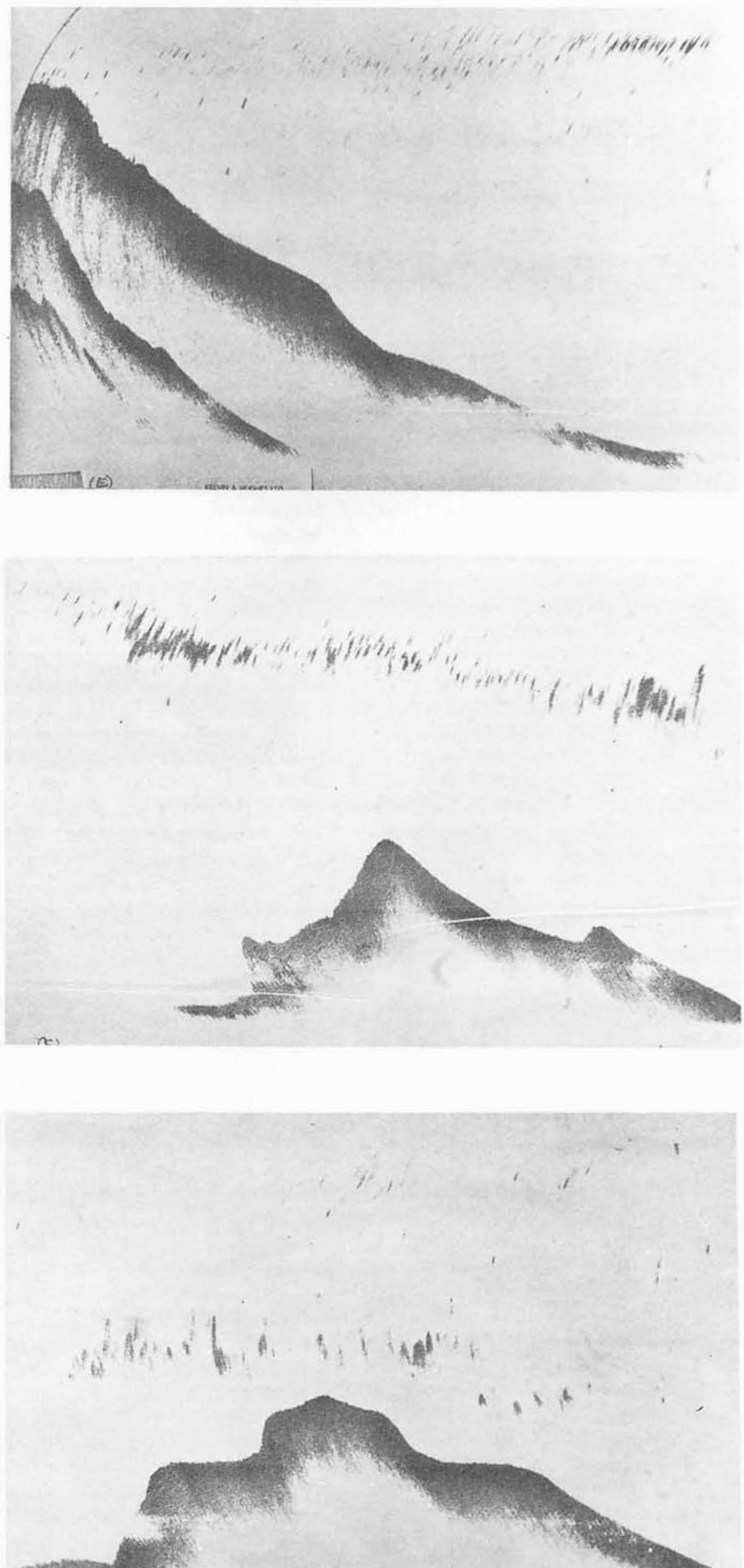


Plate VIII

Dawn. A record of downward migration at dawn. From being scattered in the night the fish form shoals which migrate downwards as the light increases

C.—Research on Lake Mweru

During the year alarm and concern had been felt over the rapid decline in numbers of the important *Tilapia macrochir* (Blgr.), the most commercially valuable species of this fishery, itself the most important fishery at present in the Territory of Northern Rhodesia. Poor catches of this fish are causing increasing hardship to the very large numbers of people engaged in this fishery, and the loss of the revenue which accrues from the fishing industry is considerably impoverishing the treasuries of the various native authorities concerned. As was mentioned in the J.F.R.O. 1959 report No. 9, it had been intended to post the Temporary Zoologist, when recruited, to work on this area; this was done in 1960, and Mr. T. G. Carey was appointed to this post. The start of his work was however delayed for the reasons given in section 2A, and it was not in fact until November, 1960, that Mr. Carey was able to start serious work on the lake.

Mr. Carey started a comprehensive programme of work aimed specifically at elucidating the life history of *Tilapia macrochir*. Due to the late start, little of his results can be treated in detail in this report dealing with the year 1960, and a comprehensive report of his results will be published in next year's annual report. Only a brief synopsis of the Mweru research up to the end of the year is therefore given here.

It has so far been found that the life history of *Tilapia macrochir* falls into two phases. The first phase is that of an open-water lacustrine existence, which is lived by the adult and catchable fish, called " Mpale " by the Africans, and the gill-net fishery for the species for which Lake Mweru has long been famous has been built up on this phase of the fish's life-history. The famous " Mpale " fishing camps, where the bulk of the species has in the past been caught, are those which lie to the south of the lake, such as Kashikisi, Kilwa, Isokwe, etc. The " Mpale " in the past formed the bulk of the Mweru wet fish trade, where traders took fresh fish chilled in ice to Copperbelt markets. It is very largely the failure of the supply of " Mpale " from camps such as these that caused the dramatic drop in the amount of wet fish exported to Northern Rhodesian markets from 4,380 short tons in 1959 to 2,780 short tons in 1960, as recorded in the annual reports of the Department of Game and Fisheries.

The second phase in the life history of *Tilapia macrochir* is that of the juvenile fish, which are called " Kakenje " by the local Africans. These juveniles are found solely in the shelter of vegetation, particularly in Hippo Grass (*Vossia cuspidata*), especially in the extensive lagoons and swamps bordering the southern part of the lake, from whence they do not emerge until they are at least eight inches long. It is believed that a spawning migration of adult *Tilapia macrochir* occurs, whereby the adult fish move from the offshore habitat to the juvenile habitat, at or in the vicinity of which eggs are laid, the fry brooded and the juveniles have their being, using the vegetation as a refuge and source of food until a length of about eight inches is attained. Preliminary work on these juvenile habitats shows that they are occupied by a number of other species also, either in the juvenile or adult stage; one of these is the commercially important " Makobo " (*Serranochromis macrocephala* (Blgr.)), when in the juvenile stage. Attempts are being made to assess interrelationships and competition, if any, between fish species in this habitat.

Work has been done on breeding, feeding and shoaling habits of *Tilapia macrochir*. The fish prefer shallow water for breeding, as all the nests seen in the Mifimbo area have been in water four to six feet deep. This may also be one of the reasons why, as is thought, the fish migrate annually from deep waters to the shallower areas in the southern part in September–December, where the average depth is about six feet.

While there is much indirect evidence that a spawning migration occurs, direct evidence remains to be found. A tagging programme, for which the fish-tags have already been obtained, has had to be shelved because of the attitude of the local people, who fear that by some witch-craft if some fish are tagged the whole species might disappear. The disappearance of the " Pumbu " (*Labeo altivelis*) here some years ago was blamed on tagging by Belgian scientists; although this was done when the species was already on the way out. Shallow-water breeding grounds are, it is suspected, not wholly confined to the southern area of the lake, although these are probably the most extensive. Another breeding ground is believed to exist round the mouth of the Kalungwishi River, and it is further believed that the stocks of *Tilapia macrochir* occurring in the Lower Luapula and those in the lake are separate and distinct so that one does not recruit to another. Only a comprehensive programme of tagging can resolve these and other points, such as which of the populations go to one spawning area to breed and which to another, whether there is any return by the adults to open-water habitats in between successive spawnings, etc., but it seems clear that a programme of education and information among the people will have to precede any tagging work.

Ovary counts show that a mature female fish has, as a rule, between 1,000 and 1,300 eggs. Oral incubation takes place, the female taking up the eggs in her mouth, where the fry develop and are protected until they can look after themselves. One female *Tilapia macrochir* caught off Nchelenge Point had ten to fifteen fry still in her mouth. These had almost lost their yolk sacs, and as the female had ripe ovaries, it is possible that the female fish looks after the fry until she is ready to breed again, by which time the fry have developed sufficiently to look after themselves; that is, when the yolk sac has been used up.

Young fry and fingerlings are always found in shoals in the shallow waters. At times they have been found shoaling with the young of other fish such as *Serranochromis angusticeps* (Blgr.), *Serranochromis macrocephalus* and *Hepsetus odoe* (Bloch). This is very interesting as these fish are all predators. Some shoals of older fish have also been seen, but it is not known whether they all shoal as adults.

Studies are in progress on the water levels of the lake and their variation throughout they year, as it is very probable that this has an effect on the breeding of the fish. In years when there is heavy rain over the catchment and the lake reaches a high annual level, there is a greater extent of suitable area for fish to breed in, as it takes some time before the lake reverts to its normal level. Past records of water levels of the river and lake are being examined in regard to the production figures of fish.

In collaboration with staff of the Department of Game and Fisheries, records of catches are being examined and summarised, fishing effort and types of fishing being examined, fishermen and traders questioned, fishing camps visited and conservation measure assessed, in order to obtain as much information as possible into causes of the recent decline in the fishery. The matter is complex; there is little doubt that a major cause is driving immature and breeding fish into small-mesh gill-nets (the so-called " Kutumpula " method of fishing) on their breeding grounds. Also there has in the immediate past been a good deal of illegal fishing aggravated by the disorganisation resulting from the independence of the Congo which took place on the 1st July. Other interrelating causes seem to be the effect of the traders withholding their custom, and the question of water levels. When the bream (" Mpale ") which the traders desired was no longer obtainable in the quantity previously available, the traders began going elsewhere for their bream which left local fishermen without a market for their fish other than bream, which were still available in quantity throughout the year. This had the effect both of discouraging fishing in general and forcing the fishermen to dry or salt their product which was then sold largely to Katanga. Study of water levels may reveal that a proportion of the decline in " Mpale " catches was due to a natural fall from abnormally high catches caused by abnormally high water levels in previous years. If this is so, it may mean that target figures of Mweru production will have to be revised downwards.

D.—Research on Kariba

The work on Lake Kariba has perforce been sketchy in the past due to inadequate staff and lack of a shore base on the lake. Visits to the area by the staff of J.F.R.O. which began as two annual visits at the high and low water periods were increased in 1960 and towards the end of this year preparations were made for Mr. Harding to leave Samfya for Chilanga in order to devote all his time to the lake. The Fish Ranger, Mr. Adams, was able to devote a considerable amount of time to collection of routine hydrological and fishery data when his programme of stocking allowed. Water samples have been sent to the Government Analyst in Salisbury, and the results are listed in table 2 D 1 in the appendix to this section. Temperature measurements were regularly made at the boom situated about a mile upstream from the dam in Kariba Gorge and these indicated the lake to be stratified in February, with a distinct thermocline at approximately thirteen metres. Below the thermocline the water was completely devoid of oxygen (table 2 D 2). Thermal stratification broke down in July and an overturn occurred, and at this stage oxygen was found to penetrate to the bottom of the lake. The stratification became re-established in September, and by late November a well-defined thermocline was recorded below which the water was again devoid of oxygen.

Toward the end of the year the Federal Power Board began to sample water from different levels at the boom just upstream of the dam site, and the results of these analyses have been made available to J.F.R.O. in exchange for records of temperature stratification and so on taken during 1959 and 1960. The record for 29th December is given in table 2 D 3, in the appendix to this section.

The advent of the fern *Salvinia auriculata* on Lake Kariba is still causing considerable concern to the various authorities interested in developing the lake for hydro-electric power, fisheries, navigation and tourism. The fern spread with a burst of growth which has been described as " explosive " by some writers and an initial survey, conducted by Dr. Schelpe, Mr. Phipps and myself, indicated that approximately 200 square miles of lake surface were affected in April, 1960. The growth of secondary colonisers on the floating mat of *Salvinia auriculata*, e.g. *Scirpus cubensis*, have resulted in the development of a " Sudd " which has become something of a hazard in many areas. The effects are three-fold; the floating mat of weed extracts nutrient from the water which would otherwise have been utilised for the growth processes of phytoplankton and ultimately fish; the floating mat also excludes exchange with the atmosphere, and a feature of the water beneath *Salvinia* mats, which have been long-established, is the low concentration of dissolved oxygen; finally there is the mechanical effect of choking of backwaters, blocking access to harbours and fishing pitches and to movement of all craft in the areas so affected. Eradication of this weed menace is impossible, but it would be very desirable to have, if possible, a certain measure of control. The Kariba Lake Co-ordinating Committee have therefore employed a firm of specialists to study the aspect of chemical control, they have approached the problem of physical control and the possibility of utilisation in industry, and have provided facilities for the scientific study of the fern and associated aquatic plants. Aerial surveys of the distribution of the weed mass will continue in 1961.

The commercial fishery on the Northern Rhodesian shore of Lake Kariba got away to a good start during 1960. The Tonga tribe, the inhabitants of the valley, had little or no experience of fishing practices, apart from the most primitive methods of basket-trap, weir and spear fishing. Therefore the Game and Fishery Department set out a programme of training in the use of gill-nets, a method of fishing well suited to African lake fisheries and an item of gear within the purchasing power of most of the potential fishermen. In addition, trained staff were put in the field at several widely dispersed fishing camps to record landings, and the exports of fish from the area were also recorded, as indicated in the appendices. Finally experimental fleets of gill-nets of varying mesh size have been used throughout the year to assess population changes and potential of the varying lake areas, and as a demonstration of fishing technique to the Tonga fishermen.

The commercial fishery suffered considerable set-back in areas infested by *Salvinia* sudd, where nets were often lost or damaged due to large-scale movements of the floating mat of weed. Furthermore the lack of sufficient craft from which gill-nets could be worked also delayed development of the industry. However, it can be seen from table 2 D 4 approximately 600 short tons of fish were exported from the area to markets as far away as the Copperbelt towns in Northern Rhodesia and Bulawayo in Southern Rhodesia, and an unknown but large quantity, was consumed locally.

The most interesting feature of the fishery has been the rapid build-up of the stocks of *Tilapia mossambica*, which have found the changed environmental conditions eminently suitable to their survival and rapid growth, and now feature prominently in the commereial landings. Experimental nets used by the J.F.R.O. show that the most effective nets for the selection of *Tilapia mossambica* are of the order of five-inch stretched mesh (table 2 D 5). This is also reflected in the commercial catches. Fleets of experimental nets ranging from two-inch to six-inch have been fished regularly in various areas of the lake on both north and south banks; these indicate that there is a distinct preference for the shallow water, inshore environment by certain species, particularly *Tilapia mossambica*, *Tilapia melanopleura*, *Labeo congoro*, *Labeo altivelis* and so on, at least during part of their life histories. Just prior to the breeding season, which coincides with the onset of the rains, it has been found by echo-sounding that congregations of fish occur near the mouths of rivers, and a breeding run up the rivers occurs with the first flooding. Of the several species which run to the rivers to breed *Clarias mossambicus*, the two *Labeos*, *Hydrocyon vittatus* and *Alestes imberi* are perhaps the most important.

Thus a marked differentiation between fish which breed in the lake, e.g. *Tilapia mossambica*, and those which run up rivers to breed, e.g. *Labeo congoro* and *Hydrocyon vittatus*, is already noticeable amongst the population of fishes living in Lake Kariba. Open waters of the lake are at present only sparsely populated, as has been shown by experimental nettings. An example of this is the open lake netting carried out in September, 1960. Here only six species were represented in the catches, the predatory *Hydrocyon vittatus* forming 53 per cent. of the total (table 2 D 6).

Part of the duties of J.F.R.O. are to advise Government on legislation and other policy in connection with the fisheries, and legislation introduced by Government Notice No. 325 for Kariba provides for the protection of fish stocks in the lake and its inflows. A minimum mesh size of four-inch stretched mesh and a closed season between 16th December and 15th March are two of the measures introduced to this end, while provision is made for prohibition of weir fishing in rivers, and closure of complete sections of the coastline to all fishing should this ever become necessary. The closed season is prolonged over three months principally to protect the mouth-breeding *Tilapia mossambica*, which has a rather prolonged breeding season, and scheduled to commence on the 16th December, just before the main breeding runs to rivers occur, and to protect breeding concentrations of such species as *Labeo altivelis* and *Labeo congoro*, which form as much as 50 per cent. of the fish landed in the commercial fishery.

Research in 1961 is scheduled to include a more detailed study of the hydrology of Lake Kariba in relation to basic productivity and the effects on the fishery. Experimental netting with fleets of standard mesh gill-nets will continue to give information on population distribution and size, mesh selection and catch per unit effort. An application to the United Nations Special Fund for money to staff a fisheries research institute and develop the fishing industry on Lake Kariba was tabulated in 1960 and a team of F.A.O. experts is scheduled to visit the area in early 1961 to consider the application. Meanwhile the research of the J.F.R.O. and the Fisheries Department of Northern Rhodesia will continue in the area along the lines indicated in this report until such an institute is established.

TABLE 2 D 1

WATER ANALYSES FROM LAKE KARIBA*

	Date Collected										
	24–10–58	15–12–58	17–2–59	31–3–59	2–5–59	11–6–59	30–9–59	23–11–59	29–1–60	11–4–60	31–8–60
Odour...	None	None	None	None	None	None	None	None	None	None	None
Colour (Hazen Units)	—10	—10	Slight	10	10	10	15	15	Slight Green T.	Slight Yellow T.	None
Total Solids at 180°C.	103	91	105	88	87	84	74	71	72	70	69
Total Solids ignited	78	77	91	69	65	69	59	55	56	51	60
Organic Matter	25	41	14	19	22	15	16	16	16	19	9
Specific Conductivity at 20°C. (× 104)	1·21	1·16	1·22	1·17	1·16	1·15	1·00	0·91	0·90	0·88	0·93
Approximate dissolved salines from S.C.	69	66	68	67	66	65	58	52	51	51	52
Alkalinity as Ca Co_3	59	56	58	60	59	59	54	50	48	45	51
Total Hardness as Ca Co_3	49	50	51	53	54	51	45	40	41	40	42
Chloride	3	3	2	1	2	2	2	2	2	1	1
Sulphate	3 approx.	3 approx.	4 approx.	4	3	2	2·5	TR.	TR.	0	0
Nitrate Nitrogen	0	0	0	TR.	0.1	0.1	TR.	TR.	TR.	TR.	0
Nitrite Nitrogen	0	TR.	0	0	0	0	0	0	0	0	0
Ammoniacal Nitrogen	0·06	0·11	0·02	0·01	0·01	0·01	0·05	0·04	0·06	0·05	0·06
Albuminoid Nitrogen	0·26	0·21	0·14	0·16	0·14	0·16	0·14	0·21	0·20	0·11	0·13
Oxygen absorbed (4 hrs. at 27°C.)	1·2	1·6	1·6	1·5	1·65	1·8	1·8	1·7	1·6	1·5	1·5
Bicarbonate	72	69	71	73	72	72	66	61	59	55	62
Calcium	14	14	14	16	16	14	14	13	12	12	13
Magnesium	3·4	3·7	4	3	3	4	3	2	2	2	2
Total Iron	0	0	0	0	0	0	0	0	0	0	0
Sodium	8	7	7	7	6	6	7	6	4	3	5
Potassium	0	0	0	0	0	0	0	not done	not done	not done	—
Phosphate	TR.	TR.	0·13	0·10	0·03	0·1	0·07	0	—0·01	—0·01	0
Copper	0	0	0	0	0	0	0	0	0	0	0
Silica Si O_2	10	10	8	8	7	7	8	8	8	8	11
PH.	7·3	6·9	7·1	7·2	7·2	7·2	7·2	7·7	7·3	7·3	7·2
Main Salines											
Calcium Carbonate	35	35	34	40	40	35	33	32	30	31	32
Magnesium Carbonate	12	13	14	11	12	14	10	7	9	8	8
Sodium Carbonate	11	6	7	7	5	8	10	11	7	5	10
Sodium Sulphate	4	6	6	6	4	3	4	TR.	TR.	—	—
Sodium Chloride	5	5	4	2	4	3	3	3	3	2	2
Sodium Nitrate	—	—	—	1	1	1	—	—	—	—	—
TOTAL	67	65	65	67	66	64	60	53	49	46	52
Plus Silica	10	10	8	8	7	7	8	8	8	8	11

*Analytical results are recorded in parts per million and were carried out at the Government Analysis Laboratory in Salisbury, Southern Rhodesia

Table 2 D 2

HYDROLOGICAL DATA FROM LAKE KARIBA

Temperature fluctuations at the boom in Kariba Gorge

Metres	26–2–60	17–3–60	4–4–60	10–4–60	25–5–60	26–5–60	2–6–60	7–6–60	10–6–60	15–6–60
0 ...	29·70	28·50	29·90	28·30	25·70	25·35	24·75	25·10	24·80	24·10
5 ...	28·30	28·30	29·25	28·10	25·55	25·40	24·70	24·45	24·40	24·20
10 ...	28·00	28·20	28·00	27·60	25·50	25·40	24·70	24·40	24·30	24·20
15 ...	26·35	27·70	27·60	27·40	25·50	24·40	24·70	24·40	24·30	24·20
20 ...	24·40	25·30	25·50	25·75	25·50	25·40	24·70	24·40	24·30	24·20
25 ...	24·00	24·70	24·05	24·20	25·50	25·40	24·70	24·40	24·25	24·20
30 ...	23·60	23·80	23·45	23·80	24·90	24·15	24·45	24·30	24·15	24·15
35 ...	23·55	23·50	23·35	23·40	23·65	23·70	23·50	23·65	23·65	23·65
40 ...	23·45	23·50	23·25	23·40	23·45	23·35	23·40	23·45	23·50	23·50
45 ...	23·40	23·40	23·20	23·30	23·35	23·35	23·35	23·40	23·40	23·45
50 ...	23·30	23·30	23·20	23·20	23·30	23·30	23·30	23·35	23·30	23·40
55 ...	23·30	23·30	23·15	23·20	23·30	23·30	23·20	23·30	23·30	23·35
60 ...	23·30	23·30	23·10	23·20	23·30	23·30	23·15	23·25	23·25	23·35
65 ...	23·30	23·30	23·10	23·20	23·30	23·30	23·15	23·25	23·25	23·35
70 ...	23·30	23·30	23·10	23·20	23·30	22·50	23·15	23·25	23·25	23·35

HYDROLOGICAL DATA FROM LAKE KARIBA

Temperature fluctuations at the boom in Kariba Gorge

Metres	16–6–60	20–6–60	26–6–60	28–6–60	6–7–60	23–8–60	20–9–60	29–9–60	1–10–60	17–10–60
0 ...	24·52	23·90	25·10	24·70	23·25	23·90	23·80	26·20	25·00	26·70
5 ...	24·25	23·90	24·05	23·85	23·40	22·50	23·25	24·10	24·60	25·10
10 ...	24·15	23·85	23·80	23·70	23·40	22·35	22·50	23·20	22·80	24·00
15 ...	24·15	23·85	23·75	23·70	23·40	22·25	22·45	22·60	22·40	23·40
20 ...	24·15	23·85	23·70	23·65	23·40	22·25	22·25	22·20	22·20	22·70
25 ...	24·15	23·85	23·65	23·60	23·40	22·20	22·15	22·10	22·20	22·30
30 ...	23·90	23·85	23·65	23·60	23·40	22·20	22·05	22·10	22·00	22·20
35 ...	23·55	23·85	23·60	23·60	23·40	22·20	22·00	22·00	21·80	22·10
40 ...	23·50	23·60	23·55	23·50	23·40	22·15	21·90	21·70	21·60	21·70
45 ...	23·45	23·45	23·45	23·35	23·40	22·15	21·75	21·60	21·30	21·45
50 ...	23·40	23·40	23·35	23·35	23·40	22·10	21·70	21·50	21·10	21·30
55 ...	23·35	23·35	23·35	23·35	23·40	22·05	21·60	21·45	21·05	21·25
60 ...	23·35	23·35	23·35	23·30	23·40	22·05	21·50	21·35	21·05	21·10
65 ...	23·35	23·40	23·35	23·30	23·40	22·05	21·40	21·15	21·05	21·00
70 ...	23·35	23·40	23·30	23·25	23·35	22·05	21·35	21·00	21·00	21·00

HYDROLOGICAL DATA FROM LAKE KARIBA

Temperature fluctuations at the boom in Kariba Gorge

Metres	1–11–60	14–11–60	22–11–60	2–12–60	5–12–60	12–12–60	19–12–60	2–1–61
0 ...	28·00	27·30	28·40	30·00	27·50	29·00	29·50	28·10
5 ...	26·75	26·90	27·90	27·60	27·20	27·10	28·30	27·20
10 ...	24·50	26·70	27·10	27·10	26·20	26·30	27·20	27·10
15 ...	22·80	24·10	26·70	25·50	25·50	26·00	26·50	26·00
20 ...	22·60	22·80	24·70	24·95	24·05	23·70	25·10	23·50
25 ...	22·40	22·50	22·50	23·90	22·90	23·40	—	22·70
30 ...	22·10	21·90	22·10	22·75	22·60	23·10	—	22·60
35 ...	21·90	21·90	22·10	22·40	22·10	22·60	—	22·40
40 ...	21·70	21·60	22·00	22·40	21·90	22·40	—	22·40
45 ...	21·40	21·40	21·70	22·30	21·70	22·00	—	22·30
50 ...	21·20	21·40	21·40	22·10	21·40	22·00	—	22·20
55 ...	21·15	21·30	21·40	21·85	21·50	21·90	—	22·20
60 ...	21·10	21·20	21·30	21·60	21·50	21·80	—	22·20
65 ...	21·10	21·10	21·20	21·50	—	21·80	—	22·20
70 ...	21·10	21·10	21·20	21·45	—	21·80	—	22·20

TABLE 2 D 3

ANALYSIS OF WATER FROM LAKE KARIBA, DECEMBER, 1960*

Analysts' results (in parts per million except where stated), 5th December, 1960*
All samples contained a trace of suspended matter. Sampling ports were, as before, at the centre of the boom.

Sample number ...	1	5	2	3	4
Times, samples†: A	11.30	?	11.50	12.05	12.30
B	12.45	—	13.00	13.05	13.15
C	13.30	—	13.45	14.30	15.00
Depth of sample (feet)	2	57	76	151	225
Temperature (deg.C.)	27·50	—	23·20	21·60	—
Dissolved oxygen	6·80	—	1·10	1·10	1·80
Percentage saturation (of oxygen)	85	—	13	12	—
Oxygen consumed from N/80 KM no_4 in three minutes	0·40	—	0·50	0·40	0·60
Oxygen consumed from N/80 KM no_4 in four hours	1·60	—	1·40	1·80	2·20
Alkalinity to Phenolphthalein	Nil	Nil	Nil	Nil	Nil
Total alkalinity as $CaCo_3$(M)	48	44	44	33	32
Total harness, as $CaCo_3$ ...	40	37	36	27	27
Calcium harness, as $CaCo_3$	28	26	27	18	17
Magnesium harness, as $CaCo_3$	12	11	11	9	10
Phosphate as PO_4	1	Nil	Nil	Nil	Nil
Chloride as CL	1	2	2	1	1
Sulphate as SO_4	3	2	1	2	1
Nitrate as NO_3	0·90	—	0·90	0·90	0·90
Ammonia as NH_3	0·10	0·18	0·18	0·23	0·18
Free CO_2 ...	0·50	6·80	9·90	8·80	9·20
Nitrite as NO_2	0·50	—	0·50	0·50	0·50
Silica as SIO_2	12	12	13	12	12
Odour of H_2S when sampled	Nil	—	Strong	Faint	Fairly strong
Sulphide as H_2S	Nil	—	Present	Present	Present
Sodium as Na	4·00	3·80	3·70	2·70	2·50
Potassium as K	2·10	1·90	1·80	1·10	0·90
Iron as Fe ...	0·079	—	0·094	0·199?	0·085
Copper as Cu	0·023	—	0·016	0·21	0·025
Calcium as Ca	11	10	11	7	7
Magnesium as Mg	3	3	3	2	2
Electrical conductivity	—	—	—	—	—
Reciprocal megohms	98	91	87	64	63

*Analyses were carried out at the Federal Power Board laboratory in Salisbury.
†Sampling times given as A—H_2S sample.
B—General sample.
C—Dissolved oxygen.

TABLE 2 D 4

FISH EXPORTS FROM KARIBA (RECORDED AT LEVY POINTS)

	Sinazongwe		*Munyumbwe*		*Lusitu*		*Monthly Total*	
	Dried fish lb.	*Fresh fish lb.*	*Dried fish lb.*	*Fresh fish lb.*	*Dried fish lb.*	*Fresh fish lb.*	*Dried fish lb.*	*Fresh fish lb.*
March	48	—	124	510	2,543	—	2,751	510
April	901	—	406	694	6,915	2,400	8,222	3,094
May	8,463	13,064	405	1,764	7,629	12,279	16,497	27,107
June	8,954	27,392	418	8,535	5,287	19,355	14,749	55,282
July	7,955	25,112	85	10,220	13,762	41,024	21,802	76,356
August	6,546	34,215	307	10,340	21,511	51,188	28,364	95,743
September	5,791	16,491	1,422	7,148	41,471	37,048	48,684	60,687
October	6,040	16,934	1,493	3,532	35,968	38,520	43,501	58,986
November	230	10,708	400	2,354	5,277	18,972	5,987	32,034
December	141	432	100	60	1,758	6,320	1,999	6,812
ANNUAL TOTALS ...	45,069	144,348	45,157	42,141	227,106	92,520	192,520	416,611

Total dried fish exported = 192,450 lb. = 96·225 short tons.
Total fresh fish exported = 416,611 lb. = 208·306 short tons.

FRESH EQUIPMENT ... = 384·100 short tons.

TOTAL ... ... 592·406 short tons.

TABLE 2 D 5

CATCHES FROM EXPERIMENTAL GILL-NET ON LAKE KARIBA

Species Variation at Camps on the North Bank

Species	*2-inch mesh* No.	*2-inch mesh* Weight	*3-inch mesh* No.	*3-inch mesh* Weight	*4-inch mesh* No.	*4-inch mesh* Weight	*5-inch mesh* No.	*5-inch mesh* Weight	*6-inch mesh* No.	*6-inch mesh* Weight	*Total* No.	*Total* Weight
September and October, 1960— Kayuni Camp:	%	%	%	%	%	%	%	%	%	%	%	%
Mormyrops deliciosus	?	—	0·68	0·51	—	—	—	—	5·00	19·01	1·13	3·90
Mormyrus longirostris	—	—	1·59	2·39	2·17	1·43	—	—	12·50	20·95	3·25	4·95
Marcusenius discorhynchus ...	4·18	2·05	—	—	—	—	—	—	—	—	0·83	0·41
Alestes imberi	34·90	30·92	—	—	—	—	—	—	—	—	6·98	6·18
Hydrocyon vittatus	29·45	37·33	0·91	1·52	—	—	—	—	—	—	6·07	7·97
Distichodus shenga	—	—	6·61	7·13	32·22	24·90	—	—	6·25	9·45	9·03	8·30
Distichodus mossambicus ...	—	—	—	—	21·96	11·07	—	—	—	—	3·35	2·23
Labeo altivelis	4·23	4·64	41·19	44·81	5·11	5·48	—	—	—	—	10·30	10·98
Labeo congoro	—	—	29·14	29·95	10·87	8·74	—	—	—	—	8·00	7·73
Eutropius depressirostris ...	13·55	9·88	2·81	1·16	—	—	—	—	—	—	3·27	2·20
Synodontis zambezensis ...	13·66	15·21	16·43	12·86	5·38	2·62	11·11	1·29	5·00	4·54	13·11	7·30
Clarias mossambicus	—	—	—	—	11·76	18·05	28·20	55·28	6·25	13·02	9·24	17·67
Tilapia mossambica	—	—	0·68	0·29	15·21	27·67	60·68	42·93	45·00	30·99	24·31	20·37
Tilapia menlanopleura ...	—	—	—	—	—	—	—	—	—	—	—	—
Sargochromis codringtoni ...	—	—	—	—	—	—	—	—	—	—	—	—
November and December, 1960— Gwena Camp:												
Alestes imberi	24·40	19·08	8·53	4·53	—	—	—	—	—	—	6·85	4·72
Hydrocyon vittatus	40·52	47·68	4·17	8·21	6·18	9·80	3·21	4·83	—	—	10·81	14·10
Distichodus shenga	—	—	2·31	3·56	8·25	10·54	2·25	1·75	—	—	2·56	3·17
Distichodus mossambicus ...	0·11	0·14	7·60	6·72	6·76	4·76	3·35	3·64	—	—	3·56	3·05
Labeo altivelis	33·85	28·58	31·44	25·77	12·98	11·66	1·15	0·27	—	—	15·88	13·25
Labeo congoro	0·92	2·32	44·49	47·89	48·01	55·04	—	—	10·00	4·47	20·68	21·94
Eutropius depressirostris ...	0·38	0·63	2·83	2·65	—	—	—	—	—	—	0·64	0·65
Clarias mossambicus	—	—	—	—	2·76	3·95	7·15	10·56	10·00	19·80	3·98	6·86
Tilapia mossambica	0·11	0·02	1·47	0·64	5·23	2·70	81·12	78·74	32·50	30·68	24·08	22·51
Tilapia melanopleura	—	—	0·18	0·08	1·24	0·92	1·15	0·72	—	—	0·51	0·34

TABLE 2 D 6

COMPOSITION OF TONGA FISHERMEN'S CATCHES FOR SEPTEMBER, OCTOBER, NOVEMBER AND DECEMBER, 1960

Using four-inch and five-inch gill-nets. Percentages from numbers calculated from two daily samples in each month

SPECIES	Sinantandabale	Sinalulongwe	Namazambwe	Chavonga and Mundulundulu	Kayuni	Combined
Tilapia mossambica	15·5	28·0	6·0	8·0	49·0	12·0
Tilapia melanopleura	2·0	1·0	0·6	0·7	0·1	0·8
Sargochromis codringtoni	7·0	11·0	7·0	3·0	2·0	2·5
Hydrocyon vittatus	2·0	3·0	—	1·0	0·1	0·9
Distichodus shenga	18·5	9·0	21·0	19·0	11·0	11·0
Distichodus mossambicus	7·0	6·0	7·0	20·0	9·0	8·0
Labeo altivelis	21·0	14·0	31·0	5·0	3·0	8·0
Labeo congoro	29·0	20·0	20·0	46·0	9·0	20·0
Marcusenius discorhynchus	—	—	0·2	—	—	—
Mormyrops deliciosus	0·2	—	0·5	—	—	0·1
Mormyrus longirostris	1·0	—	1·0	—	—	0·3
Synodontis zambezensis	0·1	—	1·0	—	—	0·1
Heterobranchus longifilis	0·1	—	1·0	—	0·1	0·5
Clarias mossambicus	4·0	5·0	1·0	2·0	8·0	2·5
Total nets	158	50	29	316	98	651
Total fishermen	88	38	27	70	62	285
Nets/fishermen	1·8	1·3	1·0	4·5	1·6	2·3

Calculated from records collected on two separate days at each camp in each month

TABLE 2 D 7

EXPERIMENTAL GILL-NET CATCHES FROM SEVERAL DIFFERENT AREAS OF LAKE KARIBA

	20–9–60 *Sanyati River*		21–9–60 *Naodsa River*		22–9–60 *Sibilobilo River clearing*		22–9–60 *Chezia River*		23–9–60 *Open Lake*		24–9–60 *Sinazongwe clearing*		25–9–60 *Luzilukulu estuary*	
	No. %	*Weight* %	*No.* %	*Weight* %	*No.* %	*Weight* %	*No.* %	*Weight* %	*No.* %	*Weight* %	*No.* %	*Weight* %	*No.* %	*Weight* %
Mormyrops deliciosus	—	—	—	—	—	—	0·94	1·82	—	—	—	—	—	—
Mormyrus longirostris	—	—	—	—	0·56	2·04	—	—	—	—	—	—	—	—
Marcusenius discorhynchus ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alestes imberi	31·92	5·68	1·53	0·46	17·92	4·93	7·52	2·27	5·26	0·83	22·00	9·40	81·92	31·81
Hydrocyon vittatus	48·64	59·63	51·00	16·90	26·88	46·75	19·74	11·83	52·60	53·08	30·00	22·05	10·24	21·21
Distichodus shenga	—	—	1·02	0·92	—	—	4·70	6·37	10·52	8·25	—	—	—	—
Distichodus mossambicus ...	0·76	0·81	0·51	0·46	0·56	1·36	3·76	5·11	—	—	—	—	2·56	5·33
Labeo altivelis	2·28	2·11	26·52	21·56	20·72	22·27	25·38	30·03	7·89	8·80	24·00	35·70	—	—
Labeo congoro	6·08	7·55	0·51	0·23	6·16	6·29	—	—	21·04	27·78	4·00	6·84	2·56	12·12
Barbus marequensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Synodontis zambezensis	—	—	—	—	—	—	29·14	23·66	2·63	0·83	2·00	1·30	—	—
Eutropius depressirostris ...	0·76	0·28	—	—	—	—	3·76	4·89	16·00	—	16·00	14·19	—	—
Clarias mossambicus	2·28	9·58	17·85	59·91	1·12	7·99	0·94	6·15	—	—	—	—	2·56	29·57
Heterobranchus longifilis	—	—	—	—	—	—	3·76	7·84	—	—	—	—	—	—
Tilapia mossambica	7·60	13·81	—	—	22·95	47·77	—	—	—	—	2·00	10·50	—	—
Tilapia melanopleura	—	—	1·02	0·23	3·36	6·12	—	—	—	—	—	—	—	—
Tilapia macrochir	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sargochromis codringtoni ...	—	—	—	—	0·56	1·70	—	—	—	—	—	—	—	—
TOTAL CATCHES	132·00	153·32	196·00	218·88	180·00	146·50	106·00	54·94	38·00	45·27	50·00	23·57	39·00	16·51

TABLE 2 D 8

CATCH/UNIT EFFORT FROM FLEETS OF EXPERIMENTAL GILL-NETS ON LAKE KARIBA, 1960

A.—STANDARD NETS* ON THE NORTH BANK

Catch in pounds per 100 yards fishing*

	2-*inch mesh*	3-*inch mesh*	4-*inch mesh*	5-*inch mesh*	6-*inch mesh*	*Average*
August—Mundulundulu	28·65	36·20	15·81	8·08	1·15	17·97
September—Kayuni ...	21·00	24·63	16·00	20·38	31·56	22·71
October—Kayuni ...	31·88	28·63	13·50	11·25	10·50	15·50
November—Gwena ...	28·70	36·14	26·28	35·70	2·28	25·82
December—Gwena ...	38·42	34·18	32·32	26·50	2·34	26·75

B.—CATCHES IN STANDARD GILL-NETS FROM VARIOUS AREAS OF LAKE KARIBA

Catch in pounds per 100 yards fishing

September, 1960	2-*inch mesh*	3-*inch mesh*	4-*inch mesh*	5-*inch mesh*	6-*inch mesh*	*Average*
Sangati Gorge	49·88	52·75	51·00	123·25	28·50	
Naodsa River	67·25	139·00	138·00	83·00	10·50	
Sibilobilo Cleared Area...	44·00	68·50	82·50	146·50	91·50	
Open Lake (Chezia) ...	16·50	13·50	36·25	14·75	9·50	
Sinazongwe	17·63	24·50	—	—	5·00	
Luzilukulu River ...	17·50	5·00	5·75	—	9·75	

*Each net mounted to fish fifty yards long and seven feet deep, made of number six thread nylon, and are of similar dimensions to those used in the commercial fishery.

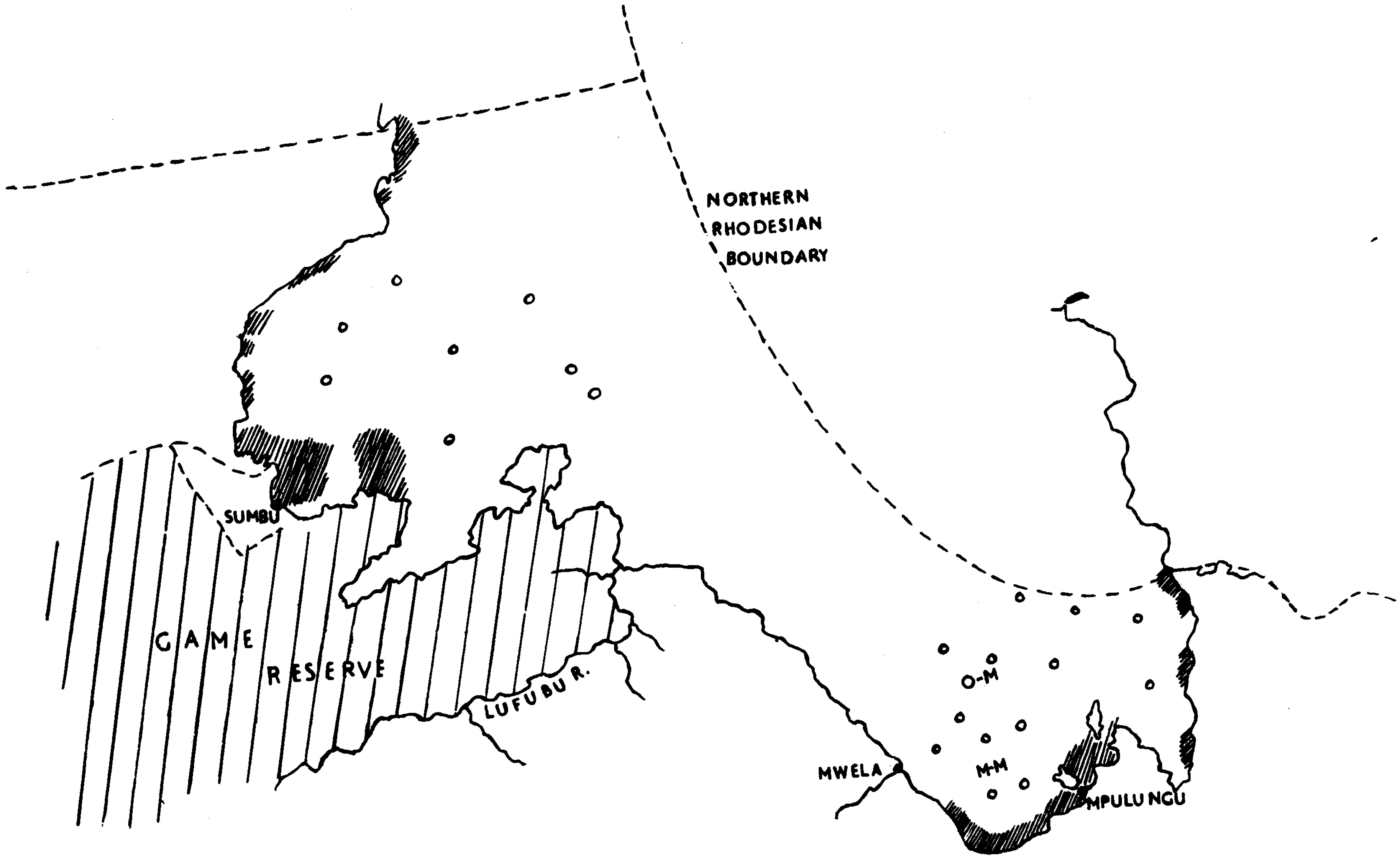
TABLE 2 D 9

EXPERIMENTAL GILL-NETS* IN LAKE KARIBA, 1959–60

Catch in pounds/100 yards set net

	2-*inch mesh*	3-*inch mesh*	4-*inch mesh*	5-*inch mesh*	6-*inch mesh*	*Average*
BINGA KANCHINDU CLEARED AREA						
October, 1959	59·95	23·78	28·94	20·25	18·50	30·27
November, 1959 ...	109·22	44·75	53·56	57·80	28·73	58·81
December, 1959 ...	117·67	37·32	54·97	75·78	60·03	69·15
January, 1960	78·94	59·92	56·21	42·00	62·78	59·97
February, 1960 ...	43·25	70·75	88·25	31·13	62·88	59·25
SINAZONGWE AREA—MAZE RIVER						
June, 1960	34·75	58·90	86·90	70·30	23·42	54·85
July, 1960	25·69	48·91	89·79	46·63	23·02	46·80
KARIBA AREA—SANYATI BUSH INSHORE						
September, 1960 ...	25·29	75·08	88·54	64·00	35·29	57·64
October, 1960	64·50	65·19	60·56	16·73	32·46	47·88
November, 1960 ...	26·30	31·37	46·77	46·55	49·57	40·11
December, 1960 ...	19·25	81·13	33·31	3·25	46·50	36·68

*Each of the nets in the experimental fleet was mounted to fish fifty yards and twenty-six meshes deep.



Map 2 B 1
Sketch map of the Northern Rhodesian part of Lake Tanganyika
M-M: Mid-Mwela sampling station. O-M: Outer-Mwela sampling station. Hatching: Areas exploited by the native Lusenga nets. Circles: Places well off-shore where good catches of sardine have been made

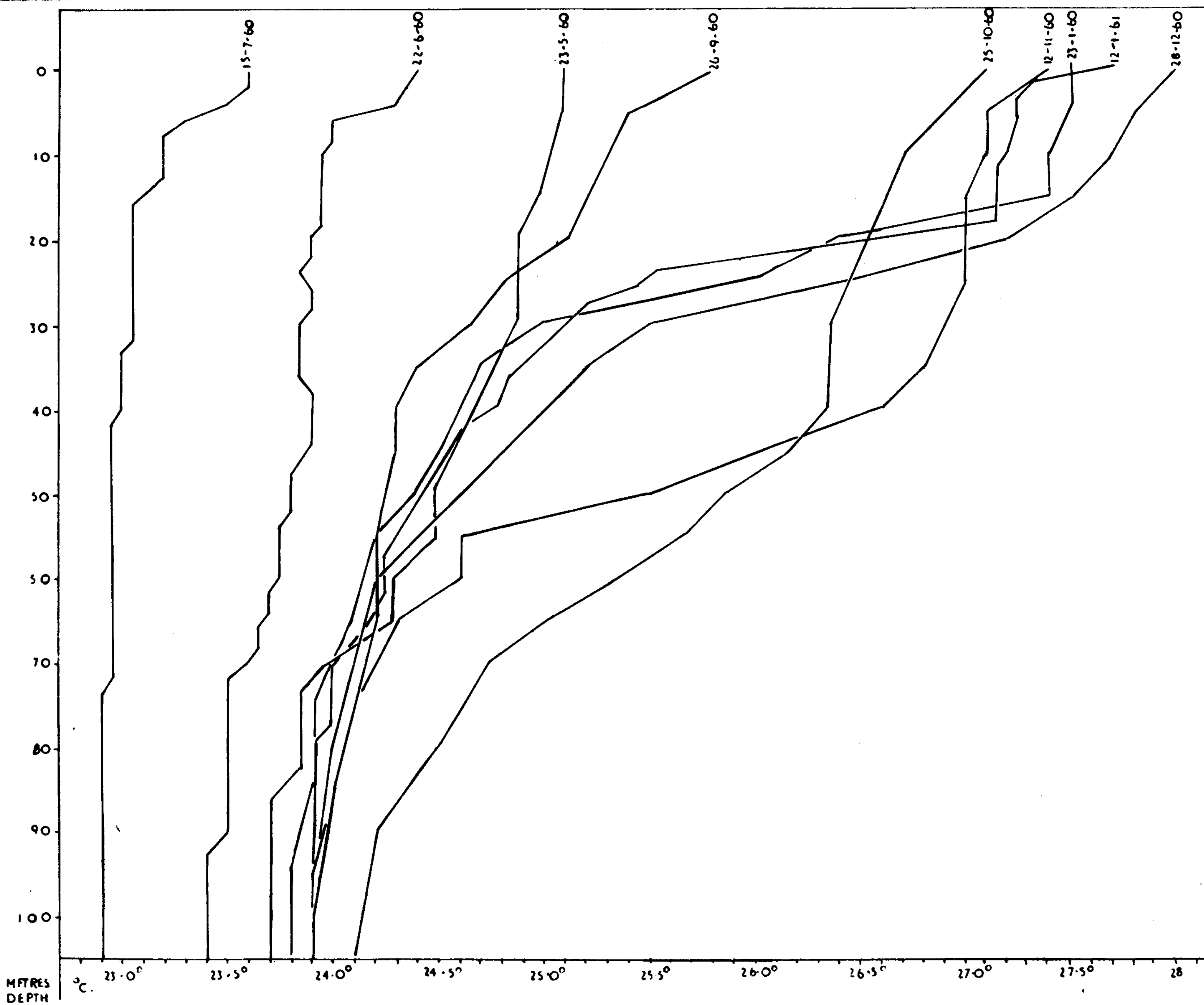


Fig. 2 B 1

A representative group of temperature gradients showing the general scheme of thermal changes at the mid-Mwela station from January, 1960, to January, 1961

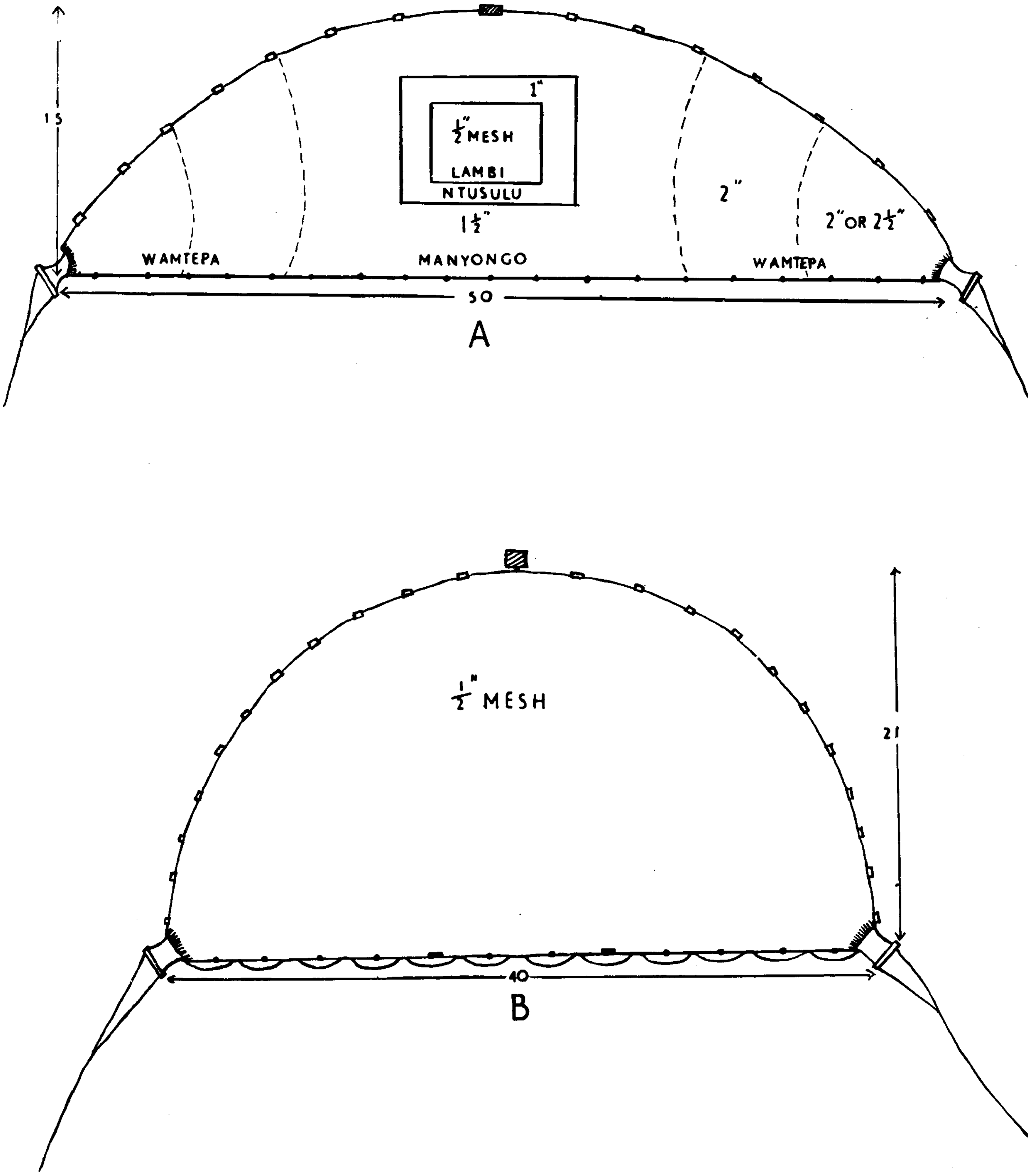


Fig. 2 B 2 A
The Chirimila Net
A. The net as used on Lake Nyasa.
B. The net as adapted for use on Lake Tanganyika.

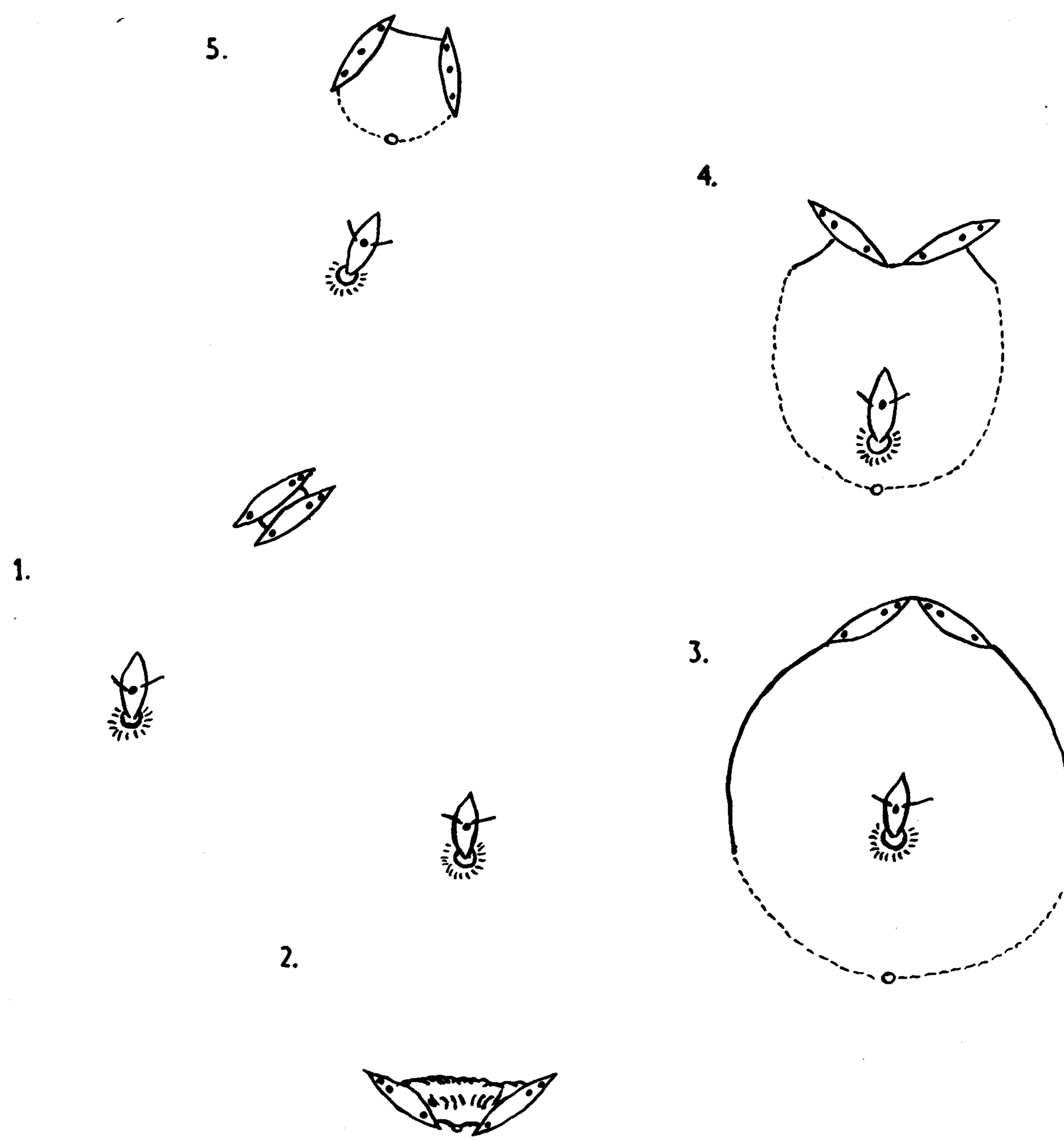


Fig. 2 B 3
Diagrammatic representation of the shooting and hauling of the Chirimila net on Lake Tanganyika at night, in five stages

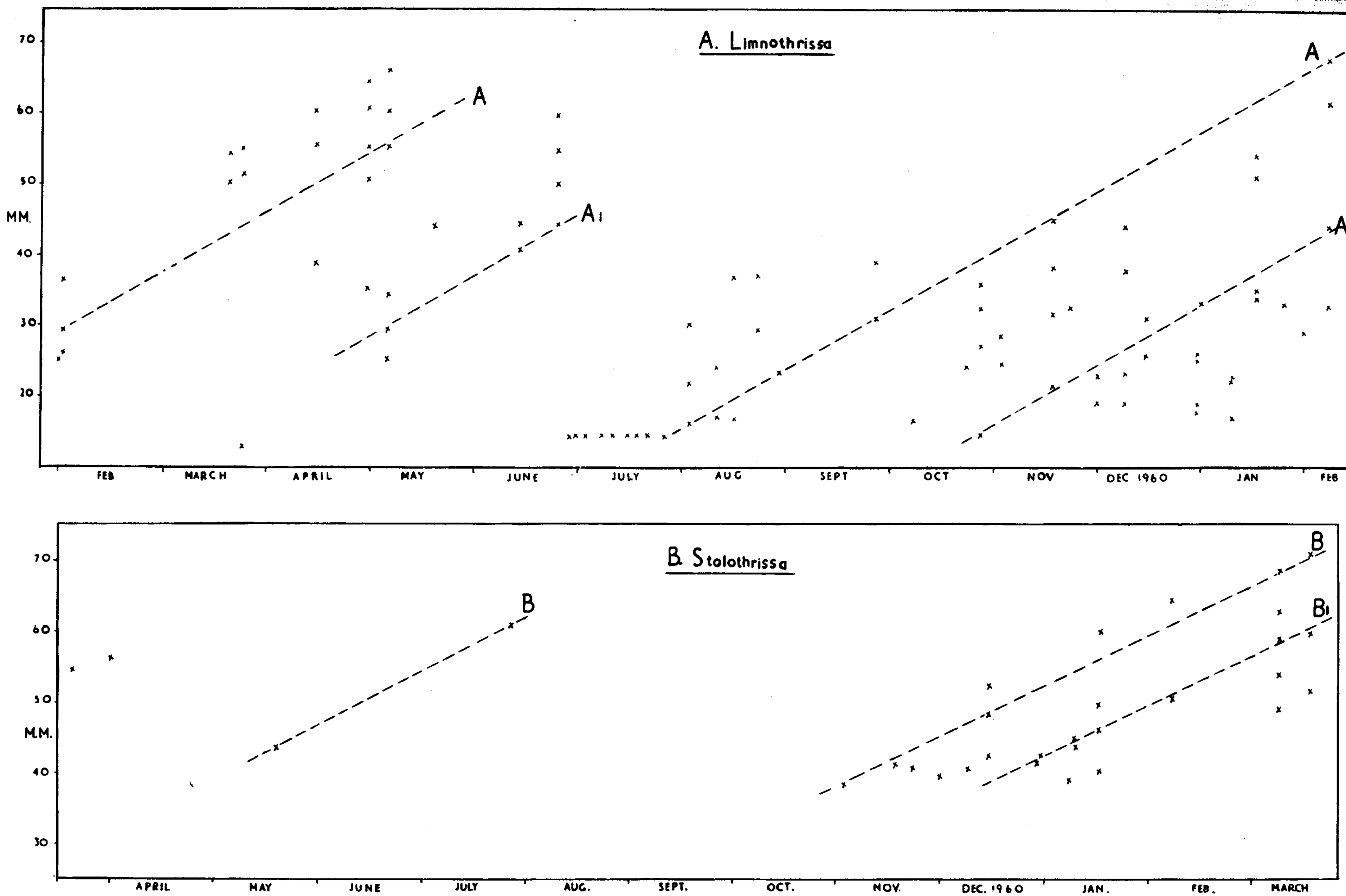
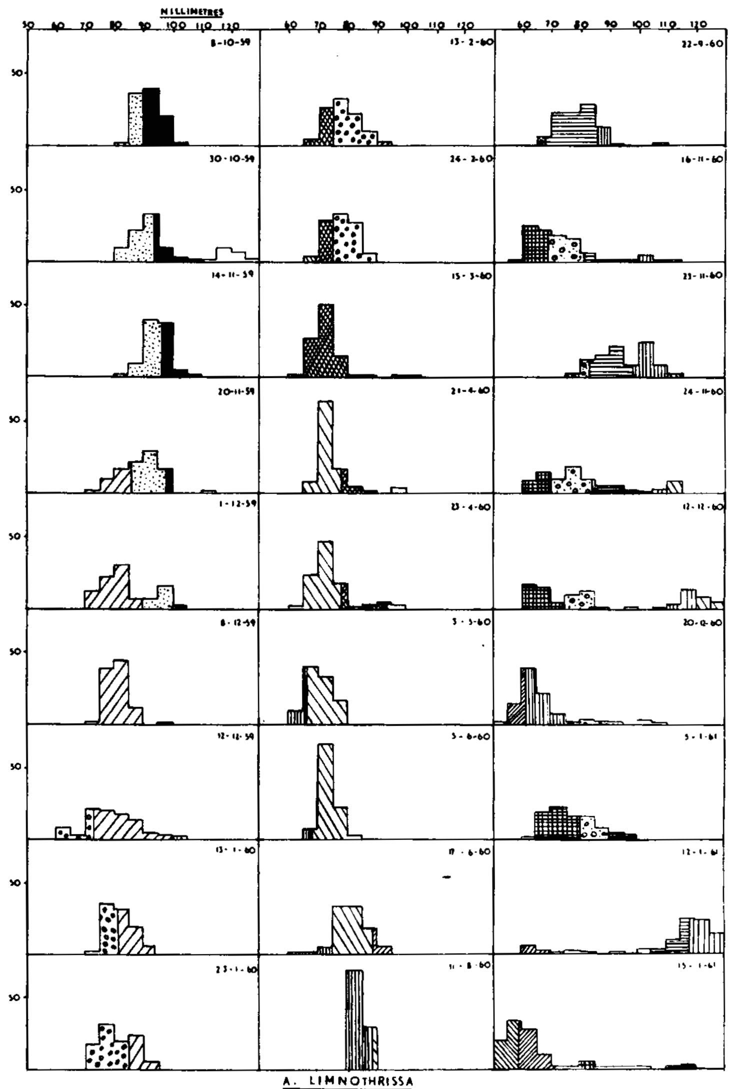


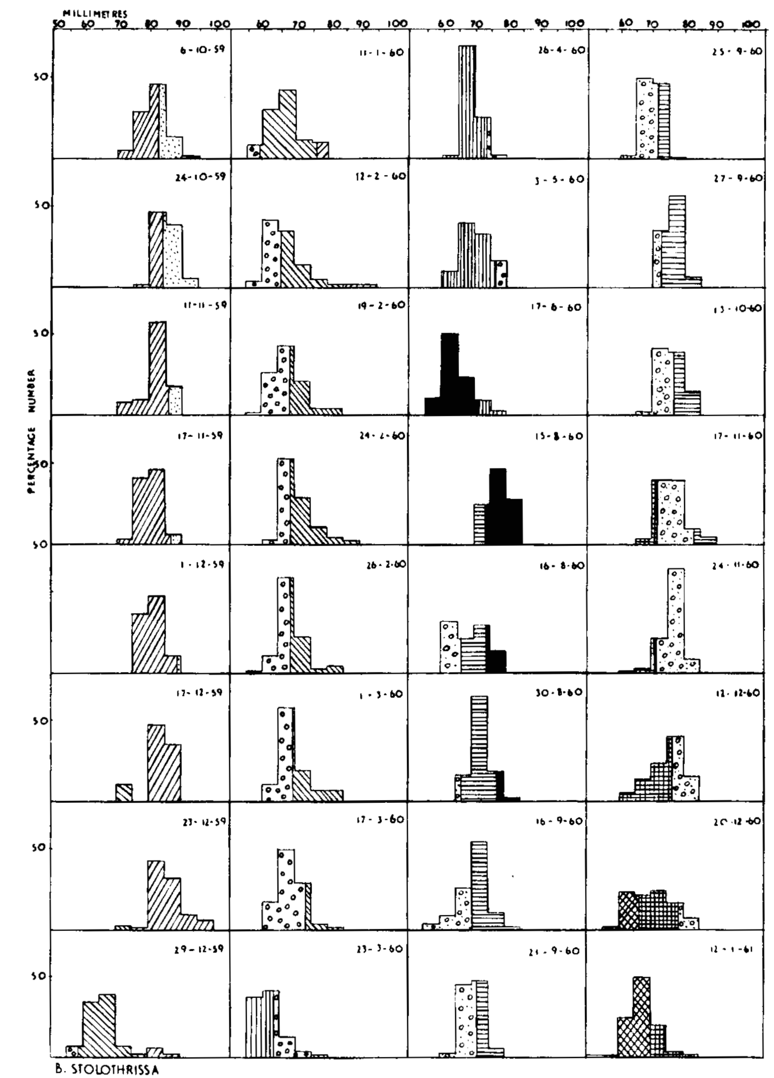
Fig. 2 B 4

Scatter graphs of length-frequency modes of populations of *Limnothrissa* and *Stolothrissa* over a yearly period, showing growth rates (examples in lines A, A1 and B, B1, etc.) of successive broods

A. *Limnothrissa*, February, 1960–February, 1961.

B. *Stolothrissa*, March, 1960–March, 1961.





Figs. 2 B 5 A and 2 B 5 B

Histograms showing the size composition of (*a*) *Limnothrissa* and (*b*) *Stolothrissa* in samples taken by various means between October, 1959, and January, 1961. Each sample is divided into groups according to standard length, the range of each group being 5 mm. (thus there can be sixteen length-groups between the lengths of 50 and 130 mm.). The number of fish in each group is expressed as a percentage of the sample. An attempt is made to trace the fate of each brood, its recruitment, growth and ultimate disappearance, by various types of shading. The shading conventions represent different broods and have no relation to one another

NOTE.—(*a*) The typically regular increase of a brood to a maximum abundance, and the decline as it disappears. The increase is due to a recruitment to the mature stocks and the decline seems largely due to predators.

(*b*) There is a major recruitment of young fish of both species in December.

(*c*) A wider size range has resulted from the more comprehensive sampling which was commenced in November, 1960, especially in the case of *Limnothrissa*.

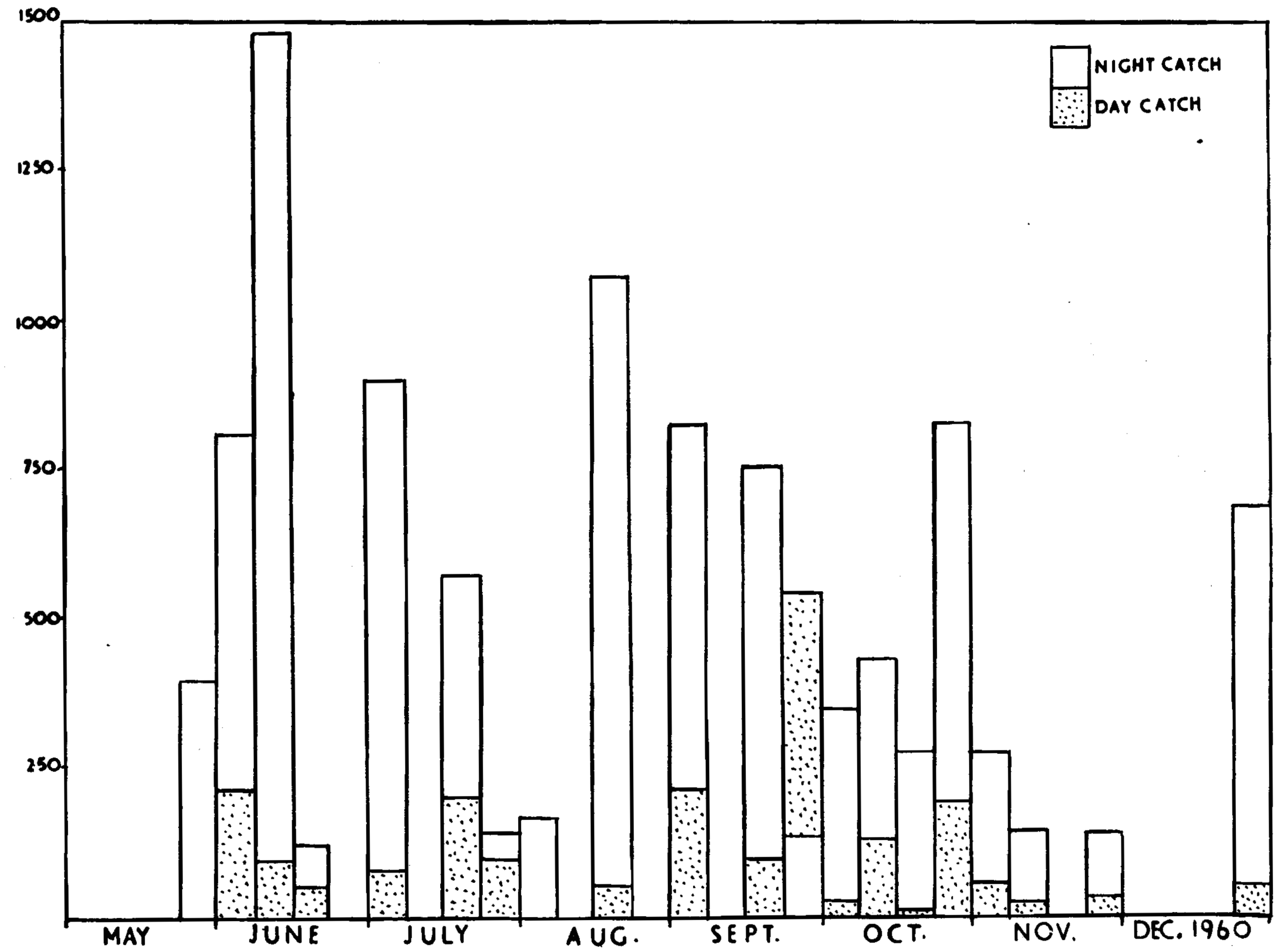


Fig. 2 B 6
Seining data from Lake Tanganyika. Day and night catches (in actual numbers) for all species

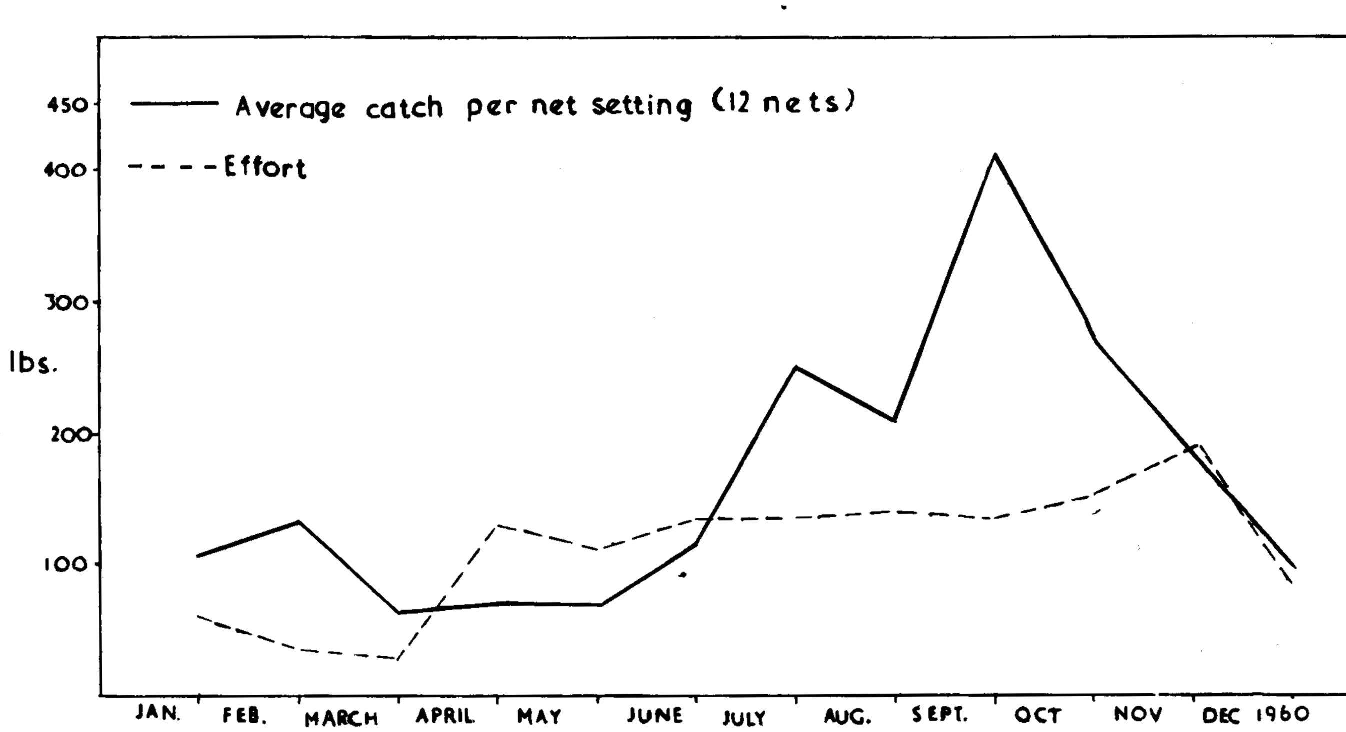


Fig. 2 B 7
Average catch per setting of a fleet of twelve nets, over the period February–December, 1960. A unit of effort is also expressed (*see* text)

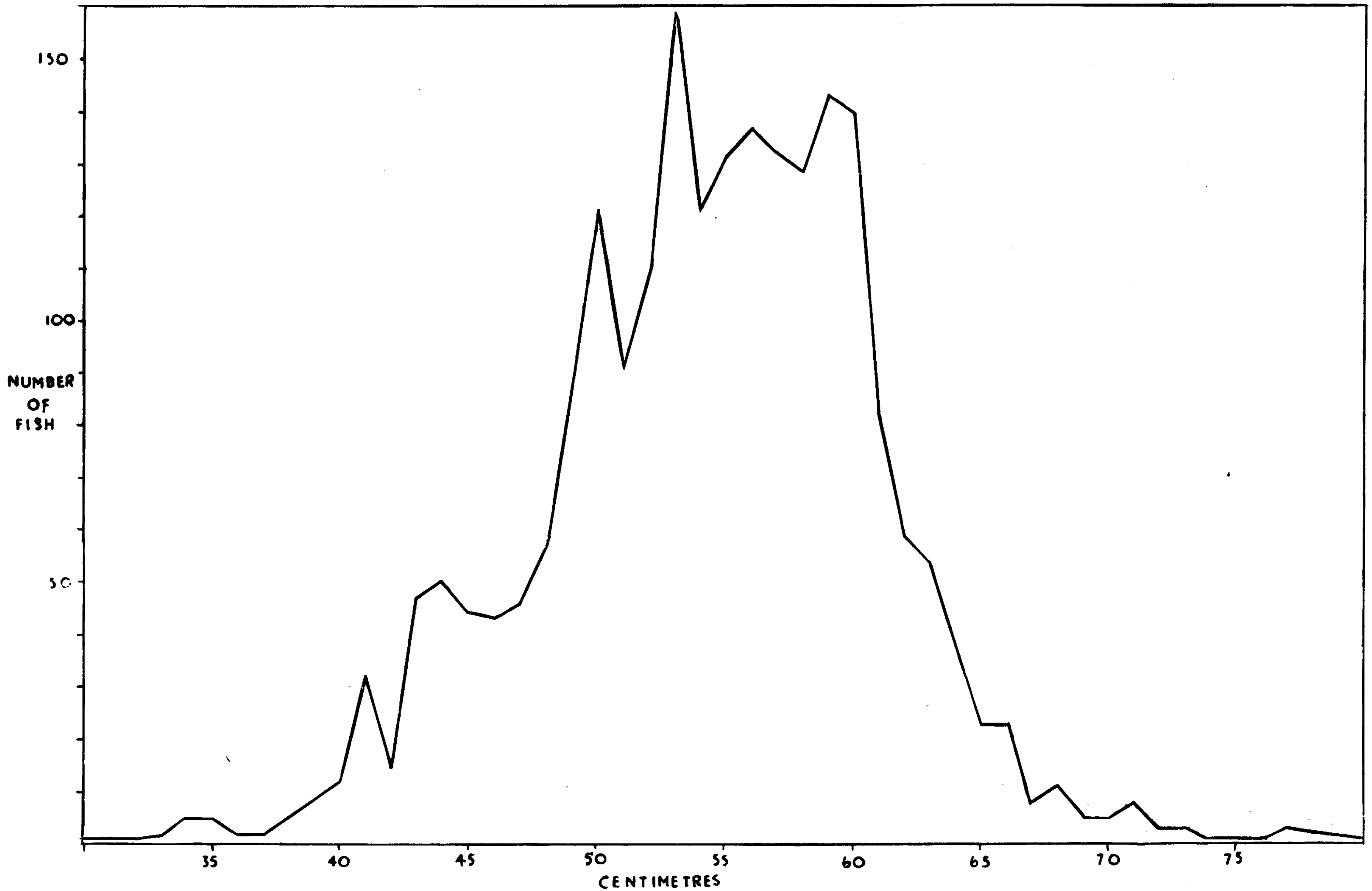


Fig. 2 B 8
The probable selectivity curve for *Lates mariae* taken in the four-inch-mesh (stretched) gill-nets

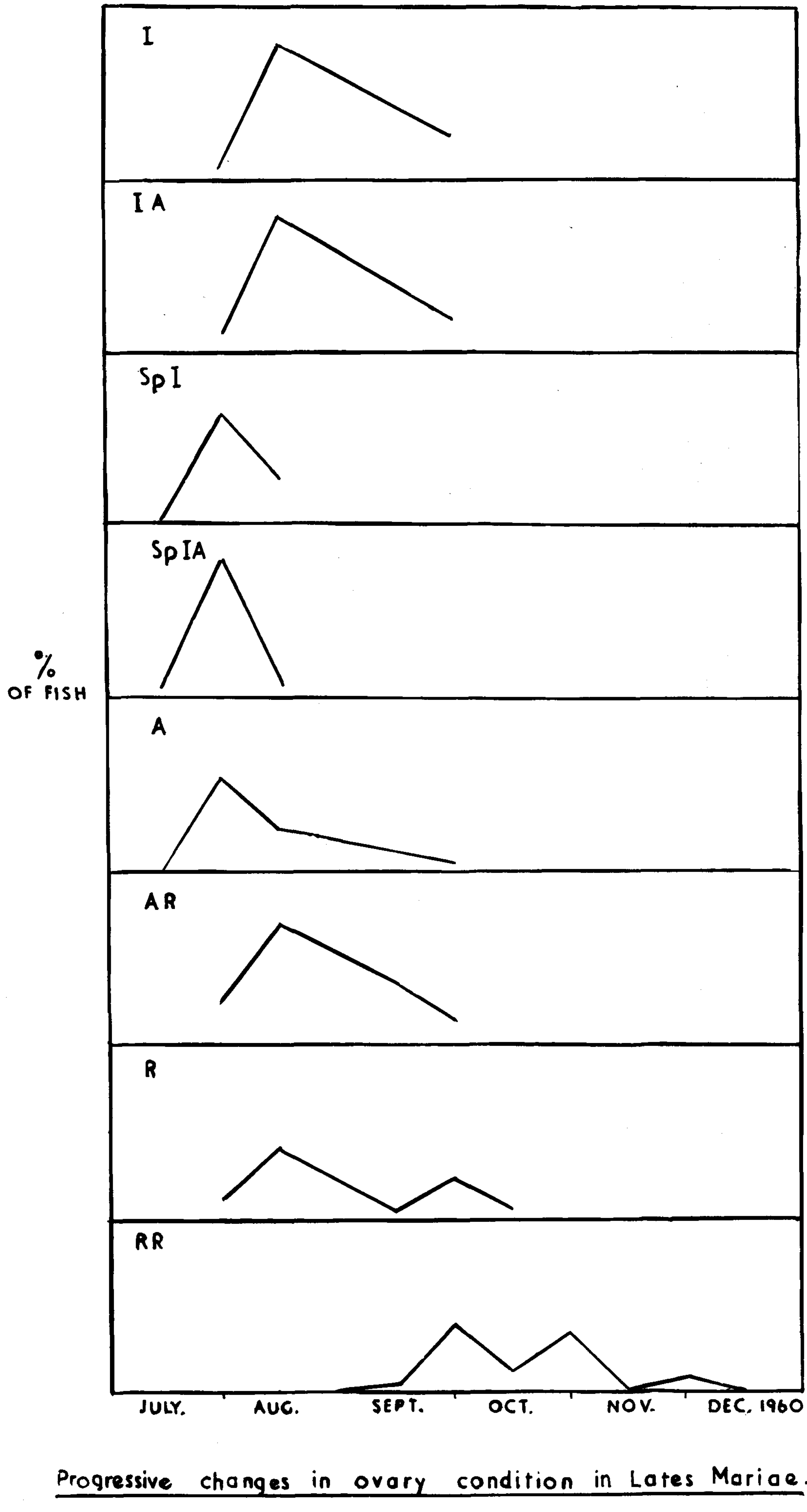


Fig. 2 B 9
Progressive changes in ovary condition in *Lates mariae* sampled from commercial gill-nets between July and December, 1960

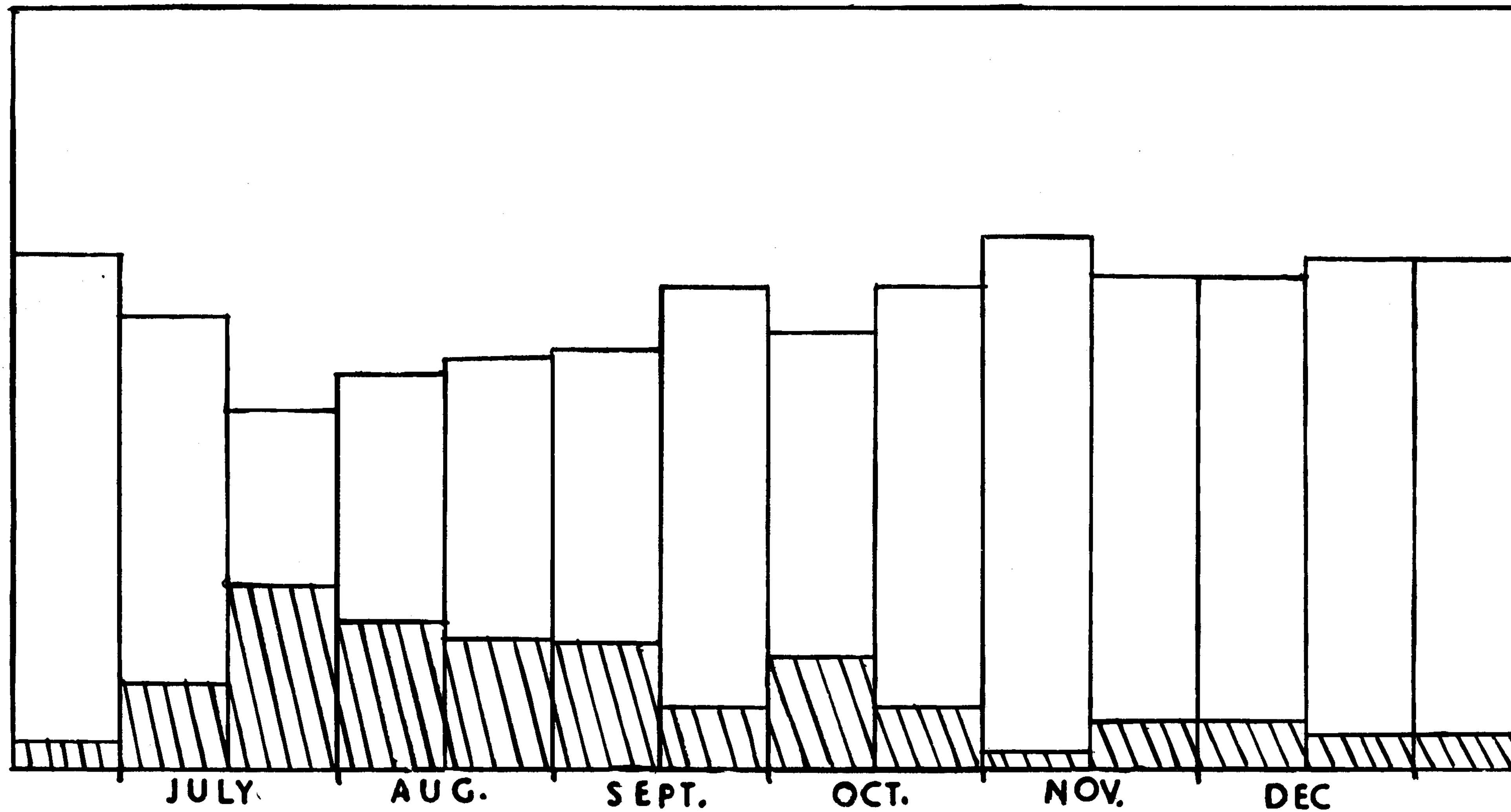


Fig. 2 B 10
Relative proportions of males and females of *Lates mariae* in the samples from commercial gill-nets of four-inch mesh

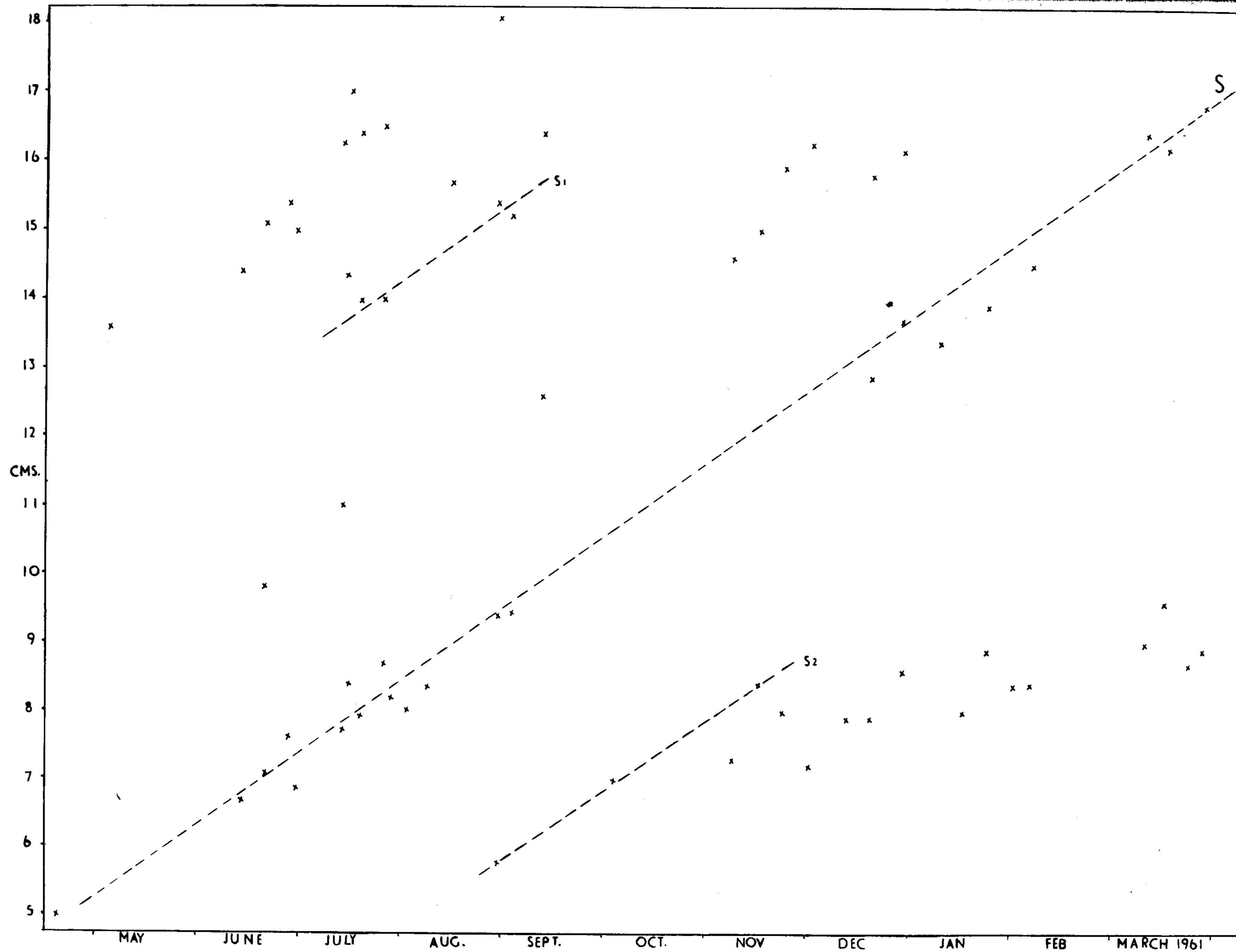


Fig. 2 B 11
Scatter graph of length-frequency modes of juvenile *Lates mariae* over the period May, 1960, to March, 1961, showing growth rates (examples in lines S, S1, S2, etc.) of successive spawnings

3. ACTIVITIES OF THE ORGANISATION IN NYASALAND

A.—Report for the Year Ended 31st December, 1960

The arrival of Mr. D. Eccles in February, 1960, brought the establishment of Fishery Research Officers up to two. Mr. Iles left in March on vacation leave for six months so that for most of the year only one scientist was present. The launch *Search* arrived in December, 1959, but was put out of action almost immediately and was not available again until mid-March. She was transferred to the Fisheries Officer at Fort Johnston at the beginning of July. The launch *Edmund Rhoades* arrived in late March and was available under an agreement with the Provincial and District Administration. Although she could not be used in the south of the lake, the arrangement worked smoothly and well, and there was no instance of work being held up as a result of conflicting needs.

In July and August the Senior Fishery Assistant went to the south of the lake to conduct a gill-net experiment on *Labeo mesops*. While catches were low, it represented a demonstration that such experiments can be efficiently and adequately conducted by unqualified but trained staff. Even though the results of the 1960 *Labeo* experiment were comparatively meagre, it has been possible, by further analysis of earlier experiments, to gain much further valuable information relating to this species and this is reported below.

Hydrological work during the year indicated that no general overturn occurred, but temperature profiles obtained on a long cruise indicate mechanisms by which transfer of nutrients and heat across the thermocline can take place.

The library is in the process of being reorganised and expanded by Mr. D. Eccles, and about 500 reprints were received during the year. We are most grateful to the authors for their generosity.

During the year plans for the establishment of a new and main base at Monkey Bay were prepared. Work had not started by 1961, but it is hoped that a move to the centre of gravity of the Nyasan Fisheries will take place in 1961.

A meeting of all J.F.R.O. scientists was held at Nkata Bay in October, before the Advisory Committee meeting and it proved to be both stimulating and useful. It is to be hoped that such meetings will become a regular feature since it became clear that much mutual benefit is to be derived.

Mr. Eccles attended a C.S.A. symposium at Lusaka on the major African lakes in August. At this meeting two contributions by Mr. Iles were presented.

In May the laboratory was visited by Dr. Kevin Burke of the Atomic Energy Division of the Geological Survey of Great Britain who was doing a survey of dissolved gases in the abyssal water. We are indebted to him for permission to publish his results.

B. Research Results, Lake Nyasa

I.—Hydrology

Routine sampling at the deep station off Nkata Bay has been maintained although it was interrupted from late January to mid-March as the *Search* had broken down, and the *Edmund Rhoades* had not yet arrived. From June to August sampling was again interrupted, this time by the loss of the water bottle and thermometer when the wire broke. Spares were borrowed from J.F.R.O. in Northern Rhodesia, but did not arrive until early August. Thus no samples were taken over the critical period of the coldest weather when the southerly winds are at their fiercest. This emphasises the necessity of maintaining a stock of spare equipment, and orders have been placed for three extra water bottles and reversing thermometres, in addition to the replacements for those lost. From mid-August until early September there was another hiatus due to the absence of Mr. Eccles at the C.S.A. symposium and of Mr. Mzumara, who was conducting the *Labeo* experiment in the south-east arm.

Until December, 1960, all hydrographic work was done using Swiss apparatus. This was not suitable for use in this lake as it must be attached to an eye at the end of the sampling wire, and it is therefore impossible to use several bottles in series. With this apparatus it was necessary to spend at least three hours to obtain each series of samples. Further, the wide hinged lids of the bottle, the upper of which was kept closed only by a small spring can be forced open by gas escaping from solution as the gear is raised from considerable depths, allowing contamination of the sample. This equipment is therefore being replaced by Knudsen bottles, which can be used serially, and have a more effective closure mechanism. From 7th to 24th January, 1961, both sets of gear were used in series. In December, 1960, a thermistor was used as well as the reversing thermometer, but was not operated below ninety-four metres.

Temperature

Deep Station Observations

Temperature data from the deep station are tabulated under two categories:

Table 3 B 1—Temperature readings at specified depths.

Table 3 B 2—Levels of isotherms obtained graphically from temperature profiles.

On 30th December, 1959, a thermocline was present in a very rudimentary form, there being a gradual increase in temperature towards the surface with a maximum rate of increase between twenty and thirty metres. By 5th January, 1960, a definite thermocline was established at about forty to forty-five metres. This persisted until June, but varied in level from forty to ninety metres, showing a general downward trend with time, upon which are superimposed fluctuations of the order of twenty to thirty metres (*see* below). By 13th August, 1960, there was a temperature difference of only 0.45°C. between forty and 200 metres, most of the change occurring between 100 and 120 metres. The upper 100 metres had warmed up through about 1°C. by the end of September, but on 12th October there was no trace of a thermocline above 200 metres, the temperature rising gradually all the way to the surface. On 21st November, 1960, a poorly defined thermocline had developed at about forty metres, but was partly dispersed by 29th November. It began to reform in mid-December, but was not firmly established until mid-January, 1961.

In addition to the thermocline discussed above, which breaks down and is reformed annually, there is a more permanent stratification at about 200 metres. The minimum temperature recorded in the period under review was 22.58°C. at 250 metres on 28th March, 1960, and only once (12th October, 1960) was a temperature of over 22.70°C. recorded below 220 metres (22.72°C. at 243 metres). The minimum temperature observed at twenty metres was 23.68°C. on 4th August, 1960, from which it would appear that the lake did not approach an isothermal condition. This contrasts with 18th August, 1958 (figure 3 B 1 A), when the lake became isothermal from 110 metres to the surface, and dropped only 0.06°C. in the next forty metres, and a further 0.12°C. from 150 to 200 metres before dropping a further 0.25°C. between 200 and 220 metres. Despite this small temperature difference between 220 metres and the surface on that occasion overturn apparently did not take place*, though apparently some enrichment occurred. In the two years subsequent to that the temperature at 250 metres has risen by only about 0.03°C., indicating that mixing on a large scale has not occurred, though on 25th April, 1960, there appears to have been some temporary local mixing (figure 3 B 1 B). Temperature, oxygen and silica profiles in figures 3 B 1 C and 3 B 1 D show this lower thermocline distinctly. Unfortunately it has been impossible to obtain samples from below 250 metres as we have only 250 metres of wire and so we have no estimates of the amounts of nutrients bound up in the abyssal layer.

Cruise Observations

In addition to the deep station data a series of temperature readings were made with a thermistor thermometer in the course of a triangular cruise from Nkata Bay, ninety miles south to Kota Kota, then thirty miles north-east across the lake to Metangula in Portuguese East Africa, and finally back to Nkata Bay. The cruise was undertaken during the second week of December, 1960, the positions of the stations being shown on the accompanying map of the central portion of Lake Nyasa (figure 3 B 2). The depths of selected isotherms are shown in figure 3 B 3.

On both the southward and the northward legs of the cruise the thermocline shows a marked wave form, with an amplitude of about twenty-two metres. From Kota Kota towards Metengula there is a slope down to the north-east, representing a diagonal traverse across the face of this internal wave. A significant fact which emerges from the data is that the thermocline is less well developed on that part of the internal wave which approaches the surface, some of the isotherms diverging here (figure 3 B 3). The most likely explanation for this is that horizontal currents are generated by the displacement, of the epilimniom. the resultant turbulence bringing about some mixing.

It has not yet been established whether these waves represent part of a plurinodal seiche, or whether they are transient travelling phenomena initiated by local disturbances or currents, though the seiche hypothesis is the more probable. It is also unlikely that the waves are simple, as it is to be expected that there will be a transverse as well as a longitudinal component and that there may be a complex of different periodicities. To elucidate this it will be necessary to amass a large amount of data from both the deep station and from further such cruises, and if possible to have more than one set of equipment in operation at any one time.

The discovery of these internal waves and the partial dispersal of the thermocline as a result of the associated turbulence clarifies the observed behaviour of the thermocline at the deep station. It explains both the fluctuations in level of the thermocline, and its apparent dispersal and re-establishment, though part of the dispersal may be due to the greater effect of wind when the thermocline approaches the surface.

These observations also throw light on the problem of the greater fertility of the south-east arm of the lake, where the main commercial fisheries are centred. It has been suggested that this is due to the tilting of the thermocline under the influence of the strong south-east winds of the cold season, with consequent upwelling of nutrient-rich water, but this mechanism would not operate in the hot season when the prevailing winds are north-easterly and of lower average

* Joint Fisheries Research Organisation annual report, 1959.

velocity. However, in shallower water with a gently sloping bottom, as is the case in the south-east arm where the slope is about 1.5 m/Km., the thermocline will intersect the bottom during the hot season. Under these circumstances a rise of even a few metres in the thermocline over a period of several days will generate considerable horizontal currents below it with an inflow of cold water, as was observed by Beauchamp for Lake Victoria.* The resultant turbulence will not only accelerate the transfer of nutrients across the thermocline but will also facilitate their regeneration from the bottom deposits.† This emphasises the necessity for intensive study of the physics and chemistry of this area.

Chemistry

The only determinations made were those for oxygen and silica in samples from the deep station. These are shown in table 3 B 3.

As in the period 1958–59‡, silica was present in very low concentrations in the upper seventy metres. Only once did it exceed 0.5 p.p.m. at any level above eighty metres. On 25th April, 1960, a concentration of 1 p.p.m. was found at seventy and sixty metres and 0.5 p.p.m. occurred at fifty and forty metres. It is obvious from this together with the temperature data, that some mixing occurred then as is shown by the near uniformity of the curves for temperature, silica and oxygen number from 120 to 250 metres (figure 3 B 1 B). On that day a fall of 3.01 inches of rain was recorded at Nkata Bay, and there is little doubt that local cooling as a result of this caused the observed phenomena. However, there was no significant increase in silica concentration during or after the cold season, confirming the deduction from temperature data that the lake did not circulate completely.

On all occasions oxygen was present at a concentration of 7–8 p.p.m. down to the thermocline, from which it showed a gradual decline until, at 200 metres, it was virtually absent. Samples from deep levels may have become contaminated by partial opening of the bottle as indicated above. This would explain the presence of hydrogen sulphide at 250 metres on 3rd November, 1960, although 0.2 p.p.m. of oxygen was recorded.

At any given level there are large fluctuations of oxygen and silica concentration, as a result of the internal waves demonstrated above.

In May, 1960, Dr. K. Burke, of the Atomic Energy Division of the Geological Survey of Great Britain, visited Lakes Nyasa and Tanganyika to sample the dissolved gases in the abyssal layers. Samples were obtained from 450, 400 and 300 metres in the very deep water eight miles north-east of Nkata Bay. A winch was made available to him for use on Lake Tanganyika, where samples were obtained off Kigoma. The gases come out of solution as the pressure is released, and are collected under water. This could cause opening of the Swiss water bottle used here, as mentioned earlier.

The gas analyses were made by N. J. D. Prosser of the Mass Spectrometer Group, A.E.R.E. Harwell. The results are shown in the following table.

Table 3 B 4

Average compositions of the dissolved gases

	Volume	
	Lake Nyasa	*Lake Tanganyika*
	%	%
Methane	0·2	0·2
Nitrogen	87·5	94·8
Argon	1·0	1·1
Carbondioxide ...	11·3	3·8
Hydrogen	tr.	0·2

The above observations bear out the suggestion of Beauchamp (1953)§ that the lake only rarely undergoes a complete circulation, although the upper 200 metres and thus the shallower parts of the lake do circulate more or less completely every year. The fact that a stable stratification can be maintained by a temperature difference of as little as 0.5°C. is surprising, but is a result of the great depth of the lake and the enormous amount of energy required to bring about mixing of very thick layers although only a small density difference exists. The gradual warming of the abyssal layer over a period of years, as a result of slight mixing, and of the flow of geothermal heat through the crust, will bring about a situation in which complete circulation can occur. Thus the lake would show a fertility cycle of several years, periodic bursts of productivity being followed by longer periods of decline, as is borne out by figures from the model fishery of the Department of Game and Fish and Tsetse Control at Nkata Bay. Tabble 3 B 5 shows the number of hundreds of yards of gill-net set per month and catch per unit effort for 1959 and 1960. A general decline in catch is shown in the figures. and it is unlikely that this can be attributed to overfishing as there is no large gill-net fishery in the area.

*East African Fisheries Research Organisation annual report for 1953.
†Thermistor observations in the south-east arm in February, 1961, appear to confirm this hypothesis.
‡Joint Fisheries Research Organisation annual report, 1959.
§Hydrological data from Lake Nyasa—*J. Ecol.*, **41**, 2, 226–239.

Table 3 B 1

TEMPERATURE READINGS AT VARIOUS DEPTHS, DEEP STATION, NKATA BAY

T=Reversing Thermometer; R=Resistance (Thermistor) Thermometer

Depth	30–12–59 T	5–1–60 T	11–1–60 T	16–3–60 T	28–3–60 T	4–4–60 T	8–4–60 T	22–4–60 T	25–4–60 T	29–4–60 T	10–5–60 T*	3–6–60 T	7–6–60 T	4–8–60 T	13–8–60 T†	30–9–60 T
0 ...	27·44	28·34	27·58	27·42	27·50	27·00	27·38	26·88	27·50	—	27·85	25·50	—	—	24·90	24·05
10 ...	27·40	27·80	27·37	27·32	—	27·06	27·00	26·45	27·02	—	26·62	25·50	—	—	23·90	24·48
20 ...	27·26	27·65	27·37	27·28	—	27·06	26·96	26·45	26·84	—	26·58	25·50	—	23·68	23·80	24·48
30 ...	26·49	27·59	27·37	27·26	—	27·02	26·90	26·45	26·70	—	26·58	25·50	—	—	23·56	24·45
40 ...	25·71	27·50	27·37	27·20	—	27·00	26·80	26·42	26·52	—	26·52	25·50	—	—	23·34	24·45
45 ...	—	26·55	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50 ...	25·10	25·86	27·30	26·38	—	26·98	26·80	26·40	26·12	26·60	26·44	25·50	—	23·67	23·32	24·30
55 ...	—	24·45	27·10	—	—	—	—	—	25·90	—	—	—	—	—	—	—
60 ...	24·83	25·09	25·64	24·66	27·20	25·56	24·94	26·34	24·22	25·80	25·82	25·50	—	—	23·32	24·20
70 ...	24·40	24·59	24·90	24·00	—	24·48	24·08	26·20	23·70	25·80	25·12	25·40	—	—	23·30	24·20
80 ...	24·18	24·18	24·25	23·78	24·98	24·02	23·72	25·98	23·50	25·80	23·98	24·85	—	—	23·24	24·18
85 ...	—	—	—	—	—	—	—	24·60	—	—	—	—	—	—	—	—
90 ...	23·99	23·89	23·79	23·48	—	23·64	23·48	23·88	23·38	25·20	23·68	23·50	—	—	23·26	24·02
100 ...	23·70	23·58	23·59	23·28	23·88	23·52	23·32	23·30	23·20	23·40	23·60	23·42	—	23·12	23·36	23·58
120 ...	23·45	23·28	23·09	23·10	23·72	23·18	23·10	23·12	23·05	23·20	23·14	23·25	23·30	—	23·00	23·20
150 ...	23·18	22·99	22·98	23·02	23·26	22·88	22·84	22·98	22·90	22·98	23·00	23·00	23·10	—	23·04	—
175 ...	—	—	—	—	—	—	—	—	—	—	22·97	—	—	—	—	—
200 ...	22·85	22·74	22·78	22·88	22·90	—	22·70	22·78	22·90	22·80	22·69	22·70	22·80	22·92	22·96	22·70
220 ...	22·77	22·70	22·70	22·78	22·70	—	22·66	22·70	22·90	22·78	—	22·70	22·75	—	22·90	—
225 ...	—	—	—	—	—	—	—	—	—	—	22·67	—	—	—	—	—
250 ...	22·68	22·67	22·65	22·78	22·58	—	22·62	22·65	22·90	22·70	—	22·70	22·65	22·70	22·62	22·68

Depth	12–10–60 T	3–11–60 T	21–11–60 T	23–11–60 T	29–11–60 T a.m.	29–11–60 T p.m.	6–12–60 T‡	15–12–60 T	19–12–60 T	19–12–60 R	23–12–60 T	23–12–60 R	7–1–61 T	13–1–61 T	21–1–61 T	24–1–61 T
0 ...	24·94	27·24	27·88	26·88	27·25	27·85	27·52	28·12	27·70	27·80	27·70	27·70	28·16	18·10N	28·25	28·24
10 ...	24·82	26·30	27·08	26·85	27·10	27·80	27·48	28·24	27·70	27·70	27·55	27·61	28·18	28·50F	28·30	28·30
20 ...	24·42	26·00	27·08	26·85	27·05	27·00	27·42	28·20	27·68	27·66	27·30	27·34	28·10	28·10N	26·02	28·20
30 ...	23·34	25·76	27·02	26·80	27·02	27·00	27·14	28·14	27·24	26·93	26·50	26·51	27·48	28·10F	26·80	28·25
40 ...	24·10	25·12	26·90	—	26·90	26·58	26·83	27·24	26·20	26·38	25·32	25·40	26·46	27·72N	25·60	27·40
50 ...	23·82	24·80	25·50	—	—	26·05	26·32	26·20	25·22	25·17	24·58	24·56	25·10	25·81F	24·68	25·80
60 ...	23·70	24·30	24·70	—	—	24·80	—	24·98	24·40	24·43	23·75	23·75	24·39	25·04N	24·20	24·70
70 ...	23·45	24·08	23·96	—	—	23·90	—	24·37	23·98	23·97	23·60	23·67	24·04	24·45F	24·02	23·90
80 ...	23·22	23·90	23·78	—	—	23·64	—	23·88	23·80	23·67	23·50	23·48	23·68	24·40N	23·74	23·71
90 ...	23·20	23·83	23·60	—	—	23·48	—	23·56	23·52	23·37	23·28	23·42	23·70	24·30F	23·48	23·40
100 ...	23·18	23·44	23·56	—	—	23·30	—	23·62	23·46	—	23·20	—	23·60	23·40N	23·50	23·28
120 ...	23·08	23·44	23·38	—	—	23·10	—	23·28	23·20	—	—	—	23·15	23·20F	23·20	23·20
150 ...	23·00	23·40	23·08	—	—	22·82	—	23·20	23·05	—	22·98	—	23·12	23·22N	23·20	22·80
200 ...	22·95	22·82	22·78	—	—	22·70	—	22·98	22·90	—	22·84	—	22·70	22·68F	22·80	22·65
220 ...	22·80	—	22·70	—	—	22·70	—	22·85	22·79	—	22·80	—	22·68	22·85	22·70	22·65
240 ...	—	—	—	—	—	—	—	22·70	22·70	—	—	—	—	—	—	—
250 ...	—	22·68	22·70	—	—	22·68	—	—	—	—	22·70	—	—	—	—	—

*8 miles off-shore. †Small boat in violent motion. ‡Intermediate depths also read.

Table 3 B 2

ISOTHERMS AT ·2°C. INTERVALS, DEEP STATION, NKATA BAY

	30–12–59	5–1–60	11–1–60	16–3–60	28–3–60	4–4–60	8–4–60	22–4–60	25–4–60	29–4–60	10–5–60 8 miles out	3–6–60	7–6–60	13–8–60	30–9–60
29·0 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28·8 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28·6 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28·4 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28·2 ...	3·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28·0 ...	—	6·5	—	—	—	—	—	—	—	—	—	—	—	—	—
27·8 ...	—	10·0	—	—	—	—	—	—	—	—	0·2	—	—	—	—
27·6 ...	—	29·0	—	—	—	—	—	—	—	—	2·0	—	—	—	—
27·4 ...	10·0	40·5	9·0	3·0	—	—	—	—	2·0	—	3·5	—	—	—	—
27·2 ...	21·0	41·5	52·5	40·0	60·0	—	—	—	6·5	—	5·0	—	—	—	—
27·0 ...	23·5	42·5	55·5	42·5	61·8	40·0	10·0	—	11·5	—	6·5	—	—	—	—
26·8 ...	26·0	43·5	56·2	45·0	63·7	51·4	50·0	2·0	22·5	—	8·0	—	—	—	—
26·6 ...	28·5	44·8	56·9	47·5	65·5	52·8	51·0	6·5	35·5	50·0	15·0	—	—	—	—
26·4 ...	31·2	46·2	57·5	50·0	67·3	54·2	52·2	50·0	43·0	52·5	50·5	—	—	—	—
26·2 ...	33·8	47·8	58·2	52·0	69·1	55·3	53·3	70·0	48·2	55·0	54·5	—	—	—	—
26·0 ...	36·5	49·4	58·8	54·0	70·9	56·8	54·4	79·0	53·0	57·5	58·5	—	—	—	—
25·8 ...	39·2	51·0	59·5	55·4	72·7	58·2	55·5	80·7	55·4	70·0	61·8	—	—	—	—
25·6 ...	42·0	53·4	60·5	56·3	74·5	59·8	56·6	81·4	56·0	83·3	64·0	—	—	—	—
25·4 ...	45·0	56·6	63·0	57·2	76·3	61·5	57·7	82·1	56·6	86·6	66·5	70·0	—	—	—
25·2 ...	47·2	58·0	65·8	58·1	78·0	63·5	58·8	82·8	57·2	90·0	69·0	73·5	—	—	—
25·0 ...	53·5	61·5	68·5	59·0	80·0	65·3	59·9	83·5	57·8	91·1	70·6	77·0	—	—	—
24·8 ...	60·5	64·5	71·5	60·0	83·2	67·0	62·0	84·2	58·4	92·2	71·5	80·3	—	1·0	—
24·6 ...	65·5	68·0	74·6	62·5	88·3	69·0	64·2	85·0	59·0	93·3	72·4	81·8	—	3·0	—
24·4 ...	70·0	73·0	77·8	65·0	90·0	72·0	66·5	86·4	59·6	94·4	73·6	83·3	—	5·0	43·3
24·2 ...	79·5	79·5	81·4	67·5	94·0	76·3	68·8	87·8	60·5	95·5	76·0	84·8	—	7·0	65·0
24·0 ...	89·5	86·5	85·5	70·0	97·5	80·5	72·5	89·2	64·5	96·6	79·8	86·3	—	9·0	90·8
23·8 ...	96·5	93·0	89·5	79·0	110·0	86·0	78·0	91·6	68·6	97·7	86·0	87·8	—	21·0	95·2
23·6 ...	108·0	99·5	99·5	86·5	127·5	93·0	85·0	95·0	75·0	98·8	100·0	89·3	—	28·5	99·6
23·4 ...	126·0	113·0	108·0	93·0	142·0	107·5	95·0	98·4	88·5	100·0	108·5	102·0	—	37·5	109·0
23·2 ...	149·0	129·0	116·0	108·5	160·0	118·5	112·5	111·0	100·0	120·0	118·5	127·0	135·0	105·0	120·0
23·0 ...	183·5	149·0	147·0	155·0	186·0	138·0	131·5	145·0	131·0	148·0	150·0	150·0	168·0	160·0	152·5
22·8 ...	216·0	189·0	199·0	215·0	210·0	172·5	165·0	197·0	—	200·0	191·5	185·0	203·5	212·5	185·0
22·7 ...	242·0	220·0	220·0	—	220·0	—	200·0	220·0	—	240·0	199·0	200·0	234·0	220·0	200·0
22·6 ...	—	—	—	—	245·0	—	—	—	—	—	—	—	—	—	—

Table 3 B 2—*continued*

ISOTHERMS AT .2°C. INTERVALS, DEEP STATION, NKATA BAY

	12–10–60	3–11–60	21–11–60	23–11–60	29–11–60 *a.m.*	29–11–60 *p.m.*	6–12–60 *R* *Wire angle taken into account*	15–12–60 *T*	19–12–60	23–12–60 *T*	7–1–61	13–1–61	21–1–61	24–1–61
28·4 ...	—	—	—	—	—	—	—	—	—	—	—	13·0	—	—
28·2 ...	—	—	—	—	—	—	—	19·8	—	—	—	18·0	13·0	30·5
28·0 ...	—	—	—	—	—	—	—	30·4	—	—	21·8	32·5	21·5	33·0
27·8 ...	—	—	1·0	—	—	10·0	—	32·6	—	—	24·8	38·0	22·0	35·4
27·6 ...	—	—	3·2	—	—	12·5	—	34·8	22·0	7·0	27·8	40·5	23·5	37·5
27·4 ...	—	—	6·8	—	—	15·0	19·5	37·0	26·5	16·5	30·8	41·6	25·2	40·0
27·2 ...	—	0·5	8·4	—	3·0	17·5	25·0	38·8	30·2	21·5	32·8	42·8	26·6	41·3
27·0 ...	—	2·4	33·0	—	32·0	25·0	35·5	40·3	32·1	24·0	34·8	44·0	27·2	42·6
26·8 ...	—	4·6	40·5	30·0	—	35·0	41·5	42·2	34·1	26·5	36·8	45·0	30·0	43·9
26·6 ...	—	6·8	42·0	—	—	39·5	45·5	43·9	36·0	29·0	38·8	46·0	31·6	45·0
26·4 ...	—	9·0	43·5	—	—	42·0	51·0	45·8	38·0	31·0	40·5	47·0	33·5	46·2
26·2 ...	—	13·6	45·0	—	—	44·2	52·5	47·8	40·0	32·6	42·0	48·0	35·3	47·4
26·0 ...	—	20·0	46·5	—	—	46·4	53·0	48·0	42·0	34·2	43·5	49·2	37·0	48·6
25·8 ...	—	28·0	48·0	—	—	48·7	53·8	50·2	44·0	36·9	45·0	50·5	38·6	50·0
25·6 ...	—	32·7	49·5	—	—	51·0	54·5	51·5	46·0	37·5	46·5	53·0	40·0	52·0
25·4 ...	—	35·7	51·6	—	—	53·3	52·2	53·0	48·0	38·2	48·0	55·5	42·2	53·8
25·2 ...	—	38·7	54·0	—	—	55·6	55·8	54·4	50·1	41·8	49·5	58·0	44·5	55·6
25·0 ...	—	43·8	56·4	—	—	58·0	—	54·4	52·5	44·4	51·5	60·6	46·8	57·4
24·8 ...	10·5	50·0	58·8	—	—	60·0	—	57·2	55·0	47·2	54·3	64·0	49·0	59·0
24·6 ...	15·5	53·9	60·8	—	—	62·5	—	61·4	57·5	49·8	57·0	67·4	52·0	61·5
24·4 ...	22·0	51·8	62·5	—	—	64·5	—	64·5	60·0	52·3	59·8	80·0	56·0	63·8
24·2 ...	36·0	64·5	64·2	—	—	66·7	—	67·8	65·0	55·0	65·5	91·2	60·0	66·2
24·0 ...	43·5	74·5	69·0	—	—	68·8	—	70·0	69·8	57·2	71·0	93·4	71·0	69·0
23·8 ...	51·5	90·6	79·5	—	—	74·0	—	75·0	80·0	59·8	77·0	95·6	78·0	75·5
23·6 ...	64·0	96·6	90·0	—	—	83·0	—	90·0	88·0	70·0	100·0	97·8	85·0	84·0
23·4 ...	72·5	150·0	113·5	—	—	95·0	—	112·5	105·0	86·0	109·0	100·0	107·0	90·0
23·2 ...	90·0	175·0	140·0	—	—	110·0	—	148·0	120·0	100·0	118·0	135·0	135·0	120·0
23·0 ...	150·0	200·0	164·0	—	—	131·0	—	192·5	166·0	146·0	165·0	171·0	174·0	135·0
22·8 ...	220·0	225·0	199·0	—	—	162·5	—	220·0	218·0	220·0	189·0	194·0	200·0	150·0
22·7 ...	—	248·0	220·0	—	—	200·0	—	227·0	238·0	250·0	200·0	198·0	220·0	185·0

TABLE 3 B 3

OXYGEN AND SILICA CONCENTRATIONS (PARTS PER MILLION) DEEP STATION, NKATA BAY

	30–12–59		5–1–60		11–1–60		16–3–60		28–3–60		4–4–60		8–4–60		22–4–60	
Depth	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*	O_2 *p.p.m.*	*Silica p.p.m.*
0 ...	8·76	TR	8·66	TR	8·42	TR	7·64	TR	—	—	8·30	TR	7·76	TR	7·68	TR
10 ...	8·80	—	8·60	—	8·40	—	7·60	—	—	—	7·70	—	7·70	—	7·68	—
20 ...	8·30	—	8·60	—	8·28	—	7·60	—	—	—	7·64	—	7·70	—	7·56	—
30 ...	8·40	—	8·56	—	8·02	—	7·50	TR	—	—	7·60	TR	7·44	TR	7·50	—
40 ...	8·30	—	8·30	—	7·90	—	7·20	0·5	—	—	7·52	0·5	7·24	·5	7·50	—
50 ...	7·90	—	8·26	—	8·30	—	7·00	0·5	—	—	7·40	0·5	7·10	·5	7·40	—
60 ...	7·62	—	7·40	—	7·64	TR	6·10	0·5	7·70	0·5	6·20	0·5	5·90	·5	7·20	—
70 ...	7·66	TR	7·28	TR	7·60	0·5	5·80	0·5	—	—	6·00	0·5	7·00	·5	7·10	TR
80 ...	7·24	0·5	7·00	0·5	6·80	0·5	5·70	1	7·20	0·5	5·90	0·8	5·24	·5	7·00	·5
90 ...	7·60	0·5	6·62	0·5	6·50	0·5	5·68	1·5	—	—	5·60	1	4·90	·5	5·30	·5
100 ...	6·28	0·5	6·36	1·0	6·00	0·5	5·40	1·8	5·40	0·5	5·52	1	4·40	1	4·68	1·5
120 ...	5·78	1	5·20	1·5	3·20	1·5	3·70	2·0	5·10	0·5	3·80	2	3·20	2	3·30	2·5
150 ...	4·70	1·5	3·50	3	0·90	3	3·40	3·0	4·80	0·8	1·20	3	1·60	3	3·20	3
190 ...	—	—	—	—	—	—	—	—	—	—	1·00	4·5	—	—	—	—
200 ...	2·20	3	1·60	4	0·00	4	1·80	3·5	1·60	3	—	—	0·40	4	1·50	4
220 ...	1·20	4	0·40	4·5	0·00	4·5	0·80	4	0·40	4	—	—	0·20	4	1·00	4
250 ...	0·80	5	0·40	5	0·00	5	0·60	4	0·00	6	—	—	0·00	6	0·80	5
	25–4–60		29–4–60		3–6–60		7–6–60		6–9–60		30–9–60		12–10–60		21–11–60	
0 ...	7·27	—	7·82	TR	8·00	TR	—	—	8·80	TR	7·30	TR	7·10	TR	7·30	TR
10 ...	7·60	—	8·38	—	7·96	—	—	—	8·10	—	7·8	—	7·70	—	7·60	—
20 ...	7·44	—	7·88	—	7·90	—	—	—	7·68	—	7·66	—	7·60	—	7·20	—
30 ...	7·36	—	7·70	—	7·96	—	—	—	7·80	—	7·64	—	7·28	—	7·60	—
40 ...	7·30	·5	7·80	—	7·90	—	—	—	7·20	—	8·30	—	7·24	—	7·80	—
50 ...	7·00	·5	8·70	—	7·90	—	—	—	7·60	TR	8·30	—	6·80	TR	7·80	—
60 ...	5·50	1	7·60	TR	7·90	—	—	—	7·60	·5	7·70	TR	6·10	·5	6·90	—
70 ...	4·90	1	8·10	0·5	7·60	TR	—	—	7·80	TR	7·40	·5	5·70	TR	6·20	—
80 ...	4·56	1	8·80	0·5	6·40	0·5	—	—	6·02	·8	7·10	·5	5·19	1	5·81	—
90 ...	4·00	1·5	8·30	0·5	4·80	1·5	—	—	5·95	·8	6·80	·5	4·90	1	5·70	—
100 ...	3·90	2	7·70	0·5	4·80	1·5	—	—	5·66	·8	5·95	·5	4·90	1	5·52	TR
120 ...	2·60	3	4·60	2	4·80	1·5	4·40	—	5·05	1	4·10	1·2	4·30	1	5·12	1
150 ...	1·30	3·5	2·60	3	3·20	2·5	3·40	—	2·50	3	—	—	3·50	1·8	3·15	2
200 ...	0·80	4	0·80	4	0·60	4	1·10	—	0·52	4	0·3	3	2·70	2·8	0·10	3
220 ...	0·60	4	0·80	4	0·40	4	0·80	—	0·40	4	—	—	1·05	3	0·05	4
243 ...	—	—	—	—	—	—	—	—	—	—	—	—	0·30	4	—	—
249 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·18	4
250 ...	0·00	4	0·00	5	0·40	4·5	1·00	—	0·49	4	0·20	4	—	—	—	—

TABLE 3 B 5

Catch data, all species, from model fishery nets, 1959 and 1960

	1959		1960	
Month	*Sets× 100 yards Stretched*	*C.P.F.*	*Sets× 100 yards Stretched*	*C.P.F.*
January ...	181	6·0	—	—
February ...	94	5·5	152	6·9
March ...	99	11·0	145	3·9
April ...	115	10·0	123	5·3
May ...	83	11·0	157	7·6
June ...	—	—	157	4·8
July ...	—	—	114	8·7
August ...	57	7·8	117	8·8
September ...	115	7·5	45	7·3
October ...	64	11·0	154	7·9
November ...	86	10·5	172	4·8
December ...	—	—	221	5·3

II.—THE LONG-LINE FISHERY

During December, 1960 and January, 1961 a number of observations were made of the long-line fishery for *Rhamphochromis* spp. and *Diplotaxodon* spp. This fishery is carried out from canoes, each man having a line about 100 yards in length, on the end of which is a wire spreader to which are attached two to five small hooks baited with *Engraulicypris* or with a spinner.

Observations were made from Nkukuti Point at Nkata Bay. A pair of Ross Stepmur 10×50 binoculars was used and it was possible to count the number of men in a canoe up to four miles away. Counts were made of the total numbers of canoes and of fishermen offshore from about three miles north to about four miles south of Nkata Bay. The observations are tabulated below:

TABLE 3 B 6

Average Nos.* of men and canoes engaged in long-line fishery—(No. of counts in brackets).

	December (17 *days*)		*January*	
	a.m. (9)*	*p.m.* (19)	*a.m.* (1)	*p.m.* (4)
Canoes	44	54·16	46	51·25
Men	77	98·16	68	89·25

Most of the fishermen come ashore at midday and go out again in the afternoon. In each period a man may catch from fifteen to forty-five fish, worth 2*d*. to 6*d*. each on the local market. The fishery is affected by weather, high wind causing the fishermen to come ashore though they often stay out in rain.

This fishery is active from November until March, but is at its peak in December, very few people engaging in it later in the season.

III.—FURTHER NOTES ON GILL-NET EXPERIMENTS FOR "LABEO MESOPS"

The 1959 J.F.R.O. annual report included a brief discussion of the results of a gill-net experiment carried out in the south-east arm of Lake Nyasa. The experiment was designed primarily to determine the selectivity of gill-nets for *Labeo mesops* but this aspect was not dealt with at that time since it was hoped that a further experiment in January, 1960 would amplify the results of the earlier one. The January, 1960, experiment could not be carried out as no launch was available but the 1959 experiment did give very valuable information which is set out below. Details of the experimental method are referred to in last year's report.

Gill-nets are highly selective for size since for a net of a given mesh size and a particular species there are upper and lower limits of size beyond which the probability that a fish which comes into contact with the net is caught or "gilled" is very low. A curve which describes the variation of the relative probability of capture between such size limits is the selectivity curve for that species and that size of net and would be expected to rise to a maximum as the size of fish increases, and thereafter decrease. Holt, on the assumption that the curve is a normal curve of error, has developed a method for determining this maximum, termed the Mean Selection Length (M.S.L.), and the standard deviation of the curve, these two parameters or constants then defining the curve uniquely. The 1959 experiment followed the method as laid down by Holt's theory. Two further assumptions were made, that the fishing power of gill-nets differing only slightly in mesh size are the same and that the standard deviations of the selectivity curves of such nets can be taken to be equal.

The basic assumption does not apply accurately, although as will be shown below it is accurate enough certainly to give a M.S.L. for *L. mesops* which is of direct application to problems concerning fisheries exploiting this species, and the general conclusions drawn from the results of this experiment are therefore of practical value.

General Catch Data

Table 3 B 7 gives for each net the numbers, mean length and mean weight for males and females and the sex ratio male/female. This sex ratio varies from about 3.0 to 0.79 falling off as mesh size increases. Figure 3 B 4 gives the length frequency histograms for males and females of the catches from all nets.

Females are more numerous in the larger length frequencies and the higher sex ratio in the larger size nets is explained on the grounds that these nets sample these length frequencies more efficiently. The total sex ratio is 1,614/1,443=1.12 but there is no reason to believe that the ratio representing the relative numbers of males and females hatched differs from 1.1.

It is clear however that sex ratios obtained from gill-nets of one size only can be misleading if there is any difference in the size structure of the populations of males and females. For *Bagrus meridionalis*, for instance, the five-inch gill-net gives a high proportion of females but over a range of mesh sizes the sex ratio is almost unity. Similar instances of anomalous sex ratios have been recorded for *Labeo cylindricus*, *Mormyrus longirostris* and *Haplochromis quadrimaculatus* so that interpretations of gill-net catches from nets of a single or a few mesh sizes must always be made with caution.

Growth Rates

Labeo mesops has a relatively short and well defined breed-season which coincides largely with the main rains. Lowe's data (Lowe 1952, p.68) is confirmed by observations over the past few years that fish ripen by December and run to rivers, streams and lagoons in the period January to March. A high proportion breed in February and for a general picture we can take mid-February as a mean birth date for the species as a whole. This is not likely to vary greatly from year to year. Neither is the growth rate, since temperature is not likely to be an important source of variation and as *L. mesops* is a bottom feeder it is not likely to be subject to great fluctuations in the availability of food. Certainly not of the same order as would a Zooplankton feeder or a Phytoplankton feeder experience. Bearing this in mind we can incorporate data from Lowe (loc. sit. pp. 121–124) and our own observations to build up a picture of the growth rate.

Lowe's figures for December, 1945 (loc. cit. p.121) show a sample of uniform size, obviously mainly of the same age distributed about a mean of 11.5 centimetres.

The following May another similar sample is distributed about a mean length of 16.5 centimetres. We can assume that this is the same year class. Figure 3 B 4 above allows us to calculate mean lengths for males and females of 25.4 and 27.3 centimetres which are associated with a date in mid-July. Mean lengths of breeding fish are, according to Lowe, 29.1 centimetres and 34.7 centimetres for males and females respectively and we assign these to mid-February. More information results from data concerning gonad development in the 1959 experiment. Female gonads were typically almost transparent and all were " inactive " although showing under microscopic examination individual oocytes. A proportion however, were suffused with a reddish discolouration while still showing under the microscope the typical appearance. This condition was found only in the larger females, mostly above mean breeding size and it was concluded that these individuals had bred at least once in earlier years.

TABLE 3 B 7

Catch data of *Labeo mesops* caught with each gill-net in the experiment.

Net No.	Mesh Size (mm.)	Mesh Size (in.)	Males No.	Males Mean Length (mm.)	Males Mean Weight (gm.)	Females No.	Females Mean Length (mm.)	Females Mean Weight (gm.)	Male/Female Sex Ratio
1	101·0	3¾	20	290·10	449·35	57	336·02	668·35	2·85
2	103·4	4	13	255·80	303·33	38	293·17	558·06	2·92
3	97·4	3¾	22	282·14	411·45	52	327·40	623·50	2·36
4	90·2	3½	34	294·56	467·29	80	320·36	582·07	2·35
5	84·9	3¼	100	294·51	458·60	154	300·84	491·96	1·54
6	77·7	3	173	277·68	379·73	267	282·44	404·67	1·54
7	71·4	2¾	289	262·10	311·48	322	274·59	355·04	1·11
8	66·2	2½	373	254·67	287·36	319	265·87	308·02	0·86
9	59·1	2¼	325	245·81	247·46	237	256·15	271·48	0·73
10	53·7	2	66	225·55	206·80	66	233·33	196·68	1·00
11	47·0	1¾	28	205·14	159·11	22	221·18	163·43	0·79

A similar phenomenon was examined for males. Figure 3 B 6 gives the length frequency histogram for these " bred " fish for males and for females. Means of 30.8 centimetres and 34.9 centimetres were calculated and it is assumed that these lengths are associated with individuals one year older than the main 1959 populations. Finally, figure 3 B 7 indicates a small population of males of mean length eighteen centimetres and a less obvious one for females of mean length approximately twenty centimetres which are concluded to be one year younger.

This data is plotted in figure 3 B 5 to give an estimate of the growth curve for *L. mesops*. On the time scale T_0=mid-February and the divisions are in months. The mid-December, 1944 population is assumed to be ten months old and the May, 1945 population fifteen months. The eighteen centimetres (male) population of 1959 and the twenty centimetres (female) population are seventeen months old. The main 1959 population is one year older and would reach mean breeding size in mid-February, 1960. The "bred" populations represent mainly fishes which bred in February, 1959, and would be a year older. The curve indicates that:

1. Both males and females breed for the first time at the end of the third year of growth.
2. Females grow faster than males.
3. Individuals of both sexes survive the first and subsequent breeding seasons.

We can get an estimate of the percentage survival after first breeding by comparing the numbers of " bred " and " non-bred " fish. The " non-bred " fish represent almost in their entirety one year class, while the " bred " fish represent all year classes which survive breeding and we assume that recruitment to the year classes concerned were the same, but even so we can determine the order of survival. Table 3 B 8 gives the information:

TABLE 3 B 8

	Males	*Females*
Bred (Nos. Fish)	177	126
Non-Bred (Nos. Fish)	1,226	1,488
Percentage Survival	14·4	8·5

Labeo mesops: *Survival After Breeding*

The percentage survival rate of the order of 10 per cent. is not unduly low for a fish which floods breeding grounds as they become available. The higher percentage survival of males is to be expected, since the main fishing for *L. mesops* exploits far more females and males and this will be discussed in more detail below.

The Gill-net Selection Curve for Labeo mesops

Before giving results of the calculations used to estimate the parameters of the selection curves we must deal with some factors which in this experiment may affect the values.

The fleet of nets used had the same number of meshes between head and footropes and thus differed in depth between nets and it would be necessary to allow for or to eliminate this factor. The data was worked out therefore using a correction factor to allow for the smaller net area of the smaller meshed nets (e.g. the numbers in each size group for the 2½-inch mesh were multiplied by two to compare them with that of the five-inch net, the depth of which was taken to be standard) and the results compared with those for the uncorrected data. It was found that the uncorrected results gave a better overall " fit " and this can be taken to mean that the extra area of the larger meshed nets do not result in an increased fishing power. This in turn indicates that the bulk of the population fished is concentrated in a relatively narrow zone near the bottom which is covered adequately by even the smaller meshed and shallower nets. While this evidence cannot be taken to be conclusive it is obvious that detailed studies of the distribution of *L. mesops* relative to the substrate would be informative and of practical value.

The assumption that the selection curve can be represented by a single normal curve of error corresponds to the assumption that the fish are all gilled at one place, presumably the operculum. The mesh parameter (=twice mesh size given here) would be very nearly equal to the girth of fishes gilled here, and the selection curve would in part at least be a measure of variation in the girth at operculum length ratio. Such an assumption is not wholly true of *L. mesops* since these fish can be gilled at any place between the eye and the dorsal and also more rarely at the mouth and in front of the eye. Once this was realised the position of gilling for each fish was noted; five categories being arbitrarily delimited. The percentage of fish in each of the nets in each of the categories is given below in table 3 B 9:

TABLE 3 B 9

Position of Capture	*Decreasing Net Size* / *Net Number*								
	3	4	5	6	7	8	9	10	11
Eye	—	1·52	1·72	1·12	1·41	6·39	6·66	20·0	33·36
Eye—Operculum ...	1·88	9·00	6·03	8·43	15·35	9·44	17·61	32·0	33·36
Operculum	33·97	40·91	36·20	29·22	36·71	53·25	62·34	34·0	22·22
Operculum D.	52·83	30·30	34·48	41·03	32·12	29·92	12·38	8·0	11·12
Dorsal	11·22	18·18	21·55	20·23	14·12	4·62	0·95	6·0	—

The highest percentage of fish gilled at the eye occurred in the smallest meshed nets, and the highest percentages gilled at the dorsal occurred in largest meshed nets. The nets catching the greatest number of fish also had the highest proportion of fish gilled at the operculum.

Most fish were caught at the operculum or between the operculum and the dorsal and the selectivity was calculated using only data from these fish. The mean selection length so calculated was almost the same as for that for all fish but the standard deviation was smaller. Unfortunately since large numbers of individuals are needed for each calculation it was not possible to calculate the selectivity for fish not gilled at the operculum, but it may eventually be possible to estimate at least the mean selection length from catch data for these fish.

It may be found that a more accurate selection curve is obtained by building up a single curve from a number of normal curves each representing fish gilled in a particular region, but the selectivity curves described below, based on Holt's method, certainly give a good estimate of the mean selection length and it is this parameter which is of most use in making catch predictions.

Table 3 B 10 gives the mean selection lengths and standard deviations for males and females separately for nets from 2½-inch to 3½-inch mesh size, which were those which caught sufficient numbers of fish to allow the calculation.

TABLE 3 B 10

Mesh Size (Measured) (mm.)	Mesh Size (Nominal) (in.)	Females M.S.L.	Females Standard Deviation	Males M.S.L.	Males Standard Deviation
90·2	3½	336·2	—	—	—
84·9	3¼	320·0	24·32	315·2	—
77·7	3	298·1	32·03	292·6	34·34
71·4	2¾	279·2	38·36	273·0	27·56
66·2	2½	263·4	30·06	256·7	29·22
57·1	2¼	242·0	31·49	234·6	32·10
Mean Standard Deviation			31·56		30·92

There is no indication that the standard deviation varies systematically with mesh size so that this assumption apparently holds.

The relationship between mean selection size and mesh size is linear and by the method of least squares the regression is calculated as follows:

Females Y=3.020 X+63.32 millimetres.

Males Y=3.124 X+49.98 millimetres.

Where Y=Estimated mean selection length (millimetres).

X=Mesh size (millimetres).

These allow us to calculate mean selection lengths for any mesh size in the range and to estimate those for nets certainly up to four-inch mesh size, since it is unlikely that this linear relation breaks down below this size. Table 3 B 11 gives this information for nets from four-inch to 2¼-inch size (actual size).

TABLE 3 B 11

Mesh Size (in.)	Females M.S.L. (mm.)	Males M.S.L. (mm.)
4	370·6	367·4
3¾	351·4	347·6
3½	332·2	327·8
3¼	313·0	308·0
3	293·8	288·2
2¾	274·6	268·4
2½	255·4	248·6
2¼	236·2	228·8

It also enables the calculation of the mesh size which fishes most efficiently a fish of any length and table 3 B 12 gives the information for the estimated mean breeding length for males and females.

TABLE 3 B 12

	Length (mm.)	Mesh Size (mm.)	Mesh Size (in.)
Breeding Male	291	77·2	3·04
Breeding Female	347	93·8	3·69

In table 3 B 10 the M.S.L. of males and females differ significantly and it must be clearly understood that this is not related to any difference in the size structure of the population since the M.S.L. is a function of the net itself and the shape of the fish, but not of the length frequency of the population which yields the data. The difference does indicate a difference in the shapes of the males and the females, probably most easily expressed as a difference in length/girth relationship (girth being measured at the mean point of gilling).

We can now introduce other relevant information before discussing briefly the application of the information given in tables 3 B 10 and 11.

Figure 3 B 10 shows the mean length of fish caught for each net and for males and females separately and also the M.S.L. for males and females. There are several points of interest. Considering the mean length of fish caught it can be seen that this actually falls for the largest mesh sizes for both males and females and this can be accounted for by the fact that these nets fish most efficiently at lengths of fish above the length of the bulk of the population (*see* figure 3 B 4 above), so that a high proportion of smaller fish are caught.

This phenomenon is well known from gill-net records for Nyasa fishes collected over a period of years and when it does occur, as it does for *Bagrus meridionalis* and *Mormyrus longirostris* to name only two, the assumption has been that the nets concerned fish most efficiently at a size larger than the normal size range for that species. The remaining section of the curve shows, again for both sexes, distinct sections of inflexion labelled A-A, and B-B. These sections cover the mesh sizes which, from the M.S.L. exploit most efficiently the lengths of fish which make up the bulk of the population. Finally the sections X-A, A-X and Y-B, B-Y which cover the sections of the population represented by the ascending and descending arms of the length frequency histogram are very nearly parallel to the M.S.L. curves, having much the same slope.

Considering the M.S.L. curves, they intersect the mean length curves for both males and females so that under certain conditions the mean length of fish caught can equal the mean selection length, for a particular net.

Now if this length and the mesh size associated with it is known, we have a point on the linear curve expressing the relationship between the M.S.L. and mesh size, and if the slopes X-A, A-X, Y-B and B-Y can be taken to be equal to the slopes of the respective selection curves then the curve is defined uniquely. Now with a further assumption for the *L. mesops* population under consideration, that the M.S.L. curve intersects the mean length of fish caught at a point which corresponds to the mesh size giving the largest catch per unit effort, all of the data required is available from the catch data alone. The point of intersection has been calculated from information in table 3 B 7 by multiplying each mesh size by the number of fish caught and finding the mean of the totals for all nets.

This for males was found to be 68.01 millimetres and for females 70.71 millimetres.

The slopes were calculated for the sections X-A and A-X in the case of the females and Y-B and B-Y in the case of the males. The weighted means in each case were calculated as 2.83 for males and 2.98 for females. The corresponding curves are now:

$Y=2.83 \times 65.18$ millimetres for males.

$Y=2.98 \times 63.02$ millimetres for females.

These are to be compared with the ones given above in table 3 B 11. Table 3 B 13 gives the mean selection lengths of two sets for comparison.

TABLE 3 B 13

	Males		*Females*	
	Holt's Calculation	*Catch Data*	*Holt's Calculation*	*Catch Data*
4-inch	366·97	352·71	370·15	365·79
$3\frac{3}{4}$-inch	347·16	334·74	350·98	346·86
$3\frac{1}{2}$-inch	327·34	316·77	331·80	327·94
$3\frac{1}{4}$-inch	307·54	298·80	312·62	309·01
3-inch	287·72	280·82	293·44	290·09
$2\frac{3}{4}$-inch	267·91	262·86	274·27	271·17
$2\frac{1}{2}$-inch	248·10	244·89	255·09	252·25
$2\frac{1}{4}$-inch	228·29	226·91	235·91	233·27
2-inch	208·48	208·94	216·74	214·40
$1\frac{3}{4}$-inch	188·87	190·97	197·56	195·48

The correspondence, which is remarkably close, may of course be fortuitious, and at present no rigorous proof can be put forward that the slopes of the portions of the curves X-A, etc., should be the same as for the corresponding curves worked out on Holt's assumption that the selection curve approximates to a normal curve of error. On the other hand for a population which like the *L. mesops* one being considered is unimodal for length frequency it is intuitively obvious that the net giving the best catch per unit effort should be fishing a population whose mode of length is nearest the M.S.L. for that net, since the net would be expected to be working at or near maximum fishing power under these circumstances and nets differing in mesh size would be working at a relatively lower efficiency.

It may be possible to show whether the method here developed has a wider application by developing catch curves from the intersection of hypothetical curves representing gill-net selectivity on the one hand and the length frequency of fish populations on the other hand. In this instance the selectivity curve is assumed to be normal and the population curve unimodal. If a curve calculated showing the relationship between mesh size and mean length of fish then has the characteristics of the curves in figure 3 B 7, it will be clear that some definable relationship exists between the mean selection length and the mean length of fish for a given mesh size and a given population.

There is a further point of interest. Analysis of gill-net catches obtained over a long period shows that for many species the mean length of fish mesh size curve is a straight line over much of the range of size and the question arises as to the relationships between this curve and the true selection curve, particularly as far as the M.S.L. is concerned. It should be possible to deduce a relationship which under specified conditions would enable the calculation of M.S.L. from catch data obtained over a long period.

The advantages would be twofold. To begin with, it is unlikely in the extreme that the selection curve for a fish the shape of *Bagrus* sp. or *Bathyclarias* spp. is simple since these can be gilled in so many different places and it may never be possible to deduce a M.S.L. and the other parameters of the selection curve analytically.

Again it is necessary to have data on relatively large numbers of individuals to make the calculation, and for relatively uncommon fishes the expenditure of time and effort would be great. To be able to obtain a parameter equivalent to the M.S.L. from simple and routine catch data is therefore most desirable.

We are now in a position to comment on some aspects of the *L. mesops* gill-net fishery which in the south of the lake has undergone a marked expansion in the past few years.

Variation in Catch Throughout the Year

There are two periods during which catches/unit effort are large. The first at about July is shown in catch data from the African Fishery. This would be the result of the influx of third-year fish into the fishing ground and if, as is suspected, most of the nets are of relatively small mesh size, about $2\frac{1}{2}$-inch, they would be exploited quite efficiently. The fall-off in the following months would then be the result of the unimodal population growing to such an extent that they pass out of the maximum efficiency zone for these small-meshed nets. The second period and the most important, occurs over the breeding season and concerns mainly the larger European managed commercial fisheries. For these the minimum mesh size is $3\frac{1}{2}$-inch and such a net would fish most efficiently males of length thirty-three centimetres and females of length 33.6 centimetres.

The increase of catches over this period is therefore partly the result of the third-year population growing into the high efficiency for the mesh sizes allowed. We must also take into account the probable large increase in activity of the fishes during the breeding season. The relative effect of these two factors can indeed be investigated. If the first is more important then the rise in catch/unit effort would be gradual, as would changes of the mean gonad state of the individuals caught; whereas, if the second is more important a relatively sudden rise would result, which would be accounted for mainly by individuals at or near breeding condition. Comparison of the total catches of the African and European fisheries indicates that the bulk of fishing mortality has in the last few years occurred in the breeding season since during these years the European effort has been proportionately very high.

" Breeding " Mortality of Males and Females

If we take the mean breeding sizes of males and females to be 291 millimetres and 347 millimetres respectively, the corresponding mesh sizes to give maximum catching efficiency will be 3.04-inch and 3.70-inch respectively. The minimum mesh size allowed in the south-east arm commercial fishery is 3½-inch and the commonly used nets are 3¾-inch and four-inch. The fishery therefore exploits far more females than males since these nets will fish the female population far more efficiently than the male. Under present conditions it is unlikely that the maximum mesh size will be lowered, so management and control must be designed primarily to protect the female sex and it will be necessary to treat the sexes as two distinct populations as far as the recording and treatment of data is concerned. This is all the more important as the fishery exploits predominantly one-year class.

Since fishing mortality differs markedly between the sexes and since the main fishing mortality (i.e. from the large-scale commercial firms) coincides with the breeding season when high natural mortality is experienced it should be possible to determine the relative extent of the two kinds of mortality from the resultant percentage of total survival of the sexes.

We have given above an estimate of the percentage of total survival of males and females and if we can assume that breeding mortality is the same for both sexes we can make a tentative estimate of both fishing and breeding mortality.

We are considering a year group preceeding first breeding and all year groups following first breeding. Fishing mortality here is that caused by the large-scale gill-net fishing, operating between December and March.

" Breeding " mortality is in effect the total natural mortality over the breeding season and would include that caused by seining over the breeding grounds. The fishing exploits about three females to every male.

We have: X as the percentage of fish subject to " breeding " mortality; Y as the percentage of males subject to fishing mortality; and 3Y as the percentage of females subject to fishing mortality.

The total percentage survival of males is taken to be fourteen and of females eight. This is the total survival for fish who survive the first breeding season and those who survive subsequent ones. A rough adjustment can be made to compare two adjacent year groups by deducting one-ninth from each of the figures. (If one-tenth survive the first breeding, one-hundredth will survive the second, one-thousandth the third, etc., and the total survival will be $10+1+\cdot 1$ per cent.$=11.11$ per cent.) The yearly survival is 10 per cent. which is one-ninth lower.

We can now say: $100—X—Y=12.45$ males.
$100—X—3Y=7.11$ females.

And we get: $X=85$ per cent. $Y=2.7$ per cent. $3Y=8.1$ per cent.

Fishing mortality of the females is approximately one-tenth of the breeding mortality. While this calculation is very crude and its validity depends on a number of assumptions both explicit and implicit it nevertheless results in an estimate which is valuable in its implications. It is as well to indicate some of the more obvious assumptions. These are:

1. A graded fleet of nets gives a reasonable picture of the size structure of the populations being considered. This will be dealt with below.
2. Pre-breeding and post-breeding fish do not differ markedly in behaviour and distribution. For a gregarious species like *Labeo mesops* this is unlikely and experience over several years of gill-net catches in a wide variety of habitats does indicate that in fact relatively few large individuals of *L. mesops* are found.
3. " Breeding " mortality is high, of the order of 90 per cent. so that the total survival is not much more than the survival of first breeding (on the assumption that breeding mortality is the same for fish of all ages).
4. The estimate of percentage survival based on examination of the gonads is reasonably accurate.

At the very least however, we can say that fishing mortality is much lower than natural mortality over the first breeding period and we can in the most general terms discuss the effects of increasing fishing mortality at the expense of " breeding " mortality.

L. mesops, like many cyprinids forms very large and dense breeding shoals and the onset of egg laying and fertilisation tends to be sudden, often following spates of small streams and rivers which allow access to breeding areas. Under these conditions breeding areas are likely to be very crowded and since the female produces many thousands of eggs, mortality of the zygotes larvae and very young fish, must be very high indeed. We have in fact a situation whereby a large reduction in the numbers of fish reaching the breeding grounds would probably have little effect on subsequent recruitment. It would not appear to be unreasonable to allow a fishing mortality of 80 per cent. or more without affecting recruitment markedly, and this represents a tenfold increase.

In the south-east arm in recent years about 300 tons of *L. mesops* have been caught by the fishery (G.F.T.C. annual report, etc.) so that the potential may be of the order of 3,000 tons per annum, even if females are exploited far more than males as at present.

A further important point concerns the origin of this south-east arm population.

The area available for breeding purposes in the immediate neighbourhood of the south-east arm is relatively small. Lowe suggests that young fish stay inshore for the first part of the life history and we conclude that movement from inshore nursery grounds occurs in the third year of growth.

Few small fish were recorded inshore in this experiment, despite the fact that the smallest gill-nets used would sample small fish adequately. Figures given in the annual reports of the Game, Fish and Tsetse Control Department are particularly interesting. Catches of *L. mesops*, in small and large meshed seines from the Shire, Malombe, Matawere, Mpemba and Malindi—all in the general south-east arm area—are very low. At Monkey Bay, Salima, Domira Bay, Chia Lagoon and Mpamba, all north of the south-east arm, catches are much higher. In the three years 1957 to 1959 the mean numbers of fish per haul for the first group was 1.4 and for the second 39.4. These seines would sample inshore populations of all sizes and we can assume therefore that the south-east arm is not an important breeding area. The third year population therefore is likely to represent an overflow from other areas and the south-east arm can be looked upon as a fattening-up ground.

Study of the movements of these populations between the south-east arm and other areas becomes extremely important as does the breeding behaviour of the south-east arm populations.

There are two possibilities. The south-east arm population may attempt to breed in the south-east arm and suffer extremely high mortality or it may move away to more suitable breeding areas. If the first applies the south-east arm population would contribute little to recruitment and could be fished heavily without affecting stock. Any estimate such as the one given above would refer to the south-east arm alone and would perhaps be doubled to include other areas. If the second applies then it would be necessary to determine the contribution the population makes to recruitment before intending estimates of potential. A study of breeding grounds in the south-east arm is therefore essential before such questions can be answered.

The Use of a Fleet of Gill-nets as a Sampling Method

The assumptions made in calculating the selection curves, are that the curve approximates to a normal curve; that the standard deviations do not vary with the mesh size and that fishing power does not differ markedly between nets differing only slightly in mesh size. On these assumptions we can set up a model to test the efficiency of a fleet of nets of known graded mesh size as a sampling method for a particular species. For *L. mesops* we have the following information:

The slope of the curve relating M.S.L. to mesh size is nearly equal to 3.0.

The standard deviation of the M.S.L. is about 30 millimetres.

If we have a fleet of nets differing in mesh size by ten millimetres increments, then the M.S.L. of the nets will differ by increments of thirty millimetres. The fleet can therefore be represented by a series of normal curves each displaced one standard deviation from its neighbours.

For fish of any length a position on the abscissa can be assigned which represents their position in relation to the fleet and the total fishing power of the fleet of that length can be calculated as the sum of the ordinates of all the curves at the position represented by the length of fish. This can be repeated for other lengths of fish so that the total fishing power of the fleet for all lengths of fish can be compared. In this instance one need only consider lengths between a M.S.L. for a given net and lengths, half a standard deviation away since the maximum variation in fishing power is covered by this distance. The total variation in fishing power has been calculated for this particular case, i.e., nets differing in increments equal to one standard deviation of the M.S.L. The maximum variation was found to be of the order of .1 per cent or less (related to maximum power). Other models representing fleets differing by increments equivalent to two, three or four standard deviations have been examined and the maximum variation of all these are given in table 3 B 14.

TABLE 3 B 14

Mesh Increment	*Maximum Variation* %
1 Standard Deviation	0·1
2 Standard Deviation	2·82
3 Standard Deviation	36·47
4 Standard Deviation	72·91

The ½-inch increments of the fleet used in this experiment represents an increment of M.S.L. of nineteen millimetres, i.e., considerably less than one standard deviation so there is no reason to believe that the population sample obtained by the fleet is unduly biased in size structure, a conclusion that is in contradiction to that of Kesteven (1950) who states that a graded fleet does *not* give a true estimate. Unfortunately I have not had access to the paper referred to but it is difficult to accept his conclusion for it is intuitively obvious that a fleet of nets differing by infinitesimably small increments of mesh size would give an unbiased sample so that one must determine, as I have done above, the size of increments at which this no longer holds.

For *L. mesops* ¼-inch increments seem to be well within the maximum difference allowable.

Even if the selection curve did not approximate to a normal curve but to a skewed curve, a bimodal one or a curve compounded from a number of normal curves each representing the normal curve of fish gilled at a different place, it is unlikely (although it has not been tested) that the " efficiency " of sampling would be influenced greatly. Such influence would not be important provided the increments are reasonably small.

Now *L. mesops* by reason of its shape is a good subject for investigation of gill-net selectivity. The majority of individuals are gilled at or near the operculum and the selectivity curve approximates to a single normal curve. Even so, the determination of the exact selectivity curve analytically is by no means easy and an experiment would involve catching a sufficient number of individuals to be able to treat each gilling point separately. For the eye region this would involve a total of about 60,000 fish for the whole experiment, if a precision comparable to that for the operculum is required. Such an experiment is, practically, beyond the scope of the resources ever likely to be available in Central Africa. For a fish with the shape of *Bagrus meridionalis* the selectivity curve would be very complex if treated analytically and there are few biologists available or likely to be available whose mathematical experience would be equal to the task.

It would appear that the estimate of what can be called a M.S.L. is much less influenced by the exact shape of the selection curve, provided it *does* approximate to a normal curve, than is the estimate of a standard deviation.

I have shown above that standard deviations estimated (*a*) for all fish wherever they are gilled and (*b*) fish gilled only at or near the operculum are thirty millimetres and twenty-five millimetres respectively. If the size structure of a population is being built up from the catch of a single net then this difference can lead to widely different results. Thus at fifty millimetres from the M.S.L. the factor by which the number of fish recorded is multiplied to give an estimate of the numbers in the population is 3.70 if the standard deviation is taken to be thirty millimetres, and 7.35 if twenty-five millimetres (referred to an arbitrary efficiency of 1.00 at the M.S.L.), a difference of a factor or two, so that the exact shape of the selectivity curve must be determined very accurately indeed if such reconstructions of the population are required over a wide size range and the data required would include a knowledge of the point of gilling of every individual fish.

To sum up, the advantages of a graded fleet of nets as a sampling method are numerous.

1. Under certain conditions it may be possible to calculate the M.S.L. from simple catch data—and the M.S.L. is of very great practical use as far as development and management is concerned.
2. A fleet can be chosen to cover the full size range of the population with sufficient overlap at either end to ensure accuracy over the whole size range.
3. There seems no reason why reasonable accuracy cannot be assumed even if the shape of the selectivity curve is not known with any degree of precision.
4. It allows for the occurrence of fish gilled in ways which cannot be accommodated by built up curves, e.g. the fish gilled diagonally or caught by the lower jaw.
5. The experimental technique is much simpler as is the analysis of data.

Since there is some doubt as to the validity of the method, it is essential that it be confirmed. Certainly there is no evidence in the data from this experiment that it is greatly misleading. The deduction that few fish in the first two years of life are found in the south-east arm seems to be confirmed by their relative absence from shore seine hauls. The growth pattern, based largely on the size structure obtained from this experiment fits well, both with the earlier data of Lowe and with data obtained from seines and open water hauls at Bana and Nkata Bay in 1960 and early 1961.

Finally, by taking the size structure and growth rates of the population as here determined; using the M.S.L's. and their relation to mesh size, it has been possible to calculate data concerning the commercial gill-net fishing carried out in the breeding season. In particular the mesh sizes giving the highest catch/unit effort in (*a*) numbers of fish and (*b*) total weight and the sex ratios for different mesh sizes at a given part of the breeding season have been estimated.

The correspondence between these estimates and data from the commercial fisheries and from Lowe is close enough to give confidence that the method is not greatly inaccurate.

Thus for the four-inch net in January (assuming mid-breeding season is mid-February) catches are calculated as being made up of about 80 per cent. females and 20 per cent males, Lowe gives for the four-inch net 85 per cent. females and 15 per cent. males, for the breeding season as a whole.

The conclusion must be therefore that the use of a graded fleet of gill-nets is a very powerful tool for the study of fish populations and its general use in Central African waters would lead to an accumulation in a relatively short time of a great body of useful data.

TABLE 3 B 15

LENGTH-WEIGHT RELATIONSHIPS OF MALE AND FEMALE *LABEO MESOPS*.

	Females					Males				
Length Group	*No.*	*Mean Weight (gms.)*	*Calculated Weight (1) (gms.)*	$K \times 10^{-5}$	*Calculated Weight (2) (gms.)*	*No.*	*Mean Weight (gms.)*	*Calculated Weight (gms.)*	$K \times 10^{-5}$	*Calculated Weight (gms.)*
170–79 ...	1	96·00	81·94	1·7914	87·06	3	90·67	86·87	1·6919	89·32
180–89 ...	8	97·00	97·55	1·5319	102·86	11	98·82	103·04	1·5606	105·54
190–99 ...	17	116·53	114·95	1·5715	120·46	11	117·73	121·10	1·5815	123·59
200–09 ...	8	128·88	134·51	1·4945	139·95	9	138·00	141·20	1·6019	143·59
210–19 ...	9	154·67	156·02	1·5563	161·44	8	161·25	163·44	1·6226	165·64
220–29 ...	18	182·17	179·44	1·5994	185·03	44	192·43	187·91	1·6895	189·84
230–39 ...	37	206·19	206·19	1·5885	210·86	123	213·98	214·76	1·6486	216·34
240–49 ...	116	237·19	234·90	1·6124	238·96	241	244·24	244·07	1·6604	245·17
250–59 ...	180	263·88	266·08	1·5915	269·34	266	275·59	275·96	1·6622	276·34
260–69 ...	212	296·71	300·31	1·5943	302·32	167	311·29	310·61	1·6727	310·17
270–79 ...	217	335·61	337·00	1·6135	337·79	115	349·15	347·98	1·6786	346·67
280–89 ...	133	374·67	376·81	1·6184	376·07	66	401·29	388·25	1·7334	385·84
290–99 ...	136	427·18	419·81	1·6641	417·01	42	432·69	431·62	1·6856	427·84
300–09 ...	95	480·80	466·03	1·6948	460·87	39	473·90	478·15	1·6704	472·84
310–19 ...	97	522·81	514·30	1·6725	502·82	34	522·82	527·91	1·6725	521·01
320–29 ...	49	567·25	568·60	1·6523	557·69	27	561·48	581·06	1·6355	572·18
330–39 ...	34	627·35	624·81	1·6685	610·81	21	622·71	637·70	1·6562	626·68
340–49 ...	33	684·94	685·17	1·6681	667·02	4	695·00	697·99	1·6926	684·35
350–59 ...	27	735·26	749·17	1·6434	726·80	—	—	—	—	—
360–69 ...	30	801·53	817·41	1·6482	789·99	—	—	—	—	—
370–79 ...	5	822·00	889·28	1·5589	856·60	—	—	—	—	—
380–89 ...	8	929·25	966·10	1·6283	927·10	—	—	—	—	—
390–99 ...	4	990·75	1,046·10	1·6076	1,001·18	—	—	—	—	—
TOTAL ...	1,474				TOTAL ...	1,231				
MEAN ...		381·53	381·48	1·6245			305·60	305·71	1·6667	

IV.—LENGTH-WEIGHT RELATIONSHIPS OF SOME NYASA FISHES

Labeo Mesops

Table 3 B 14 gives the length-weight relationship for both males and females of this species.

The data from which this table was prepared was collected during the 1959 experiment in the south-east arm of Lake Nyasa (*see* above).

Curves expressing the length-weight relationship were fitted using the method of least squares. In logarithmic form these are expressed so:

Log_{10} W=3.1285 Log_{10} L—5.1037 females.

Log_{10} W=3.0699 Log_{10} L—4.9470 males.

Where W is the weight in grammes.

L is the length in millimetres.

In exponential form these become:

$W=7.8759\times10^{-6}\times L^{3.1285}$ females.

$W=1.1298\times10^{-5}\times L^{3.0699}$ males.

The figures in the calculated weight (1) column are derived from these formulae.

K is the condition factor obtained from the formula.

$W=KL^3$ when W is expressed in grammes and L in millimetres.

It is worked out separately for each length group, and the mean K is the mean for all fish. The calculated weight (2) is that calculated using the mean K for each sex, and comparison of the two calculated weights for each sex indicates the error that is involved in assuming that the weight is proportional to the cube of the length, i.e. that the growth is isometric.

Over much of the size range considered here for both males and females the difference is of the order of 1 per cent. or 2 per cent. which is not very great. It means that the mean length of a sample could be estimated with reasonable accuracy from the numbers and total weight of that sample.

The difference in length-weight relationship between male and female is significant; males of the same length are heavier than the females by about 3 or 4 per cent. This could be interpreted as meaning that males are " stouter " than females and that their girth/length ratio is higher.

The fact that the M.S.L. for females is, for a given mesh size, greater than that for males is partly at least explained, since for a given girth (it is the girth/length ratio that determines largely the M.S.L.) a female would be longer. Inspection of table 3 B 15 above shows that the difference in M.S.L. between males and females is of the order of 1 or 2 per cent. It is clear that a definable relationship exists between M.S.L., length/girth ratio and length-weight relationships and the elucidation of these relationships would throw much light on gill-net selectivity as a whole.

It has been asserted above that a fleet of graded nets as used in the 1959 experiment gives, as far as net selectivity itself is concerned, an accurate estimate of the length structure of the population. It remains to show whether such a fleet gives also an accurate length-weight relationship, since it is known that fish from a single gill-net of a one mesh size gives systematic errors for this relationship. For a graded fleet one would expect anomalous errors in K, for fish at the extremes of length for the population, and preliminary investigation, using a calculated K (from length and calculated weight (1)) for comparison with estimated K for each length group indicates that the difference is random rather than systematic. It is unlikely therefore that the length-weight relationship is unduly biased.

Bagrus Meridionalis

Tables 3 B 15A and B give the length-weight relationship for males and females of *B. meridionalis*. They are set out in the same way as table 3 B 15. The specimens from which the data was obtained were collected over a period 1953 to 1959 by gill-nets, but most of the specimens were caught by five-inch and four-inch gill-nets.

Logarithmically the length-weight relationship is as follows:

Log W=2.78720 Log L—4.33473 females.

Log W=2.92335 Log L—4.71675 males.

In the exponential form these become:

$W=4.6267\times10^{-5}\times L^{2.78720}$.

$W=1.9198\times10^{-5}\times L^{2.92335}$.

TABLE 3 B 15A

LENGTH-WEIGHT RELATIONSHIP OF MALE AND FEMALE *BAGRUS MERIDIONALIS*

FEMALES

Length	*No.*	*Mean Weight (gms.)*	*Calculated Weight* (1) *(gms.)*	*K*	*Calculated Weight* (2) *(gms.)*	*Length*	*No.*	*Mean Weight (gms.)*	*Calculated Weight* (1) *(gms.)*	*K*	*Calculated Weight* (2) *(gms.)*
350–59 ...	1	453·60	593·30	1·014	544·61	560–69 ...	73	2,217·91	2,166·60	1·230	2,195·52
360–69 ...	4	396·90	641·03	0·816	591·94	470–79 ...	66	2,271·43	2,275·20	1·195	2,314·21
370–79 ...	3	661·41	691·21	1·254	641·93	580–89 ...	75	2,353·82	2,387·30	1·176	2,437·03
380–89 ...	3	529·29	743·81	0·927	694·68	590–99 ...	49	2,490·18	2,502·70	1·182	2,564·13
390–99 ...	5	907·20	798·93	1·472	750·22	600–09 ...	41	2,646·93	2,621·70	1·195	2,695·71
400–09 ...	10	961·07	856·60	1·447	808·65	610–19 ...	33	2,790·32	2,744·40	1·196	2,831·56
410–19 ...	11	873·69	916·85	1·222	870·04	620–29 ...	31	2,769·14	2,287·04	1·134	2,971·91
420–29 ...	23	1,050·20	979·76	1·368	934·47	630–39 ...	28	2,973·72	3,000·20	1·162	3,116·90
430–39 ...	21	1,049·23	1,045·40	1·275	1,002·00	640–49	15	3,050·46	3,133·90	1·138	3,266·50
440–49 ...	22	1,122·40	1,113·70	1·274	1,072·70	650–59 ...	14	3,128·62	3,271·00	1·113	3,420·73
450–59 ...	36	1,162·35	1,184·80	1·234	1,146·65	660–69 ...	15	3,345·30	3,412·20	1·138	3,579·84
460–69 ...	38	1,260·72	1,259·00	1·254	1,223·87	670–79 ...	12	3,801·25	3,557·00	1·236	3,243·81
470–79 ...	59	1,331·03	1,335·80	1·242	1,304·58	680–89 ...	6	3,694·86	3,706·00	1·150	3,912·65
480–89 ...	63	1,443·01	1,415·70	1·265	1,388·70	690–99 ...	10	3,770·55	3,858·70	1·123	4,086·48
490–99 ...	87	1,527·78	1,498·60	1·260	1,476·46	700–09 ...	6	4,139·20	4,015·60	1·181	4,265·42
500–09 ...	87	1,611·41	1,584·60	1·251	1,567·76	710–19 ...	5	4,428·27	4,176·40	1·211	4,449·60
510–19 ...	107	1,697·88	1,673·60	1·243	1,662·71	720–29 ...	1	4,450·95	4,341·20	1·168	4,638·89
520–29 ...	89	1,768·53	1,765·60	1·222	1,761·43	730–39 ...	6	5,003·79	4,510·10	1·260	4,833·53
530–39 ...	74	1,797·53	1,861·00	1·174	1,864·05	740–49 ...	4	5,032·13	4,683·30	1·217	5,033·14
540–49 ...	68	1,931·14	1,959·60	1·193	1,970·57	750–59 ...	4	4,982·51	4,860·60	1·158	5,238·89
550–59 ...	73	2,033·04	2,061·40	1·189	2,080·97						
						TOTAL ...	1,378				
MEAN ...					4·33473			1,988·28	1,978·66	1·2173	

TABLE 3B 15B

LENGTH-WEIGHT RELATIONSHIP OF MALE AND FEMALE *BAGRUS MERIDIONALIS*

MALES

Length	*No.*	*Mean Weight (gms.)*	*Calculated Weight (1) (gms.)*	$K \times 10^{-5}$	*Calculated Weight (2) (gms.)*	*Length*	*No.*	*Mean Weight (gms.)*	*Calculated Weight (1) (gms.)*	$K \times 10^{-5}$	*Calculated Weight (2) (gms.)*
250–59 ...	2	141·75	208·16	0·855	199·09	500–09 ...	71	1,551·17	1,534·30	1·204	1,546·42
260–69 ...	2	376·00	232·77	2·020	223·96	510–19 ...	51	1,601·35	1,624·80	1·172	1,640·08
270–79 ...	1	226·80	259·60	1·091	249·72	520–29 ...	40	1,701·71	1,718·70	1·176	1,737·46
280–89 ...	4	290·59	288·20	1·255	277·90	530–39 ...	28	1,814·40	1,816·30	1·185	1,838·68
290–99 ...	2	464·00	318·71	1·807	308·25	540–49 ...	25	1,880·17	1,971·40	1·161	1,943·74
300–09 ...	2	411·08	351·31	1·449	340·68	550–59 ...	28	1,935·90	2,022·10	1·132	2,052·65
310–19 ...	12	356·73	386·10	1·141	375·30	560–69 ...	29	2,045·11	2,130·50	1·134	2,165·64
320–29 ...	8	393·36	423·16	1·147	412·19	570–79 ...	31	2,148·20	2,242·40	1·130	2,282·71
330–39 ...	12	425·25	462·26	1·128	951·42	580–89 ...	19	2,111·33	2,358·30	1·056	2,403·87
340–49 ...	12	472·50	503·73	1·151	493·07	590–99 ...	14	2,466·95	2,478·00	1·171	2,529·22
350–59 ...	12	517·38	547·65	1·156	537·20	600–09 ...	11	2,788·61	2,602·00	1·259	2,659·02
360–69 ...	10	535·82	593·89	1·110	583·88	610–19 ...	3	2,853·90	2,729·60	1·227	2,793·02
370–79 ...	10	558·49	642·69	1·059	633·19	620–29 ...	11	2,992·21	2,861·50	1·226	2,931·47
380–89 ...	11	677·82	694·03	1·188	685·22	630–39 ...	11	3,659·73	2,997·10	1·429	3,074·47
390–99 ...	14	698·43	748·17	1·133	740·01	640–49 ...	7	3,341·25	3,137·60	1·245	3,222·04
400–09 ...	29	793·80	805·03	1·195	797·65	650–59 ...	9	3,301·20	3,281·70	1·175	3,374·18
410–19 ...	28	879·86	864·37	1·226	858·20	660–69 ...	2	3,246·07	3,430·10	1·104	3,531·11
420–29 ...	45	939·33	926·83	1·224	921·75	670–79 ...	5	4,031·37	3,583·50	1·311	3,692·85
430–39 ...	27	1,030·05	991·74	1·251	988·36	680–89 ...	5	4,224·15	3,741·10	1·314	3,859·39
440–49 ...	36	1,171·01	1,060·00	1·329	1,058·10	690–99 ...	3	3,780·00	3,903·00	1·126	4,030·86
450–59 ...	49	1,199·96	1,131·10	1·274	1,131·04	700–09 ...	1	3,628·80	4,069·00	1·036	4,207·36
460–69 ...	54	1,225·88	1,205·30	1·219	1,207·22	710–19 ...	1	3,175·20	4,240·30	0·869	4,389·04
470–79 ...	77	1,308·18	1,282·50	1·221	1,286·82	720–29 ...	1	4,054·05	4,415·70	1·064	4,575·75
480–89 ...	58	1,377·42	1,363·30	1·207	1,369·80	730–39 ...	1	4,621·05	4,596·30	1·164	4,767·75
490–99 ...	51	1,438·07	1,447·10	1·186	1,456·37	740–49 ...	1	4,082·90	4,781·80	0·949	4,964·91
						TOTAL ...	976				
						MEAN ...		1,484·88	1,478·92	1·2007	

TABLE 3 B 16

LENGTH-WEIGHT RELATIONSHIPS OF MALE AND FEMALE *MORMYRUS LONGIROSTRIS*

	Females					Males				
Length	*No.*	*Mean Weight (gms.)*	*Calculated Weight* (1) *(gms.)*	$K \times 10^{-4}$	*Calculated Weight* (2) *(gms.)*	*No.*	*Mean Weight (gms)*	*Calculated Weight* (1) *(gms.)*	$K \times 10^{-4}$	*Calculated Weight* (2) *(gms.)*
300–09 ...	1	396·92	382·16	1·399	332·92	—	—	—	—	—
310–19 ...	2	496·16	414·05	1·587	366·75	—	—	—	—	—
320–29 ...	5	442·30	447·22	1·288	402·79	2	737·00	424·55	2·1526	356·22
330–39 ...	14	496·15	481·93	1·320	441·12	5	498·96	457·03	1·3722	390·12
340–49 ...	17	518·53	518·20	1·263	481·86	3	544·32	490·94	1·3255	426·12
350–59 ...	26	524·59	556·04	1·172	524·95	3	510·30	526·28	1·4060	464·26
360–69 ...	35	587·14	595·47	1·207	570·57	4	552·83	563·05	1·1369	504·60
370–79 ...	37	621·18	636·52	1·178	618·76	9	606·41	601·33	1·1499	547·22
380–89 ...	35	673·98	679·22	1·181	669·60	12	643·83	691·08	1·1282	592·18
390–99 ...	28	731·47	723·57	1·187	723·14	15	666·23	682·36	1·0810	639·53
400–09 ...	9	737·11	769·34	1·110	779·46	34	716·69	724·90	1·0789	689·34
410–19 ...	17	822·95	817·32	1·221	838·64	43	758·86	769·34	1·0617	741·68
420–29 ...	12	918·07	866·76	1·196	900·74	56	791·25	815·36	1·0307	796·60
430–39 ...	9	971·81	917·93	1·181	965·83	82	860·43	862·80	1·0453	854·16
440–49 ...	12	1,044·10	970·85	1·185	1,033·98	89	905·40	911·89	1·0276	914·43
450–59 ...	9	1,058·30	1,025·50	1·124	1,105·26	60	961·92	962·48	1·0212	977·47
460–69 ...	7	1,073·30	1,082·00	1·068	1,179·70	62	1,019·18	1,014·70	1·0087	1,043·30
470–79 ...	5	1,148·20	1,140·10	1·071	1,257·49	43	1,059·44	1,068·60	0·9886	1,112·10
480–89 ...	7	1,312·30	1,200·50	1·150	1,338·57	19	1,181·63	1,124·20	1·0358	1,183·81
490–99 ...	8	1,286·50	1,262·50	1·061	1,423·17	18	1,175·11	1,181·50	0·9688	1,258·63
500–09 ...	9	1,357·70	1,326·30	1·054	1,511·17	13	1,210·26	1,240·30	0·9397	1,336·45
510–19 ...	2	1,190·70	1,392·00	0·872	1,602·69	12	1,301·83	1,300·10	0·9531	1,417·39
520–29 ...	3	1,488·40	1,459·60	1·029	1,697·85	13	1,462·29	1,363·20	1·0106	1,501·55
530–39 ...	2	1,353·70	1,529·20	0·884	1,796·77	8	1,474·20	1,427·20	0·9627	1,589·03
540–49 ...	2	1,460·00	1,600·30	0·902	1,899·44	3	1,653·66	1,493·00	1·0215	1,679·83
550–59 ...	4	1,159·20	1,676·40	0·678	2,005·86	5	1,601·78	1,560·50	0·9370	1,773·95
560–69 ...	1	2,268·00	1,749·50	1·257	2,116·27	1	1,488·38	1,629·90	0·8252	1,871·60
570–79 ...	318	780·59	779·36	1·173	—	1	1,445·85	1,699·40	0·7605	1,972·77
580–89 ...	—	—	—	—	—	2	1,885·28	1,773·70	0·9417	2,077·48
						2	2,090·81	1,848·40	0·9927	2,182·70
					TOTAL ...	614				
					MEAN ...		935·71	937·24	1·038	

Mormyrus Longirostris

The data for this species is shown in table 3 B 16, the formulae representing the length-weight relationship being:

$$\text{Log } W = 2.4665 \text{ Log } L - 3.54503 \text{ females.}$$

$$\text{Log } W = 2.4325 \text{ Log } L - 3.48222 \text{ males.}$$

$$W = 2.8508 \times 10^{-4} \times L^{2.46650} \text{ females.}$$

$$W = 3.2952 \times 10^{-4} \times L^{2.4325} \text{ males.}$$

The specimens from which the data was obtained were again caught over a long period of time, and in gill-nets of four-inch and five-inch mesh.

Bearing in mind the effects of gill-net selectivity we can make the following observations:

1. For both *Bagrus meridionalis* and *Mormyrus longirostris* the length-weight relationship differs significantly between males and females. This indicates differences in shape which would be reflected in the mean selection length for gill-nets of the same size, so that the sexes would have to be treated separately.
2. The error that would be introduced by assuming growth to be isometric is greater for both species than for *Labeo mesops*, and certainly for *M. longirostris* would be greater than would be considered acceptable for any growth studies.
3. The individual variation in weight for *B. meridionalis* is greater than that for the other species considered. This may well be related to the fact that it is a predator, rather than a substrate feeder.

V.—" Bagrus meridionalis ": Variation in Catch Per Unit Effort and Changes in Gonad State

Gill-net catches of *Bagrus meridionalis* show great variation in the numbers of fish caught per standard set throughout the year. The highest catches are associated with the breeding season which extends from about December to about April. In the report of the survey of Lake Nyasa carried out from 1953 to 1955 (Jackson *et al.* in Press) the breeding season has been defined by variations in the percentage of " inactive " (i.e. quiet) fish from month to month. This was necessary because ripe running fish leave the fishing grounds rather abruptly as they reach peak breeding condition and do not figure in gill-net catches, because at Nkata Bay where the data was collected the breeding areas for *B. meridionalis* are inshore in shallow water whereas gill-nets were set deep. Figure 3 B 8 shows the relationship for each month of the year between the percentage of inactive fish and the catch per unit effort (numbers of fish). The correlation is marked, the highest catches occurring in months when fewest fish are " inactive ".

Now since gill-nets are stationary, variation in catches must be accounted for by changes in density and distribution or of activity. Ripe running fish were virtually absent from gill-net catches so that the change in activity, which the close correlation must indicate to a substantial degree, cannot be accounted for by epigamic behaviour. The explanation must be sought in a general increase in activity associated with the maturation of the gonads, presumably as a result of hormonal changes. Increased gill-net catches of Nyasan fishes over the breeding season are common, it being shown in *Labeo mesops*, *Mormyrus longirostris*, *Haplochromis quadrimaculatus* and others and it would be interesting to compare the relative importance in each of epigamic activity changes of distribution and density and changes in activity related to gonad maturation.

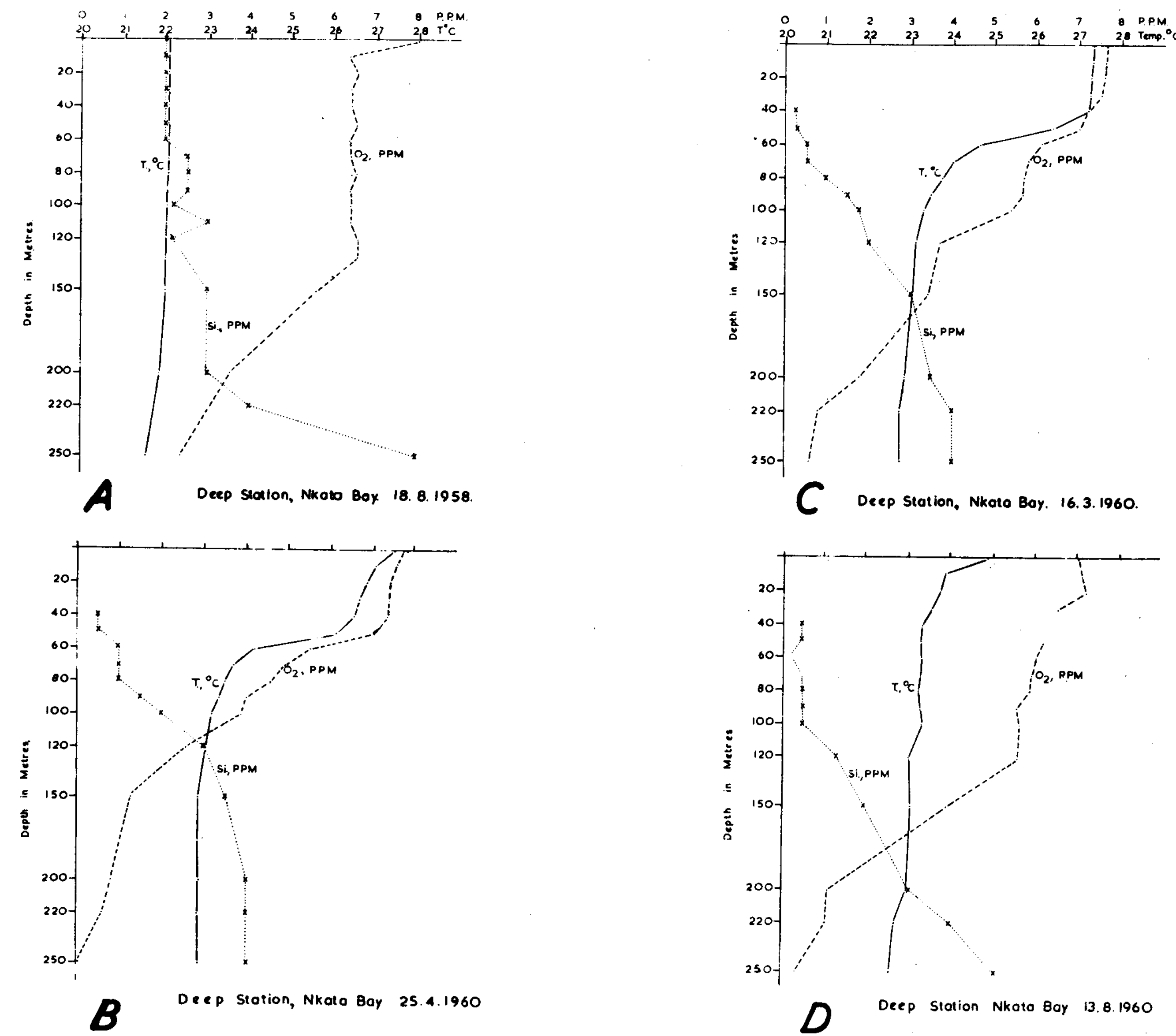
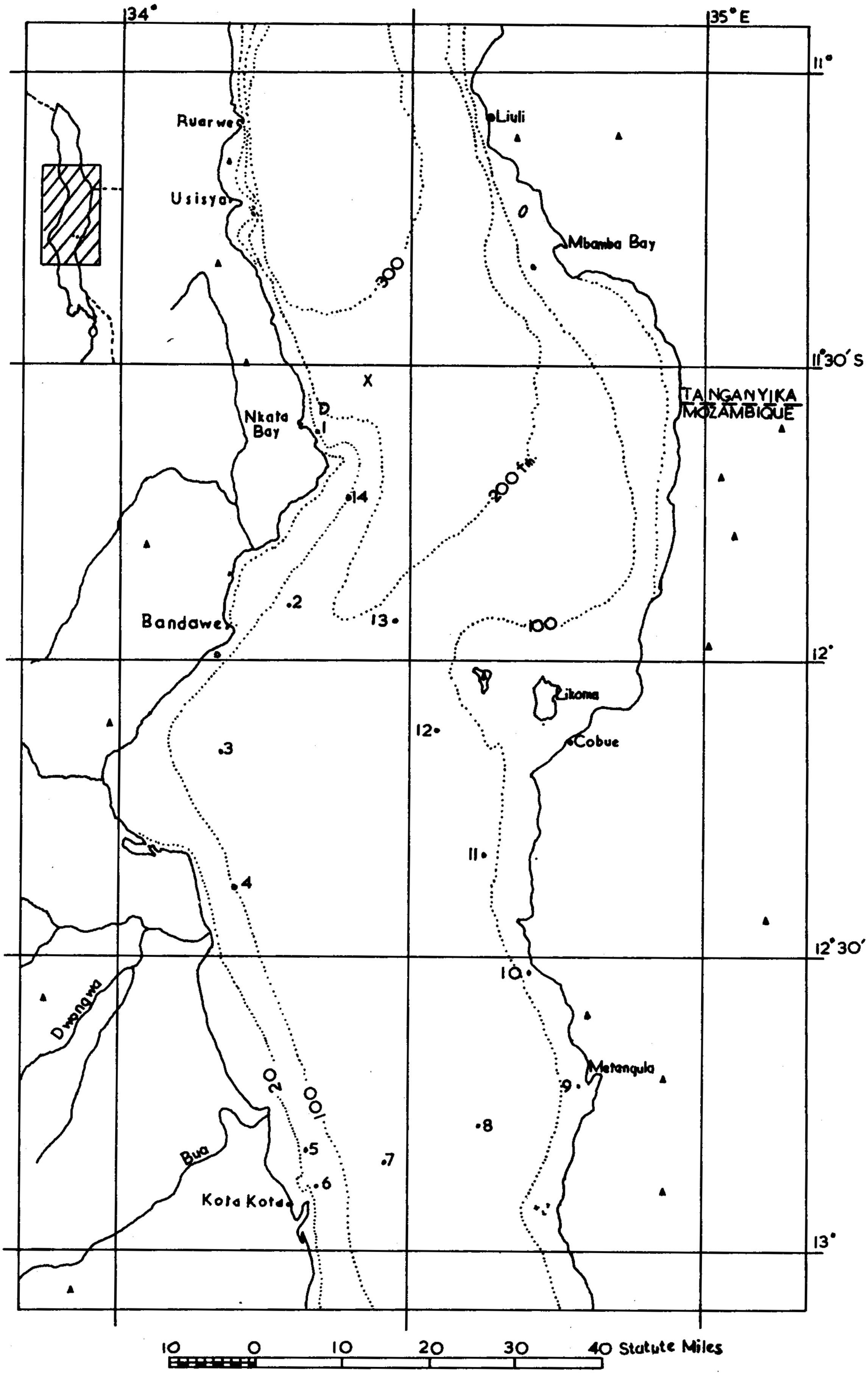


Fig. 3 B 1
Temperature, silicate and oxygen values at Nkata Bay Deep Station, Lake Nyasa
A. On 18th August, 1958.
B. On 25th April, 1960.
C. On 16th March, 1960.
D. On 13th August, 1960.

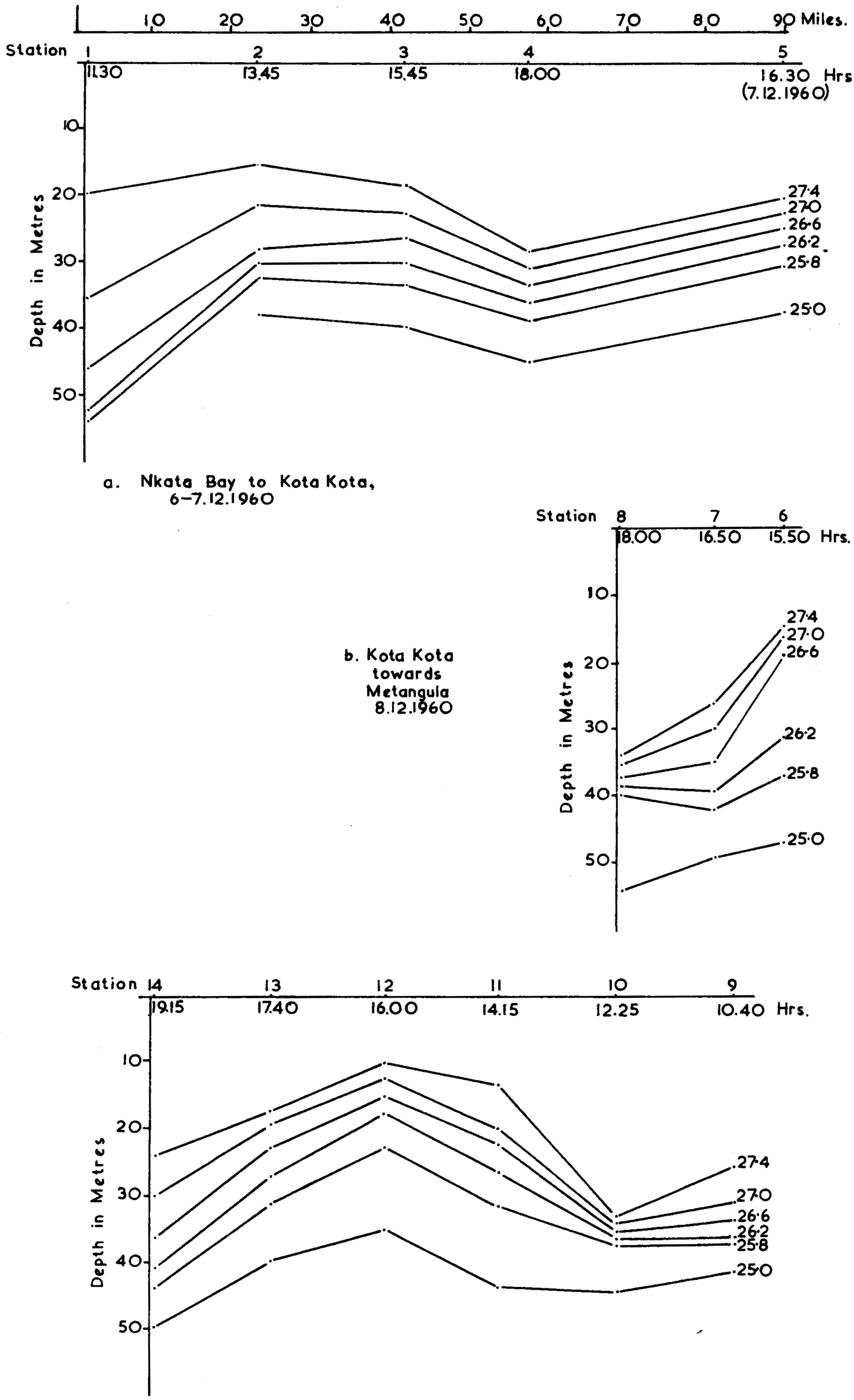


Scale 1:1,000,000. Depths in Fathoms

Central Portion of Lake Nyasa (See inset)

Sampling stations:- D Deep station
X Very deep station, 10.5.1960.
1–14, Stations on cruise, Dec. 1960.
1–4, 6.12.1960: 5, 7.12.1960: 6–8, 8.12.1960: 9–14, 11.12.1960.

Fig. 3 B 2
Stations sampled for temperature with the thermistor thermometer, December, 1960



c. Metangula towards Nkata Bay, 11.12.1960.

Isotherms (°C) obtained graphically from thermistor readings taken on cruise in December 1960.

Fig. 3 B 3

Isotherms obtained graphically from thermistor readings taken on the cruise in December, 1960

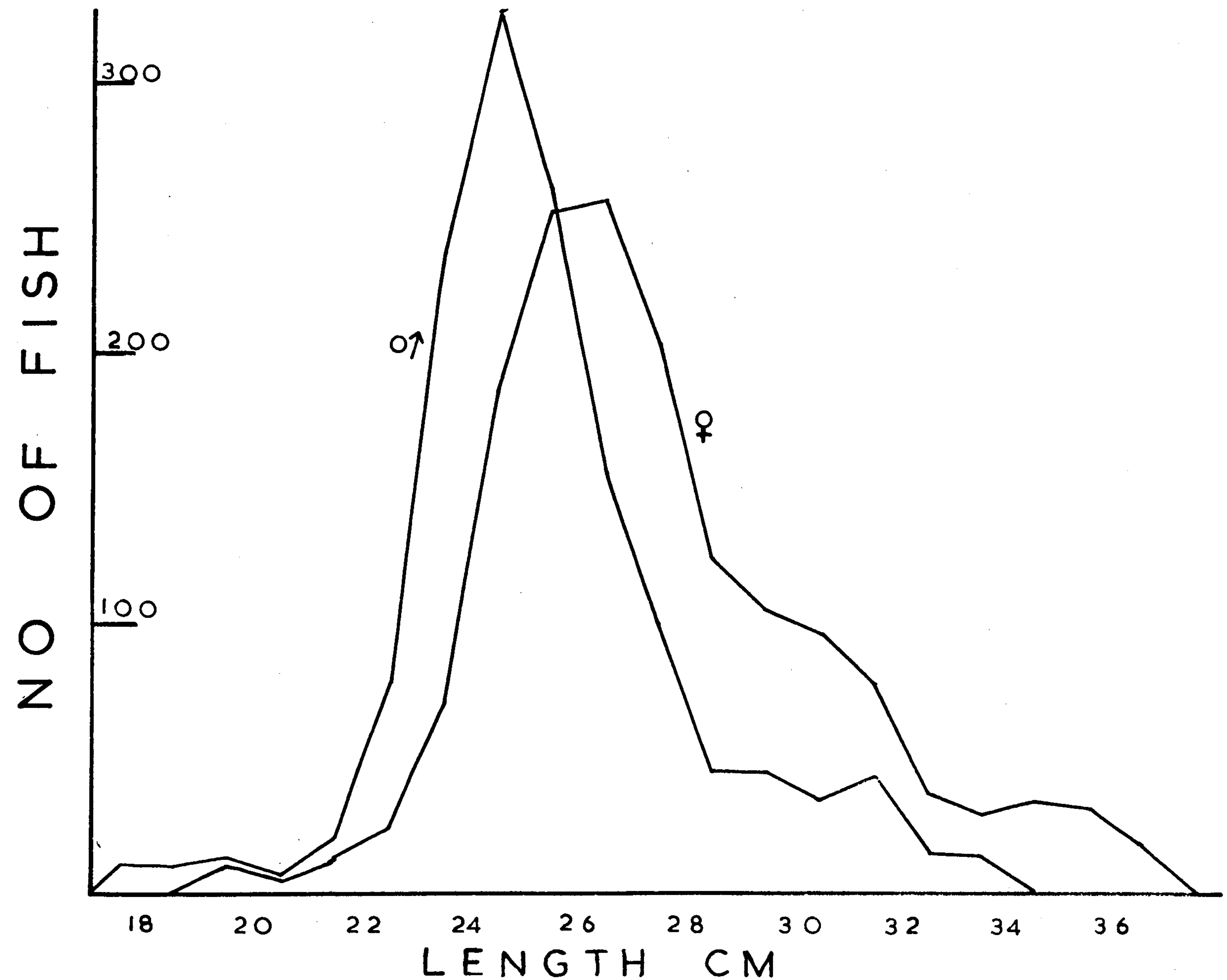


Fig. 3 B 4
Length-frequency data of the catches of *Labeo mesops* from all nets

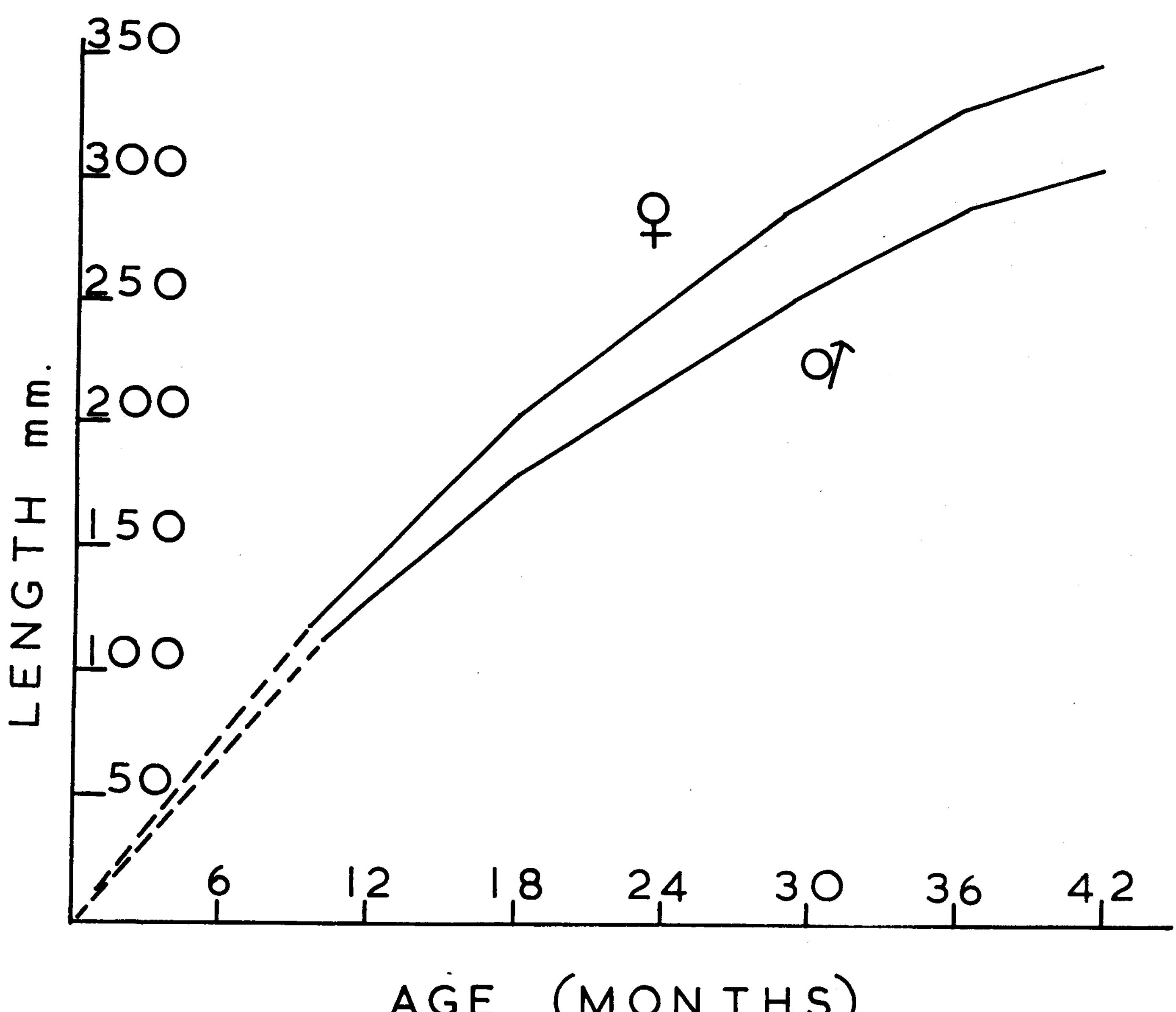


Fig. 3 B 5
Estimated growth rate of *Labeo mesops*

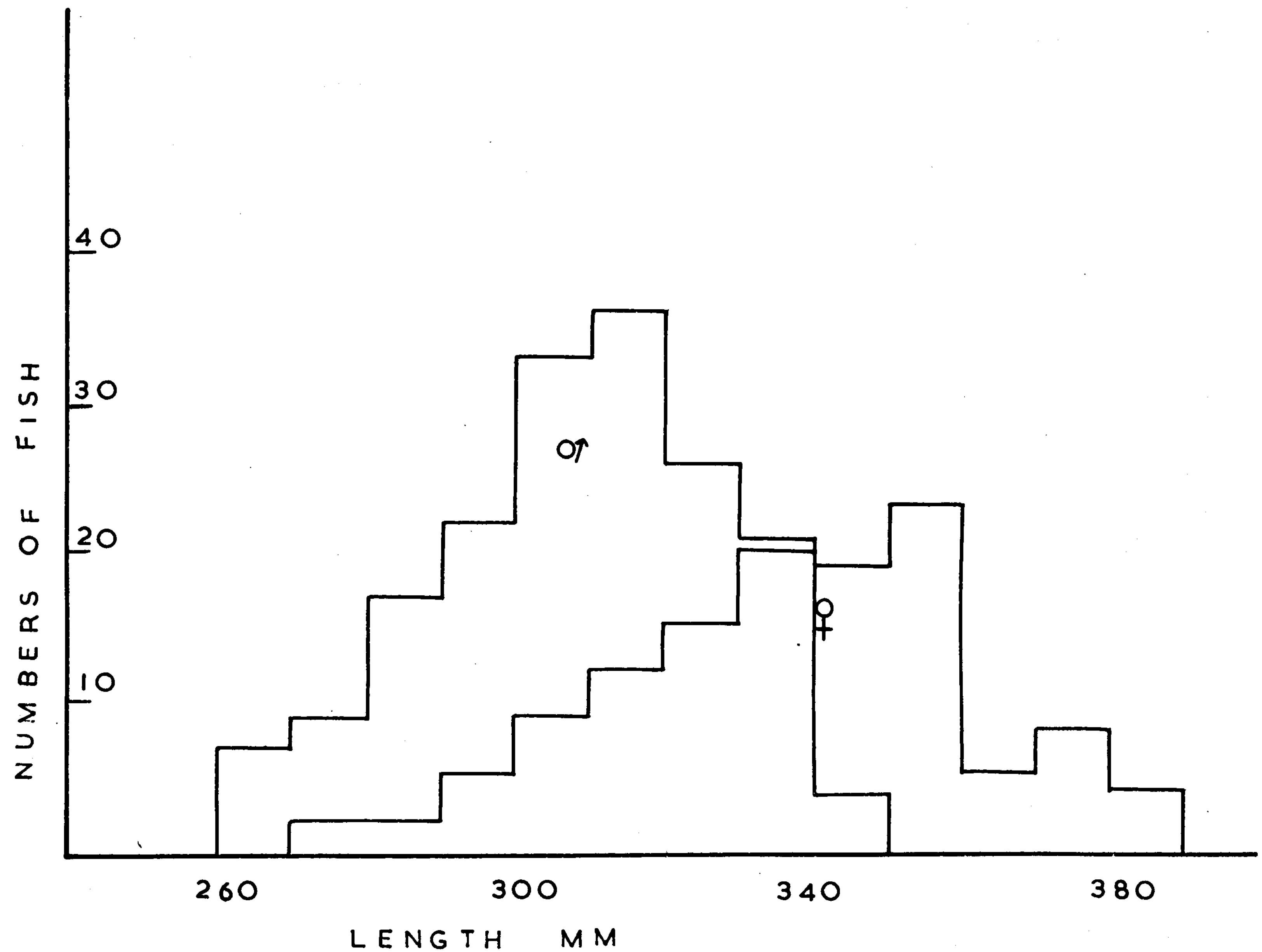


Fig. 3 B 6
Length-frequency histograms for " bred " males and females of *Labeo mesops*

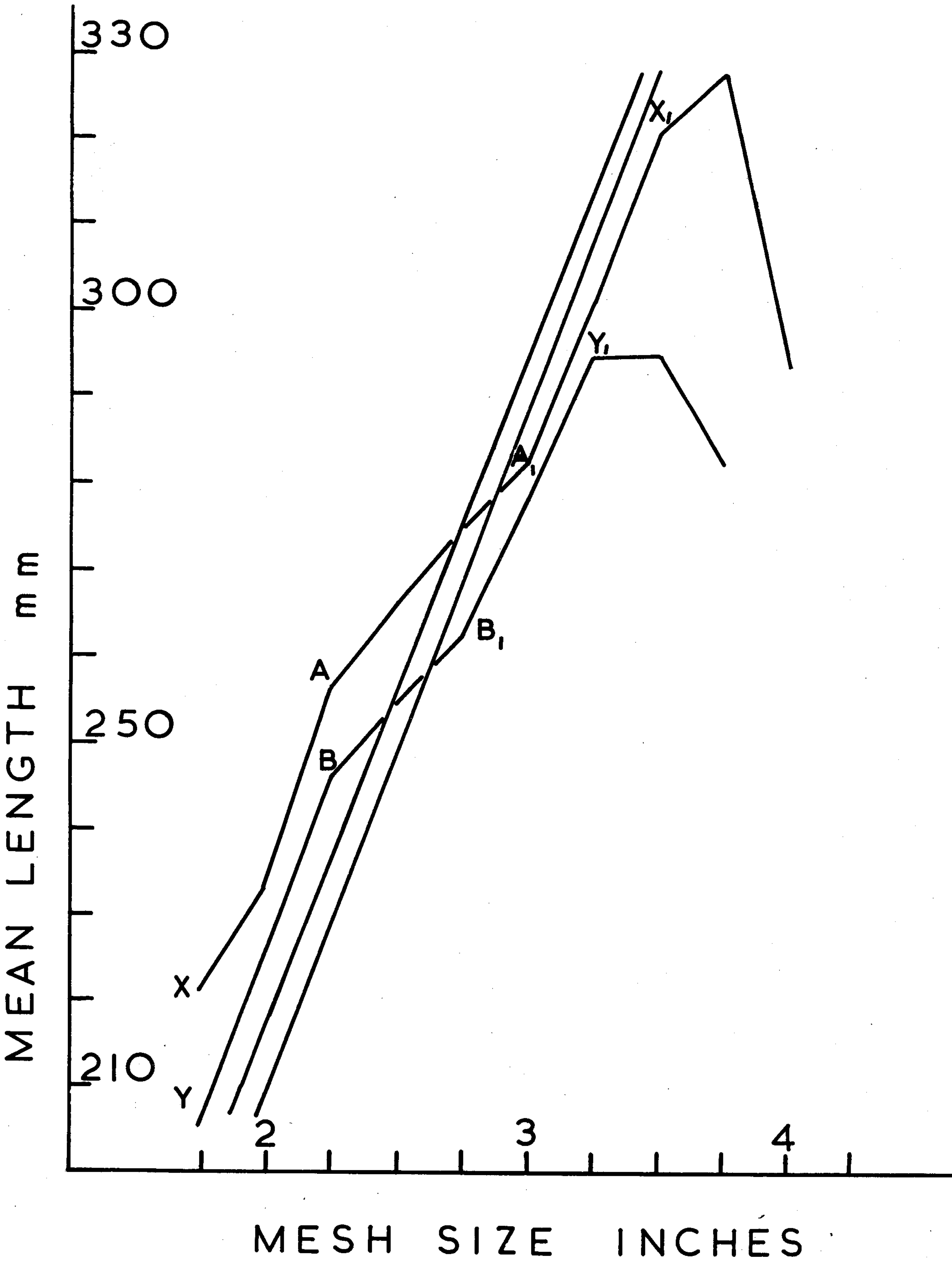


Fig. 3 B 7
Gill-net selectivity. Relationship between mesh size and mean length in *Labeo mesops*

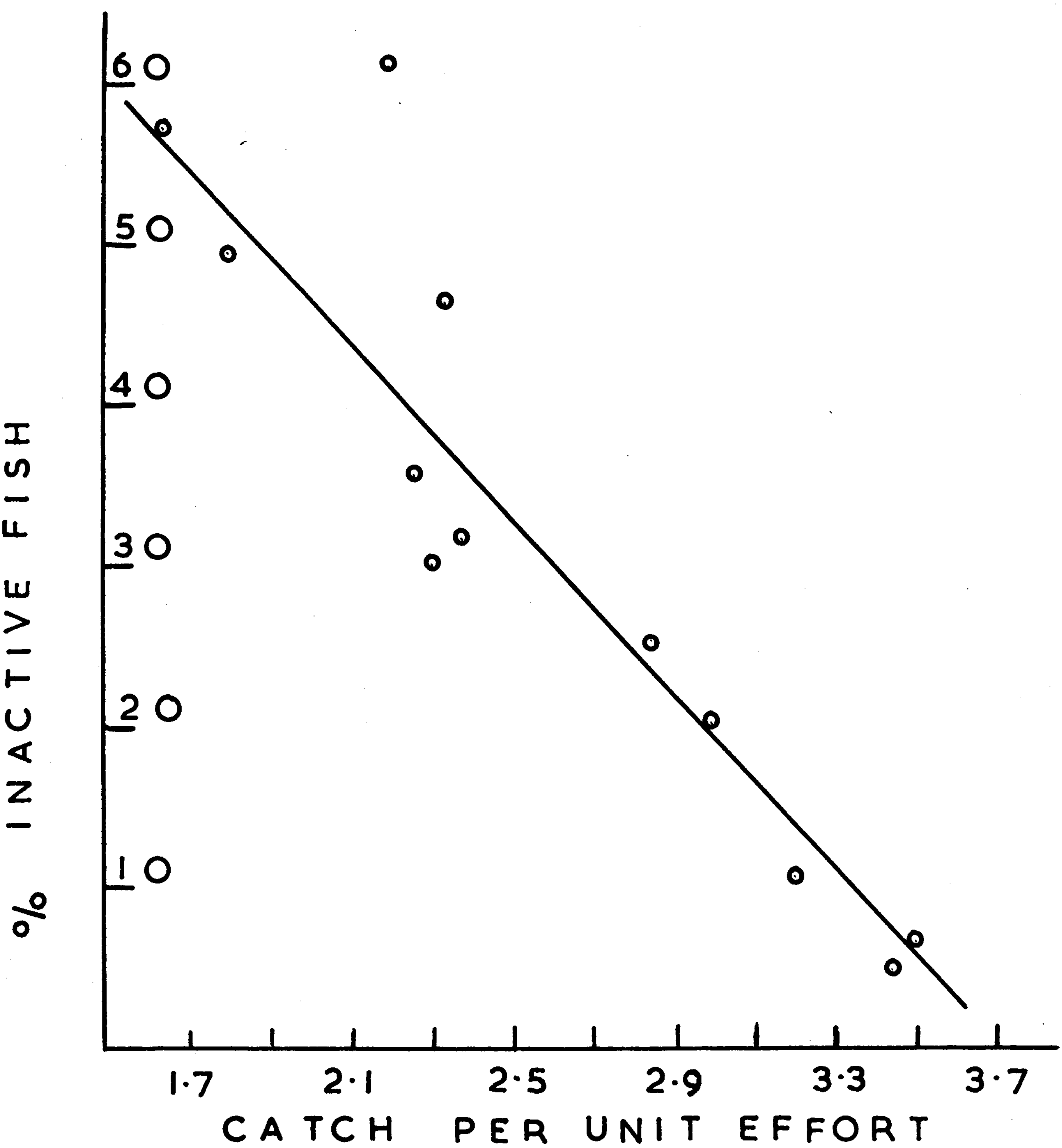


Fig. 3 B 8
The relationship for each month of the year between catch per unit effort and percentage of inactive fish caught

4. CONTRIBUTIONS

(i) Notes on the Salinity Tolerations of Certain *Tilapia* species (Cichlidae: Pisces) in Northern Rhodesia, by M. A. E. Mortimer, M.Sc.*

INTRODUCTION

The ability of *Tilapia mossambica* (Peters) to live in estuarine conditions of salinities of over 30 per cent. as well as fresh water has been recorded (Chimits, 1955).

In Northern Rhodesia *T. mossambica* occurs naturally in the Zambezi River below the Victoria Falls and in certain tributaries, such as the Luangwa River. In the Zambezi River above the Victoria Falls and in the Kafue River, an allied species, *Tilapia andersonii* (Castelnau) occurs, with which *T. mossambica* will interbreed under certain conditions (Mortimer, 1960); there are, however, some definite morphological and biological differences between the species.

The geographical isolation of *T. andersonii* from naturally occuring estuarine conditions has led the author to suppose that this species, unlike *T. mossambica*, might not tolerate high salinities. The following notes describe a preliminary experiment accordingly to determine whether a gross difference in the salinity tolerations of *T. mossambica* and *T. andersonii* occurs. An experiment with *Tilapia macrochir* (Boulenger) (Kafue variety) and *Tilapia melanopleura* (Dumeril) was carried out for comparison.

METHODS

The *T. mossambica* specimens used in the experiments were inbred pond specimens, originating from the Luangwa River and the *T. andersonii* used were inbred pond specimens originating from the Kafue River.

The experiments were carried out in rectangular brick, cement-plastered tanks, each holding about 170 gallons of water. Borehole water was used to fill the tanks and had a sodium chloride content of only 8 p.p.m. A number of specimens of each species were stocked into each of two tanks.

One tank was used as a control, and the other, after a period of acclimatisation, had amounts of sodium chloride added at approximately twenty-four-hour intervals. Salinities were determined at twenty-four-hour intervals, by titration against silver nitrate.

RESULTS

A.—*T. mossambica* and *T. andersonii*

(i) Ten fish of each species were stocked; the *T. mossambica* being twelve to fifteen centimetres and *T. andersonii* thirteen to eighteen centimetres in total length.

(ii) The temperature of the water throughout the experiment was 68° to 70°F.

(iii) The results of adding sodium chloride to a tank containing *T. mossambica* and *T. andersonii* are given in table 1, from which it can be seen that both species tolerated a gradual increase in salinity up to 26 per cent. NaCl., and deaths occurred at salinities of 38.4 to 35.5 per cent. NaCl.

(iv) Three *T. mossambica* and five *T. andersonii* transferred from water with a salinity of about 33 per cent. NaCl., to fresh water survived and were still alive and active two days later. It was noted, however, that on transference to fresh water *T. andersonii* lay moribund on their sides on the bottom for an hour or two.

(v) The fish in the untreated control tank (No. 6), were alive and active from 14th January, 1961 to 25th January, 1961, when they were transferred to water with a salinity of 33.8 per cent. In 3½ hours all the fish had died.

B.—*T. melanopleura* and *T. macrochir*

(i) Nine specimens of *T. melanopleura* of 13.2 to 15.5 centimetres and ten specimens of *T. macrochir* of 11 to 17.7 centimetres in total length, were stocked into a tank with a salinity of 7 per cent. NaCl.; nineteen hours later all were alive. The salinity was then increased to 13.5 per cent. NaCl. and twenty-four hours later all but three *T. macrochir* were dead. It was noted that the dead *T. melanopleura* were floating on the surface but the *T. macrochir* were on the bottom.

(ii) The temperature of the water throughout the experiment was 68° to 70°F.

(iii) Ten *T. melanopleura* and ten *T. macrochir* in an untreated tank were alive and active throughout the experiment.

*Department of Game and Fisheries, Chilanga, Northern Rhodesia.

Conclusions

The results given above, although of a preliminary nature only, indicate that no gross difference exists in the salinity tolerations of *T. mossambica* (Peters) and *T. andersonii* (Castelnau), although small differences might exist, since at salinities of 28.4 per cent. NaCl. to 35.5 per cent. only three out of seven *T. mossambica* died, whereas six out of ten *T. andersonii* died.

One clear fact is that *T. andersonii* is more closely related to *T. mossambica* in its osmoregulatory mechanism than to *T. melanopleura* and *T. macrochir*, which can tolerate salinities of 7 per cent. to 13.5 per cent. NaCl. only.

The ability of *T. mossambica* and *T. andersonii* to withstand an extreme change from high salinity to low salinity and not vice versa, is of some interest.

Table I

TANK 7

Date and Time	*NaCl added lb.*	*Salinity NaCl %*	*Temperature °F*	*Observations*
14th January, 1961	—	8 p.p.m.	70	Stocked ten *T. mossambica*, ten *T. macrochir*.
16th January, 1961				
06.30	—	8 p.p.m.	70	All alive.
08.30	8·25	4·1	—	
17th January, 1961				
06.30	—	—	68	All alive.
08.00	8·25	8·1	—	
18th January, 1961				
06.30	—	—	68	Heavy rain diluted water. Three *T. mossambica* jumped out. All remaining in tank alive.
07.30	8·25	9·8	—	
19th January, 1961				
06.30	—	—	68	All alive.
07.00	10	14·9	—	
20th January, 1961				
06.30	—	—	70	All alive.
07.00	8·25	16·2	—	
15.15	10	21·6	—	All alive.
21st January, 1961				
06.30	—	—	70	All alive.
07.00	10	26·0	—	
22nd January, 1961				
08.45	—	—	—	All alive.
09.00	10	28·4	—	
23rd January, 1961				
06.30	—	—	70	One *T. mossambica* dead.
07.00	10	33·3	—	
14.00	—	—	—	One *T. andersonii* dead.
24th January, 1961				
06.30	—	—	70	One *T. mossambica* dead, two *T. andersonii* dead, remainder alive but not active. One *T. mossambica* and one *T. andersonii* transferred to fresh water in tank 5.
07.00	6	35·5	—	
14.15	—	—	—	One *T. andersonii* dead. Two fish in tank 5 alive.
25th January, 1961				
06.30	—	33·8	68	Two *T. andersonii* and one *T. mossambica* dead. Two *T. mossambica* and four *T. andersonii* transferred to fresh water in tank 5.

References

Chimits, P. (1955). *Tilapia* and its Culture. *F.A.O. Fish. Bull.* **8**, 1.

Mortimer, M. A. E. (1960). Hybrid *Tilapia* in Northern Rhodesia. *CCTA/CSA/Hydrobiol. Inl. Fish Symposium, Lusaka.*

(ii) Notes on Misidentifications of *Serranochromis* species (Pisces, Cichlidae) in recent Literature, by M. A. E. Mortimer, M.Sc.

In recent years there has often been confusion as to the specific identity of certain of the fish species of Northern Rhodesia, but the publication of *The Fishes of Northern Rhodesia: A Check List of Indigenous Species* by the Government Printer, Lusaka (Jackson, 1961, in Press), will do much to clarify the position. In particular, misidentification of *Serranochromis robustus*

(Gunther) and *Serranochromis thumbergii* (Castelnau) has occurred, and it is now necessary to correct references to these species, in recent publications, as follows:

(1) J.F.R.O. Annual Report No. 8 for 1958:

(c) pp. 55–57, for *S. thumbergii* read *S. robustus.*, pp. 42 ff., the references to *S. thumbergii* are correct.

(b) p. 7, Tables IVc and Va, for *S. thumbergii* read *S. robustus*; p. 8, Tables Vb and Vc, for *S. thumbergii* read *S. robustus*; p. 11, Table Xa, for *S. thumbergii* read *S. robustus*; p. 12, Table XII, for *S. thumbergii* read *S. robustus*; p. 40, Table of Local Names, "Nembwe" is *S. robustus* and not *S. thumbergii*, although it is probable that "Nembwe" refers to both species in the Kafue; p. 40, Table of Local Names, for *Serranochromis macrolepidotus*, which is a *lapsus calami*, read *S. macrocephala.*

(2) J.F.R.O. Annual Report No. 9 for 1959:

p. 67 ff., for *S. thumbergii* read *S. thumbergii* and *S. robustus.*

(3) Department of Game and Fisheries, Northern Rhodesia, Annual Reports:

1958: p. 10, para. 57, for *S. thumbergii* read *S. thumbergii* and *S. robustus.*

1959: p. 16, para. 106, for *S. thumbergii* read *S. thumbergii* and *S. robustus.*

(4) Proceedings of the First Federal Fisheries Day, 1957, Salisbury, Government Printer:

p. 32 ff., for *S. thumbergii* read *S. thumbergii* and *S. robustus.*

I am grateful to Mr. P. B. N. Jackson for allowing me to read his *Check List of Northern Rhodesian Fishes* in manuscript form.

(iii) The Spoilage of Dry Fish Products through Insect Infestation and Damp, by E. G. R. Pike*

The importance of fish in the diet of the peoples of Northern Rhodesia cannot be overestimated, and the economy of many thousands of people dwelling in the vicinity of the great lakes depends upon fish alone. The dry fish trade, in particular, is especially important to the country as a whole. During the year 1960, for example, from the Bangweulu Fisheries area alone, a total quantity of 1,291,770 lb. of dried fish was exported to Copperbelt markets. The value of the dried fish trade per annum from the three main northern fisheries areas under consideration, namely the Bangweulu Fisheries area, the Mweru-Luapula Fisheries area, and the Mweru-Wantipa Fisheries area, has amounted in recent years to well over £1,500,000. This already large sum will doubtless increase very considerably in the future in spite of spasmodic setbacks to the trade through political and other circumstances.

It is most necessary, therefore, that in these fisheries, in addition to the existing conservation measures aimed at protecting the fisheries from overfishing and destructive methods of fishing, some consideration should be given to assisting the fishermen to produce a better quality dry fish product, and to try to prevent serious losses to dry fish consignments which are caused all the time by insect infestation and damp.

The total annual losses of dry fish from these fisheries areas caused by insect infestation and damp cannot be accurately stated without statistics. These could only be obtained by a comprehensive survey which would begin at the fish camps in the central swamps, and end at Copperbelt fish markets, but a valuable estimate has been arrived at in the following manner: During 1960, each bundle of fish passing through the fish check posts at Samfya and Kapalala was opened for the purpose of checking species making up the consignments. It was thus not only easy to detect the presence of infested fish, but frequently, although by no means always, possible to weigh the total quantity of infested fish.

It must be remembered that this is an early stage of the product's life, and infestation becomes progressively worse as the product becomes older. At Samfya and Kapalala spoilage through insect infestation and damp in dry fish consignments arriving from the central Bangweulu Swamps for export to Copperbelt markets can safely be put at 3 per cent. of the total, by weight, in the rainy season and 1½ per cent in the dry season. That these figures must be a considerable underestimate makes the position all the more serious. Losses from the same cause in the country's other fisheries areas will not be less; probably more, as the Bangweulu product is generally the best.

It will be seen, therefore, that the quantity of dry fish infested per annum is very considerable at the present time, and will certainly not decrease unless remedial measures are taken. Considering the Bangweulu Fisheries area alone, the swamps have a vast fisheries potential which will be increasingly exploited in the years to come by reason of great increases in human population and demands for protein in the form of fish. It is evident, therefore, that in any long-term fisheries policy, it would be advisable to give a certain degree of priority to the investigation of the problem of insect infestation and means of combatting it. Producers of dry fish must be helped to understand, and to take action against infestation, which can certainly be brought under a degree of control quite easily if the right methods are adopted. In other countries in Africa the infestation of dry fish products became such a problem that it was necessary to promulgate and to enforce legislation governing the management and general hygiene of fish camps.

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It is not suggested that such a course be contemplated here yet, but there can be no doubt that some action will have to be taken as soon as funds and additional fisheries staff are available. Already advice and help on a limited scale have been given to fishermen and to trade generally by J.F.R.O. and the Department of Game and Fisheries. At present, however, staff and funds available are totally inadequate to attempt to put into operation any scheme aimed at the efficient control of infestation and the education of fishermen and traders.

The insect causing the most damage to dry fish, after the smoking stage (i.e. fish in storage and in transit), is the larva of the *Dermestes* beetle. There is no doubt at all about this, as specimens from infested consignments have frequently been sent to Chilanga for identification. The dermestid beetle is very well known in other parts of the world as a first-class enemy of many kinds of animal food products, including dry fish. The insect seems to be a very hardy one, and from experiments carried out at Samfya, once it has established itself at a fish camp, it will " stay put " for an apparently indefinite period, living in the thatch of the smoke houses, and in the cracks of the poles. Even when fishing and processing is finished for a period of three months or more, and the fishing camp is deserted, the beetle lingers on, awaiting the opening of the next fishing season. It was found that, once the beetle had got a foothold in the fishing camp, the only way to get rid of it was to burn the camp down, and saturate the ground with D.D.T. 10 per cent. in water. The utmost care is taken at the fish check points, where dry fish is often in storage, to disinfect the stores after the loading of each consignment, in order to prevent dermestid beetles getting into the stores from infested fish. In 1952, in the fish trade of the Upper Nile and Equatoria Provinces, South Sudan, it was estimated that the dermestid beetle caused damage to dry fish in store amounting to £17,000.

Apart from the *Dermestes* beetle, there are of course many other insects which infest dry fish, and important among them are cockroaches, of several species, a species of weevil believed to be *Trichobaris trinotata*, ants, and various species of flies, including house-flies and blow-flies, which lay their eggs in the crevices of the tissues of the fresh and dry fish. Blow-flies are of course very abundant at fish camps to which they are attracted by the blood, guts, and entrails left lying about, and the fresh fish which is put into the sun to dry prior to smoking.

A few of the more intelligent fishermen and traders are becoming increasingly aware of the necessity of trying to avoid the infestation of their fish as much as possible, but the majority show no interest because it is still possible for them to sell dry fish which would be condemned as unfit for people to eat in countries with better standards. This state of affairs is not likely to continue much longer, however, and there is no doubt that Copperbelt and local markets are becoming much more discriminative, and the time cannot be far distant when fishermen and traders alike will be forced to improve the overall quality of their dry fish products. This they cannot do if they do not understand how to avoid bringing fish from fish camps for sale which has become useless for food through infestation by insects and damp.

Both fishermen and traders, therefore, should take greater notice of this problem, and be warned that the public which buys their product will soon demand a higher standard. It seems necessary also for Government, through the Department of Game and Fisheries, to initiate a campaign to help and educate the fishermen, and provide means of disinfestation. Insect infestation is a problem to fisheries the world over, and in most fisheries efforts are made to combat it in various ways. In unsophisticated fisheries such as these, it is obviously not possible and practicable to impose regulations concerning hygiene etc., which fishermen would find difficult to understand, but it is possible to demonstrate to them desirable methods of disinfestation and cleanliness. The problem is one which can be solved by fishery experts working with the fishermen in the fisheries areas over a reasonable period; the co-operation of fishermen and traders would be forthcoming. An entomologist working with fisheries field staff would be a great help in the early stages, and a special section of the Fisheries Department should ultimately be responsible for anti-infestation work in the field. A great deal of research work has been carried out on the fisheries of Northern Rhodesia, but nothing so far has been done on an aspect of the fisheries which is so very important to the fish trade as a whole, namely insect infestation of dry fish.

5. PUBLICATIONS

This list of publications, written by members of the J.F.R.O. or on material provided by the J.F.R.O., is of papers either already published or accepted for publication by the end of the year 1960, papers in preparation not being included. Serial numbers 1–24 are listed at the end of the two previous annual reports. Reprints are in short supply in many cases, but requests for reprints will be met as far as possible.

25. ILES, T. D. ... ... 1960 A group of zooplankton feeders of the genus *Haplochromis* (Cichlidae) in Lake Nyasa. *Ann. Mag. nat. Hist.* (13), 2.

26. JACKSON, P. B. N. ... 1960 Hydrobiological research at Kariba. *New Scientist* **17**, 177.

27. FRYER, G. ... ... 1958 A note on *Lernea bistricornis* Harding, a parasitic copepod from Lake Tanganyika. *Rev. Zool. Bot. Afr.* **58**, 214.

28. FRYER, G. ... ... 1960 Evolution of fishes in Lake Nyasa. *Evolution* **14**, 3, 296.

29. BOWMAKER, A. P. ... 1960 Preliminary observations of a survey being carried out to study the effects of seasonal changes of water conditions on the ecological regime of Luaka Lagoon, an inlet on the southern swampy shore of Lake Bangweulu. *CSA/CCTA 4th Hydrobiol. Inl. Fish. Symposium, Lusaka.*

30. HARDING, D. ... ... 1960 Preliminary observations on the effects of seasonal change in water condition on the fishery in the Bangweulu area of Northern Rhodesia. *CSA/CCTA 4th Hydrobiol. Inl. Fish. Symposium, Lusaka.*

31. ILES, T. D. ... ... 1960 Prebreeding migration of common Lake Nyasa fishes. *CSA/CCTA 4th Hydrobiol. Inl. Fish. Symposium, Lusaka.*

32. ILES, T. D. ... ... 1960 An opinion as to the advisability of introducing a non-indigenous zooplankton feeding fish in Lake Nyasa. *CSA/CCTA 4th Hydrobiol. Inl. Fish. Symposium, Lusaka.*

33. JACKSON, P. B. N. ... 1960 On the desirability or otherwise of introducing fishes to waters that are foreign to them. *CSA/CCTA 4th Hydrobiol. Inl. Fish. Symposium, Lusaka.*

34. JACKSON, P. B. N. ... 1960 *Kariba Studies: Ichthyology, the fish of the Middle Zambezi.* Manchester University Press.

In Press

JACKSON, P. B. N., HARDING, D., FRYER, G., and ILES, T. D. —— *Report on the Survey of Northern Lake Nyasa by the Joint Fisheries Research Organisation.* Govt. Printer, Zomba, Nyasaland.

JACKSON, P. B. N. ... ... —— The ecological effects of flooding by the Kariba Dam on Middle Zambezi fishes. *Proc. 1st Fed. Sci. Congress, Salisbury.*

JACKSON, P. B. N. ... ... —— *A Check List of the Fishes of Nyasaland.* S. Rhod. Mus. Memoir, Salisbury.

JACKSON, P. B. N. ... ... —— The impact of predation by the tiger-fish (*Hydrocyon vittatus* Cast.) on Central African fishes. *Proc. Zool. Soc. Lond.*

GULLAND, J. A., and HARDING, D. —— The selection of gill-nets of the cat-fish *Clarias mossambicus*. *J. Conseil.*

HARDING, D. ... ... —— Limnological trends in Lake Kariba. *Nature, London.*