EAST AFRICAN COMMON SERVICES ORGANIZATION

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# EAST AFRICAN FRESHWATER FISHERIES RESEARCH ORGANIZATION

## ANNUAL REPORT 1962/63

Six Shillings - 1964

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P.O. Box 343,
Jinja,
Uganda.

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## INTRODUCTION

Since the appearance of the last E.A.F.F.R.O. Annual Report, for the year 1961, the Organization has passed through a period wherein many of its research staff retired under the compensation scheme, or left on completion of contract, so that for a time it was virtually without scientific staff. The position was made more critical by the sudden and unexpected death of its Director, Dr. V. D. van Someren, of a coronary thrombosis on 28th March 1962. For a period of time in 1962 the continued future existence of the Organization was a matter of some doubt, but recruitment started again in the latter part of 1962, following discussions between the East African Common Services Organization and the United Kingdom Department of Technical Co-operation.

By mid-1963 completely new scientific staff had been recruited, and by the end of this year the establishment was entirely filled. Several trainee posts, also, had been estimated for under the Africanization programme of replacing expatriate with local personnel, and progress was made in selecting and arranging for candidates to fill these posts.

A new research programme was drawn up and approved in mid-1963, and by the end of the year work was proceeding on all aspects of the programme. This Annual Report, accordingly, deals with the two years 1962 and 1963, in view of the hiatus in the research work mentioned above, and the fact that for much of these years the Organization was without a Director and virtually on a care-and-maintenance basis.

## STAFF

*Director*:
P. B. N. Jackson, M.Sc.

*Research Officers*:
M. J. Mann, B.Sc.
D. A. Cadwalladr, B.Sc., M.I. Biol.
R. L. Welcomme, B.Sc.
J. M. Gee, Ph.D., F.Z.S.

*Experimental Fisheries Officer*:
M. P. Gilbert.

*Secretary*:
Miss E. M. Keatinge.

*Senior Field Officer*:
R. I. M. Baxter.

*Accounting Assistant*:
L. F. D'Costa.

*Foreman Artisan*:
Pragji Dossa Meswania.

*Laboratory Assistants*:
Habill Oduke.
Flaminio Moini. James Oguti ?

*Coxswains*:
William.
Edward.

## GENERAL

As mentioned in the Introduction, the present staff position shows an almost complete change from that obtaining at the end of 1961. Of the staff present then, Mr. C. C. Cridland was the first to leave, on 15th February 1962. Mr. Cridland, who had been with the Organization since 1947, retired after this long and valuable service under the compensation scheme.

On 28th March 1962, Dr. V. D. van Someren, the Director, died suddenly and unexpectedly of a coronary thrombosis. Dr. van Someren was a distinguished scientist in both the hydrobiological and ornithological fields. His death was the more tragic in that he was to retire in June 1962 under the compensation scheme.

Mr. H. Y. Elder became the acting Director, but he himself left on 2nd June 1962 on completion of his contract. Mr. E. L. Hamblyn, similarly, left on completion of his contract on 1st May 1962.

After this Mr. J. D. Roberts, Experimental Fisheries Officer, was appointed Officer in Charge of the Organization. The only occupant of the laboratories was Dr. M. Hyder, who had arrived on 1st April 1962 on a three years Nuffield Research Scholarship for research especially on aspects of the physiology of *Tilapia*. In view of the death of the Director the administration of Dr. Hyder's scholarship went to Makerere University College. After remaining at Jinja for a year, Dr. Hyder went to the Inland Fisheries Research Centre at Sagana, Kenya, on 22nd March 1963 to pursue his studies there. In July, Dr. Hyder took up an appointment at the Royal College, Nairobi, as a lecturer.

On 8th September 1962, Mr. D. B. C. Scott arrived on secondment from Glasgow University for one year. Mr. Scott undertook work on the reproductive physiology of *Mormyrus kannume* and left on completion of his year's secondment, on 27th August 1963. A preliminary report on his work is attached at Appendix I to this Report.

Mr. J. D. Roberts, Experimental Fisheries Officer, proceeded on leave pending retirement, his last day of leave being 14th October 1963, after over 11 years' service with the Organization.

The staff position at the end of the year 1963 is shown in the staff list above. Mr. P. B. N. Jackson arrived on 4th March 1963 to take up appointment as Director on secondment from Northern Rhodesia.

Mr. D. A. Cadwalladr arrived on 1st November 1962 to take up one of the Scientific Officer vacancies. He was followed by Mr. R. L. Welcomme on 12th January 1963 on a similar appointment. Mr. M. J. Mann arrived on 25th April 1963 to fill the third of the vacancies. Mr. Mann had previously served for four years as a Fisheries Research Officer in Nigeria. The fourth and final of the Scientific Officer vacancies was filled by Dr. J. M. Gee, who arrived on 1st September 1963.

The post of Field Officer to the Organization has now been abolished, and the holder, Mr. R. I. M. Baxter, will proceed on leave pending retirement on 1st March 1964. Some reorganization of staff duties is planned, and part of the present duties of Field Officer will be taken over by the Foreman Artisan, while it is planned to recruit a trainee Maintenance Supervisor, on the "D" (trainee) scale, work on the routine estate maintenance aspects of the post, the whole coming under the general supervision of the Experimental Fisheries Officer.

Mr. M. P. Gilbert arrived on 29th November 1963 to take up the appointment of Experimental Fisheries Officer, a post made vacant by the retirement of Mr. Roberts. Mr. Gilbert had previous service in a similar capacity in Northern Rhodesia and Nyasaland.

Messrs. J. Okedi and C. Odora, undergraduate students of Makerere University College, Kampala, worked at the laboratory for three months of their long vacation from 1st April to 30th June 1963. Similarly, Mr. M. L. Modha, undergraduate student of the Royal College, Nairobi, worked at the laboratory from 1st August to 14th September 1963.

Mr. O. K. Itazi was appointed to us on appointment as learner Laboratory Technician, and arrived on 1st May. However, Mr. Itazi was accepted as an undergraduate student by Makerere University College and left to commence reading for a B.Sc. degree on 25th June 1963.

Mrs. D. Grahame, Secretary to the Organization, left on 30th April 1963 following her husband leaving Uganda. The post of Secretary was then taken over by Miss E. M. Keatinge on 1st May on a full-time basis. The filling once again on the establishment and the revival in the activities of the Organization, necessitated again the provision of a full-time Secretary.

## LAUNCHES AND VEHICLES

Apart from routine maintenance slipping, both the Organization's launches have given good service for the two years under review. Due to the increasing age of both these vessels, both of wartime vintage, maintenance work becomes more frequent, but, given adequate and skilled maintenance of engines and hull, both are capable of giving many more years service.

No order has yet been placed for the much larger new motor fishing vessel for long range work, sufficiently seaworthy for the open waters of Lake Victoria, arrangements for the purchase of which were mentioned in the 1959, 1960 and 1961 Annual Reports. During 1961, details were finalized regarding the craft of 55 feet length overall, the welded steel hull of which was to be made by the African Marine and General Engineering Co., of Mombasa, and railed in sections to Lake Victoria, as mentioned in the 1961 Annual Report. The total cost of the craft, finished and fully equipped was in the neighbourhood of £24,000, of which 50 per cent was to be contributed by the Directorate of Technical Co-operation in Britain. The uncertainty as to the future of E.A.F.F.R.O. which prevailed at the time, however, led the East African Agricultural and Fisheries Research Council, at their 17th meeting on 25th/26th January 1962 to agree that no further action be taken for the time being.

Following the death of the Director, Dr. van Someren, shortly thereafter, and the departure of the remainder of the research staff, the matter was then left in abeyance until mid-1963, when the question of obtaining this urgently needed vessel was taken up again. At the time of writing it is hoped to negotiate a United Nations Special Fund Aid Scheme (*see* below) in which the provision of a large and sea-worthy launch figures as part of the aid.

The urgency with which this craft is needed is temporarily mitigated at the present time by the loan to us for a short period of the launch *Pelican*, by the Kenya Fisheries Department. *Pelican*, one of the Fairmile launches of the old Lake Victoria Fisheries Service, has been loaned following upon redisposition of the Kenya Fisheries Department's staff and funds as a result of retrenchment in that Department. She was taken over on 11th September 1963 and as she is a much more seaworthy craft than either of our other two launches, has already been considerably used on the open lake, especially in connexion with the Nile Perch work.

It is now planned to transfer our small No. 2 launch to Lake Rudolf where, as our work there develops, she will become most useful as providing a means of transport and a research tool for the study of the Lake Rudolf fishes to which we are committed.

The Bedford pick-up truck ran some 2,500 miles on duty during the year 1962, and 5,500 miles in 1963. Considering the age of the vehicle (purchased new in 1954) its condition is very fair, and it has considerable use in estate maintenance work and is also capable of sedate running on the shorter *safaris*. As mentioned in the 1961 Report, the body work shows inevitable deterioration and in 1962 the vehicle was spray-painted and the bodywork repaired, while in 1963 further repairs to the body and brakes were carried out and the engine decarbonized.

Owing to calls from the Fisheries Departments of all three countries for work on some of the remoter fisheries of East Africa, which entails long *safaris* over difficult roads, representations were made in 1963 for the purchase of a Land-Rover. It was not possible to obtain a new one, but an old vehicle was made available by East African Agriculture and Forestry Research Organization. This vehicle, though useful, is unsuitable because of its age and mileage to undertake any extensive *safaris*, though spare parts have been ordered to place it in a more roadworthy condition.

## BUILDINGS

While the existing buildings are fundamentally sound, there continues to be deterioration in parts of the fabric as mentioned in the previous Annual Report, particularly in some of the tiled roofs and in the electrical wiring. While routine maintenance has continued, the sum available is insufficient to tackle the larger jobs, and with the help of the Property and Maintenance Officer, an estimate has been obtained for the large work of rewiring the buildings to modern standards. An estimate has also been obtained for the retiling of certain of the roofs. It is hoped that these sums will be provided as special expenditure in the 1964/65 Estimates.

Costing has also been done for the provision of new junior staff quarters. The position in regard to junior staff quarters, never very good, has been made worse by the abnormal height to which the level of Lake Victoria has risen in the two years since the previous Annual Report. This has resulted in housing on the lake shore now being unfit for habitation. Provision for special expenditure for new housing is therefore also being sought for next year's Estimates.

## LIBRARY AND ADMINISTRATION

Subscriptions to periodicals, etc., continued to be paid during the care-and maintenance period of the Organization in 1962, so that there was at no time any break in the normal acquisitions to the Library.

During 1963, the book section of the library was reclassified according to the Universal Decimal System by Mrs. S. Scott. There was not time to classify similarly the Organization's collection of reprints of scientific papers, now approaching 6,000 in number. These are therefore kept under the old classification system, a system which has been found to work satisfactorily in practice.

In February 1963 Mr. Scott attended the East African Natural Resources Research Council's first meeting, on behalf of E.A.F.F.R.O. The Freshwater Fisheries Research Co-ordinating Committee meeting was held at Jinja on 22nd May 1963, some three months after the arrival of the new Director. In order to resume the normal sequence of having Co-ordinating Committee meetings towards the end of the year, the second Co-ordinating Committee meeting was held on 27th November 1963 at Zanzibar.

During the latter half of the year negotiations were in progress towards the formation of a United Nations Special Fund Scheme in order to strengthen freshwater fisheries research in East Africa. Following on a directive from the East African Social and Research Ministerial Committee, a Working Party, comprising Permanent Secretaries or their representatives from all three countries, with the Research Secretary of the Common Services Organization and the Director, E.A.F.F.R.O., met on 18th September 1963 to discuss details. A detailed scheme was drawn up with the agreement of all concerned, embodying strengthening of research in biological, statistical and economic fields, and by the end of the year the scheme was in a form suitable for submitting as a request to the Special Fund, once authorization for the expenditure of the necessary local funds has been obtained.

Some discussion was also undertaken during the year in regard to the possibility of some fundamental biological work on biological productivity being done at Jinja under the auspices of the International Biological Programme. The International Biological Programme is at present in the planning stage, and it is hoped that it will be possible for it to undertake some of its fundamental research here.

During the year also closer liaison was also mooted between E.A.F.F.R.O. and Makerere University College. This would follow the example set of the liaison formed between the Royal College, Nairobi, and the East African Veterinary Research Organization, and would have similar advantages of closer co-operation in scientific work and better facilities and opportunities for the instruction of the trainee local staff which are coming to the Organization in increasing numbers.

The Director attended the General Assembly of the International Union for the Conservation of Nature held in Nairobi in September 1963 and contributed a paper to it on the impact of man on the natural environment in regard to impounded waters. In Nairobi also the Organization contributed as usual to the Royal Show, held in October.

## SCIENTIFIC WORK OF THE ORGANIZATION

As has been mentioned above, there has been a complete turnover of staff since the appearance of the last Annual Report, which means that apart from the published work listed in the Publications section, and the reports of the work done by Messrs. Hamblyn and Elder, while they were here, which are still awaited, none of the research work has been in hand for longer than a year at most, and in some cases projects were started only a few months ago, depending on the date of arrival of the new Scientific Officers. None of this new work has yet been finalized, of course, thus the present reports are largely more preliminary in nature than was usual in previous years, when there was more continuity between one year and the next.

Following on the completion of a new sewage pond system by the Jinja Municipal Council, 480 *Tilapia nilotica* and 150 *T. zillii* were stocked into the lowermost of the series of three ponds and 150 *T. zillii* were stocked into the middle of the three, on 13th December 1963.

### FISHERIES OF LAKE VICTORIA

As another result of the cessation of activity in 1962, the analyses of commercial fish statistics supplied by the Fisheries Departments has been discontinued since the publication of the last Annual Report. Moreover, none of the officers on the present establishment of the Organization have been assigned to such work, all being engaged on other priorities; none, moreover, of the present staff have been especially trained in statistical work so that none are especially qualified to do it. While Tanganyika and Uganda, also, have continued to send in some returns, the collection of data as to the commercial catches from Kenya waters, including the very productive Kavirondo Gulf has been stopped owing to financial stringency, resulting in the Kenya Fisheries Department having to withdraw from Lake Victoria.

This situation is very undesirable because of the impossibility of managing and calculating adequately the scope of this very large and valuable fishery without proper collection and analysis of statistical data pertaining to it, and a large part of the proposed Special Fund scheme referred to above is designed to provide a more adequate service for the analysis of fisheries statistics. In this scheme an expert statistician would be provided who during his tenure would train local staff; these would then continue the service on a permanent basis as one of the functions of the E.A.F.F.R.O., much as it was intended it should be one of the functions of the erstwhile Lake Victoria Fisheries Service.

In the meantime, there is no doubt that the greatly increased height of Lake Victoria during the last two years, which has raised it to a maximum of some seven feet above its previous highest level, has had a very beneficial effect on the fisheries. It is probable that much of this effect has been caused by the flooding creating larger spawning grounds better protected by vegetation for many of the important commercial species including the *Tilapias*. It is almost certain also that a further most important contributory factor caused by the flooding is the fact that it is now no longer possible in most areas to use seine nets. The high level of water has resulted in most of the shoreline being of flooded shrubs and other vegetation which makes the use of this gear, which drags along the bottom, impossible. The well-known adverse effects of this gear in destroying the nests and interfering with the courtship display no longer exist, and the fish have, it would appear, responded by greatly increased productivity, which, after a year or two had elapsed to allow the more numerous broods to grow to catchable size, has resulted in greatly increased catches. This effect is particularly noticeable in the Kavirondo Gulf where heavy seine-netting used to take place but has now virtually ceased.

In general, improved catches are noticeable all around the lake. Table I gives returns from the Fish Market at Massesse, near Jinja, Uganda, where accurate records have been taken since March 1962 and where the improvement in the landings especially of wet (fresh) fish can clearly be seen.

TABLE I

Monthly totals, in lb. of wet and dried fish landed at the Massesse Fish Landing, Jinja, in 1962 and 1963. Thanks are due to Dr. P. D. Kemp, Medical Officer of Health, Jinja, for kindly providing these figures.

| Month | 1962 | | 1963 | |
|---|---|---|---|---|
| | Fresh | Dried | Fresh | Dried |
| January | 41,399 | 13,101 | 85,952 | 18,130 |
| February | 48,723 | 19,527 | 95,701 | 12,149 |
| March | 43,962 | 9,722 | 98,526 | 13,071 |
| April | 44,086 | 3,360 | 92,273 | 9,720 |
| May | 54,917 | 2,885 | 108,544 | 9,304 |
| June | 33,507 | 3,453 | 97,214* | 25,372* |
| July | 22,996 | 3,553 | 137,372 | 29,258 |
| August | 34,626 | 11,163 | 112,627 | 7,300 |
| September | 49,182 | 6,429 | 166,018 | 10,020 |
| October | 54,025 | 8,096 | 133,367 | 5,819 |
| November | 60,058 | 14,010 | 104,935 | 6,480 |
| December | 57,204 | 6,321 | 113,922 | 8,705 |

* According to the Medical Officer of Health the figures for June 1963 were in fact heavier than here stated.

## The Nile Perch in Lake Victoria

It is now clear that the Nile Perch (*Lates niloticus*) is firmly established at two points in Lake Victoria, both in Uganda waters. These are the coastline and islands immediately outside of the Napoleon Gulf near Jinja, and similarly the costline round about Entebbe Bay. There is evidence that fish are spreading from these two focal points and the extent of spread will be further investigated in 1964.

Work on the spread of Nile Perch in Lake Victoria, their biology and impact upon the endemic species in the lake started in September 1963 on the arrival of Dr. J. M. Gee, whose report on his four months' work is given as Appendix A to this Report. In addition to the history of the stocking of Lake Victoria and of other waters in Uganda to which the Nile Perch was not endemic, some interesting points have already emerged from this brief period of work and are given in Appendix A.

Over 120 specimens have so far been received at this laboratory from Lake Victoria. None of these however have yet been caught in our own nets by ourselves or the Uganda Fisheries Department, despite the fact that both Departments have fished especially for Nile Perch both near Jinja and Entebbe. This is because the population of perch in Lake Victoria is as yet so small that the odds are enormously against a specimen being caught in any one fleet of nets such as ours, while the chances of capture in any one of the thousands of commercial nets operating in the area are immensely greater. Therefore, a reward system was instituted which resulted in most of the fish being caught in the Jinja area being brought to the laboratory.

Preliminary results on the feeding of these fish (most of which are in the 24-35 cm. size range though being caught mainly in gill-nets, as commercially used in the local fishery of 4 in. and 4½ in. mesh, selective in these sizes for Nile Perch) show that thus far the main fish consumed by them in Lake Victoria are mormyrids, especially *Marcusenius* and cichlids, particularly *Haplochromis*, which latter genus was found in over half of the stomachs. In Lake Kyoga the fish examined had a similar preponderance of *Haplochromis* though mormyrids were absent. *Tilapia* remains were found in 9 of the 20 fish examined (in which prey occurred) from Lake Kyoga, or just under 50 per cent, but in only 8 of the 77 fish with prey in the stomach from Lake Victoria, or just over 10 per cent of the total. These preliminary figures showed also that a greater variety of prey fish was found in the Victoria stomachs than in the Kyoga or Albert stomachs, that the Kyoga fish appeared to live almost exclusively on Cichlidae and that in neither of these two lakes non-endemic to the perch was freshwater prawn (*Caridina nilotica*) used to anything like the same extent as in Albert.

A study of comparative condition factors showed fish from where they are not endemic to be fatter and in generally better condition than they are in Lake Albert, where they are endemic. If this trend persists in future years, it will be an interesting reflection on the ability of the perch to thrive better in those waters whose fauna is at once more varied and less adapted to co-existence with a predator of this stature than is the case where it is endemic.

## Ecology and Productivity Studies, Especially on Young Tilapia

These are studies to obtain a fuller knowledge of the ecological and physiological requirements especially of young *Tilapia*, aimed primarily at seeking to improve the productivity of *Tilapia*; one hope being, by increasing our understanding of the factors involved, to increase the natural input of young fish into heavily exploited lakes.

Appendices B to E to this Report give an account of the work done thus far in this field by Mr. R. L. Welcomme since his arrival here. The work includes a study of the fishes of a typical small river/swamp system, which flows into Lake Victoria and is much used by Lake Victoria fishes, observations on several shores of Lake Victoria in order to determine the factors governing the distribution of *Tilapia* and *Haplochromis* species, with special reference to their fry, experiments on the resistance of species of *Tilapia* and *Haplochromis* to extremes of temperature and low dissolved oxygen, and a study on the present distribution of the several species of *Tilapia* that have been artificially introduced into Lake Victoria.

The study of the river/swamp system has showed that the fish using the system are firstly migrant from Lake Victoria, which run into the river as sexually active fish, spawn at discrete sites up river and thereafter return to the lake. The juvenile fish develop at the spawning grounds and subsequently move lakewards. It is an interesting point that all fish found in this category during the first 10 months have all been or no or little commercial importance. Yet records from less extensive studies done on the same river in previous years have indicated that the river was then used by such commercially important species in this category as *Labeo victorianus, Clarias mossambicus* and *Schilbe mystus*. The present study is of course incomplete as yet, and further data on this question will be collected. A second category is of fish which are found associated with the river system at all stages of their lives. The only resident found here was the Egyptian Mouthbrooder (*Hemihaplochromis multicolor*) a well-known aquarium fish.

The third and final category is classed as facultative, i.e. those species which normally are found in alternative habitats in Lake Victoria and have spread into the lower part of the system, using the increased area of swamp produced by the rise in lake level during the rainy season. These include a number of important commercial species, especially four species of *Tilapia*, viz., *T. nilotica, zillii, esculenta* and *leucosticta*. The environment in which this category is found is clearly an important one in the economy of the lake, particularly at the present time when the lake has risen to such a high level, creating large areas favourable to fish in this category.

Supplementary to this work is the study of the juveniles of *Tilapia* and *Haplochromis* on the shallow shores of beaches. Previous work by E.A.F.F.R.O. has defined the habitats of the adults of the Lake Victoria *Tilapia*, and this work elicited also the knowledge that fry were to be found on the lake shore, the size of fry increasing with depth or distance from the shore. The present study is designed to increase our knowledge of the physical and ecological factors governing the distribution of the fry and their growth and productivity, about which little is as yet known. In latter years moreover the existing picture has been obscured by the increasing influence of certain of the species which have been introduced into the lake when they were previously not endemic.

An important factor is the existence, on different types of beaches, of gradients of such physical measurements as temperature, dissolved oxygen, turbidity, etc., and *Tilapia* appear to be more tolerant of adverse conditions than are *Haplochromis*. On a particular shallow, grass-flooded beach *Tilapia zillii* were particularly abundant, a preliminary estimate of numbers of fry in shallow water being 14 per square metre. Nevertheless, the loss of fish in the small size range up to about 5 cm. is low, representing a survival rate of 75 per cent. After this there is a greater loss which is, however, probably due largely to emigration to the deeper waters.

Studies of *Tilapia* fry on the beaches and their productivity are extremely important and are continuing, although the work is made extremely difficult both by the present high level of Lake Victoria and the unusually rapid fluctuations in height at that level, so that what is one day a beach may be flooded a few weeks later.

An increasing amount of time has to be spent, on Lake Victoria, in studying the influence and behaviour of the now quite numerous non-endemic species which have been artificially stocked and established themselves in the lake. These now include three species of *Tilapia, T. leucosticta, T. zillii* and *T. nilotica,* and notes during the year have been made on the habits of each.

*Tilapia leucosticta* often stunts, and fish have been found breeding at as small a size as 7 cm. Few fish appear at present in the commercial catches (only 40 individuals were recorded at the large Massesse fish landing during each of the months of November and December 1963), but fairly numerous isolated populations of the species are to be found in lagoons and other outer marginal limits of the lake. In some cases deformed individuals have been found, indicating perhaps that some environments used are marginally harsh. *T. leucosticta,* apparently, has not expanded in the lake but rather has colonized those areas which previously were unoccupied by the native species of *Tilapia.*

*Tilapia nilotica,* again, has not yet fulfilled the presumed hopes of those who stocked it, of increasing the commercial fishery, and only 66 of the many thousands of *Tilapia* landed at Massesse in November 1963 were of this species. There is some evidence that it is at times cross-breeding with the native *T. variabilis,* and in general it appears at present to occur mainly in papyrus lagoons and grass swamp fringes than in the main lake.

*Tilapia zillii* continues to be the most successful of the introduced species of *Tilapia.* It is to be found all round the lake in the shallower areas, and commercially now rivals (and possibly competes successfully with) the native *T. variabilis.* In November 1963 the quantity caught and landed at Massesse represented 30.2 per cent of the *Tilapia* catch (*T. variabilis* was 20.8 per cent of the catch). Fry are to be found in variable proportions on all types of beaches, but, in addition, *T. zillii* seems to share with the other two introduced species the penchant also for colonizing the lagoons and swamps "behind" but adjacent to Lake Victoria, not normally used by the native species. More than any other species, perhaps, *T. zillii* has benefited from the rise in lake level of recent years, and swarms in all the areas of flooded grass terrain.

Finally some experiments have commenced on the resistances of species of *Tilapia* and *Haplochromis* to extremes of temperature and dissolved oxygen as part of the studies on the distribution and productivity of these species on the beaches of Lake Victoria. The work is in progress, but preliminary results indicate that *Haplochromis* are generally more sensitive to high temperatures than are *Tilapia zillii.*

FISHERY SURVEYS ON LAKES IN KENYA AND TANGANYIKA

Following requests from the Fisheries Departments of Kenya and Tanganyika, an important part of the E.A.F.F.R.O. research programme for 1963/64 is a programme to investigate and report upon some of the remoter waters of East Africa, in these two countries, where an actual or potential fishery exists, notably Lakes Rudolf in Kenya and Rukwa and Kitangiri in Tanganyika.

Mr. M. J. Mann commenced this work after his arrival in April 1963 and by the end of the year had completed and reported upon one visit each, of about six weeks' duration, to Lakes Rukwa and Rudolf. Further visits are planned for 1964 to examine the areas both in the wet and dry seasons of the year. Reports of his preliminary visits are contained in Appendices F and G to this Report.

In both cases experimental fishing was done and compared to the commercial fishing effort, and ecological notes taken of the commercial species concerned. Data was accumulated on relative abundance of species and the species towards which the major commercial fishing effort is at present directed. In the case of Lake Rukwa, the present commercial fishery is increasing, but is principally dependent on a single species, *Tilapia rukwaensis*. However, several other commercially valuable species such as *Gnathonemus* and *Hydrocyon* are hardly exploited. While this need for a more balanced fishery exists, Lake Rukwa nevertheless has a productive fishery capable of considerable expansion. Marketing and transport services for the fishery products, however, stand in need of considerable improvement at present.

A preliminary visit was made to Ferguson's Gulf, Lake Rudolf, during October and November 1963, but work on this visit was restricted to areas close to the Gulf. In common with other East African lakes during the past year or two, the level of Lake Rudolf has risen considerably and a good deal of the adjacent land which was above waterline some years ago is now flooded, so that a large number of palm trees and other vegetation along the lake shore are submerged and, in some cases, dead. Possibly associated with the high lake level is the presence of a large growth of bulrush (*Typha* sp.) in a flourishing condition. The growth of this plant is stated not to be a permanent feature, the plant in some years dying out completely and then, after a period of time, re-establishing itself.

Lake Rudolf is the last great lake remaining in Africa with its fish population in a pristine, natural condition, though it will not long remain so, and this is reflected in the experimental gill-net catches, as well as those of the present small commercial fishery. Thus the fish population is at present balanced, with a number of large, old fish of all species in addition to larger numbers of younger fish. Lake Rudolf is famed for the large size of its *Tilapia nilotica*; this natural large size of this species, coupled with the fact that many old, and therefore big, fish remain due to the absence of a large commercial fishery, results in enormous specimens, of the order of 20 lb. in weight, sometimes being taken.

As is usual in most African freshwater fisheries, *Tilapia*, in this *T. nilotica*, is the most esteemed species and thus the most sought for by the fishermen. However, it is predominantly an inshore fish.

Catches from the experimental gill nets showed a marked distinction in catches with depth of water and distance from shore. Bottom-set nets laid off-shore took mostly: *Labeo, Lates, Citharinus, Barbus, Distichodus, Bagrus* and *Clarias* in the larger meshes, with *Hydrocyon, Schilbe* and *Synodontis* in the smaller meshes. In surface-set nets laid off-shore, the proportions of *Citharinus* increased greatly, and far fewer, though nearly always some, *Synodontis* were taken. *Tilapia* were taken in negligible quantity only in any nets set off-shore.

In general, *Tilapia* are taken within 100 yards of the shore and in sheltered bays and inlets such as Ferguson's Gulf. Beyond the 100-yard mark *Citharinus* predominate.

The present commercial fishery of the area is centred at Ferguson's Gulf, and consists of fishermen of the nomadic Turkana tribe who have been trained to the fisherman's trade, and very well trained, by the Kenya Fisheries Department. The main commercial net-setting effort took place around the mouth of Ferguson's Gulf, and the catch was composed of *Citharinus*, *Lates* and *Tilapia nilotica* with occasional *Distichodus*, *Labeo* and *Synodontis schall.*

While *Tilapia* are held in most esteem and are most readily saleable, certain others are held in considerably less esteem, and this is particularly of note in the case of *Citharinus*, as it forms the largest single component of both the commercial and the experimental gill-net fishery. The effective marketing and sale of fishery products from Lake Rudolf forms in any case a considerable problem because of the remoteness of the area from centres of urban population. Every effort must be made to ensure a sale for the less popular as well as the more popular species if the fishery is to flourish.

The present commercial fishery of Lake Rudolf has its origin in attempts to provide food and employment for the Turkana tribesfolk, a nomadic people who because of increase in their population (in common with the rest of the human race) in recent times, coupled with some severe droughts, have been threatened with famine, and for whom for many years now famine relief measures have been applied. Some hundred families are now employed, and fish very skilfully. The problem, however, of integrating their catch from this isolated area into the market of East Africa, which is at present adequately filled by fish from more accessible areas, remains, and is being tackled by the Kenya Fisheries Department.

Considerable quantities of crocodiles exist in Lake Rudolf, but these are now being actively hunted apparently in accordance with the school of thought that holds that the crocodile population must be virtually exterminated before a successful commercial fishery can be developed, and it would appear that even very immature reptiles of only 18 in. long are being destroyed when found. While there is no doubt that the presence of numerous very large crocodiles can wreak havoc with a gill-net fishery, the economic fact is that crocodile skins are a most valuable export commodity, and a far greater and more valuable demand exists, as things are at present, for the crocodiles of Lake Rudolf than for its fish. Destroying young crocodiles which are in the insect-eating phase of their life, and will not begin to eat fish, and thus become even a remotely possible threat to a gill-net fishery for many years yet, seems to be at variance with a correct economic policy for this area. It appears to be desirable to apply modern wildlife management methods, especially in regard to controlled cropping, to derive the greatest possible financial advantage from this valuable resource, while at the same time protecting the gill-net fishery adequately.

### Studies on Anadromous Fish

A programme of study on those fish which migrate up rivers at certain seasons of the year to spawn has been started. One of the most important commercial groups of fishes with this habit are those of the genus *Labeo*, and most of the work for the past year has been concentrated on *Labeo victorianus*, which has most of its life in Lakes Victoria and Kyoga, but which migrates into the affluent rivers in order to spawn.

A report from the officer concerned is attached at Appendix H. A considerable amount of data on the breeding biology of *Labeo victorianus* in Lake Victoria has been obtained, mainly from the Nzoia River in Kenya, the Kagera River in Uganda and the Buvuma Channel, Jinja. In these rivers *Labeo victorianus*, as is usual for fish of this genus, form the basis of a very important seasonal fishery for the local people. The peak seasons are March and April, and October and November of each year, coinciding with the maximum rainfall months of the two rainy seasons, and the fishery is mainly one of weirs and traps to capture the fish on their spawning migrations up river. A method of fishing with drifting gill-nets, one end of which is attached to a canoe, is however, also very effective.

There is much evidence that in both the Nzoia and Kagera Rivers, the fishery has declined very considerably in recent years, perhaps more particularly in the Kagera River. To take the Nzoia River as an example, however, the recorded landings in 1959 were 157,510 in number, but in 1962 they were only 16,062, and similar figures could be quoted for the Kagera. A river fishery for spawning fish where fish put themselves into a position of danger in response to the reproductive urge, and are easily caught in large quantities while in a gravid condition, is perhaps the most vulnerable to overfishing of all fisheries. Thus it is possible that the low catches of recent years may be attributable to overfishing, bearing in mind that in no case are there any management techniques employed, and the position must be watched.

A tagging programme was undertaken for *L. victorianus* at Jinja, during February and March, resulting in 13 per cent of the 340 fish tagged being returned. One Jinja fish tagged in February was caught off the Nzoia in March, having taken a maximum of 34 days to cover a minimum of 60 miles. Recovery of tags from the Nzoia area is at present difficult owing to the absence of Kenya Fisheries Department staff from Lake Victoria, but tagging in this area has started and will continue in 1964 in the hopes of determining the sites from which they migrate and will presumably return to.

Morphological examination of a large number of fish, by cutting and staining sections of the reproductive organs has given a greater insight into the rate and extent of development of the ovary, and the times of year and size of ovary at which primary oocytes develop into secondary oocytes and thence into mature eggs. Counts of mature eggs were made to determine the primary fecundity of female *L. victorianus*. Mature females were found down to a length of 11.9 cm. standard length, and the number of eggs is directly proportioned to the lengths of fish. The maximum number of eggs counted was 113,847 in a fish of 21.6 cm. standard length.

Work has also been done on the age and rate growth of this species, and preliminary results indicate that a size of about 11 cm. standard length is attained after the first year, and that fish begin to become sexually mature after the first year. Correlated with this age work, the selectivity of gill-nets of various meshes has been worked out. The conclusion has been reached that fish caught in a mesh size of two inches, apparently the smallest normal size used in the commercial fishery, are of a length greater than 16.5 cm. and are in their second or third year's growth. Studies on the growth and fishing effort for this important species are continuing.

## PUBLICATIONS

The following is a list of publications appearing during the years 1962 and 1963 written by members or past members of E.A.F.F.R.O., or by visiting research workers. The serial numbers are continued from the Annual Report for 1961. Reprints are available in some cases, and requests for them will be met as far as possible.

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160. EVANS, J. H.—Some New Records and Forms of Algae in Central East Africa. *Hydrobiol., 20 (1), 1962.*

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165. JACKSON, P. B. N.—Ecological Factors affecting the Distribution of Freshwater Fishes in Tropical Southern Africa. *Ann. Cape, Prov. Mus. II,* 162, 1963.

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167. GARROD, D. J.—An Estimation of the Mortality Rates in a Population of *Tilapia esculenta* Graham in Lake Victoria, East Africa. *J. Fish. Res. Bol. Canada, 20* (1), 1963.

168. TALLING, J. F.—Origin of Stratification in an African Rift Lake. Limnol. Oceanog., *8 1,* 1963.

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171. JACKSON, P. B. N., ILES, T. D., HARDING, D. and FRYER, G.—*Report on the Survey of Northern Lake Nyasa* 1954-55 *by the Joint Fisheries Research Organization.* Govt. Printer, Zomba, Nyasaland, 1963.

*APPENDIX A*

## NILE PERCH INVESTIGATION

BY J. M. GEE

### I.—INTRODUCTION OF NILE PERCH INTO UGANDAN WATERS

The Nile Perch, *Lates niloticus albertianus*, is endemic only in Lake Albert and the Nile below the Murchison Falls although fossil evidence does point to a wider distribution of the species in Miocene times. Since 1955 a systematic programme of stocking Nile Perch into various lakes in Uganda has been followed by the Uganda Fisheries Department and is summarized below:—

*Lake Kyoga*

*Lates* from Lake Albert were stocked at Masindi Port and at Jinja (Victoria Nile, below the Owen Falls Dam) in September 1955 and April 1956. The first report of capture of a perch in the lake came in July 1958 from Lwampango, 35 miles from Masindi Port. Returns became regular after July 1959. Nile Perch were reported from the Kadunguru Peninsula, 70 miles from Masindi Port, in 1961 and in December 1962 they were reported from Lale and the North Busoga shore. The latest report is from Sambwe and because of dense papyrus swamp penetration is unlikely to continue eastwards. Nile Perch, therefore, had spread throughout Lake Kyoga by December 1962, a distance of 80 miles in seven years. No recoveries have so far been made below the Owen Falls Dam.

*Kabaka's Private Lake in Kampala*

Nile Perch were originally stocked here to estimate their effect on the *Tilapia* population of Lake Victoria. Thirty fish (total length varying from 23-64 cm. and the largest weighing 4 lb.) were stocked in April 1960. There is evidence that these have bred early in 1962 and again in 1963. In this latter year a 50-lb. Nile Perch was taken in the lake on rod and line.

*Lake Nabugabo*

This lake was suggested by Worthington (*Report on the Fisheries of Uganda.* Crown Agents; London, 1932) as a possible site for a pilot introduction of Nile Perch. Information gathered from such a scheme however could not be directly applied to Lake Victoria as the former, among other things, is decidedly more acid than the latter. Eighty-five fish (lengths varying from 30-40 cm.) were stocked in May 1960. Although no reports of capture have come from the local fishermen, perch from the lake have been seen for sale in the local market. An additional stocking of 180 fish was made in July 1963.

*Lake Kijanebalola*

There was no commercial fishing on this lake until *Tilapia* were stocked just before the War. These have flourished and formed the basis of quite a rich fishing industry. Nile Perch were introduced into the lake as a pilot scheme to ascertain probable effects of any introduction into Lake George and Lake Edward. Nineteen perch were introduced in February 1962 and because there was no evidence that these had bred or even survived a further 180 fingerlings were stocked in August 1963.

*Lake Awoja*

A small swampy lake connecting Lake Salisbury with the southern arm of Lake Kyoga was stocked with 30 fingerlings in June 1963.

*Lake Salisbury*

No recoveries were made from some fish stocked in 1961 and in June 1963 a further 80 fingerlings were stocked.

*Lake Saka*

Is a crater lake of 640 acres near Fort Portal. *Tilapia nilotica* and *Haplochromis* sp. are present in the lake but the growth of these fish is very stunted. As the lake has great angling possibilities and a plentiful food supply 75 fingerlings were stocked here in July 1963.

*Lake Victoria*

For a number of years the advisability of stocking Lake Victoria with Nile Perch has been much debated. However in May 1960 a perch was caught at Bugungu just above the Ripon Falls and another at Waigali in Hannington Bay in November of the same year. There are three possibilities as to how perch gained entry into the lake:—

(1) Through the turbines of the Owen Falls Dam.

(2) By anglers bringing live fish from Lake Albert.

(3) From the Luwala Dam, draining into Lake Victoria at Nyenga, which was stocked with 18 fish by E.A.F.F.R.O. in October 1959. Although the dam is separated from the lake by papyrus swamp it is possible for fish to have been washed through in the heavy rains of August 1961.

It is now certain that a breeding population exists in the lake, probably centred in Hannington Bay and down the Buvumu Channel. In May 1962, 35 perch were stocked off Entebbe Pier by the Uganda Fisheries Department. Their lengths varied between 16.0 and 43.5 cm., and the fish were marked by clipping the second and third dorsal spine. A further stocking of 339 fingerlings was made off Entebbe in September 1963. No perch have been artificially stocked at Jinja but eight Nile Perch from Lake Rudolf were stocked at Kisumu in the latter half of 1963 by the Kenya Fisheries Department.

II.—DISTRIBUTION OF NILE PERCH IN LAKE VICTORIA

Between September and December 1963, 13 fishing trips have been made to various localities for the specific purpose of catching Nile Perch. A graded fleet of nets ($3\frac{1}{2}$-8 in. mesh), all mounted by the $\frac{2}{3}$rd had been used. So far no Nile Perch have been caught, which is very probably due to the fact that they are still comparatively rare in the lake, so that the chances of a specimen being caught in any one fleet of nets are small. All records of, and data for, perch on Lake Victoria therefore has been obtained from fish bought from local fishermen (primarily at the Massesse Fish Market, near Jinja). Because of this, information on their distribution is limited to those places within the hinterland of Massesse or to the distance local fishermen are prepared to travel to Jinja for the reward.

Figure A1 shows the numbers of perch caught at various localities in the lake. The density of native nets around the Napoleon Gulf, Hannington Bay and Buvumu Channel is roughly the same. Thus the numbers of fish caught in these various localities are probably comparable. It seems likely that some perch originally got through the turbines of the Owen Falls Dam, the first record from Lake Victoria being at Bugungu in the Napoleon Gulf. It would appear that there has been a southward and eastward movement out from the Napoleon Gulf (where no perch have been caught in the last year), round each side of Buvumu Island. Populations now appear to be established at the western end of Hannington Bay and down the Buvumu Channel. The one record for Lufu is a reliable record as the fish was brought to the laboratory and I examined it. The record shown for Lolui Island, however, is not certain as I was not able to examine that fish. It was caught on rod and line and eaten, but the person who caught it had seen Nile Perch before in the E.A.F.F.R.O. laboratory.

In order to gain more information on the distribution of Nile Perch in Lake Victoria it is planned to visit all the fishing stations and fishing camps along the coast and on the islands in the lake, from Entebbe round as far as the Kavirondo Gulf.

## III.—Biological Notes on Nile Perch

### *Length frequency and gill-net size for Nile Perch from Lake Victoria*

The data compiled from returns by local fishermen is presented in Fig. A2. Since Nile Perch have so many spiny projections on the fins and opercula it may have been assumed that the fish would become easily entangled in any size net, thus reducing the gill-net selectivity. The results, however, show a definite selectivity of the various gill-nets, particularly 3, 4 and 4½ in. nets. The proportional number of fish caught in each net is probably not significant due to the preponderance of 4 and 4½ in. nets over the smaller mesh sizes used by local fishermen. When the histograms for the different net sizes, given in Fig. 2, are combined a definite peak occurs at 28-30 cm. However, because the gill-nets are highly selective and the effort of the various size nets is not the same, this cannot, at the moment, be taken to represent an age class. Because the sampling of the size range of fish caught in the 4 and 4½ in. gill-nets is being done efficiently by local fishermen, the E.A.F.F.R.O. graded fleet of Nile Perch nets has recently been modified to include 500 yards of both 5 in. and 6 in. nets. A 9½ in. net has also been made but as no perch have, as yet, been caught in the 5-8 in. nets, this 9½ in. net has not yet been used.

### *Weekly returns of Nile Perch from Massesse*

The histogram in Fig. A3 shows the weekly catch of Nile Perch from September to December, within the hinterland of Massesse Fish Market. Also shown is the total weekly rainfall for the same period and the number of rain days in each week. From these figures it can be seen that the approximate duration of the rainy season was from the week beginning 20th October to the week 14th December. It would appear that there is some correlation between the rainy season and the weekly catches of Nile Perch, more fish being caught during the rains than during the dry season. However, the records will have to be continued for many months before such a statement can be made with certainty. When fishing on Lake Kyoga and Lake Albert a correlation was noted between the numbers of perch caught and the weather on the night of fishing, as is shown below:—

| | Date | No. of Perch caught | Weather |
|---|---|---|---|
| L. Kyoga .. | 11–11–63 | 4 | Fine, slightly overcast. |
| | 12–11–63 | 22 | Heavy rain most of night. |
| | 13–11–63 | 5 | Fine, slightly overcast. |
| L. Albert .. | 11–12–63 | 11 | Fine and clear. |
| | 12–12–63 | 33 | Overcast, slight rain. |
| | 13–12–63 | 4 | Fine and clear. |

On both lakes all three fishing were in the same place with the same nets.

### *Standard length/weight relationships*

The data for length/weight analysis has been obtained within the period October to December 1963 for fish from four lakes in Uganda; the Kabaka's Lake in Kampala, Lake Victoria, Lake Kyoga and Lake Albert. Seine nets only were used to catch fish in the Kabaka's Lake and gill-nets of varying sizes were used in the other three lakes. Because of the varying type and mesh size of the nets, there is no overlap in the data for the first three above-mentioned lakes but the data for Lake Albert overlaps with that for Lake Victoria and Lake Kyoga.

The standard length of all fish was measured from the tip of the praemaxilla to the end of the last caudal vertebra. The fish from Lake Kyoga and Lake Albert were weighed in the field on spring balances. Because of the wide range in weight, from 300-11,500 gm., a number of different balances were used varying in accuracy from 1-250 gm. This and smaller samples of larger fish, are the main reasons for the greater scatter towards the upper limits of the graphs.

The data for length/weight, for each 1 cm. group, plotted on double logarithmic graph paper, is given in Fig. A4. This does not take into account age, sex or maturity of the fish. It can be seen that for each group of fish the points lie about a straight line. Thus log length is directly proportional to the log weight according to the formula:—

$$\text{Log } l = \text{Log } n + K \text{ Log } w$$

where w = weight
l = length
n = a constant, due to the non-intersection of the origin by the graph.
K = a constant, for the slope of the graph.

The constant K (or the slope of the line) is slightly different for fish from the different lakes, indicating a slight difference in condition.

Although the condition factor K cannot be worked out with great accuracy for each lake because of the varying sizes of gill-nets and the limited accuracy of weighing in the field, it is possible to arrive at approximate values. The value of K was calculated for each fish from each locality according to the formula:—

$$K = \frac{100W}{L^3}$$

where W = weight in grams
L = Length in cms.

The average K for each 1 cm. group from each locality was then plotted on arithmetic graph paper and the median value of K determined. This, and the mean value of K are given in Table 1. From this it can be seen that Nile Perch from Lake Albert, where they are endemic, have a lower condition factor than Nile Perch from Lake Kyoga, Lake Victoria and the Kabaka's Lake where they were recently introduced. It was most noticeable that fish from Lake Kyoga had a greater amount of fat lining the body cavity, and were generally healthier looking than fish from Lake Albert. These differences in condition between fish from Lake Albert and those from the other lakes, can, perhaps, be correlated with the colonization of new habitats with a relatively greater abundance of prey and the absence of competition from other voracious predators, particularly the Tiger-fish, *Hydrocyon*.

*Ageing of Fish*

Studies on growth of Nile Perch in the natural habitats depends largely on being able to determine the age of fish and the most common and accurate method of doing this is by the number of rings on the scales or opercular bones. Scales and opercular bones have been collected from most of the fish examined from all four above-mentioned lakes. Graphs of scale length or opercular bone length against body length show that their growth is proportional. A preliminary examination of the scales shows that there are no traces of true rings in the annuli on scales for fish from Lake Victoria and Lake Kyoga but rings may be present at irregular intervals on the scales of fish from the first two above-mentioned lakes, areas of denser and less dense dermal bone can be seen when the scales are held up to the light but as these cut across the line of the annuli they can be of no practical significance. The opercular bones have not yet been examined but here the problem is ossification, the bones becoming very thick and opaque in fish over about 50 cm. in length.

*Food and Feeding of Nile Perch*

Table 2 gives the total number of stomachs examined for fish from Lake Victoria, Lake Kyoga and Lake Albert and the percentages with and without stomach contents. It shows that more than twice as many Nile Perch from Lake Victoria and Lake Kyoga contained prey than from Lake Albert. This correlated with the differences in the K factor discussed earlier and from these two sets of data it is obvious that Nile Perch are more flourishing in the new environments which have not previously been subject to predation by this or any other important predatory species. Casual observations on the composition of the fish fauna of these three lakes indicates that the number of smaller species (e.g. *Haplochromis*) which appears to form the major part of the food supply of Nile Perch of any size, are far more abundant in Lake Victoria and Lake Kyoga than in Lake Albert.

Table 3 is an analysis of the types of prey taken by Nile Perch in Lakes Victoria, Kyoga and Albert. It indicates that they do not feed specifically on any one species, or even group, of fish but are catholic in their tastes. The Cichlidae are by far the most abundant group of fish found in Lake Victoria and Lake Kyoga whereas in Lake Albert only four species of *Haplochromis* are known, and these are not common, and the *Tilapia* stocks in the lake are rapidly declining judging by recent catch figures. This varying faunal composition is reflected in the food of Nile Perch. In Lake Victoria Cichlidae, particularly *Haplochromis*, forms the main basis of the food of Nile Perch (being found in over half the fish with any stomach contents). Mormyridae appear to be next in importance with *Alestes, Barbus* and *Engraulycypris* also making a significant contribution. In Lake Kyoga the Cichlidae appear to be almost the only form of food taken by Nile Perch. In Lake Albert, on the other hand, the Cichlidae form an insignificant part of the food of Nile Perch, and their place appears to be taken by *Alestes, Engraulycypris* and the freshwater prawn *Caridina nilotica.*

From the figures in Table 4 it can be seen that only a small percentage of the fish with stomach contents had more than one prey species in the gut at any one time. Most of the perch however had when examined more than one fish of the same species in the gut, all of which were in approximately the same stage of digestion, suggesting that they had been taken more or less simultaneously. These two points may be a reflection of the feeding habits of Nile Perch. It would appear that they attack a shoal of one particular species of prey and gorge themselves on it, rather than attacking a wide variety of isolated individuals.

So far little data has been obtained on the size of prey in relation to size of fish, due to the largely digested nature of the prey. However, such information as is available is given in Table 5. In African freshwater predatory fish it is not usual for the prey within the stomach to exceed 25 per cent of the length of the fish. Here however, it will be seen that on four occasions prey have been found to exceed the 25 per cent limit, and in one case (from Lake Kyoga) the prey was as much as 33 per cent of the length of the fish.

*Breeding of Nile Perch*

Although Nile Perch are obviously breeding in Lake Victoria, no information has yet been gained about their breeding habits. The gonads of all fish from Lake Victoria have been examined and the data is presented in Table 6. Up to now it has not been possible to determine the sex of those fish whose gonads are inactive but the striking feature of this Table is the absence of females with gonads in the active and ripe stages (3 compared with 56 males).

The only definite information on breeding has been obtained from the Kabaka's Lake where Nile Perch were known to have bred in April of this year as large numbers of fry and fingerlings were recovered in the seine nets in May and June. A second, smaller spawning took place at the end of October or the beginning of November as a few 5 cm. fingerlings were caught in a seine net on 21st November.

It would seem therefore that Nile Perch breed twice a year, to coincide with the two rainy seasons, but that the April breeding is the main one.

TABLE 1

| | Mean Value of K | Median Value of K |
|---|---|---|
| Kabaka's Lake .. | 2·028 | 2·075 |
| Lake Victoria .. .. | 2·165 | 2·180 |
| Lake Kyoga .. .. | 2·180 | 2·250 |
| Lake Albert .. .. | 1·993 | 1·940 |

TABLE 2

| | Lake Victoria | Lake Kyoga | Lake Albert |
|---|---|---|---|
| Number of Fish Examined .. .. | 124 | 31 | 48 |
| Per cent with stomach contents .. .. | 74 | 77 | 35 |
| Per cent without stomach contents .. | 26 | 23 | 65 |

TABLE 3

| | L. Victoria | | L. Kyoga | | L. Albert | |
|---|---|---|---|---|---|---|
| | No. of prey | No. of fish in which prey occurred | No. of prey | No. of fish in which prey occurred | No. of prey | No. of fish in which prey occurred |
| Unidentified fish remains | — | 16 | 22 | 8 | 2 | 2 |
| *Mormyridae* (unidentified) | 19 | 15 | — | — | — | — |
| *Marcesenius nigricans* .. | 6 | 3 | — | — | — | — |
| *Marcusenius grahami* .. | 6 | 3 | — | — | — | — |
| *Alestes jacksoni* .. .. | 5 | 4 | — | — | — | — |
| *Alestes baremose* .. .. | — | — | — | — | 6 | 4 |
| *Engraulycypris* .. .. | 7 | 6 | — | — | 3 | 3 |
| *Barbus* .. .. .. | 3 | 1 | — | — | — | — |
| *Clarias* .. .. .. | 1 | 1 | — | — | — | — |
| *Lates* .. .. .. | — | — | 1 | 1 | — | — |
| *Cichlidae* (unidentified) .. | 34 | 15 | — | — | — | — |
| *Tilapia* .. .. .. | 18 | 8 | 18 | 9 | 1 | 1 |
| *Haplochromis* .. .. | 58 | 24 | 40 | 14 | — | — |
| *Caridina nilotica* .. .. | — | — | — | — | V. many | 6 |
| Insects .. .. .. | — | 2 | — | 2 | — | — |
| Dragonfly larvae .. .. | — | — | — | — | 2 | 1 |
| Bivalve molluscs .. .. | 1 | 1 | — | — | 2 | 1 |

TABLE 4

| | L. Victoria | L. Kyoga | L. Albert |
|---|---|---|---|
| Number of fish with prey .. .. | 77 | 20 | 14 |
| Per cent with more than one prey species .. .. .. .. | 13 | 30 | 14 |
| Per cent with more than one prey of same species .. .. | 41 | 50 | 57 |
| Per cent with only one prey .. | 46 | 20 | 29 |

TABLE 5

| | S. length of Nile Perch | S. length of prey | Prey length as % of predator length | Species of prey |
|---|---|---|---|---|
| L. Victoria .. | 22·3 | 5·3 | 23·7 | *Haplochromis* |
| L. Albert .. | 26·7 | 3·0 | 15·0 | *Tilapia* |
| L. Victoria .. | 28·0 | 6·0 | 21·4 | *Haplochromis* |
| | 28·2 | 6·0 | 21·2 | ,, |
| | 28·2 | 4·9 | 17·6 | ,, |
| | 29·2 | 5·7 | 19·5 | *Engraulycypris* |
| | 29·7 | 7·7 | 25·9 | *Alestes* |
| | 30·1 | 5·4 | 17·9 | *Haplochromis* |
| | 30·2 | 7·6<br>6·7 | 25·1<br>22·1 | *Alestes* |
| | 31·1 | 8·0 | 25·7 | *Marcusenius* |
| | 31·2 | 6·5 | 20·8 | *Haplochromis* |
| | 33·0 | 5·3 | 16·1 | *Tilapia* |
| L. Kyoga .. | 44·9 | 13·0 | 28·9 | *T. esculenta* |
| | 51·6 | 15·0<br>16·0 | 29·0<br>31·0 | *Haplochromis* |
| | 59·2 | 19·5 | 32·9 | *T. variabilis* |

TABLE 6

| Lake | Month | Sex | Gonad States | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Im | Ia | Iaa | a | ar | r | rr | sp | |
| L. Victoria .. | Sept. .. | M | — | — | 4 | — | — | — | — | — | |
| | | F | — | — | — | — | — | — | — | — | 4 |
| | Oct. .. | M | — | — | 3 | — | — | 1 | — | — | |
| | | F | — | — | — | — | — | — | — | — | 4 |
| | Nov. .. | M | — | — | — | 19 | 5 | 7 | 1 | — | |
| | | F | 9 | 25 | 15 | 3 | — | — | — | — | 83 |
| | Dec. .. | M | — | — | — | 16 | 4 | 3 | — | — | |
| | | F | — | 24 | 9 | — | — | — | — | — | 56 |
| L. Kyoga .. | Nov. .. | M | — | — | — | — | 3 | 2 | — | — | |
| | | F | — | 23 | — | — | 2 | 1 | — | — | 31 |
| L. Albert .. | Dec. .. | M | — | — | — | 8 | 2 | 1 | — | — | |
| | | F | — | 27 | 5 | — | 2 | 3 | — | — | 48 |

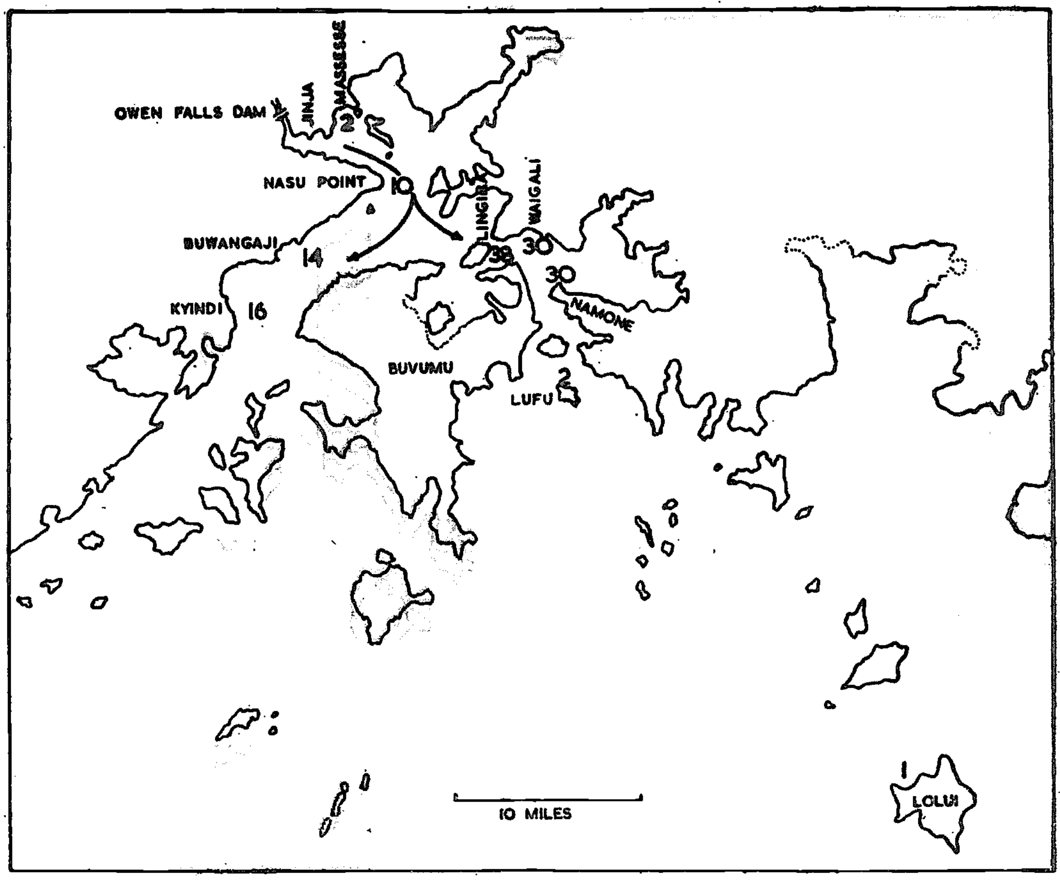


**Fig. A1—The distribution of Nile Perch in Lake Victoria. The figures show the numbers of fish returned to Massesse by local fishermen from the given localities**

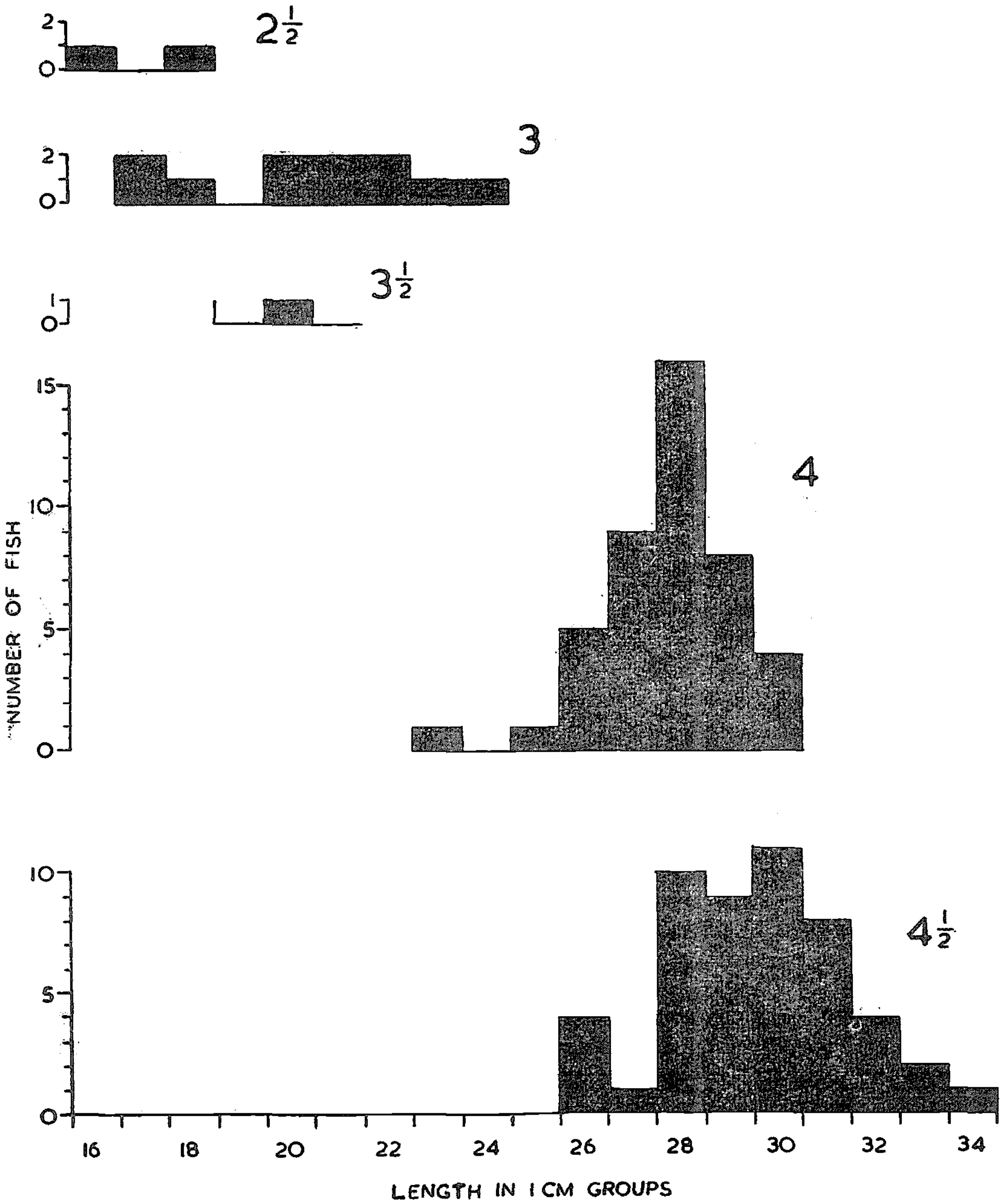


**Fig. A2—Standard length frequencies, for various gill-net mesh sizes, of Nile Perch in Lake Victoria**

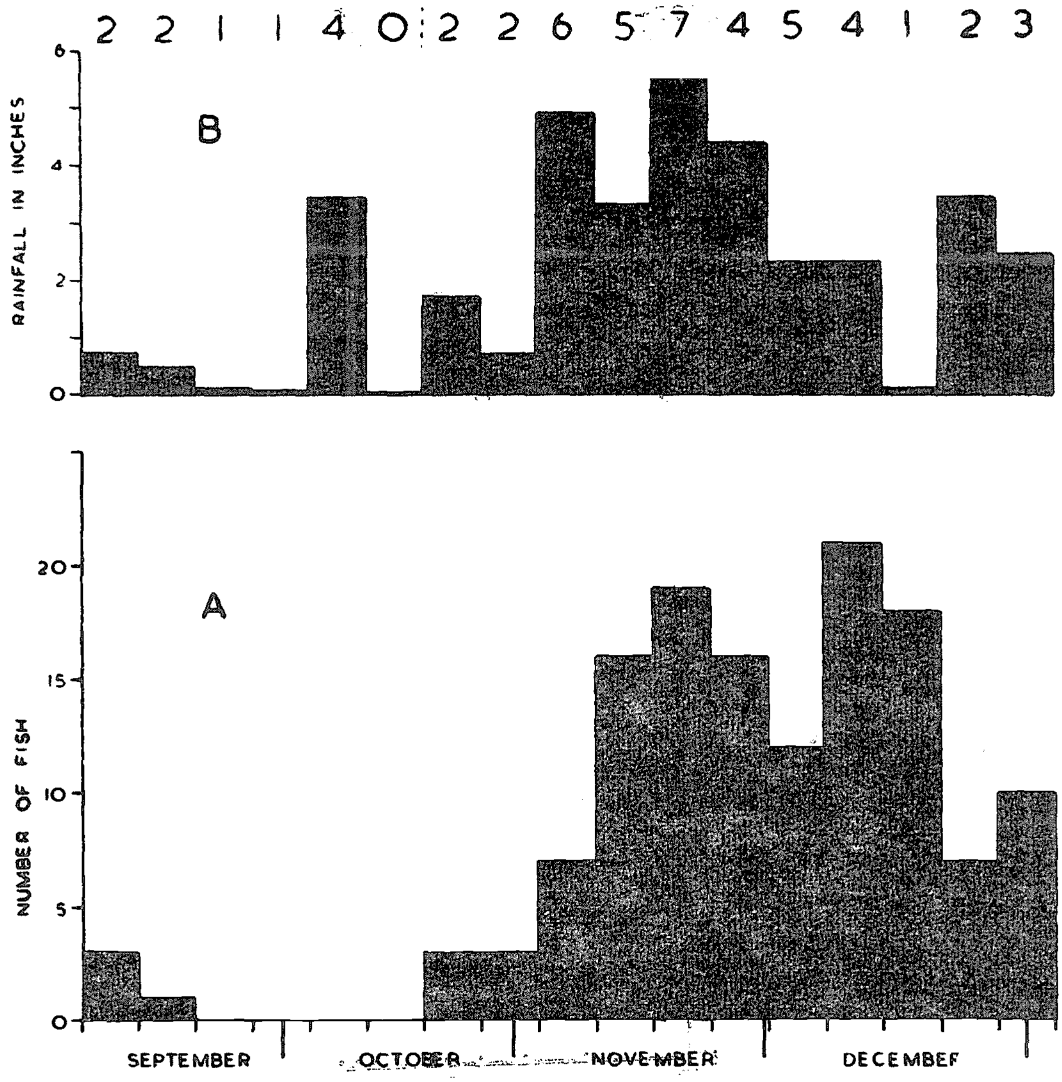


Fig. A3—(A) Histogram of the weekly catch of Nile Perch within the hinterland of Massesse. (B) The total weekly rainfall and the number of rain days per week for the same period. The dotted line indicates the approximate duration of the rainy season

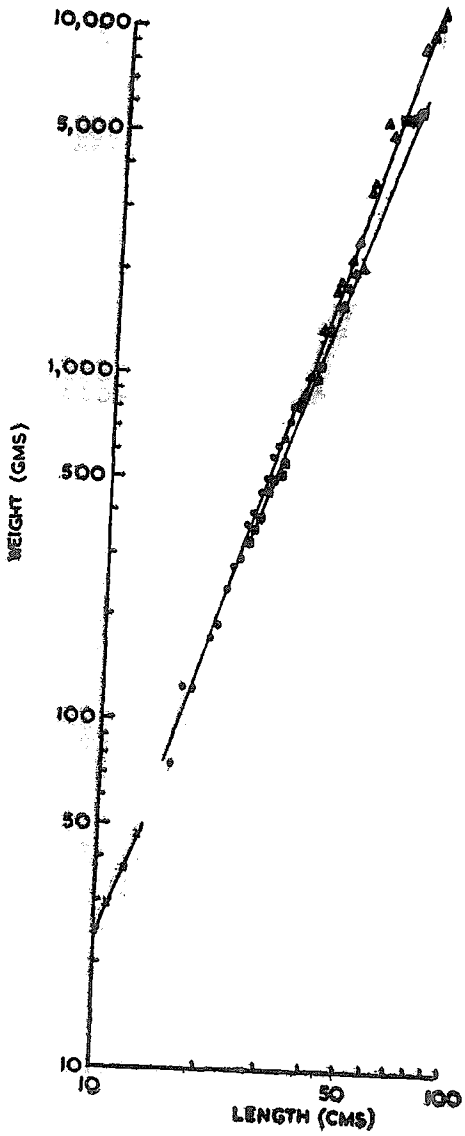


**Fig. A4—Graph of Log length and Log weight of Nile Perch from: X—The Kabaka's Lake, Kampala; ● —Lake Victoria; ■—Lake Albert; ▲—Lake Kyoga**

*APPENDIX B*

## OBSERVATIONS ON THE HABITAT PREFERENCES OF THE YOUNG TILAPIA SPP. IN LAKE VICTORIA

BY R. L. WELCOMME

### INTRODUCTION

The habitats of the adults of the Lake Victoria *Tilapia* species have been described by several authors, notably Lowe (*E.A.F.F.R.O. Supp. Pub., 1*, 1956) and Fryer (*Rev. Zool. Bot. Afr., 54*, 1961). Both of these workers noted the distribution of the fry on the lake shore, mentioning the increase in fry size with depth or distance from the shore. Little is known, however, of the factors—both physical and ecological—at play on such beaches. The picture they present is further obscured by the increasing hold certain introduced species have obtained since the date of publication of both these papers. As this problem is one of fundamental importance in the productivity of *Tilapia* species it was resolved to carry out a survey on a range of beaches.

### I.—GENERAL CONSIDERATION OF TYPES OF BEACH

A representative sample of the lake shores around Jinja were studied to assess their relative value for *Haplochromis* and *Tilapia* species. This involved sampling the environment with mosquito net seines, and also sampling the physical and chemical conditions as described below (Pt. II). Eight beaches were finally selected for examination and one of these was studied more fully in that some attempt was made to assess the number and structure of the population.

Beach No. 1. Behind the papyrus fringe many shallow pools are found that increase their extent with the rise in lake level at the time of the rains. These pools soon become populated with the fry of *Tilapia esculenta* Graham. Detailed observations show the conductivity and dissolved oxygen to be high in such localities. The temperature rises sharply and at midday may be as much as 34° C. at the edge. It is in just such regions that the *Tilapia* fry are found, the deeper, cooler water being mainly populated by "other" species. Deeper pools with very low dissolved oxygen content adjacent to these described above have been noted, with *Ctenopoma murei* Boulenger in the deep cooler water (25° C.) and *Tilapia leucosticta* Trewavas fry abounding in the shallow grass fringes at a temperature of 30° C.

Beach No. 2. In contrast to the above a deeper pool with similar characteristics of conductivity and pH (and indeed connected by a swamp channel) contained surprisingly few *Tilapia*, most of which were *T. esculenta* and *T. leucosticta*. *Haplochromis* of several species had increased in number to compensate for this lack.

Beach No. 3. The lake shore with moderate vegetation is widespread habitat, a typical section of which is described in more detail in II below.

Beach No. 4. The papyrus swamp channels which, according to Lowe (*op. cit.*), were the main habitat of the *T. esculenta* fry, were found to be virtually devoid of them at the time of observation. The only fry to be found were those of *T. zillii* (Gervais), an introduced species. It seems likely that the discrepancy is the result of the increase in lake level which has occurred over the past few years and now makes these channels about six feet deep.

Beach No. 5. Although *Tilapia* were found on the exposed lake shore with moderate vegetation the majority of them were larger fish (*T. esculenta* 5 to 7 cm.) than were normally found on other beaches, and were caught at a depth of some three to eight feet. In the shallower water *T. zillii* were moderate in number, being more plentiful in the narrow strip of grass at the shallowest edge. The sole difference between this environment and number three above is the increased slope and the consequent less protection by emergent vegetation; it was noted that this alone was sufficient to destroy the marked temperature gradient that existed on the latter beach.

— Six, seven and eight represent a series of increasingly exposed steeply shelving beaches on which *Tilapia* species were absent, except for the occasional *T. zillii.*

The conditions of the environments described above are summarized in Table 1.

## II.—Examination of a Shallow Beach with Moderate Vegetation on the Lake Shore

### *Methods*

The chemical conditions on the beach were sampled from stations on a pier and place at four-metre intervals out from the shore. Samples for dissolved oxygen were taken with a Cassella type sampler and the subsequent determination was by Winklers method. pH was read using B.D.H. cresol red and Bromo-thymol blue indicators. Conductivity was determined by a "Dionic" water tester and the turbidity estimated on a turbidiometer calibrated against a silica scale.

Fish were sampled using a seine (four meshes to the inch) which caught fish above 2 cm. Fish below this length were sampled with a mosquito net seine. Hauls with the net were made at right angles to the beach to sample the total population; and parallel to the beach at every other site used for chemical sampling, to determine the relative concentration and length composition of the fish at each site. All measurements given were standard lengths.

### *Description of Environment*

The environment studied consisted of a shallow beach (Fig. B1) shelving from 0 to 45 cm. depth over 32 metres, after which point the depth increased suddenly to nearly 2 metres. The bottom was of soft mud, becoming coarser and firmer as the depth increased. Between 9 and 25 metres from the shore sparse vegetation (a grass, *Chloris* sp.) was found and within that range between 13 to 21 metres the vegetation was dense. The stems of the grass were in many places stripped clean of leaves by the feeding of *T. zillii*; at the same time these stems supported a dense growth of epiphytic diatoms (*Gomphonema* sp.). At the extreme edges, and penetrating the water for about one metre, clumps of terrestrial grass were to be found. Normally the water on the beach was calm before 11.00 hours daily, but after this time slight wave action occasioned by the onshore wind was observed. Occasionally storms produced action that was more severe, but in all cases the vegetation damped nearly all movement and the area inshore was comparatively calm. After periods of prolonged onshore winds a difference in depth of up to 5 cm. was produced at one metre from the shore, this resulting in the inundation of normally dry ground for a distance of up to two metres from the normal shore line.

The pier from which sampling was carried out ran from the shore on raised pillars which did not interfere with the movements of either water or fish.

The beach system was isolated from other similar systems along the shore of the lake by deep water on two sides and a raised bank on the third.

TABLE 1.—SUMMARY OF PHYSICAL AND CHEMICAL CONDITIONS, AND TOTAL PERCENTAGE OF CATCH IN EACH CASE

| Type of Beach | Physical and Chemical Conditions | | | | | | Total Per Cent Composition of Catch | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Degree of Exposure (B) | Mean depth increase (cms.) | D.O. p pm | p.H. | Cond. Mmhos | T°c. | T.E. | T.V. | T.Z. | H.A. | O.Sp. |
| 1. Behind papyrus .. | 0 | 3·0 | 2·9 to 9·6 | 7·0 to 7·4 | 1100 to 500 | 32·0 to 22·5 | 80 | P | P | 5 | 15 |
| 2. Behind papyrus sparse vegetation. | 1 | 30 cms. mean depth | 0·05 to 1·8 | 6·9 to 7·0 | 260 | 24·0 to 24·0 | 18 | 2 | P | 44 | 33 |
| 3. Lake shore .. .. | 1 | 1·0 | 2·8 to 4·9 | 6·9 to 7·7 | 380 to 90 | 34·2 to 25·5 | 4·5 | 30·0 | 38·5 | 27·0 | P |
| 4. Papyrus swamp .. | 1 | all at about 2 metres | 5·6 to 8·8 | 7·3 to 7·8 | 110 to 100 | 24·8 to 25·5 | | | 2 | 57 | 41 |
| 5. Exposed lake shore vegetation moderate. | 2 | 9·0 | 3·1 to 6·7 | 7·2 to 7·8 | 120 to 100 | 28·0 to 26·0 | 3·5 | 0·5 | 2·5 | 91 | 2·5 |
| 6. Concrete slipway no vegetation. | 2 | 15·5 | 3·8 to 5·4 | 7·3 to 7·8 | 110 to 100 | 25·0 to 25·5 | | | 1 | 99 | |
| 7. Exposed sand no vegetation. | 3 | 23·0 | 3·8 to 8·9 | 7·3 to 7·9 | 110 to 90 | 28·2 to 28·0 | | P | 1 | 19 | 80 |
| 8. Exposed rock .. | 4 | 13·0 | 9·7 to 10·6 | 8·0 to 8·0 | 95 to 100 | 24·0 to 24·0 | | 2 | 5 | 49 | 44 |

A. expressed as INSHORE Reading / OFFSHORE Reading

B. O = very sheltered.
1 = Slight wave action occasionally.
2 = Waves predominantly confined to one period of day.
3 = Moderate continuous waves.
4 = Extreme wave action.

T.E. = T. *esculenta*.
T.V. = *T. variabilis*.
T.Z. = *T. zillii*.
H.A. = *Haplochromis* all species.
O = Other species.

*Chemical Conditions* (Fig. B2)

1. *Temperature.*—Although the temperature of the lake beyond 32 metres from the shore remained reasonably constant, the water in the shallower areas fluctuated considerably. A smooth gradient was maintained from the extreme conditions of the water's edge to the more equable ones of deeper water. Shortly after 05.00 hours the temperature began to rise, reaching a maximum by 12.00 hours, subsequently this temperature was maintained for about four hours and then slowly dropped. This gradient could be destroyed by severe wave action. In effect, as the lake temperature was at about 25° C. and the extremes 20° and 35° C., a diurnal reversal takes place.

2. *Dissolved Oxygen.*—Variations between the conditions at 08.00 and 12.00 hours were observed, but on the whole these were slight alterations round a gradient from low at the end to high D.O. at the deeper end. In terms of percentage saturation the conditions are more extreme at 08.00 hours, falling as low as 17 per cent saturation. In the shallow water this reduction of D.O. is probably due to the anaerobicity of the mud, and the heightened D.O. of the plant zone due to photosynthetic activity.

3. *pH.*—There was a constant gradient of pH from 7.0 in the shallow water to 8.0 at the lake end. This appeared to be independent of time of day.

*Conductivity*

A constant conductivity of about 100 mhos was observed from 32 to 13 metres from the shore; at shallower depths it then increased to a mean figure of 350 mhos. Like the pH, this gradient appeared to be constant and independent of the time of day.

*Turbidity*

As can be seen from the figure the shallow water was normally turbid at both midday and in the morning. At 08.00 hours, however, the initial turbidity was quickly lost and the deeper waters were clear, due to the prolonged calm of the night. By 12.00 hours onshore wave action was increasing thus bringing an increase in turbidity in the deeper waters; beyond the weed fringe, this turbidity dropped slightly.

Of all the conditions examined differences were found along the beach usually in the form of gradients with the more extreme conditions at the shallow end.

*Fish Present* (Fig. B3)

The majority of the permanent population of fish on the beach consisted of species of *Tilapia* and *Haplochromis*. The *Tilapia* were represented by three species mainly *T. zillii* 38 per cent, *T. variabilis* Boulenger 30 per cent and *T. esculenta* 4.5 per cent. The *T. variabilis* stock was present in modified form, showing many of the characteristics of *T. nilotica* (Linn.). *Haplochromis* (27 per cent) were represented by several species and, owing to the difficulty of identification of juvenile *Haplochromis* to the species level in our present state of knowledge, differentiation between them was not carried out. There appeared to be, however, about six herbivorous (planktonophage) and one piscivorous species. Fry and eggs were also found frequently, at about 13 metres from the shore. These may have been either those of *T. zillii* or of the various *Haplochromis* species. The size of the eggs (2 mm.) and the observation of large quantities of *T. zillii* fry 1.0-1.2 cm., migrating inshore from the region of dense weeds, suggest the former alternative.

Several species may be regarded as sparse or occasional visitors. *Astatoreochromis alluaudi* Pellegrin was found on the beach, and during the period sampled one fish of 6.0 cm. length was caught. *Hemihaplochromis multicolor* (Schoeller) and *Barbus apleurogramma* Boulenger were found occasionally in the catches. *Aplocheilidithys pumilis* (Boulenger) were found, 18 fish (M.L. 2.9 cm.) all in a sexually active condition appearing once during the period. *Engraulicypris argenteus* (Pellegrin) appeared twice in the form of a shoal of several hundred fish on each occasion.

*T. variabilis*

As mentioned above, the stock dealt with under this heading do not represent pure *T. variabilis*, about 30 per cent of the stock bearing characters intermediate between those of *T. variabilis* and *T. nilotica*. The species was most numerous in the very shallow waters, where it was represented by fish of 1 to 2 cm. to a maximum size of 8.2 cm. By plotting cumulative frequency of the fish of different lengths, some estimate could be made of the loss of fish from the beach by natural mortality predation and migration. While it is true that this is obscured slightly by the increase in numbers at certain size ranges, probably due to increased breeding activity, none the less a fairly reliable estimate may be made of the numbers of fish in each size range and the percentage reduction between each.

TABLE 2.—PERCENTAGE REDUCTION IN NUMBERS OF *Tilapia variabilis* BETWEEN INCREASING SIZE RANGES

| Size Range (cms.) | Total No. | Per cent Loss |
|---|---|---|
| 1 to 2 .. .. .. | 100 | 0 |
| 2 to 3 .. .. .. | 100 | 0 |
| 3 to 4 .. .. .. | 90 | 10 |
| 4 to 5 .. .. .. | 75 | 17 |
| 5 to 6 .. .. .. | 52 | 31 |
| 6 to 7 .. .. .. | 23 | 56 |
| 7 to 8 .. .. .. | 10 | 57 |

It may be noted that initially the loss is very low, but increases rapidly with size. After a size of about 5 cm. according to Fryer, 1961 (op. cit.), the fry are induced to seek deeper waters and it may well be that beyond this size the major loss from the beach is by emigration. Up to this, however, it would seem likely that loss is by natural mortality representing the survival of 75 per cent of the fish initially present.

*T. zillii*

In contrast to *T. variabilis*, *T. zillii*, above a certain size, seeks higher plants for its food, the greatest percentage of this species therefore are found about nine metres, where the vegetation begins. Many fish were seen in among the vegetation where they could be seen feeding actively. Estimates of numbers of *T. zillii* in this zone of dense vegetation are very probably low due to the difficulty of dislodging them by net, visual estimates are far higher. Cumulative frequencies for this species yield a complex picture, for at the time of sampling few fish of the size ranges 2 to 4 cm. were found. Fry were present in plenty and also fish from 4 to 7 cm.; this probably represented a lull in breeding activity. After 7 cm. the numbers declined sharply indicating emigration from the beach at this size. The species was also marked for the presence of adult and sexually active fish on the beach, these were four females of mean length 16.8 cm. and 11 males of mean length 15.4 cm. It is of note that this species although introduced into the lake, now comprises over 50 per cent of the *Tilapia* on this beach.

*T. esculenta*

Few of this species were found, but such as were present were about equally represented at all size ranges.

*Haplochromis*

As can be seen from the figure, it was distinctly apparent that large numbers of *Haplochromis* on the beach invariably meant that few *Tilapia* were to be found at that site, and vice versa. Reference to the total percentage composition of catch columns in Table 1 shows confirmation of this phenomenon. In fact, an inverse relationship was seen to exist between the numbers of *Haplochromis* and *Tilapia*. The size of the *Haplochromis* did not show any increase with depth, as was the case with *Tilapia*, but their total numbers decreased until they were virtually absent nine metres from the beach.

*Estimates of Total Population*

Three hundred and fifty-five fish were caught and their caudal fins clipped, subsequently among 213 fish caught 5 of those marked reappeared. The total population was accordingly calculated as 15,123 fish. These figures applied to fish above 2 cm., as below that length they were not marked or counted. From the samples of the total population of the beach it appears that 18 per cent of the fish present were below 2 cm., so by back calculation a figure of 2,730 fish could be obtained giving a total figure for the beach as 17,850. As the area of the beach was calculated as 1,264 sq. metres, this represents a mean density of 14 fish per sq. metre.

*Discussion*

It appears that the shores of the lake may be roughly divided into *Haplochromis* beaches and *Tilapia* beaches, dependent on which is the dominant cichlid to be found. It may be noted that the *Tilapia* beach usually merges at its deeper end with a *Haplochromis* zone. It further appears, with the information available, that the major physical factor distinguishing these two types is the presence or absence of a thermal gradient. The "*Haplochromis*" beach is usually exposed or shelves rapidly and such conditions are not condusive to the maintenance of such a gradient. That *Tilapia* can live under such conditions is demonstrated by their presence at least in low concentratives in most of the areas examined, and turbulence would hardly effect species which are often found in rivers in spate. In the studies in Bugungu Stream, for instance, *T. esculenta* fry have been observed to ascend for some distance on the flood, and eventually to lodge in the shallow edges of pools where the quietness of the water allows the temperature to rise. *Haplochromis* on the other hand, have never been observed in these warmer regions and when their tolerance to extremes of temperature is measured (*see* Appendix E) it becomes apparent that although they may compete successfully with *Tilapia* in cool waters, they cannot survive in the warmer marginal water where *Tilapia* predominate.

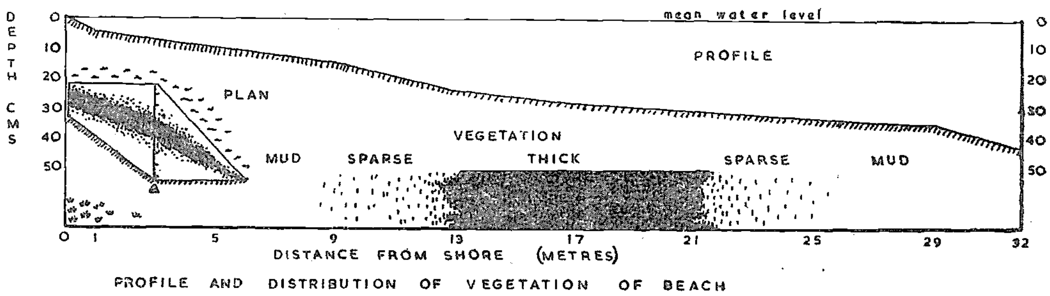


**Fig. B1—Profile and distribution of vegetation of the beach**

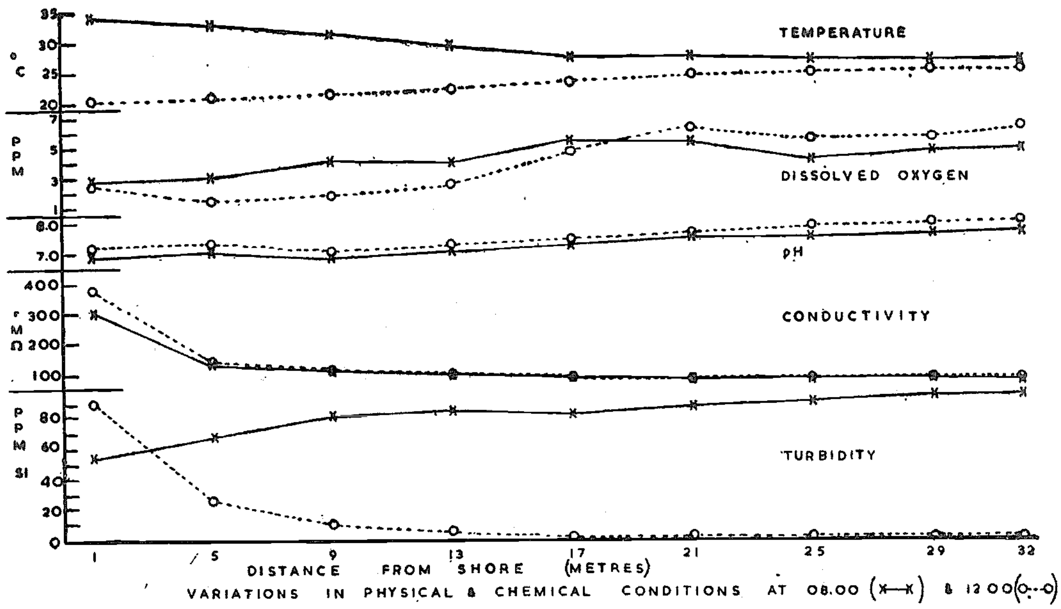


**Fig. B2—Variations in physical and chemical conditions at 08.00 and 12.00 hours on the beach**

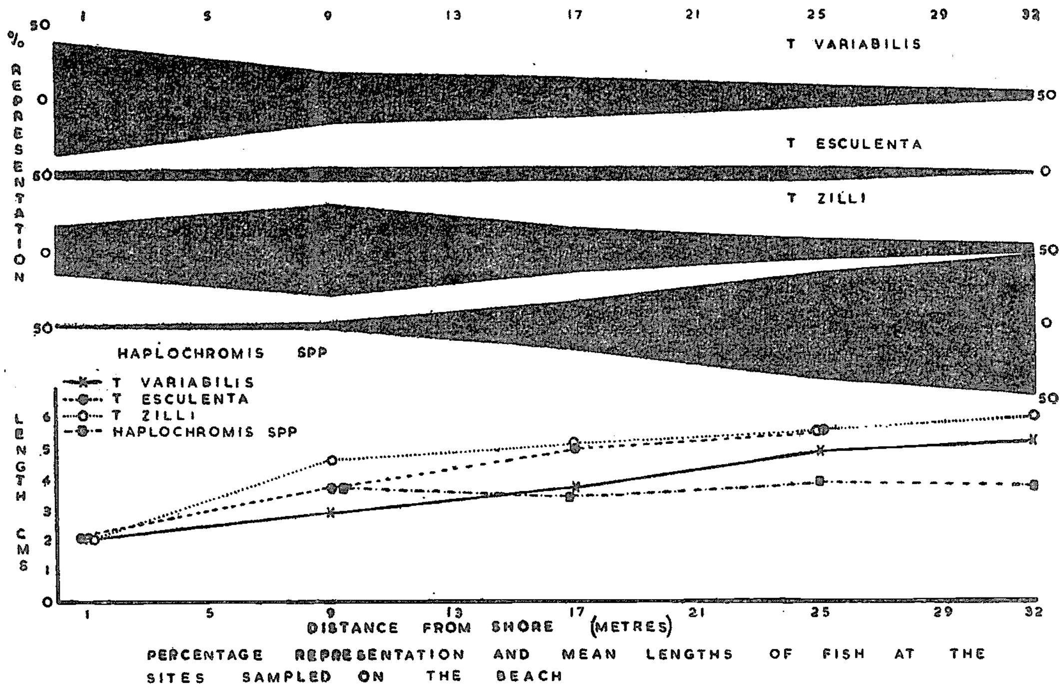


**Fig. B3—Percentage representation and mean lengths of fish at sites sampled on the beach**

*APPENDIX C*

# THE ECOLOGY OF THE FISHES OF A SMALL RIVER OF THE LAKE VICTORIA BASIN

BY R. L. WELCOMME

Observations carried out over a period of some nine months on a small river-swamp system at Bugungu have helped to elucidate the breeding habits of some of the migratory fish of Lake Victoria. The river accessible to the laboratory by road and by launch has by its small size and compact basin, proved ideal for continuous close observation. The period so far studied consists of two wet seasons and one dry season, it is hoped to continue observations to cover the whole year.

## PHYSICAL CONDITIONS

It has been possible to trace the physical and chemical conditions present in the river and swamps under flood and quiescent conditions. In general at times of low water gradients of dissolved oxygen, pH conductivity and temperature exist along the length of the stream (some 4½ kilometres from the highest point sampled to the mouth). At times of spate, however, the gradient conditions virtually disappear and the river becomes more chemically uniform along its length.

TABLE 1.—PHYSICAL AND CHEMICAL CONDITIONS IN THE BUGUNGU STREAM DURING DRY (10TH–15TH OCTOBER) AND WET (9TH–18TH NOVEMBER) SEASONS 1963

| Distance from mouth | Dry T°c | Wet T°c | Dry D.O. | Wet D.O. | Dry Cond. | Wet Cond. | Dry pH | Wet pH |
|---|---|---|---|---|---|---|---|---|
| ·5 km. .. | 24·0 | 21·25 | 4·6 | 4·7 | 410 | 320 | 7·9 | 7·4 |
| 2·25 km. .. | 23·5 | 21·4 | 3·6 | 3·5 | 380 | 270 | 7·9 | 7·2 |
| 2·75 km. .. | 23·5 | 21·1 | 2·1 | 3·4 | 330 | 280 | 7·4 | 7·3 |
| 3·25 km. .. | 23·25 | 20·8 | 3·6 | 4·2 | 345 | 290 | 7·6 | 7·2 |
| 3·50 km. .. | 22·75 | 20·5 | 3·6 | 3·3 | 305 | 315 | 7·5 | 7·4 |
| 4·5 km. .. | 22·5 | 20·6 | 0·3 | 2·7 | 320 | 262 | 7·2 | 7·2 |

*N.B.*—Discrepancies in readings at 2.75 km. are accounted for by the fact that the river passes through swamp at this point.

The swamps in the dry season are to a greater or lesser extent deficient of dissolved oxygen, and high in conductivity and temperature, after the first flush of rain the conditions are virtually those of the river (Table 2).

TABLE 2.—PHYSICAL AND CHEMICAL CONDITIONS IN THE SWAMPS DURING DRY AND WET SEASONS

| | Dry | Wet |
|---|---|---|
| T°c .. .. .. .. | 22·7 | 20·8 |
| D.O. .. .. .. | ·59 | 4·0 |
| Cond. .. .. .. | 400 | 210 |
| pH .. .. .. | 7·4 | 7·3 |

In the dry season the whole system becomes choked with a flocculent precipitate of iron salts which disappears entirely once the flow increases during the rains. This precipitate appears to present no hindrance to the maintenance of fish life. With these reservoirs of swamp water and precipitate it is natural that during the change over from typical dry to typical wet season régimes in the river some anomalous conditions result, these, however, are only temporary lasting for the first few freshets.

## General Considerations of Population

It has been found convenient to divide the species found within the river system into three categories.

1. Migrant.—Species that run into the river as sexually active fish, spawn at discrete sites up river and thereafter return to the lake. The juvenile fish develop at the spawning grounds and subsequently move lakewards.

   *Barbus kersteni* Peters.

   *Barbus apleurogamma* Boulenger.

   *Barbus paludinosus* Peters.

   *Clarias carsoni* Boulenger.

   *Clarias alluaudi* Boulenger.

   *Ctenopoma murei* Boulenger.

2. Riverine.—Species that are found associated with the river-swamp system at all stages in their development and show little or no tendency to migrate out of the system into the lake.
   *Hemihaplochromis multicolor* (Schoeller).

3. Facultative.—Those species which normally are found in alternative habitats in the lake and have spread into the lower part of the system, utilizing the increased area of swamp produced by the rise in lake level during the rainy season.

   *Aplocheilichthys pumilus* Boulenger.

   *Astatoreochromis alluaudi* Pell.

   *Tilapia esculenta* Graham.

   *Tilapia leucosticta* Trewavas.

   *Tilapia nilotica* (Linn).

   *Tilapia zillii* Gervais.

   *Protopterus aethiopicus* (Heck).

   *Haplochromis*, about five species.

The composition of the population differs between dry and wet seasons. During the former, few adults of group one fish are to be found but their fry are plentiful, the riverine species is numerous in all habitats in the river, and the shrinking swamps near the river mouth are being deserted gradually by the numerous fry of the *Tilapia* and *Haplochromis* species. At the onset of the rains the river and swamps become full of breeding cyprinids and the *Hemihaplochromis* increase their own breeding activity (that appears to be carried on for most of the year). Thus the numbers of fish in the river increase and each fresh spate brings a corresponding run. As the river sinks back into the quiescent phase, the adult fish return lakewards and the growth of the new fry begins once more.

It may be noted that no runs of *Clarias mossambicus* were observed nor subsequently were any of the fry found, although *Clarias carsoni* and *alluaudi* were frequently caught. This is a departure from the situation existing some years ago when runs of this species were described. Further none of the larger species described as anadromous by Whitehead (*Rev. Zool. Bot. Afr.*, *59*, 329, 1959) were seen to run up the river despite their presence in the Napoleon Gulf, into which this river discharges. This may be due to the papyrus "plug" blocking the mouth of the river which prevents the ripe fish which are known to have assembled from beginning their ascent.

## Brief Notes on the Main Species

I. *Barbus species.*—The adults of *B. kersteni* and *B. apleurogramma* appear remarkably alike in their habits, diet, size and lacustrine habitat. They also simultaneously undertake migrations up rivers and, in the swamps flanking the head of the streams, spawn and then return to the lake. The fry have been detected first at about 5 mm., at which length they are at the late prolarval stage. They remain confined to the shallow swamps until a length or about 1.2 cm. is reached and, by then fully developed, they move into ditches and the main stream where there is a flow of water. If the flow increases to a level beyond which they cannot hold their position, they move back into the grass swamps, they thus remain in such localities until definite size ranges are reached. *B. kersteni* move lakewards beginning at a mean size of 2 cm., when the majority migrate, and continuing with increasingly small proportions which remain at the river head growing accordingly. *B. apleurogramma* remain until the next rainy season, by which time a mean length of 3 cm. is reached; they then migrate lakewards over the period of the rains, often maturing and breeding prior to such movement.

*B. paludinosus*, a larger species than the above, appears for lack of information more unpredictable in its behaviour. Certain fish have been observed migrating up the river and fry are to be found mixed with those of the other *Barbus* species. However, on certain exposed sandy beaches on the lake shore, some of which are several miles from running water, large aggregations of fish all ripe and running have been seen. These were in frenzied action and were presumably spawning. This species would therefore appear not to be wholly dependent on the anadromous habit for reproduction.

II. *Ctenopoma murei.*—Absent during the dry season, this fish appeared in the swamp system, shortly after the beginning of the rains. Although numbers appear in the river the main concentrations of the breeding fish are in deep pools off extremely low dissolved oxygen which are shared only by *Protopterus*. Here the fry are subsequently found. Length frequencies show the females to be considerably larger than the males, and they produce up to 3,000 small eggs which float among the matted vegetation surrounding such pools. The diet, at least in the swamps appears to be exclusively mosquito larvae.

III. *Hemihaplochromis multicolor.*—In contrast to the above species this fish spends its whole life within the system where it is ubiquitous. The fry are found exclusively in the shallowest of swamp regions at the time of their release (7.5 mm.); as they increase in size they move gradually into deeper waters. At a size of 2 cm. they begin to move into the river and by 3 cm. most fish are in that environment, here they mature. The females begin maturation at about 3 cm. and the males somewhat later, about 3.5 cm. Breeding fish are found at all times of the year but their numbers increase markedly during the rainy season. Males in breeding dress occur mainly in the shallow edges of pools off the main stream and also in swampy fringes. The females return to the swamps to release their fry. which are brooded for about 15 days.

Although populations of the species have been found in the lake, it is by no means so numerous there, and little migration appears to take place into, or from, the lake. The numbers in the river have increased during the period of observation, possibly due to the favourable conditions produced by the current rise in lake level.

IV. *Other species.*—Both *Aplocheilichthys pumilus* and *Astatoreochromis alluaudi* were represented throughout the period by breeding fish and fry, the latter penetrating some distance up the flooding river. The *Haplochromis* were represented mainly by *H. obliquidents* Hilgendorf and *H. nigricans* (Boulenger), which species were found in large numbers (up to about 110 per day for a 50-yard gill-net at the peak of activity), in the papyrus lagoons. The males were in breeding coloration and were often ripe. The few females that were found were ripe or brooding. The presence of the fish accounts for the high concentrations of *Haplochromis* fry in the lower grass swamps. Other *Haplochromis* showing similar behaviour were *H. microdon* (Boulenger), *H. longirostris* (Hilg.) and *H. guiarti* (Pellegrin) which were present in far lower quantities.

*APPENDIX D*

# NOTES ON THE PRESENT DISTRIBUTION AND HABITS OF THE NON-ENDEMIC SPECIES OF TILAPIA WHICH HAVE BEEN INTRODUCED INTO LAKE VICTORIA

BY R. L. WELCOMME

## I.—INTRODUCTION

Lake Victoria, separated from other water systems since Miocene times, has during this immensely long period evolved its own endemic groups of fish, particularly among the Cichlidae. In the genus *Tilapia* only two endemic species, *T. esculenta* Graham and *T. variabilis* Boulenger, were for very many thousands of years the only two representatives of this genus to be found in the lake. Recently, however, and particularly during the last ten years, artificial stockings of *Tilapia* species found elsewhere in Africa have been made into Lake Victoria, or within its drainage basin from where escapes into the lake have been possible. Table 1 summarizes the history of such stockings so far as it is at present known.

Of the six non-endemic species listed, three, namely *T. leucosticta, T. nilotica* and *T. zillii* have succeeded and populations are established in Lake Victoria, while the remaining three, *T. nigra, T. mossambicus* and *T. melanopleura,* are apparently not established as there is no known record of their capture within the lake. One of these, *T. melanopleura,* is morphologically all but indistinguishable from *T. zillii* while the other two, as can be seen from the Table, are known to have been introduced into the Lake Victoria drainage basin but not, as far as is known, deliberately stocked into the lake.

While it may be, as Lowe (*E.A. agric. for. J., 20,* 4, 1955) has suggested, perhaps rather unfortunate that certain species should have been used rather extensively for stocking purposes before more was known about these fish, and it may even be as Fryer (*Rev. Zool. Bot. Afr., 54,* 1-2, 1961) has suggested, that *T. zillii* may become a serious competitor of *T. variabilis* and even a serious threat to its survival, such considerations, even if valid, are certainly past praying for at the present time. The populations of these three species are established once and for all in Lake Victoria, and it is therefore necessary and important to follow the progress of the introductions as far as possible, both in regard to numbers and habitats occupied and to competition with and hybridization with local species. The following are the results of preliminary work done on this in 1963.

## II.—NOTES ON EACH OF THE THREE SPECIES

(i) *T. leucosticta.*—Although few fish at present appear in the commercial catches (40 fish only were recorded from Massesse during the months of November and December), isolated populations of the species are to be found in the lagoons behind the papyrus swamps near Jinja. One such population is being studied at Bugungu where there is a lagoon system associated with a small river and grass swamp. The adults occur in these lagoons, especially during the rainy season when they are also found to run some distance up the river. The fry are found in the grass swamps and also the river at times of high water. The adults of this population are of small size; only 10 out of 300 adults examined exceeded 17.5 cm. in length, the mean length of adults was 11.5 cm. and the largest seen was one of 25 cm. Another such population came to light whilst netting in a series of ponds destined to become a sewage works. These ponds were excavated just behind the papyrus fringe, and fish probably present in a small pool escaped into one of them in the process. These subsequently have produced a large population of small fish. In both these populations, deformed individuals occur and the fish were breeding at as small a size as 7 cm. Other lagoons yield a similar

TABLE 1.—SUMMARY OF KNOWN STOCKINGS OF NON-ENDEMIC SPECIES OF *Tilapia* INTO LAKE VICTORIA OR AFFLUENT WATERS

(*The assistance of Mr. D. H. Rhodes, Chief Fisheries Officer, Department of Fisheries, Uganda, in the preparation of this table is gratefully acknowledged.*)

| Date | Place | Species | Numbers and Remarks | References* |
|---|---|---|---|---|
| 1931 | Lake Bunyoni | *T. nigra* | Stocked from L. Naivasha, Kenya and may have infiltrated into L. Victoria via tributaries of the Kagera. No records from L.V. since, so survival doubtful. | A.R. of U.G.D. 1931, para. 44 and 1936, para. 225: *T. nigra* and *T. nilotica*. |
| 1936 | Lake Bunyoni | *T. nilotica* | Stocked from L. Edward | As above. |
| 1951/53 | Lake Victoria, Entebbe area | *T. leucosticta* | In April 1951 Kidetok Dam, Teso, stocked from L. Albert, thence other Uganda waters including Kajansi Fish Farm, Uganda and L.V. | Lowe: (*Rev. Zool. Bot. afr.* 55, 3–4). |
| 1953 | L.V. Kavirondo Gulf, Kenya | *T. zillii* | 14,000 + from L. Albert stock (originally 10 specimens) stocked by L.V.F.S. (December) from ponds at Kisumu. | A.R. of L.V.F.S. 1954/55 paras. 29–37. |
| 1953? | L.V. Kavirondo | *T. leucosticta* | L.V.F.S. ponds at Kisumu stocked with this sp., so probably entered L.V. | A.R. of L.V.F.S. 1954/55 paras. 29–37. |
| 1953/54? | L.V. Kavirondo Gulf | *T. melanopleura* | L.V.F.S. Kisumu ponds similarly stocked but no record since (*see* text). | A.R. of L.V.F.S. 1954/55 paras. 29–37 and Lowe (*E.A. Agr. J.* 20, 4, 1955). |
| 1954 | Kagera River, Uganda | *T. nilotica* | Via Koki Lakes which were first stocked from L. Bunyori in 1936 (*see* above). First capture from L.V. recorded this year. | A.R. of L.V.F.S. 1954/55 para. 63. |
| 1954 | L.V. Musoma and Mwanza, Tanganyika. | *T. zillii* | 200 in Capri Bay, Mwanza; 50 in Mara Bay, Musoma. | A.R. of L.V.F.S. 1954/55, paras. 64/65. |
| 1955 | L.V. Mara Bay, Musoma, Tanganyika, Mwanza, Tanganyika, Entebbe, Uganda, Kavirondo Gulf, Kenya, Mfwangu Island, Kenya. | *T. leucosticta* and *T. zillii*. | Approximately 12,000 non-indigenous *Tilapia* introduced into L.V. by L.V.F.S. | A.R. of L.V.F.S. 1955/56 para. 17. |
| 1955 | Entebbe (Harbour) | *T. zillii* | 128 (3–5 cms.) from Kajansi Fish Farm | A.R. of U.G.F.D. 1955/56 para. 832. |
| 1956/–57 | Pilkington Bay, Bovuma, Entebbe. | *T. leucosticta*<br>*T. zillii*. | Large stocking by L.V.F.S. | A.R. of L.V.F.S. 1956/57, para. 26. |
| 1956/57 | L.V. in general | *T. nilotica*<br>*T. zillii*<br>*T. leucosticta*. | *ca.* 1,500 stocked by L.V.F.S. at points designed to fill gaps between points where non-endemics had established themselves from previous stockings. | A.R. of L.V.F.S. 1956/57, paras 24–33. |
| 1957 | Kisumu, Kenya | *T. nilotica* | Just under 200 introduced here for first time in January. | A.R. of L.V.F.S. 1956/57, para. 30. |
| 1958 | Entebbe, Uganda | *T. zillii*<br>*T. leucosticta*<br>*T. nilotica* | —440<br>—490<br>—1,290<br>all from Kajansi Fish Farm. | A.R. of L.V.F.S. 1958/59, para 39. |
| 1961/62 | Entebbe, Uganda | *T. nilotica* | 1,474 | Unpublished U.F.D. report (F 164/674 of 9th March 1962). |
| | | *T. mossambica* | Used in ponds, dams and aquaria both in Kenya and Uganda in L.V. basin and may well have escaped. Not officially stocked and no records of capture exist. | Mr. D. H. Rhodes (in litt.). |

*Abbreviations: A.R. = Annual Report. L.V.F.S. = Lake Victoria Fisheries Service. U.G.F.D. = Uganda Game and Fisheries Department. L.V. = Lake Victoria.

picture; some behind very dense papyrus have been investigated and it would therefore appear that *T. leucosticta* has not expanded in the lake but rather has colonized these areas which previously were unoccupied by the native species of *Tilapia*.

(ii) *T. nilotica*.—Such fish as are landed (66 for November), at the commercial landing of Massesse, are of mean lengths 23.3 cm. (males) and 22.9 (females). Though individual fish may occur in similar areas to the native *Tilapia* in the lake, one breeding male occurring in our gill-nets together with several *T. esculenta* and *variabilis*, fishermen report that it tends to be associated more with *T. zillii*. Further, like *T. leucosticta*, a certain quantity of *T. nilotica* appear in the Bugungu Lagoon near Jinja (*see* Appendix C). These fish are of similar size to the commercially caught species and fish up to 33 cm. have been taken in native traps. The catch from such traps both in the lagoons and the papyrus and grass swamp fringes to the lakes, appear to be relatively high. It seems therefore likely that *T. nilotica* is not well represented in the commercial catches as it tends to have different habitat preferences to the *T. esculenta* and *T. variabilis* that form the mainstay of the fishery.

The fry of this species appear to be associated mainly with those of *T. variabilis* on shallow grassy beaches, and indeed there is some evidence that hybrids are occurring between the two species as many juveniles (4 to 7 cm.) with characters intermediate to those of *T. nilotica* and *T. variabilis* are to be found, associated with *T. esculenta*, on the shores of the lagoons and also in the deeper water off the lily zone. This was first suspected during early 1963, when it was found that many of the *T. variabilis* fry had uncharacteristic barring on the normally immaculate caudal fin. The intensity of this barring ranged from the almost inconspicuous to the heavy pigmentation which is normally found in *T. nilotica*.

Of the 188 fish examined for barring on the caudal fin, 6 per cent were found with the intense *T. nilotica* coloration, 61 per cent with the immaculate *T. variabilis* fin, and 33 per cent were forms intermediate between the two. Other features of difference were noted in these intermediate forms. The orange lappets characteristic of *T. variabilis*, were present in 43 per cent of these. The "bump" over the eye of that same species was found in 58 per cent of the fish. The "*tilapia*" mark of *T. nilotica*, is more intense than the vague marbling of *T. variabilis* and in 36 per cent of the suspected hybrids this mark was intensified.

Features of similarity between the two parent stocks showed by the intermediate forms, and thus of little use for differentiation, were lateral line scale counts (mode 31) and the number of scales round the caudal peduncle (7). The principal characters for differentiation were found to be:—

(i) The scales in the caudal length.

(ii) The length/depth ratio of the caudal peduncle.

(iii) The scales from the origin of the dorsal fin to the lateral line.

(iv) The number of gill rakers.

Counts and measurements of these characters are summarized in Table II.

(iii) *T. zillii*.—Since its introduction *T. zillii* appears to have become ubiquitous in the shallower waters of the lake. Commercially it now rivals *T. variabilis* in quantity caught representing 30.2 of the catch for November (*T. variabilis* was 20.8) at the Massesse fish landing. Fry are to be found in varying proportions on all types of beach from exposed rocky shores to papyrus channels. On one beach the population of *T. zillii* comprised 35 per cent of the total number of fish and that of *T. variabilis* only 30 per cent, on what must once have been the territory of *T. variabilis* alone. The distinctive feature of these beach populations is the quantity of larger fish found, including adult fish of mean lengths 6.5 cm. Adults were found to be breeding in water about 6-12 feet deep in close proximity to the beaches, and fry 1.2 cm. long have been observed migrating inshore from these areas. Other places in which these fish have been caught include the lily zone and reed beds submerged by the recent rise in the lake level. In common with the other introduced species it is found in lagoons and flooded areas behind the papyrus fringe. In this latter environment males are prominent, comprising up to 86 per cent of the adult fish, and whilst the inactive or resting fish (7.6-10.7 cm.) are found in the shallow beaches fringing such lagoons the active males of 7.6-13.6 cm, are found in deeper water, as are the ripe and spent females (16.4 cm.). *T. zillii* appears to have benefited more than any other species from the drastic rise in lake level earlier this year as considerable areas of grass both on the lake edge and behind reed and papyrus fringes were flooded and in all such areas observed *T. zillii* was prominent.

TABLE 2.—SUMMARY OF CHARACTERISTICS OF DIFFERENCE IN THE HYBRID AND ITS TWO PARENT STOCKS

| Character | *T. nilotica* Kajansi | *T. nilotica* Lake Victoria | Intermediate type | *T. variabilis* Lake Victoria |
|---|---|---|---|---|
| No. of fish .. .. .. | | 11 | 62 | 115 |
| No. of sample .. .. | 18 | 11 | 30 | 25 |
| Mean length .. .. | 4·8 | 5·3 | 5·6 | 5·0 |
| Scales on caudal peduncle length | | | | |
| 4·0 to 4·5 .. .. | 4 | 1 | 1 | |
| 4·7 to 5·0 .. .. | 5 | 7 | 10 | 5 |
| 5·1 to 5·5 .. .. | 9 | 3 | 15 | 13 |
| 5·6 to 6·0 .. .. | | | 4 | 7 |
| Length/depth ratio of caudal peduncle | | | | |
| ·6 to ·65 .. .. .. | | 1 | 1 | |
| ·66 to ·7 .. .. .. | 4 | 8 | 6 | |
| ·71 to ·75 .. .. | 9 | 2 | 15 | 1 |
| ·76 to ·8 .. .. .. | 5 | | 5 | 2 |
| ·81 to ·85 .. .. | | | 2 | 14 |
| ·86 to ·9 .. .. .. | | | | 8 |
| Scales origin of dorsal to lateral line | | | | |
| 4 .. .. .. .. | | | | 5 |
| 4·5 .. .. .. | 5 | | 13 | 14 |
| 5·0 .. .. .. | 7 | 3 | 15 | 5 |
| 5·5 .. .. .. | 9 | 8 | 2 | 2 |
| Gill rakers | | | | |
| 19.. .. .. .. | | | 1 | 6 |
| 20.. .. .. .. | | | 9 | 14 |
| 21.. .. .. .. | 8 | 2 | 13 | 4 |
| 22.. .. .. .. | 5 | 2 | 1 | 2 |
| 23.. .. .. .. | 2 | 5 | 1 | |
| 24.. .. .. .. | 2 | 2 | | |

*APPENDIX E*

## PRELIMINARY REPORT ON LETHAL CONDITION EXPERIMENTS

BY R. L. WELCOMME

The resistance of species of *Haplochromis* and *Tilapia* to extremes of temperature and low dissolved oxygen may be of importance in determining their distribution on the beaches of Lake Victoria. In order to define these factors, lethal condition experiments on both genera of fish are being carried out, and progress to the end of 1963 is reported here.

*Tilapia zillii* of a mean length of 6.6 cm., the largest fish being 12.0 and the smallest fish 2.9 cm., and *Haplochromis* spp. of a mean length of 3.8 cm., the largest fish being 7.7 and the smallest fish 2.4 cm., were placed in an aquarium and acclimatized for one week to a temperature of 27° C. After this period had elapsed batches of five fish were removed, and placed in a tank with water at a preset test temperature. The time of death of each fish was recorded and the individual survival times were distributed normally the median period of survival being estimated graphically. The relation between these medians and test temperature is shown for both genera of fish (Fig. E1). A wide range of lengths were used for each species in order to determine whether the resistance varies with size, but no significant difference was to be found in these experiments. *T. zillii* was also tested after 23° C., acclimatization but the results differed only slightly from those at 27° C.

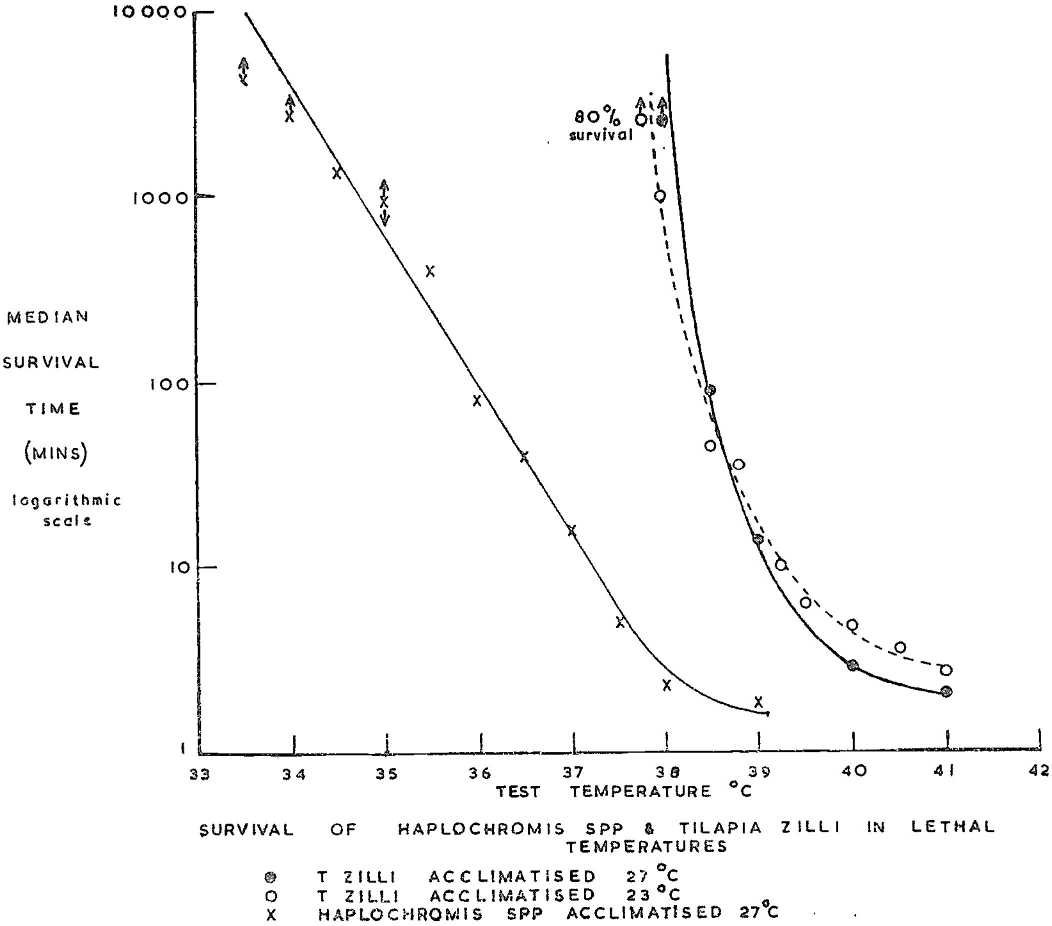


**Fig. E1—Survival of *Haplochromis* species and *Tilapia zillii* in lethal temperatures**

The results so far indicate that *Haplochromis* are generally more sensitive to high temperatures than are *Tilapia zillii*, the relative differences being 2.5° C. at 100 minutes and 3.5° C. at 1,000 minutes. The low resistance of these *Haplochromis* would account in itself for their absence from the shallow water's edge (*see* Discussion, Appendix B), where temperatures up to 35° C. have been recorded. But it is also known that the effect of low dissolved oxygen tension serves to heighten the sensitivity to lethal temperatures and as these conditions also pertain in these regions the hostility of the environment would be intensified.

*APPENDIX F*

## REPORT ON A FISHERIES SURVEY OF LAKE RUKWA, TANGANYIKA

BY M. J. MANN

### INTRODUCTION

The fisheries of Lake Rukwa were previously surveyed by Ricardo between September and November 1936 (Ricardo 1939a and 1939b), by Swynnerton briefly in 1939 and again from November 1945 to December 1946 (Swynnerton 1947). The present survey covered the period 8th August to 8th September 1963.

During the earlier visits the lake level was relatively low, Ricardo recording a depth of 3.5 metres on south lake at the end of the dry season (September 1946) while Swynnerton noted 4.3 metres in January 1946 (beginning of the rainy season) and 3.0 metres at the same point in November 1946. Similar soundings on south lake were consistent at 6.5 metres during August and September 1963.

The north lake with a depth of 2.0 to 3.0 metres in 1936 (Ricardo 1939a) and a "medium depth" in 1946 (Gunn 1956), gave soundings of 5.0 metres off Kasisi in August 1963.

This rise in lake level has had two main effects. Firstly the lake water has become more diulte, less alkaline and less turbid, as evidenced by the details in Table 1. Secondly, the commercial fishery, largely dependent on indigenous shore seines in 1936 and 1946, owing to the flooding of the seining areas, has now been converted to a nylon gill-net fishery. The remaining fishing methods are a few surface set longlines, a beach seine used at a single suitable beach near Mbangala, and numerous fish traps, set in swamps throughout the year, but particularly in water channels when the flooded rivers receed after the rains.

At present the fishermen probably numbering about 500, tend to be permanent rather than itinerant fisherfolk, and do not farm to any great extent, they belong to the local tribal groups surrounding the lake but equal numbers are immigrants from Chunya, Mbeya, Tukuyu, Mwanza, Nyasaland, etc.

Their canoes, about 250 in number, are dugouts 10 to 16 feet in length, and are produced locally. Some Sese canoes up to 30 feet overall, have been imported from Mwanza, and a couple have been constructed on the same pattern at Mbangala. One of these Sese canoes, powered by a 40 h.p. outboard, works from Mbangala ferrying passengers and produce on south lake. Similarly, two larger motor craft about 25 feet in length work on north lake.

### *Relative Abundance of the Various Species*

The following species were recorded from the lake or the affluent rivers during the survey:—

*Marcusenius discorhynchus* (Peters).
*Gnathonemus macrolepidotus* (Peters).
*Mormyrus longirostris* Peters.
*Alestes imberi* Peters.
*Hydrocyon lineatus* Bleek.
*Engraulicypris congicus rukwaensis* Ricardo.
*Barbus* sp.
*Labeo fuelleborni* Hilgendorf and Pappenheim.
*Schilbe mystus* (Linn.).
*Clarias mossambicus* Peters.
*Synodontis zambezensis* Peters.
*Synodontis fuelleborni* Hilgendorf and Papenheim.
*Tilapia rukwaensis* Hilgendorf and Papenheim.
*Haplochromis bloyeti* (Sauvage).

Several species previously recorded from the lake (Ricardo 1939a and 1939b) have not been taken or have not yet been identified from samples taken during this visit. These species are: —

*Barilius moorii* Boulenger.
*Barbus* sp.
*Leptoglanis rotundiceps* (Hilgendorf).
*Amphilius platychir* (Gunther).
*Clarias hilgendorfi* (Boulenger).
*Aplocheilichthys johnstoni* (Gunther).

Most of these species have only been recorded from the affluent rivers, and none are of direct economic importance. Several *Barbus* species have been previously noted or collected but not yet positively identified.

Two other genera not previously recorded from the lake—*Protopterus* and *Polypterus* appear to be well known to the local fishermen, but no specimens were collected.

According to results given in Table 5, from bottom set research gill-nets the most abundant species in terms of weight, was *Tilapia* followed by *Gnathonemus, Labeo, Hydrocyon, Mormyrus, Clarias, Synodontis, Schilbe* and *Marcusenius* respectively, while *Alestes* did not occur at all. *Tilapia, Hydrocyon* and *Mormyrus* were caught at maximum rates in 4 in. nets, *Labeo* in 3 in. nets, *Gnathonemus* in 2½ in. nets, and *Marcusenius, Schilbe* and *Synodontis* in 2 in. nets. However, *Schilbe, Synodontis* and *Clarias*, all species possessing elaborate pectorial spines, could be taken in any net irrespective of size. The catches of *Clarias* tended to comprise a small number of large specimens entangled in the meshes.

The most abundant species taken in surface-set research gill-nets (Table 6) was clearly *Hydrocyon*, followed by *Tilapia* and *Clarias* with small quantities of *Schilbe, Mormyrus, Gnathonemus, Labeo, Synodontis, Marcusenius* and *Alestes*. *Hydrocyon* was taken at a maximum rate in the 4½ in. mesh net, but large catches were also taken in the 2½, 3½ and 4 in. nets. *Tilapia* were caught at maximum rates in the 4 and 4½ in. nets. As with bottom set nets a few large specimens of *Clarias* were taken in all nets, but the 3 and 5 in. presented the largest catch rates.

The principal species taken by commercial fishermen using surface-set gill-nets was *Tilapia*, with small quantities of *Hydrocyon* and *Clarias*. No other species were regularly taken.

The composition of the catch from commercial nets was very different to the catch from research nets of the same mesh. This can be explained in that the commercial fishery is designed to take *Tilapia* (the principal item of the export trade, while *Hydrocyon* and *Clarias* are considered for home consumption) hence the nets are prepared using as thin a twine as possible, and are simply threaded onto the footline and headrope, hanging loosely. This method of hanging is particularly suitable for a slow-swimming fish with a laterally compressed body form. The research nets were however of thicker twine and were hung rigidly on the head-ropes and foot-ropes. Arranged by the half the research nets were more suitable for the capture of strong fast-swimming fish of round body shape. This is reflected in the high catch rate, particularly of *Hydrocyon*, and also *Clarias* shown in Table 2.

*Relative Productivity of the Different Areas*

As already indicated Lake Rukwa is separable into two principal zones; the permanent deeper south lake, and the extensive shallower north lake which may dry completely from time to time, e.g. 1897, 1920, 1929, 1936, 1948 and 1953-54 (Gunn 1956).

The north lake is presently flooded, and a shallow area of this type would be expected to be intermittently more highly productive than a permanently inundated area of the same type. The present temporary increase in production in north lake is evidenced in three ways. Firstly the local fisherman are dissatisfied with catches in the south lake and large numbers have emigrated from the south to the north lake (Hammond 1963, and personal observation). Secondly the mesh of the gill-nets employed in the north range over 5, 5½, and 6 in., whereas in the south 4, 4½ and 5 in. nets are most common. Thirdly accurate records of the catches by commercial fishermen (Table 2) show catch rates three times greater in the north than in the south.

However, the present greater level of productivity on the north lake is liable to be exaggerated by a previous concentration of effort on the south lake reducing the fish population, and conversely by a previous absence, and the present low level of fishing effort in the north.

The relative productivity of other regions of the south lake can now be considered. The main areas are: the inshore waters along the steep eastern shore; the inshore waters along the shallow shelving western shore; the grass swamps of the Luika, Milindi and Songwe River mouths; and the open waters of the lake. Unfortunately no research nets were fished along the shallow western shore.

Records of catch rates given in Table 3, expressed in grams per 50 yards per hour, for bottom-set nets in the three localities investigated indicate clearly the highest catches of both "useful" and "total" categories of fish from the Luika-Songwe Swamps, intermediate catch rates from open waters and lowest catches from the eastern shore zone.

In the swamp peak total catches were taken by the 2½ in. net with large proportions of *Gnathonemus* and *Synodontis*, followed by the 4 in. net with large catches of *Mormyrus*. The 4 in. mesh also takes the highest catches of the useful category, with *Hydrocyon* predominating.

From the open waters the largest total catches are represented in the 2½ in. net where *Grathonemus* predominates (*Synodontis* appearing in small quantities), followed by the 4 and 3½ in. meshes where *Mormyrus* were obtained, in addition to smaller quantities of *Labeo*, *Schilbe*, *Gnathonemus*, *Marcusenius* and *Synodontis*.

In conclusion, in the surface-set research fleet the percentage of useful fish in the catch is relatively high even in the smaller mesh sizes, and soon rises to a maximum of 100 per cent in the large meshes irrespective of fishing locality. This is due to the absence of *Gnathonemus*, *Marcusenius*, *Mormyrus*, *Labeo* and *Synodontis*, all of which are relatively small species and all tend to be demersal in habit.

*Processing and marketing*

Processing of the fish catch—principally *Tilapia*, was commonly effected by sun-drying and hot-smoking, with essays in cold smoking and dry salting during the period of activity of the European enterprises. Presently African enterprises have reverted to the traditional sundrying and smoking method of preparation. A very small proportion of the catch is sold fresh to the surrounding population for home consumption, the major part is processed and exported.

The market for the processed fish was expanded greatly; in 1936 smoked fish spread to the nearby Lupa Goldfields, the Makongolosi Railway, to Tabora and Morogoro. In 1946 fresh fish was transported to the Lupa Goldfields, while smoked fish was marketed throughout Tanganyika, principally the surrounding

Southern Highlands area. Presently exports are directed from the south lake to Mbeya, Tukuyu, Rhodesia, and from the north lake also to Mbeya, Tukuyu, Rhodesia, Tunduma and Songea, with smaller quantities to Iringa, Kilosa, Arusha, etc.

The quantities of fish recensused by Hammond leaving Mbangala and Ivuna are given in Tables 7 and 8 respectively, but unfortunately these do not include similar records of the large export trade now established through Sumbawanga.

The costs of transport for fish are based not on weight or volume, but on number, thus the cost by motor-driven water transport on north lake to the usual landing point near Sumbawanga is four cents per fish. From Kasisi to Mbangala the cost amounts to six cents per fish by water, or five cents per fish by road. Similarly transport from Mbangala to Mbeya or Tukuyu costs four cents per fish by private lorry, or two cents per fish by East African Railways Road Service bus from Mbangala to Mbeya.

At Mbangala in September 1963 the standard price for a single dried *Tilapia* was 20 cents which could sell at between 25 and 60 cents in Mbeya. In Tukuyu 50 cents was quoted as the standard price while in Tunduma, there was little fish for sale and the cost rose above 50 cents.

*Comment*

It is intended that a second visit shall be made to Lake Rukwa during January and February to obtain further information on the fishery. Firstly, this should include further details of the commercial fishery in terms of units of effort, rates of catch, quantities of export and methods of marketing. Secondly a great deal more information is needed on the ecology of the various fish species, in particular of their reproduction, which for many cichlid and non-cichlid species is concentrated in inshore areas and affluent rivers during the main rainy season. At this period of the year, the whole pattern of the commercial fishery is modified and is very different to that of the dry season already investigated.

The present commercial fishery is increasing but is principally dependent on a single species—*Tilapia rukwaensis*, whereas several other useful species such as *Hydrocyon* and *Gnathonemus* are hardly exploited. With an increase of fishing effort and production *balanced* exploitation of the fish population must be envisaged.

Finally, in addition to the proper improvement of the fishing effort, the marketing of the catch must also be developed logically, at present the lack of a suitable transport system for fish produce from the many small fishing centres on Rukwa is a prominent fault, leading to the spoilage and loss of a considerable quantity of dried fish each year.

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TABLE 1.—COMPARATIVE CHEMICAL CONSTITUTION OF LAKE WATER IN 1936, 1946 AND 1963

| | 1936 (Ricardo 1939a) | 1946 (Swynnerton 1947) | 1963 (Hammond 1963) | 1963 (Mann) |
|---|---|---|---|---|
| Depth of south lake (metres) | 3·5 | 4·3–3·0 | — | 6·5 |
| (Hydrogen ion concentration) p.H. | 8·5 | 9·3 | 8·4 | about 8·0 |
| Conductivity (micromhos at 25° c.) | — | — | 353·9 | 400 |
| Alkalinity as $Co_3$ (parts per million) | 212·8 | 1,019·0 | 184·0 | — |
| Chlorides (parts per million) | 25·8 | 118·0 | 16·0 | — |
| Turbidity (parts per million) | — | 38·6 | 120·0 | — |

TABLE 2.—COMPARATIVE CATCH RATES OF VARIOUS SURFACE-SET GILL-NETS

*(Results expressed in grams per 50 yds. per hour)*

| | *Tilapia* | *Hydrocyon* | *Clarias* | *Other Species* | Total |
|---|---|---|---|---|---|
| 5″ Research net | 6·9 | 23·9 | 13·6 | 1·5 | 45·9 |
| 4½″ Commercial net used Mann | 22·0 | 8·7 | 2·7 | Nil | 33·4 |
| 5″ Commercial net used Mann | 42·5 | 11·5 | 7·3 | Nil | 61·3 |
| 5″ Commercial net used Ntunje | 37·5 | 1·4 | 2·8 | Nil | 41·7 |
| 5″ Commercial net used Kasisi | 156·3 | 5·5 | 6·7 | Nil | 168·5 |

TABLE 3.—CATCH RATES FOR BOTTOM-SET NETS IN THREE LOCALITIES

*(Results expressed in grams per 50 yds. per hour)*

| Mesh (in.) | Inshore Eastern | | | | Inshore Swamp | | | | Open Water | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Useful | Total | Number of samples | Per-centage useful | Useful | Total | Number of samples | Per-centage useful | Useful | Total | Number of samples | Per-centage useful |
| 2 .. .. .. | 16·6 | 223·3 | 2 | 1 | 38·5 | 420·8 | 1 | 9 | 9·2 | 265·8 | 1 | 3 |
| 2½ .. .. .. | 55·4 | 514·3 | 5 | 11 | 60·0 | 911·8 | 1 | 7 | 32·5 | 626·0 | 2 | 5 |
| 3 .. .. .. | 82·2 | 419·6 | 4 | 20 | 80·8 | 541·2 | 1 | 15 | 160·1 | 377·8 | 2 | 42 |
| 3½ .. .. .. | 163·1 | 245·5 | 3 | 66 | 253·8 | 658·1 | 1 | 39 | 352·0 | 420·3 | 2 | 84 |
| 4 .. .. .. | 99·5 | 238·3 | 3 | 42 | 461·5 | 839·1 | 1 | 55 | 406·9 | 424·4 | 2 | 96 |
| 4½ .. .. .. | 28·6 | 55·0 | 2 | 52 | 153·8 | 505·7 | 1 | 30 | 192·2 | 195·3 | 2 | 98 |
| 5 .. .. .. | 101·2 | 122·6 | 3 | 83 | 269·2 | 269·2 | 1 | 100 | 169·9 | 207·4 | 2 | 82 |
| 5½ .. .. .. | 11·0 | 11·0 | 3 | 100 | Nil | Nil | 1 | — | 76·9 | 76·9 | 2 | 100 |
| 6 .. .. .. | 21·8 | 23·0 | 2 | 95 | 300·0 | 300·0 | 1 | 100 | Nil | Nil | 2 | — |
| Total .. .. | 579·4 | 1,852·6 | | 31 | 1,617·6 | 4,445·9 | | 36 | 1,399·7 | 2,593·9 | | 54 |

TABLE 4.—CATCH RATES FOR SURFACE-SET NETS IN THREE LOCALITIES

(*Results expressed in grams per 50 yds. per hour*)

| Mesh (in.) | Inshore Eastern | | | | Inshore Swamp | | | | Open Water | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Useful | Total | Number of samples | Percentage useful | Useful | Total | Number of samples | Percentage useful | Useful | Total | Number of samples | Percentage useful |
| 2 .. .. .. | 45·7 | 92·9 | 1 | 49 | 84·6 | 193·9 | 3 | 44 | 113·7 | 178·2 | 1 | 64 |
| 2½ .. .. .. | 287·1 | 327·8 | 1 | 88 | 194·3 | 277·8 | 3 | 70 | 196·4 | 244·3 | 1 | 80 |
| 3 .. .. .. | 307·9 | 334·1 | 1 | 92 | 253·2 | 469·3 | 4 | 54 | 112·5 | 122·0 | 1 | 92 |
| 3½ .. .. .. | 395·7 | 395·7 | 1 | 100 | 411·7 | 470·8 | 4 | 87 | 134·5 | 148·5 | 1 | 91 |
| 4 .. .. .. | 356·4 | 356·4 | 1 | 100 | 479·1 | 562·4 | 4 | 85 | 247·7 | 247·7 | 2 | 100 |
| 4½ .. .. .. | 302·1 | 302·1 | 1 | 100 | 516·9 | 555·4 | 4 | 93 | 151·2 | 151·2 | 2 | 100 |
| 5 .. .. .. | 264·3 | 264·3 | 1 | 100 | 481·4 | 500·3 | 4 | 96 | 317·9 | 317·9 | 2 | 100 |
| 5½ .. .. .. | 357·1 | 357·1 | 1 | 100 | 281·8 | 281·8 | 2 | 100 | 138·1 | 138·1 | 2 | 100 |
| 6 .. .. .. | 151·4 | 151·4 | 1 | 100 | 136·4 | 137·8 | 2 | 99 | 176·4 | 176·4 | 2 | 100 |
| Total .. .. | 2,467·7 | 2,581·5 | | 96 | 2,839·4 | 3,449·5 | | 82 | 1,588·4 | 1,724·3 | | 92 |

TABLE 5.—CATCH BY SPECIES FROM BOTTON-SET GILL-NETS IN ALL LOCALITIES

(*Results expressed in grams per 50 yds. per hour*)

| Mesh (in.) | *Tilapia* | *Hydrocyon* | *Clarias* | *Mormyrus* | *Gnathonemus* | *Marcusenius* | *Schilbe* | *Labeo* | *Synodontis* | *Alestes* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 .. | — | 4·9 | — | — | 21·7 | 3·9 | 9·0 | 7·4 | 19·7 | — | 66·6 |
| 2½ .. | 0·3 | 4·7 | 1·5 | — | 44·9 | 0·1 | 2·9 | 14·7 | 1·7 | — | 70·8 |
| 3 .. | 4·1 | 5·9 | 4·7 | 1·9 | 21·3 | — | 2·5 | 19·6 | 0·6 | — | 60·6 |
| 3½ .. | 17·2 | 12·7 | 10·0 | 6·5 | — | — | 0·3 | 14·5 | 0·3 | — | 61·5 |
| 4 .. | 27·3 | 13·6 | 1·9 | 22·3 | 0·3 | — | — | — | 0·1 | — | 65·5 |
| 4½ .. | 23·3 | — | — | 9·5 | 0·3 | — | — | 5·9 | 0·3 | — | 39·3 |
| 5 .. | 17·8 | 4·1 | 3·0 | 1·1 | — | — | 0·9 | — | 0·1 | — | 27·0 |
| 5½ .. | 0·9 | 4·1 | — | — | — | — | — | — | — | — | 5·0 |
| 6 .. | 5·6 | — | 7·6 | — | — | — | — | — | 0·1 | — | 13·3 |
| Total.. | 96·5 | 50·0 | 28·7 | 41·3 | 88·5 | 4·0 | 15·6 | 62·1 | 22·9 | — | — |

TABLE 6.—CATCH BY SPECIES FROM SURFACE SET GILL-NETS IN ALL LOCALITIES

*(Results expressed in grams per 50 yds. per hour)*

| Mesh (in.) | *Tilapia* | *Hydrocyon* | *Clarias* | *Mormyrus* | *Gnathonemus* | *Marcusenius* | *Schilbe* | *Labeo* | *Synodontis* | *Alestes* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 .. | 0·1 | 12·3 | 1·8 | 0·1 | 5·0 | 1·8 | 9·2 | 1·6 | 1·4 | 1·1 | 34·4 |
| 2½ .. | 0·5 | 34·3 | 1·2 | 0·2 | 7·2 | — | 6·1 | 2·1 | 0·3 | 0·1 | 52·0 |
| 3 .. | 1·6 | 20·9 | 14·5 | 4·8 | 6·5 | — | 5·5 | 5·2 | 0·3 | — | 59·3 |
| 3½ .. | 9·0 | 31·2 | 8·8 | 5·1 | — | — | 1·1 | 0·8 | 0·1 | — | 56·1 |
| 4 .. | 22·1 | 30·4 | 3·6 | 7·1 | — | — | 0·9 | — | — | 0·1 | 64·2 |
| 4½ .. | 13·0 | 42·8 | — | 3·4 | — | — | — | — | — | — | 59·2 |
| 5 .. | 6·9 | 23·9 | 13·6 | 1·4 | — | — | — | — | 0·1 | — | 45·9 |
| 5½ .. | 7·3 | 14·8 | 11·6 | — | — | — | — | — | — | — | 33·7 |
| 6 .. | 8·6 | 6·0 | 8·5 | — | — | — | 0·1 | — | — | — | 23·2 |
| Total.. | 69·1 | 216·6 | 63·6 | 22·1 | 18·7 | 1·8 | 22·9 | 9·7 | 2·2 | 1·3 | — |

TABLE 7.—FISH EXPORTS FROM MBANGALA 1963 (HAMMOND 1963)

*Expressed as numbers of fish (Tilapia)*

| Destination | March | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|---|
| Rhodesia | 251,098 | 295,010 | 277,175 | 187,177 | — | — | — | — |
| Mbeya | 183,228 | 375,072 | 116,194 | 205,111 | 198,383 | 259,170 | 404,036 | 346,528 |
| Tukuyu | 47,803 | 109,595 | 124,798 | 118,680 | 45,875 | 47,068 | 83,985 | — |
| Iringa | — | 4,500 | — | — | — | — | — | — |
| Kyela | 8,300 | — | — | — | — | — | — | — |
| Total number | 490,429 | 784,177 | 518,167 | 510,968 | 244,258 | 306,238 | 346,528 | 346,528 |
| Total weight (tons) | 243 | 392 | 259 | 205 | 122 | 153 | 244 | 123 |

TABLE 8.—FISH EXPORTS FROM IVUNA 1963 (HAMMOND 1963)

*Expressed as numbers of fish (Tilapia)*

| Destination | March | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|---|
| Rhodesia | | No Records | | | 288,790 | 1,452,330 | 2,756,370 | 2,914,270 |
| Mbeya | | | | | 27,600 | 250,410 | 45,040 | 147,570 |
| Tukuyu | | | | | 147,000 | 127,350 | 685,570 | 617,306 |
| Iringa | | | | | — | — | 30,000 | 49,000 |
| Tanga | | | | | — | — | — | 40,000 |
| Songea | | | | | 129,850 | — | 23,500 | — |
| Tabora | | | | | — | — | 5,800 | — |
| Total number | | | | | 585,240 | 1,830,090 | 3,547,280 | 3,768,140 |
| Total weight (tons) | | | | | 292 | 915 | 1,773 | 1,884 |

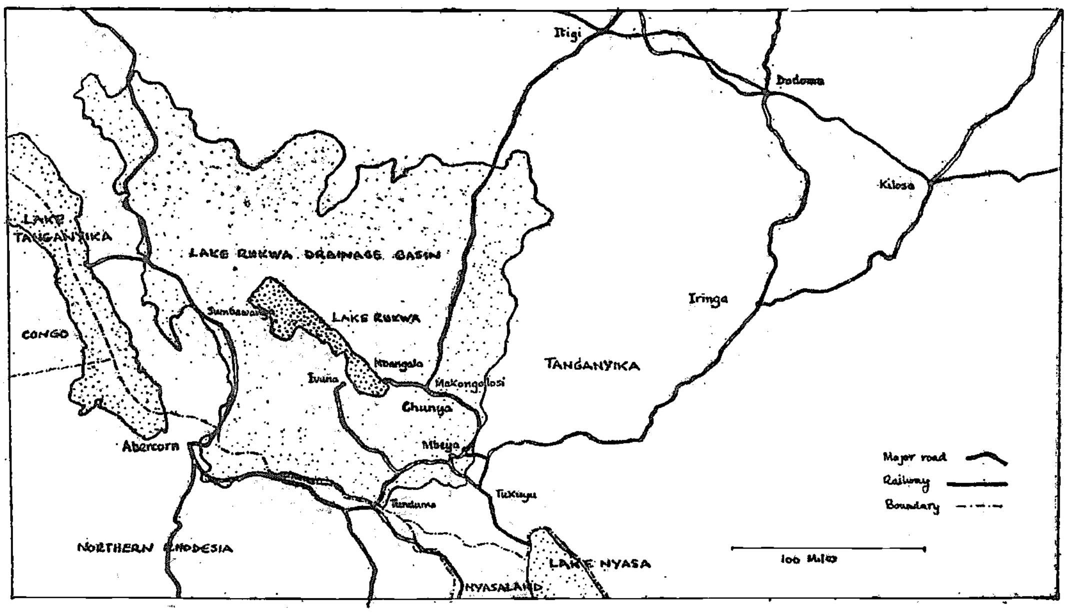


Fig. F1—Map of Lake Rukwa, its drainage basin and access roads

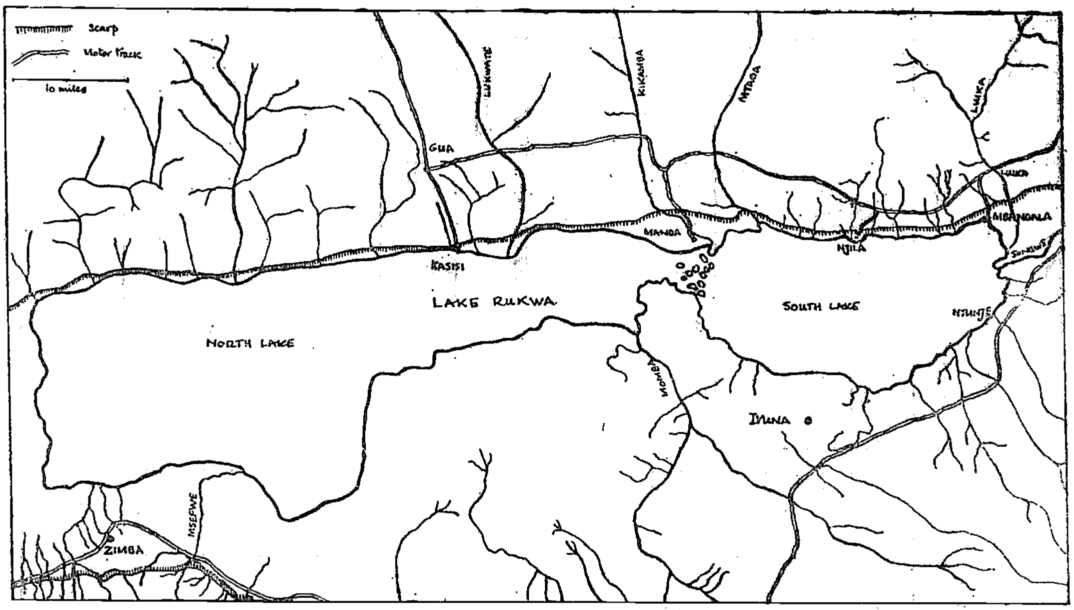


Fig. F2—Lake Rukwa to an enlarged scale

*APPENDIX G*

## REPORT ON A FISHERIES SURVEY OF LAKE RUDOLF, KENYA

BY M. J. MANN

INTRODUCTION

A preliminary visit was made to Ferguson's Gulf, situated mid-way along the western shore from 21st October to 22nd November, but work was restricted to areas close to the Gulf itself; areas further afield were not visited.

Previous visits had been made by a number of workers—principally the Cambridge Expedition to the East African Lakes who were stationed at Ferguson's Gulf from the end of December until the end of March 1931. Papers on fish biology were published by Worthington (1932), Trewavas (1933) and Worthington and Ricardo (1936). Lowe collected *Tilapia* material during January 1953 (Lowe 1954) and Hamblyn travelled to Ferguson's Gulf in February 1960, and to Loyongalani in January 1961 (Hamblyn 1961 and 1962).

Since September 1961, McConnel (Fisheries Officer, Fisheries Department, Kenya), has been stationed at Ferguson's Gulf, with the object of developing a commercial fishery in the area to support and supply the large number of Turkana people collected in the local famine-relief camps (Watson 1962 and 1963).

The state of the fishery on Lake Rudolf has changed very little since the visit of the Cambridge Expedition in 1931. The tribes bordering the lake are principally pastoralists and are not addicted to fishing. However, some individuals still follow the traditional methods, using plunge baskets and spears in the shallows, and small longlines set offshore from rafts of doum-palm trunks. It is primarily a subsistence fishery.

The northern part of the lake including the only permanent river delta (River Omo), is supposedly depopulated across a 10-mile border strip running along the international boundary with Sudan and Ethiopia.

In the south east a small group of El Molo (Samburu) people, originally restricted to fishing by the loss of their stock to the invading Nilo-Hamite tribes, still actively work traditional gear along a small section of the coast. At the adjacent centre of Loyangalani tourist sport fishing is said to have produced catches of up to 10 tons (fresh wet weight) of *Lates niloticus* (Nile Perch) per year (McConnel 1963). The larger part of their catch is exported as frozen fillets to Nairobi.

However, it is at Ferguson's Gulf that the greatest change and progress has been made and there is at present a small but lively industry producing dried fish for the population of the famine-relief camps at Ferguson's Gulf and Loragumu. About 100 families are involved; the men work some 35 surface-set 8 in. gill-nets, two small beach seines and a single longline. There are three fibreglass dinghies 14 feet in length, owned by the Turkana District Council, all of which are used co-operatively by the fishermen. Some three outboard engines of $5\frac{1}{2}$ h.p. are also owned, these being used mainly for transport of men and materials between the camp and the mainland, and also when difficulties arise in recovering the nets owing to bad weather conditions. Some of the nets are owned by the District Council, and some by the Fisheries Department, but costs of running and repairing the gear and the boats are generally borne by the Kenya Fisheries Department.

The other principal change regarding conditions on the lake is the lake level. In common with other East African lakes the level is very variable and has risen considerably in recent years. Precise records of lake level are not available save for a series of readings by McConnel in 1962 which terminated when the gauge became submerged. The rims of crater lakes A, B and C on Central Island might form a convenient bench mark, recorded as being respectively 20 feet, 200 feet and 5 feet above the lake level in 1931 (Beadle 1932), but it was not possible to visit Central Island during this survey. No other direct records are available but McConnel (1963) has indicated an increase in width of the mouth of Ferguson's Gulf from 200 yards to 2,000 yards since September 1961.

*Relative Abundance of the Various Species*

During the present survey the fishing gear used included plankton nets, mosquito seines, $1\frac{1}{8}$ in. mesh beach seine, a graded fleet of gill-nets of meshes 2 to 6 in., by $\frac{1}{2}$ in. increments, and a single 8 in. gill-net. As already noted the areas fished were all within five miles radius of Ferguson's Spit, but two other visits were made, by land to the north edge of the Turkwell River delta, and to another minor river mouth five miles northwest of Ferguson's Spit.

The species captured and identified from this limited area were:—

*Hydrocyon forskalii* Cuvier.
*Alestes dentex* (Linn.).
*Alestes baremose* (Joannis).
*Alestes nurse* (Ruppell).
*Distichodus niloticus* (Linn.).
*Citharinus citharus intermedius* Worthington.
*Labeo hourie* Heckel.
*Barbus bynni rudolfianus* Worthington.
*Barilius niloticus* (Joannis).
*Engraulicypris stellae* Worthington.
*Clarias lazera* Cuvier and Valenciennes.
*Schilbe uranoscopus* Ruppell.
*Bagrus bayad* (Forskali).
*Auchenoglanis occidentalis* (Cuvier and Valenciennes).
*Synodontis schall* (Bloch-Schneider).
*Synodontis frontosus* Vaillant.
*Aplocheilichthys rudolfianus* Worthington.
*Lates niloticus* (Linn.).
*Tilapia nilotica* (Linn.).
*Tilapia galilaea* (Artedi).
*Tilapia zillii* Gervais.
*Haplochromis rudolfianus* Trewavas.
*Tetrodon fahaka* Linn.

Those species previously noted but not collected or identified during this survey included:—

*Polypterus bichir* Geoffroy Saint-Hilaire.
*Polypterus senegalensis* Cuvier.
*Gymnarchus niloticus* Cuvier.
*Heterotis niloticus* (Ehrenberg).
*Alestes macrolepidotus* (Cuvier and Valenciennes).

*Hydrocyon lineatus* Bleek.
*Barbus meneliki* Pellegrin.
*Barbus plagiostomus* Boulenger.
*Barbus werneri* Boulenger.
*Engraulicypris bottegi* Viniciguerra.
*Mochochus niloticus* Joannis.
*Andersonia leptura* Boulenger.
*Malopterurus electricus* (Gmelin)
*Aplocheilichthys jeanneli* Pellegrin.
*Lates niloticus rudolfianus* Worthington.
*Lates niloticus longispinis* Worthington.
*Tilapia vulcani* Trewavas.
*Pelmatochromis exsul* Trewavas.

Of these species *Polypterus bichir, P. senegalensis, Gymnarchus niloticus, Heterotis niloticus, Barbus plagiostotmus, B. werneri, Engraulicypris bottegi, Mochochus niloticus, Andersonia leptura, Malopterurus electricus, Aplocheilichthys jeanelli,* are all typical nilotic fauna and are to be expected, but have not been collected by the Cambridge Expedition nor by previous workers.

McConnel (1963) has identified and photographed a specimen of *Heterotis niloticus* from catches in Ferguson's Gulf. Worthington and Ricardo (1936) consider the record for *Engraulicypris bottegi* to be dubious.

*Lates niloticus rudolfianus* and *L. n. longispinis* are considered by Worthington (1940) and David and Poll (1937) to be subspecies of *L. niloticus* rather than distinctly separate species. However, Hamblyn (1962b) says that a separation on morphological differences is not justified, although there may be acceptable physiological differences. No attempt was made to separate the two groups during this survey.

*Tilapia vulcani* is restricted to a crater lake on Central Island—a habitat not yet investigated. Similarly *Hydrocyon lineatus* is noted (Worthington and Ricardo 1936) as being typical of deep open waters and steep shores of the east coast—areas not fished during this investigation. The same argument applies to *Pelmatochromis exsul* which were rare and were only collected from the rocky shores of the east coast and Central Island (Worthington and Ricardo 1936).

*Barbus meneliki* and *Aplocheilichthys jeanneli* are known only from specimens in the Paris Museum—presumably collected from the Omo River, but have not been collected by the Cambridge Expedition or subsequently.

The relative abundance of the various species taken in research gill-nets and commercial gill-nets will now be discussed. However most records are based on a single experimental fishing and frequently results were confused by the fleet being fouled by other gill-nets, by the sinking and tangling of nets with very high catches, and by unusual hydrological conditions preventing recovery after the usual period of 12 hours fishing.

McConnel (1963) indicates that catch rates in surface set gill-nets are greater by night than by day. This is explicable; the surface set nets of heavy twine (210/24) are readily visible in these relatively clear waters under intense sunlight. The research fleets fished on the bottom or shallow waters by day and then the subsequent night gave total catches of 22,841 and 29,159 grams per hour respectively (Table 1). It is expected that surface-set nets would show a more marked difference of catch rate by day and by night.

Commercial catches are reported (McConnel 1963) to be reduced at the period of full moon. This was not investigated, but is probably a result of the increased visibility of the nets, although there may also be an activity pattern for some of the fish species based upon a lunar cycle.

McConnel also notes that storms result in higher catches, this was observed during the survey, although no details were noted. Rain, without strong winds, apparently has no significant effect on the catch rate.

Both surface-set and bottom-set research nets were of nylon and were set by the half (50 yards). The ply used varied from 210/3 in the smallest meshes, to 210/9 and 210/12 in the large meshes.

The principal species taken in bottom-set nets laid offshore were: *Labeo, Lates, Citharius, Barbus, Distichodus Bagrus, Synodontis* and *Clarias* in the larger meshes. The latter species was particularly abundant on mud bottoms, in both shallow and deep waters. In shallow waters over the marginal sand bottoms young *Labeo* appeared but *Synodontis* was taken in much smaller quantities.

In surface-set nets the proportions of *Citharinus* increased greatly, and in general the number of *Synodontis* taken fell to a low level, although a few individuals were nearly always captured. *Barbus* was not taken at all in surface nets and *Labeo* occurred in much smaller quantities.

Surface-set nets of 210/24 ply, 8 in. mesh and mounted by the third (66 yards) were used by the commercial fishery centred at the mouth of Ferguson's Gulf. The catch was composed of *Citharinus, Lates* and *Tilapia nilotica* with occasional *Distichodus, Labeo* and *Synodontis schall.* Analysis of commercial catches on 6th November 1963 and 7th November 1963 is given in Table 2. Catches by Mann using a similar commercial net are summarized in Table 3. The considerable differences may be explained in that Mann's single short net was fished closer inshore that the commercial fishermen using larger fleets, and in general *Tilapia* are taken within 100 yards of shore, while *Citharinus* predominate beyond the 100-yard mark.

*Processing and marketing*

After capture the fish are brought ashore in the early morning and cleaned on a sand spit, some fish, usually *Tilapia,* are kept back from the fisherman's own consumption, the remainder are filleted and the flesh is simply sun dried on wire-netting racks strung well above the ground. This method appears effective and few dipteran flies or dermestid beetles were to be seen on either the wet fish or the dry product. The carcasses are either discarded or more frequently now, are taken ashore to the mainland and exchanged for firewood which is scarce on the Spit. Periodically the dried product, the different species mixed together, is gathered into sacks and weighed, and is bought by McConnel on behalf of Oxfam and is distributed to the camps at Loragumu and Ferguson's Gulf. The price originally was standard at 50 cents per lb., but in October fell to 40 cents per lb. These sales have amounted to an average value of £400 per month, which is equivalent to 8,000 lb. of dried fish, or 80,000 lb. of fresh wet fish.

A very small quantity of dried fish, particularly *Tilapia* and *Lates* is sold to middle men for retail in Kitale and beyond, the price being 50 cents per lb.

*Comment*

A second visit is planned to Lake Rudolf during April and May, when the main rains might be expected. At this period many species typically tend to move inshore and up the affluent rivers to spawn, but the rains are slight (less than 5 in.

per year)—and the affluent water courses may merely seep into the lake rather than actively flow, this spawning may of necessity take place simply in shallows around the edge of the lake.

The growth rate of some fish species in Lake Rudolf appears to be unusually high—thus *Tilapia nilotica* not only reaches a far larger size than in other waters, but also reaches sexual maturity at a larger size (Lowe 1954). This may be related to the fact that in Rudolf *T. nilotica* appear to be able to digest blue-green algae, whereas in other waters the same algae are taken but are not digested (Fish 1955).

The remarkable large size of many specimens taken is also due to the presence of old fish, the fishing intensity presently being so low that many adult fish survive to a large size. These aged specimens will be eliminated as the fishing effort increases.

The sheltered waters of Ferguson's Gulf are not typical of the shores of the whole lake—and the pattern of the fish fauna obtained from this survey cannot be directly assumed to be true of the remainder of the coastline.

Finally, the commercial fishery presently developed by the Kenya Fisheries Department at Ferguson's Gulf, rests almost entirely on the market to Oxfam, if this outlet closes, without the development of another market, the present fishery would collapse.

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TABLE 1.—COMPARISON OF CATCHES IN BOTTOM-SET NETS BY DAY AND BY NIGHT
(*Expressed in grams per 50 yards per hour*)

| Date | Net | *Lates* | *Citharinus* | *Distichodus* | *Labeo* | *Barbus* | *Hydrocyon* | *Synodontis* | *Bagrus* | *Schilbe* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23–10–63 By Day | 6 | — | 5,666 | — | 286 | — | — | — | — | — | 5,952 |
| | 5½ | 286 | 3,428 | 571 | 524 | 191 | — | 76 | — | — | 5,076 |
| | 5 | 190 | 476 | 67 | 762 | 29 | 283 | 95 | — | — | 1,857 |
| | 4½ | — | 809 | — | 905 | — | — | 52 | — | — | 1,766 |
| | 4 | 333 | — | — | 619 | — | — | 190 | — | — | 1,142 |
| | 3½ | 143 | 143 | — | 4,238 | — | — | 286 | — | — | 4,810 |
| | 3 | — | — | — | 667 | — | — | 143 | — | — | 810 |
| | 2½ | — | — | — | 667 | — | 190 | 190 | — | — | 1,047 |
| | 2 | — | 76 | — | — | — | 238 | 67 | — | — | 381 |
| Totals .. | | 952 | 10,598 | 638 | 8,668 | 220 | 666 | 1,099 | — | — | 22,841 |
| 24–10–63 By Night | 6 | 169 | 5,619 | 313 | 1,838 | — | — | — | — | — | 7,939 |
| | 5½ | — | 4,081 | — | 963 | — | — | — | — | — | 5,044 |
| | 5 | 363 | 795 | — | 1,584 | — | — | 351 | 225 | — | 3,318 |
| | 4½ | 219 | 888 | — | 1,716 | — | — | 241 | 126 | — | 3,190 |
| | 4 | 26 | 1,406 | — | 1,063 | 43 | — | 781 | — | — | 3,319 |
| | 3½ | — | 88 | — | 169 | — | 88 | 1,375 | — | — | 1,720 |
| | 3 | 16 | 94 | — | 150 | 41 | — | 1,987 | — | 19 | 2,307 |
| | 2½ | — | 94 | — | 66 | 41 | 61 | 1,438 | — | 22 | 1,722 |
| | 2 | — | — | — | 38 | — | — | 534 | — | 28 | 600 |
| Totals .. | | 793 | 13,065 | 313 | 7,587 | 125 | 149 | 6,707 | 351 | 69 | 29,159 |

TABLE 2.—ANALYSIS OF COMMERCIAL NET CATCHES (TURKANA)
(*Expressed in grams per 50 yards per hour*)

| | *Tilapia* | *Citharinus* | *Lates* | *Distichodus* | *Labeo* | *Synodontis* | *Clarias* | *Hydrocyon* |
|---|---|---|---|---|---|---|---|---|
| 6–11–63 .. .. .. | 550 | 1,544 | 908 | — | Nil | Nil | Nil | Nil |
| ,, | 114 | 2,136 | 419 | — | | | | |
| ,, | — | 2,415 | 653 | 480 | | | | |
| ,, | — | 5,222 | 824 | — | | | | |
| ,, | — | 5,054 | — | 253 | | | | |
| ,, | 145 | 4,182 | 2,342 | 360 | | | | |
| ,, | 246 | 4,063 | 830 | — | | | | |
| 7–11–63 .. .. .. | 171 | 3,043 | 1,537 | 429 | | | | |
| ,, | — | 1,897 | 1,484 | — | | | | |
| ,, | 145 | 1,739 | 1,023 | 379 | | | | |
| ,, | — | 915 | 1,162 | 189 | | | | |
| ,, | — | 4,384 | 1,089 | — | | | | |
| ,, | 414 | 3,220 | 676 | 404 | | | | |
| Total .. .. | 1,784 | 39,814 | 12,946 | 2,493 | Nil | Nil | Nil | Nil |
| Average .. .. | 137 | 3,063 | 996 | 192 | | | | |

TABLE 3.—ANALYSIS OF COMMERCIAL NET CATCHES (MANN)

(*Expressed in grams per 50 yards per hour*)

| | *Tilapia* | *Citharinus* | *Lates* | *Distichodus* | *Labeo* | *Synodontis* | *Clarias* | *Hydrocyon* |
|---|---|---|---|---|---|---|---|---|
| 2-11-63 | — | 6,585 | 977 | 808 | 354 | 12 | — | — |
| 3-11-63 | 2,338 | 154 | 1,762 | — | — | 23 | — | — |
| 4-11-63 | 2,881 | 430 | 926 | 533 | — | — | — | — |
| 7-11-63 | 5,042 | 292 | 417 | — | — | — | — | — |
| 8-11-63 | 277 | 6,131 | 1,431 | — | — | — | — | 72 |
| 10-11-63 | 1,677 | 754 | 462 | — | — | — | — | — |
| 11-11-63 | 1,136 | 2,824 | 976 | — | — | — | — | — |
| 14-11-63 | 177 | 1,631 | 1,585 | 415 | — | — | — | — |
| 15-11-63 | 690 | — | 3,379 | — | — | — | — | — |
| 16-11-63 | 156 | — | 1,356 | 444 | — | — | 519 | — |
| 17-11-63 | 172 | 648 | 2,083 | — | 317 | — | — | — |
| Total | 14,546 | 19,449 | 15,354 | 2,200 | 671 | 45 | 519 | 72 |
| Average | 1,322 | 1,768 | 1,396 | 200 | 61 | 4 | 47 | 7 |

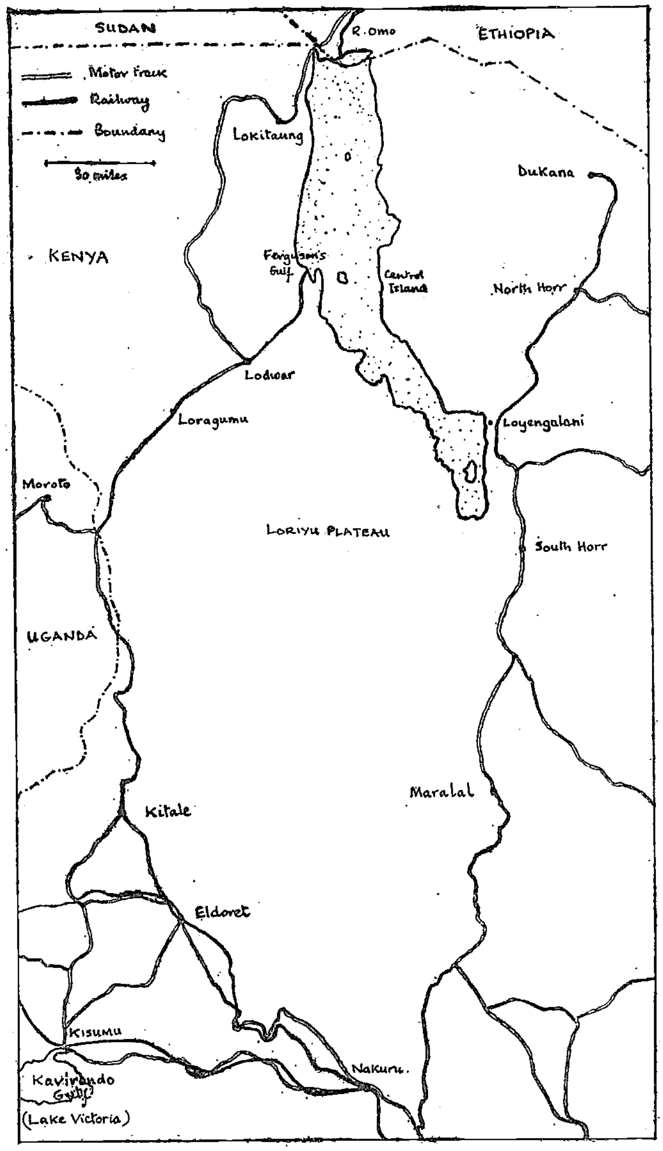


Fig. G1—Map of Lake Rudolf, showing access roads

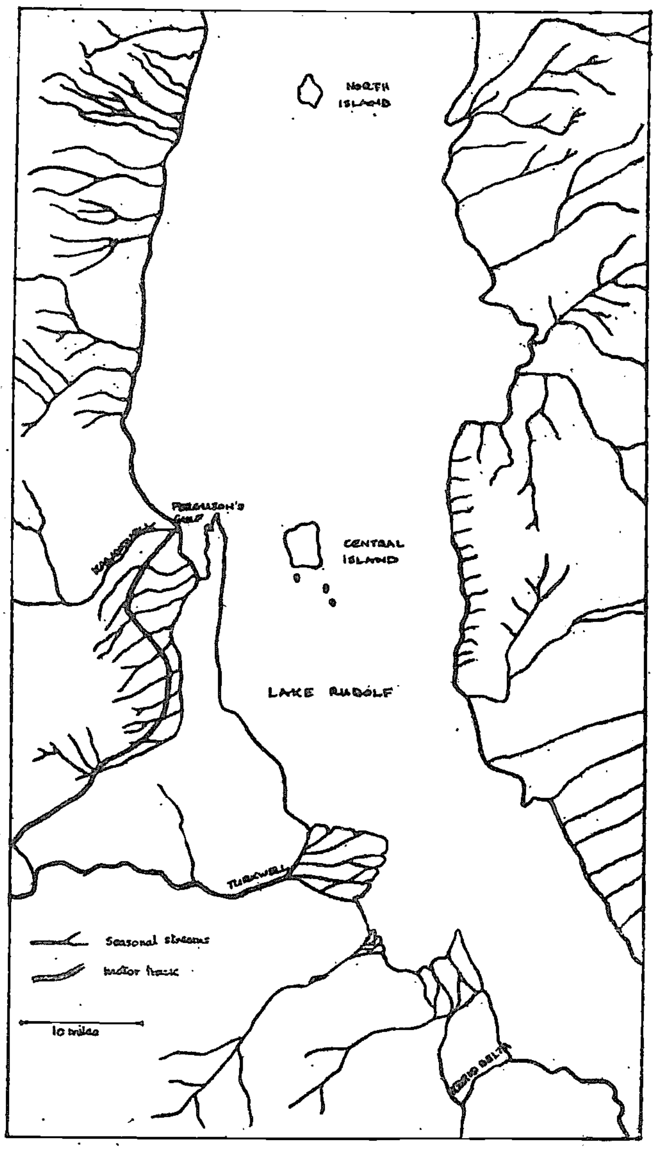


**Fig. G2—The central part of Lake Rudolf, showing the Ferguson's Gulf area**

*APPENDIX H*

# INVESTIGATION OF THE BIOLOGY OF LABEO VICTORIANUS BOULENGER IN RELATION TO ITS FISHERY

BY D. A. CADWALLADR

The cyprinid fish *Labeo victorianus* Boulenger runs up the major rivers entering Lake Victoria to spawn during the wet seasons, the concentration of fish at the river mouths forming the basis of an important seasonal fishery. The Kenyan Fisheries Department records for landings in Kenyan waters show that the highest catches occur in March and October coinciding with the maximum rainfall months of the two wet seasons.

TABLE 1.—NUMBER OF *Labeo victorianus* LANDED IN KENYAN WATERS IN 1962

| | | | |
|---|---|---|---|
| January | 1,237 | July | 681 |
| February | 6,263 | August | 343 |
| March | 30,825 | September | 6,636 |
| April | 23,216 | October | 7,924 |
| May | 720 | November | 5,979 |
| June | 3 | December | 3,719 |

Even with the major catch restricted to these times *Labeo* forms an important part of the whole commercial fisheries in Kenyan waters, it being one of the most abundant fish landed following *Haplochromis* spp., *Tilapia esculenta* and *Alestes nurse*. It is the most favoured after *T. esculenta* as it is easily smoked and sun-dried, and regarded by the local population as a delicacy.

The *Labeo* population is fully exploited in all stages of its migration in the Nzoia River in Kenya. Gill-nets of 2 in. and 2½ in. mesh size are set in the lake in the vicinity of the river mouth, the concentration of nets being such that the river is effectively blocked off from the lake. The effort by the fishermen is divided into day and night fishing so that the opportunity of the *Labeo* avoiding the nets and passing into the river must be very limited. The method of fishing the first half mile of river is similar to that described by Garrod (*C.C.T.A./C.S.A. Hydrobiol. Inl. Fish. 4th Symp.* 1961) for the Kagera River. Between the rains river fishing turns to *Barbus altianalis* when a length of 5½ in. gill-net is streamed into the current from the leading canoe of a line of canoes anchored against the river bank. The canoe is then set adrift and carried by the current out of the river into the lake for about a quarter of a mile, where the net is recovered before the canoe rejoins the queue. On one occasion in July 1963, 7 canoes were seen anchored in the river with another 14 drifting in the river and lake, so that at any one time the river was always being fished. The fishermen reported that once the *Labeo* migration started in August, they would change to 2 in. and 2½ in. nets. Nets are also set in pools and swamp channels bordering the river further up-stream. *Labeo* are also taken in basket traps with non-return entrance valves placed in the numerous, large maze traps set along the banks of the river principally for catching the large migrant species such as *Clarias mossambicus*. Those migrants, including *Labeo*, which survive to spawn are trapped as spent fish by a form of downstream barrier further up-stream. The women of the local population catch the small migrant species with large scoop traps from platforms built along the river bank. At the time of maximum migration about 100 people were seen using this method of fishing in the first two miles of the river. During the earlier part of the migration, as in December 1963, *Barbus apleurogramma* and *Barbus kersteni* are the most abundant fish taken in these traps. At the peak in migration, as in late August and early September 1963, *Labeo* fry of a similar size to the smaller *Barbus* spp. are taken as well as the fry of *Barbus* spp., *Schilbe mystus* and *Alestes nurse*. In other rivers, such as the Sio on the boundary of Uganda and Kenya, where drift nets are difficult to operate because of the numerous swamp channels and rocks, barrier weirs with traps are built across the river. In the Sio there are several such weirs within a few miles of the river mouth consisting of a series of "maze" traps right across the river. The maze traps take the larger migrants, and basket traps inside these take *Labeo* on their upward and downward migration, and larger fry on their return to the lake.

The Uganda Fisheries Department records show that at one time the Kagera River on the border of Uganda and Tanganyika, supported a flourishing *Labeo* fishery. In recent years, however, there is certain statistical evidence and local African reports to indicate that there has been a decline in the fishery. Several fishermen in the vicinity of the river now find it more economical to use their canoes for ferry service in the flooded land surrounding the river after the heavy rains earlier in the year. An experimental fishing off the mouth of this river in 1963 produced a catch only 19 per cent of that caught off the Nzoia River a week earlier. The cause of this decline is not fully understood, but it is probable that over-fishing in the last few years has caused a reduction in the number of fry returning to the lake below the critical level required to balance the mortality caused by fishing. Fryer and Whitehead (*Rev. Zool. Bot. Afr.*, *59*, 1959) have recorded *Labeo* as running up a small stream at Bugungu near Jinja. A recent survey, however, has shown that the river is no longer used as a spawning ground and because very little *Labeo* fishing is done in Napoleon Gulf it may be that overfishing has not caused this. The recent flooding and rise in lake level after heavy rains throughout 1963 may have rendered the habitat unsuitable for breeding.

It is important that a study is made of the biology of *Labeo victorianus* in view of it being an important commercial fish, and that the major fishing effort occurs at a critical time in its life history.

In the last 12 months an experimental fishing has been carried out in Napoleon Gulf, Jinja, using a graded fleet of gill-nets of mesh size 1½ in., 2 in. and 2½ in. Further fishing has been done off the mouths of the Nzoia, Sio and Kagera Rivers as a comparison with the routine fishing. The collected material was examined for sex and condition of the gonads. The fish were also weighed and their lengths recorded to provide data for measuring the parameters of the population.

The gonad weight in relation to the body weight, i.e. the gonado/somatic ratio (g/s), is an indication of the state of maturity of the gonads. The gonad weight is expressed as a percentage of the body weight, thus the more mature the fish the greater is the gonad weight giving a higher g/s. The mean g/s was worked out for both males and females of the total monthly catches (Fig. H1). The graph for females shows that there was a slight rise in February 1963, followed by a decrease to a low level in June, the g/s then increasing to a maximum of 9.1 per cent in September. This is followed by a decrease to a lower level in December. The graph for males is similar, with a slight increase from January to March, but with a second larger peak of 2.6 per cent occurring a month later in November. The two maxima in the g/s of the Jinja population occur two months before the month of maximum rainfall of the two wet seasons, March and November respectively. The g/s of the fish caught at the Nzoia have a mean maximum g/s of 17.0 per cent for females and 3.2 per cent for males, these percentages being calculated for catches of which the majority of fish were subjectively analysed as having gonads in a running state. This maximum for

Nzoia fish occurred in November, compared with that of the Jinja population which was in decline in this month. Similarly for the Sio River population a g/s of 13.8 per cent was calculated for females and 3.5 per cent for males in November, which compares with those of the Nzoia. The g/s for the Kagera River fishing, 4.3 per cent for females and 1.6 per cent for males, are particularly low when compared with those of the Nzoia of that month. This is perhaps a reflection of the decline in the Kagera fisheries.

The synchronization of the g/s indicate that there is a gradual maturation of the gonads of the fish of the Jinja population to a certain level two months before maximum rainfall. Once this level is reached the fish migrate to such rivers as the Nzoia, so causing a decline in the g/s of the Jinja population at this time. The incrcease in the g/s of the Nzoia population either reflects the maturation of a static population, or the addition to the population from elsewhere of ripening individuals. It seems likely that the latter case is true, with individuals as from the Jinja population maturing further during migration to the river. This is borne out by the increase in the g/s of the Nzoia fish after the g/s of the Jinja population has reached a maximum, the migrating, ripening fish arriving at the Nzoia during the months of maximum rainfall when the river is in spate and conditions suitable for spawning.

Maximum numbers of *Labeo* landed at the Nzoia occur in March and April, coinciding with maximum rainfall at this time of year when there is only a slight increase in the g/s of the Jinja population. It is possible that the different populations of *Labeo* in the various localities of Lake Victoria spawn only once a year, either during the first or second rains. The majority of the Jinja population would appear to spawn during the second rains of October and November, with only a few spawning in the first rains. Length weight ratios for the fish of the Jinja populations are very similar to those of the Nzoia fish (Fig. H2). The slight difference in the angles of the log graphs for females of Fig. H2 is probably the result of the mature ovaries of the Nzoia females contributing to a slightly greater body weight per cm. length. Unfortunately no fishing was carried out at the Nzoia during the first rains of 1963, so the length/weight relationships cannot be compared to show any differences in population characteristics, if indeed these do exist between different populations.

In an attempt to determine the time and extent of migration of the Jinja population, and also to determine individual growth rates a sample (340 fish) of the catch throughout the February and March rains were tagged. In the seven months since tagging 13 per cent of the fish have been returned after being caught locally. One of the fish, however, tagged in February was caught at the Nzoia in March, having taken a maximum of 34 days to cover a minimum distance of 60 miles. Although only one fish is known to have covered this distance it is significant that it occurred when the Jinja population was at its February g/s maximum, and that it arrived on the Nzoia when the maximum number of fish migrate up-river. Owing to the close down of the Lake Victoria division of the Kenya Fisheries Department no more tags will be returned by them from the Nzoia River area. A tagging programme has been started on the fish of this area to determine the sites from which they migrate and will presumably return to. Owing to the difficulty of seining for adult fish in the open waters fish for tagging purposes are caught in the standard fleet of gill-nets. Mortality appeared to be low in spite of the very severe mauling the fish received whilst in the gill-nets, many losing scales from the shoulder region, and the shock of being pierced by a hollow needly below the dorsal fin to take the silver wire of the tag. The returns of tagged fish show that the fish lose weight for only up to 58 days after tagging, whilst other fish showed an increase in weight after only 17 days.

TABLE 2.—SUMMARY OF LOSS AND GAIN IN WEIGHT OF TAGGED FISH

| Number of days between tagging and recovery | Loss in weight | Number of days between tagging and recovery | Gain in weight |
|---|---|---|---|
| 3 | 11·3 | 17 | 2·7 |
| 12 | 9·0 | 17 | 18·4 |
| 13 | 10·0 | 22 | 4·7 |
| 14 | 30·0 | 41 | 10·2 |
| 16 | 8·5 | 52 | 6·0 |
| 17 | 2·4 | 59 | 11·6 |
| 18 | 4·7 | 85 | 49·4 |
| 19 | 3·8 | 95 | 2·0 |
| 20 | 20·3 | 108 | 25·1 |
| 24 | 7·9 | 119 | 8·6 |
| 29 | 1·8 | 120 | 23·8 |
| 32 | 0·7 | 164 | 77·9 |
| 36 | 7·4 | 209 | 70·5 |
| 44 | 10·2 | 222 | 16·3 |
| 58 | 25·4 | | |
| 161 | 4·1 | | |

A selection of gonads were removed from fish over the range of subjectively classified maturation states, i.e. from resting to running, both ovaries and testes being fixed, stained, sectioned and mounted on slides. The percentage of primary oocytes, secondary oocytes and ova present in the ovaries was determined by proportion over the total gonado/somatic range by microscopical examination. The results, Table 3, showed that ovaries weighing less than 1 gm. contain 100 per cent primary oocytes, ovaries at this stage being subjectively classified as resting. The initial increase of ovarian weight from as low as 0.2 gm. to 1 gm., when eggs first appear is due to an increase in size of primary oocytes from a diameter of 0.097 mm. to 0.169 mm. As the weight increases above 1 gm. there is an increase in the number of ova (0.50 mm.-0.85 mm. diameter) and a corresponding decrease in the number of primary oocytes. The constant low number of secondary oocytes (0.23 mm.-0.46 mm.) in the ovaries over the whole range of ovary weights is a further indication of the gradual nature of maturation of the ovaries: Table 4 shows the relationship between gonad weight, gonado/somatic ratio and a subjective classification of gonads. The decrease in percentage of ova present after a weight of 23 gm. is probably due to eggs being lost from a running ovary. The graph for g/s of females in Napoleon Gulf shows that the February increase is probably the result of an increase in size of secondary oocytes, whilst during the September maximum 30 per cent to 50 per cent of ova have developed.

An important facet of the biology of commercially important fish is the egg production and the resultant fecundity of the species. This is particularly true for *Labeo* where the extent of mortality due to fishing during the spawning migration is felt more rapidly on the population. In order to estimate fecundity of *Labeo victorianus* egg counts were made of ripe and running ovaries over the size range of sexually mature forms. Egg size is constant irrespective of weight of gonads or length of fish, and egg number is directly proportional to length of fish, Fig. H3. Mature females were found down to a length of 11.9 cm. standard length, and maximum number of eggs counted was 113,847 in a fish of 21.6 cm. standard length. The eggs are olive green in colour, becoming light brown when fully ripe. Within 30 minutes of spawning the colourless vitelline membrane extends to a diameter of 0.4-0.5 cm., surrounding the yolk in colourless fluid.

TABLE 3.—MEAN PERCENTAGE EGG STAGES PRESENT IN OVARIES OF VARYING WEIGHT

| Mean ovary weight to the nearest gm. below | Primary oocytes | Secondary oocytes | Ova |
|---|---|---|---|
| >1 | 100% | | |
| 1 | 93 | 3% | 4% |
| 2 | 84 | 11 | 5 |
| 3 | 80 | 3 | 17 |
| 4 | 76 | 2 | 22 |
| 5 | 62 | 1 | 37 |
| 6 | 75 | 3 | 22 |
| 8 | 65 | 1 | 34 |
| 10 | 62 | 1 | 37 |
| 13 | 49 | 2 | 49 |
| 14 | 56 | 7 | 37 |
| 15 | 40 | | 60 |
| 16 | 55 | 2 | 43 |
| 17 | 41 | 1 | 58 |
| 18 | 41 | 1 | 58 |
| 19 | 54 | 5 | 41 |
| 23 | 5 | | 95 |
| 24 | 24 | | 76 |
| 27 | 13 | | 87 |
| 28 | 44 | 2 | 54 |
| 32 | 50 | 6 | 44 |
| 34 | 28 | | 72 |

TABLE 4.—SUBJECTIVE CLASSIFICATION OF MATURATION OF GONADS OF MALES AND FEMALES HAVING VARYING GONAD WEIGHTS AND GONADO/SOMATIC RATIOS

| Condition | Males | | Females | |
|---|---|---|---|---|
| | Testis Weight | G/S | Ovary Weight | G/S |
| Resting .. .. | >1·2 gms. | >0·9% | >2·0 gms. | >1·2% |
| Ripening.. .. | 0·4–4·1 gms. | 0·6–1·6% | 1·7–19·2 gms. | 1·5–7·9% |
| Ripe .. .. | 1·3–4·4 gms. | 1·1–2·5% | 5·4–25·3 gms. | 3·0–18·7% |
| Running .. .. | <1·1 gms. | <1·4% | <7·5 gms. | <5·3% |

The eggs are semi-buoyant and there is no adhesive disc as reported for *Clarias* sp. The time of fertilization in relation to spawning is unknown. Attempts at artificial fertilization have as yet been unsuccessful the eggs decomposing after a few days in the laboatory. Since eggs have been kept in good condition for up to a month in live boxes in the field, it appears that the time of fertilization and the factors responsible for development are critical. Fryer and Whitehead (op. cit.) record *Labeo* as spawning in flood-water pools and their channels adjacent to the river, and amongst inundated grasses at the margins of smaller, less permanent streams. *Barbus* species have similar eggs with no adhesive disc, but with less buoyancy, and have been recorded as spawning in similar habitats. The egg production of *Labeo* is extremely high per cm. body length when compared with these species, e.g. *Barbus kersteni* (standard length 6 cm.) 1,137, *B. apleurogramma* (S.L. 4.6 cm.) 755, *B. paludinosus* (S.L. 9.3 cm.) 4,900. It follows in comparison with the *Barbus* spp. and the Cichlids and Mormyrids where egg production is very low, that the high egg production of *Labeo* is a reflection on the hazardous nature of the spawning environment and its life history up to the time of sexual maturity.

Attempts were made to determine the age of individual fish by scale and opercular bone readings. Although rings could be determined on the scales of some individuals it was impossible to determine the age of the fish by back calculation from the actual length of the fish. The range of *Labeo* opercular bones, however, when back calculated appeared to have been formed at 1.1 cm. to 1.4 cm. intervals. The length of opercular bones and scales were directly proportional to body length in fish of all sizes. There is evidence, however, that the first ring to appear on the opercular bones of many individuals when back-calculated to a mean length of 9.3 cm. was formed at the end of the first year's growth.

The age-length relationships may be worked out by incorporating field data such as the appearance of fry in relation to the breeding season and length class frequencies of the fish caught in the experimental fishing. The following data when plotted gives a reasonable account of growth (Fig. H4):—

1. Fryer and Whitehead (op. cit.) describe fry as attaining a length of 0.9 cm. after 37 days.

2. On the 19th August 1963, fry of a mean length of 3.7 cm. were recovered from the scoop traps in the Nzoia River.

3. Seventeen days later fry of a mean length of 4.1 cm. appeared in the traps.

It is probable, in view of the Fryer and Whitehead data, that the fry recovered in August and September were hatched from eggs spawned in the March rains. If the end of March is taken as the time these eggs were spawned then the August fry were 142 days old and the September fry 159 days.

4. On 3rd November 1963, *Labeo* were seined off a beach near Jinja; the maximum size of fish caught was 10.1 cm., which is smaller than the minimum size caught in 1½ in. nets. The mean size of the seined catch was 9.1 cm. which fits in the graph extrapolated from the other three points at 349 days, i.e. one year old. From the gonado/somatic data it is probable that the Jinja population spawns in October and November so that the fish of the seined sample were returning to the Jinja population after hatching in the second rains of 1962.

The minimum size of sexually mature fish was 11.9 cm., indicating that the fish mature after the first year. When mean lengths are plotted against mean weights the results show that at about 20.0 cm. the body weight increases in relation to body lengths. This is better observed when the logs of weight and length are plotted where the angle of the straight line changes at about 20.0 cm. standard length, particularly in females, Fig. H2. It is difficult to explain why this increase in weight occurs but it is probable that it occurs after the end of the second year in the third year of growth.

Table 5 gives the mean weights and lengths of males and females caught in the fleet of gill-nets. The sex ratio of males to females varies from 0.95:1 in the 1½ in. nets to 1 : 3.2 in the 2½ in. nets. The sex ratio of the total catch was the same as in the 2 in. nets. The mean weights and lengths of the males and females caught in the 1½ in. nets and 2 in. nets are very similar, but in the 2½ in. nets the mean weights and lengths of the females were higher than those of the males. The difference in the 2½ in. nets is probably the result of the change in type of growth of the females after 20.0 cm. when the weight increases in relation to body length (Fig. H2). Fig. H5 shows that the size range of fish caught increases with the size of the gill-net with a corresponding decrease in the percentage of the length class most frequently caught.

TABLE 5.—LENGTH/WEIGHT DATA OF TOTAL CATCH IN GILL-NETS

| Mesh sizes | Males | | Females | | Ratio of Males to Females |
|---|---|---|---|---|---|
| | Mean length | Mean weight | Mean length | Mean weight | |
| 1½ in. .. | 15·5 cm. | 70·3 gm. | 15·1 cm. | 63·6 gm. | 0·95:1 |
| 2 in. .. | 18·3 cm. | 118·0 gm. | 18·6 cm. | 119·8 gm. | 1:1·2 |
| 2½ in. .. | 21·0 cm. | 198·7 gm. | 22·4 cm. | 249·5 gm. | 1:3·2 |
| 3 in. .. | | | 24·1 cm. | 292·5 gm. | 0:8 |

The percentage frequencies of size class of males and females caught in 1½ in. nets are similar, but the size range of males caught in the 2 in. nets is smaller than that of the females. The percentage of the most favoured size class is higher for males than females in the 2 in. nets, whilst the 2½ in. nets favour a smaller size range of males than females.

Although *Labeo* is frequently caught in 3 in. commercial nets they have only been caught once in several settings of 3 in. nets during the present survey. Two lengths of bottom-set 3 in. nets laid near Ramafuta Island in the Buvuma Channel on one occasion caught eight female fish of a mean weight of 292.2 gm., ranging from 249.8 gm. to 317.2 gm., and a mean length of 24.1 cm., ranging from 23.2 cm. to 24.9 cm.

The largest fish recorded in the present survey was a female caught in a 2½ in. net, weighing 401.8 gm. and 26.5 cm. standard length. Graham in his 1927/28 survey of the fisheries of Lake Victoria recorded an individual of 40.0-41.0 cm. long (probably overall length) caught in a 5 in. net.

The length class frequencies of total fish caught in the gill-nets, Fig. H5 shows that the majority of males and females caught in the 1½ in. nets were between 14.2 cm. and 16.5 cm. long, in the 2 in. nets between 16.6 cm. and 18.9 cm., and 21.4 cm., indicate that the results of the experimental fishing with the present graded fleet of gill-nets will be of little value in determining the age structure of the population.

The part of the *Labeo* population between sexual maturity, at approximately 11.0 cm. to 12.0 cm. attained at the end of the first year's growth, and 14.1 cm. caught in the 1½ in. nets is very low as shown by the length class frequencies of fish caught in the gill-nets. Further, the major fishing effort occurs with 2 in. and 2½ in. nets where most fish caught are greater than 16.5 cm. which includes fish in their second and third year's growth. Therefore, in spite of heavy fishing, it is probable that the population can be maintained at a level indicated by the landings from 1960-62 for the Nzoia by sexually mature first year fish of a length shorter than is selected for by the 1½ in. net. If the heavy fishing continues, however, the commercial fisheries will decline. There is evidence that the recent decline in the *Labeo* fishery at the Kagera is the result of improved fishing techniques, particularly the drifting gill-net method. The following landings for the Nzoia River area (Port Victoria), given in number of fish caught per annum, indicate that a similar thing is happening there:—

1959: 157,510. 1960: 18,440. 1961: 4,822. 1962: 16,062

If the level of fishing remains the same in future the unfished first year spawning population will contribute constant numbers to the river fishery based on 2 in. and 2½ in. nets, dependent to a certain extent on annual changes in the suitablity of the spawning habitat. From the commercial fisheries point of view this rate of recruitment will probably prove economically unsatisfactory, as has occurred at the Kagera. It would be impossible to increase the stock by net restriction as the commonly used 2 in. and 2½ in. nets are the only ones capable of catching *Labeo*, the maximum selection of both nets being at a size range of fish which is attained before or at the end of the second year's growth, when the second spawning occurs. Comparison of age/length and length/weight relationships shows there to be no decrease in growth in the third year, so that the very low numbers caught in 3 in. nets is probably due to natural mortality as well as fishing mortality. The percentage natural mortality has not been determined, but it is probable from the low catches in the 3 in. nets that it would be sufficient to outweigh any advantages to the stock of restricting fishing to 3 in. nets. Any practical attempts at increasing the stock would have to be aimed at enhancing fry survival so as to increase the first year spawning population, and the solution to this problem may well be found by seeking to manage the river rather than the lake fishery for *Labeo victorianus*.

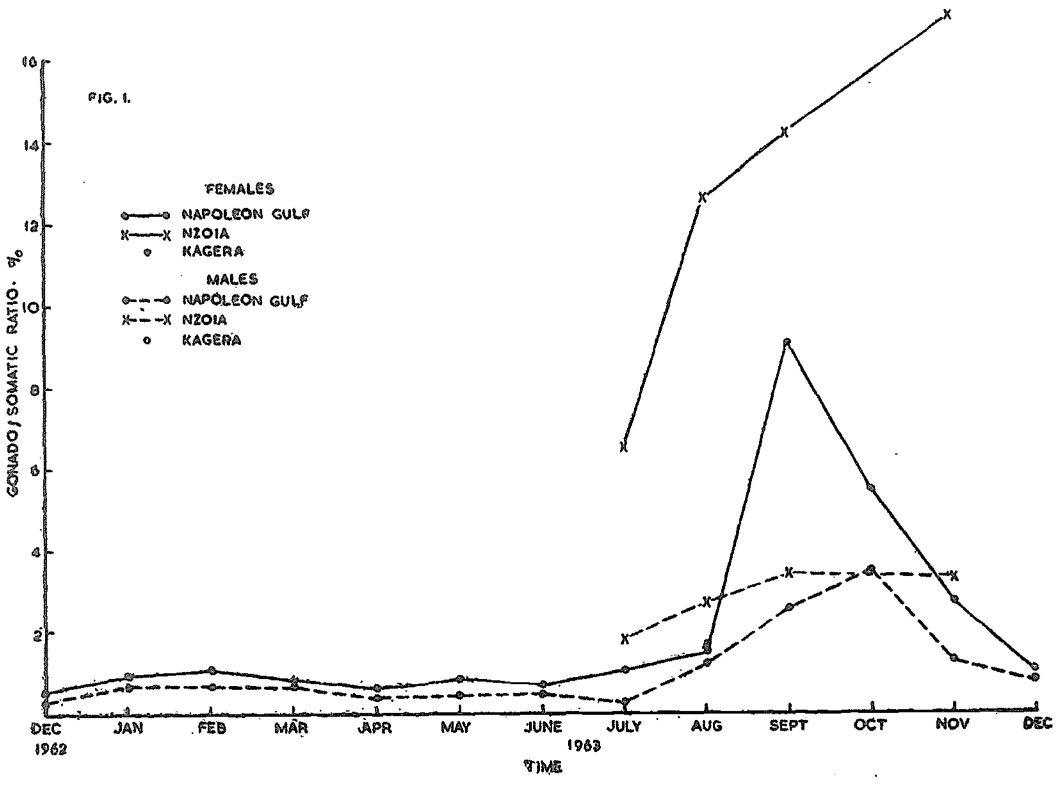


**Fig. H1—Monthly variation in Gonado/Somatic ratio of populations of *Labeo victorianus***

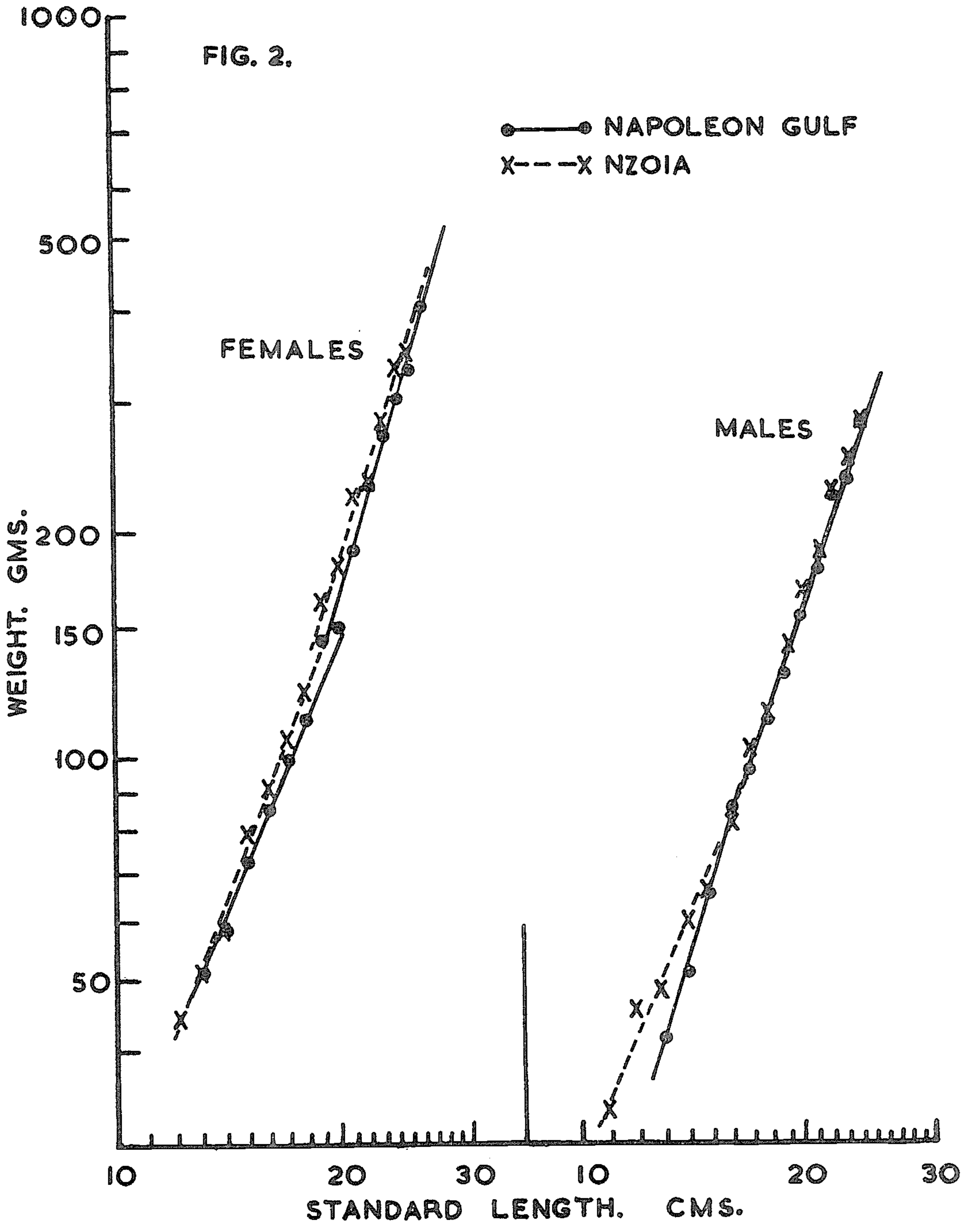


Fig. H2—Mean length/weight relationship of *Labeo victorianus*

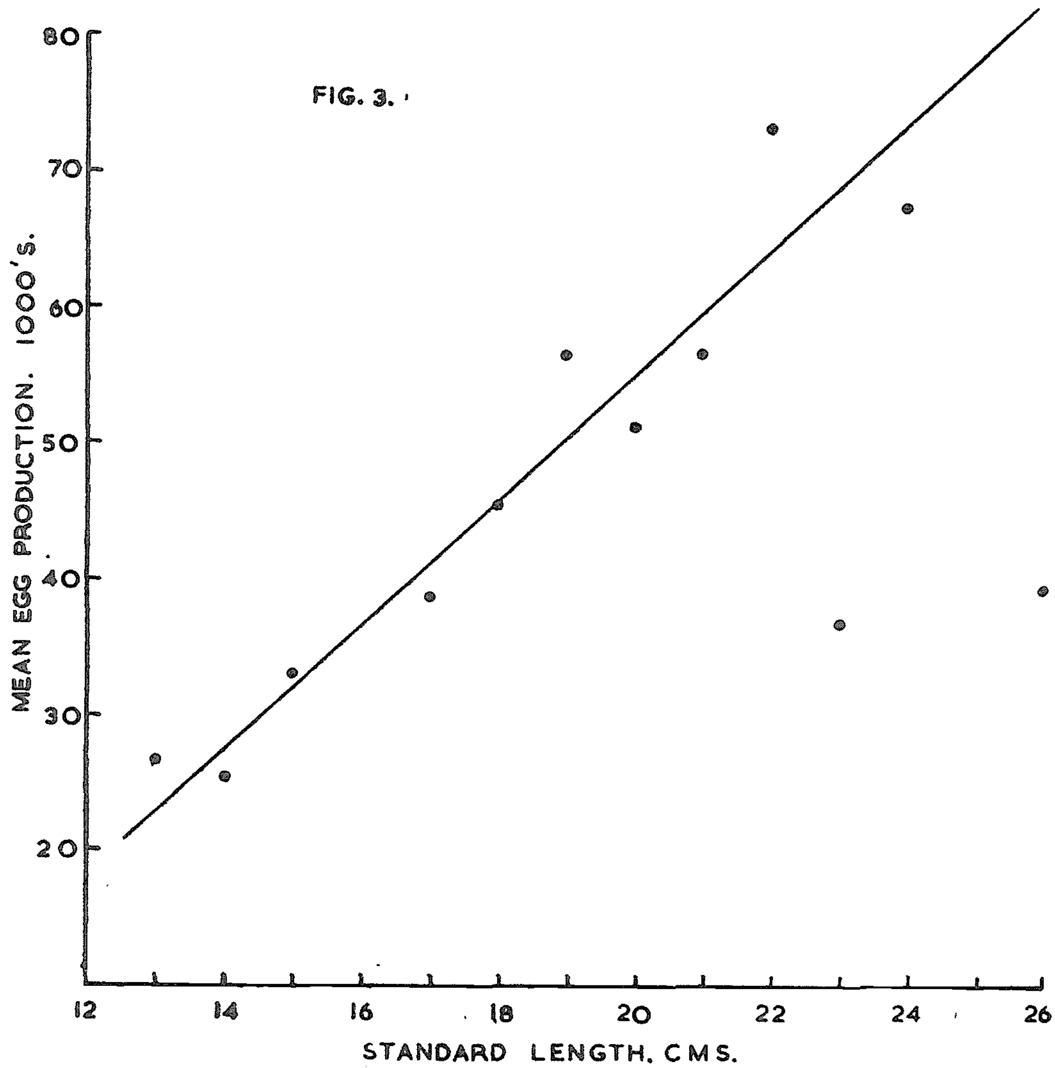


**Fig. H3—Relationship between mean number of eggs produced and standard length of** ***Labeo victorianus***

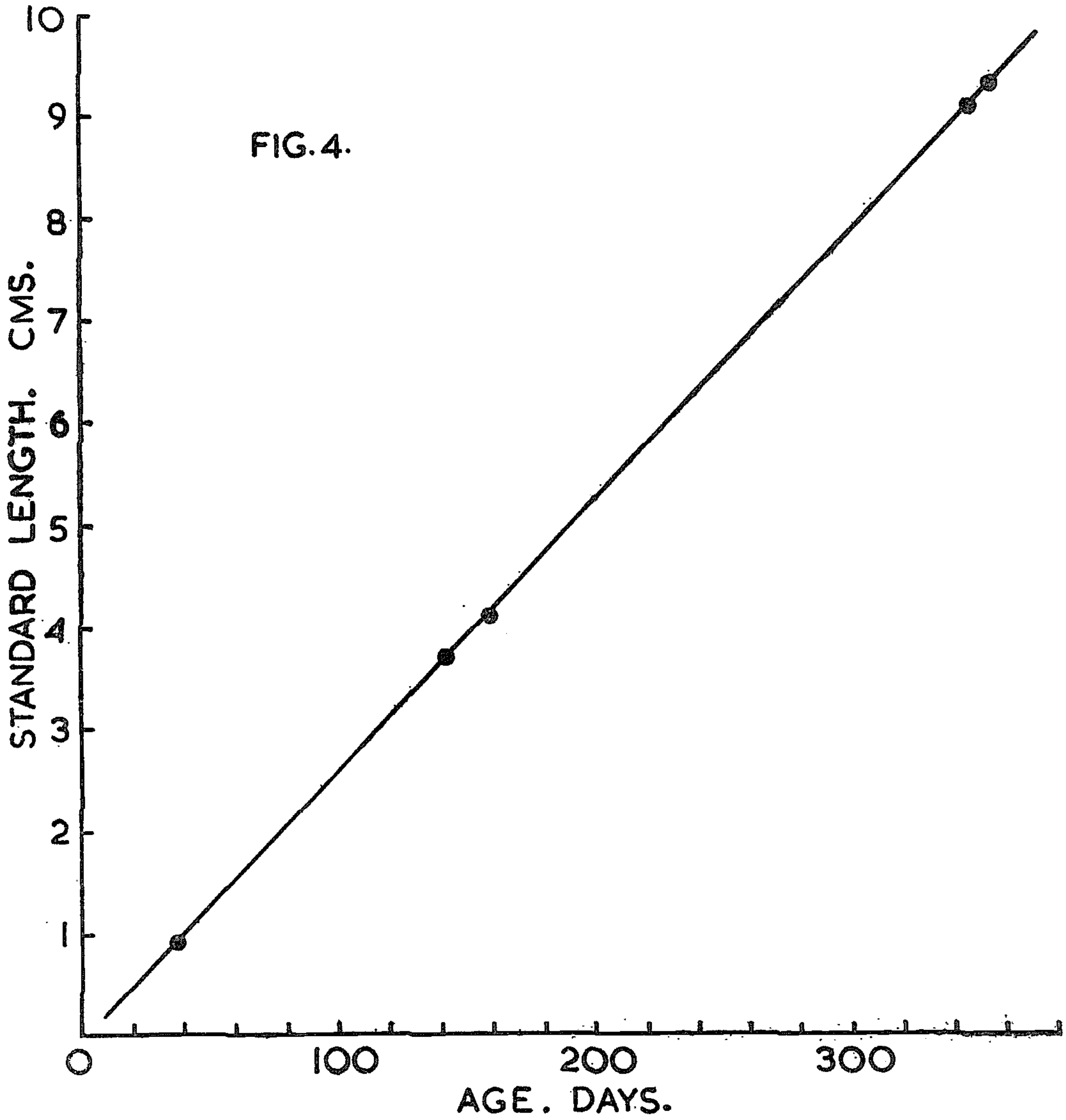


**Fig. H4—Estimated growth of** ***Labeo victorianus***

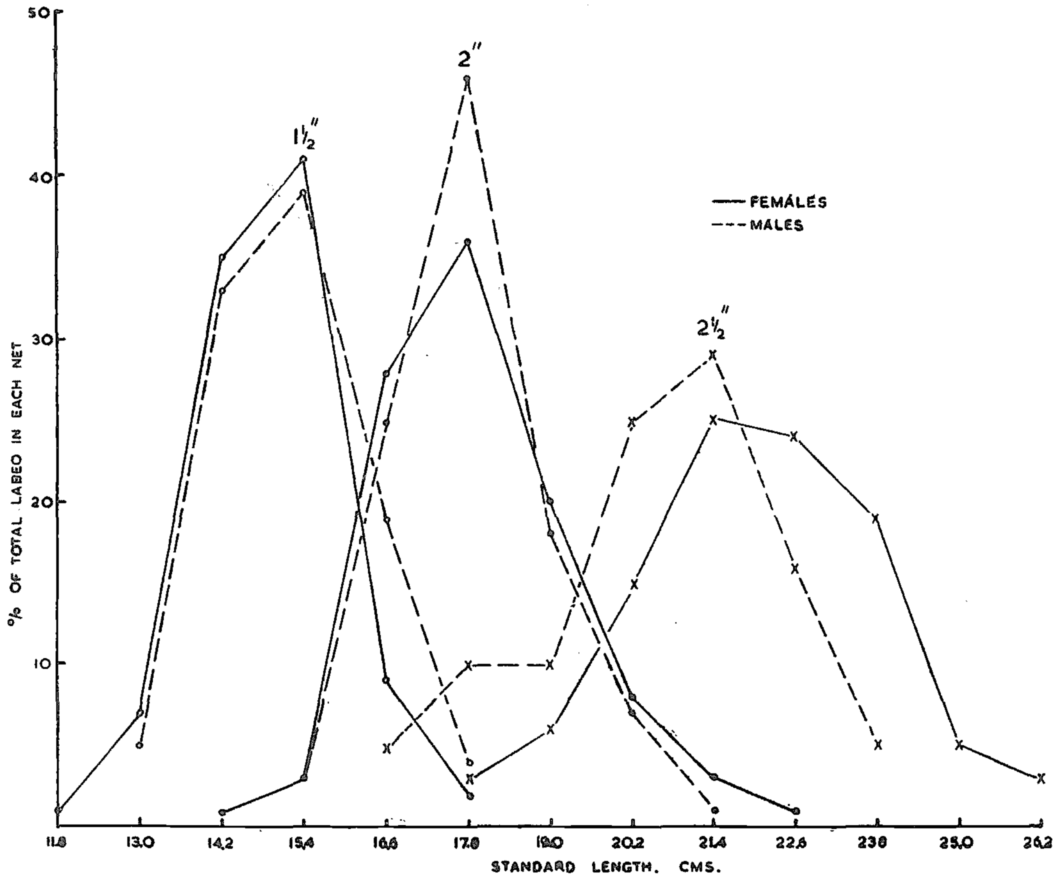


Fig. H5—Size frequency of *Labeo victorianus* caught in the three nets

*APPENDIX I*

## A—PRELIMINARY REPORT ON THE REPRODUCTIVE CYCLE IN MORMYRUS KANNUME FORSKAL

BY D. B. C. SCOTT

This one-year survey of the reproductive cycle of *Mormyrus kannume* was undertaken primarily to provide a comparison with the reproductive cycle of a temperate-zone fish (*Phoxinus phoxinus*) which the present writer has been studying during the past five years. This survey does therefore *not* pretend to be an exhaustive investigation of *M. kannume* for its own sake; its aim is to elucidate certain problems which arose during the investigation of *Phoxinus phoxinus*. Inevitably, of course, the data accumulated give some insight into the biology of *M. kannume* itself, and this information is reported here; the *comparative* aspect will be published elsewhere.

Two sampling locations were chosen, in Lake Victoria:—

(*a*) Off Lukalu Island (0° 4′ N., 33° 0′ E.), in a water depth of about 20 metres, on a bottom consisting of the rotten ironstone on which *M. kannume* is reputed to spawn (E.A.F.F.R.O. Reports).

(*b*) Off Dagusi Island (0° 10′ N., 33° 34′ E.), on a mud bottom in 17 metres of water. This is a typical Mormyrus feeding-ground (E.A.F.F.R.O. Reports).

One sample per month was taken at each station, the fish being caught by gill-netting on the bottom, for lack of a better method. The nets ranged from $2\frac{1}{2}$ in. to 5 in. mesh, set at sunset and lifted at sunrise. Bad weather prevented a sample being taken at Lukalu in July. The fish were dissected as they were removed from the net, the gonads being transferred to numbered, weighed bottles of Bouin's (aqueous) fixative. A correspondingly number metal tag was put into the coelomic cavity of the fish. On return to the laboratory, the fish were weighed and measured and the gonad weight determined by comparing the weight of the bottle plus gonad with the previous weight. From these figures was calculated the Gonadosomatic Ratio, here given by:—

$$\frac{\text{weight of gonad} \times 100}{\text{total weight of fish}}$$

All the gonads, male and female, were embedded in paraffin wax for sectioning and staining in Mallory's triple stain, for determination of the relative percentages of different oocyte and spermatocyte stages present. This histological work is still in progress, only about one-third of the gonads having so far been dealt with; it is hoped to complete it within a year.

Somewhat over 1,800 fish have been dealt with in this way, the aim being 100 fish per sample (a figure generally attained at Dagusi, but only once at Lukalu). The gonadosomatic ratios of fish under 28.5 cm. total length are not included in the figures given below, as it seems that fish smaller than this tend to be immature. The figure 28.5 cm. is at present somewhat arbitrary, but as 95 per cent of the fish caught were over this size the results are unlikely to be much affected one way or the other.

The gonadosomatic ratios were:—

| Date | ♀ $G/S^0$ | ♂ $G/S_0$ | Bottom Temp. | Number of Fish ♀ | ♂ |
|---|---|---|---|---|---|
| | | **Dagusi Island** | | | |
| Sept. 1962 .. .. | 5·63 | 0·08 | — | 4 | 1 |
| Oct. .. .. .. | 6·19 | 0·12 | 24·65 | 33 | 42 |
| Nov. .. .. .. | 5·53 | 0·08 | 24·70 | 28 | 47 |
| Dec. .. .. .. | 4·63 | 0·16 | 25·30 | 29 | 54 |
| Jan. 1963 .. .. | 2·00 | 0·16 | 25·20 | 37 | 53 |
| Feb. .. .. .. | 2·03 | 0·19 | 25·60 | 45 | 55 |
| Mar. .. .. .. | 1·16 | 0·12 | 26·00 | 49 | 47 |
| Apr. .. .. .. | 0·91 | 0·11 | 25·6 | 54 | 44 |
| May .. .. .. | 1·18 | 0·07 | 25·3 | 46 | 51 |
| June .. .. .. | 1·58 | 0·11 | 25·0 | 51 | 48 |
| July .. .. .. | 3·18 | 0·11 | 24·8 | 52 | 41 |
| Aug. .. .. .. | 4·92 | 0·16 | 24·6 | 31 | 17 |
| | | **Lukalu Island** | | | |
| Sept. 1962 .. .. | 5·15 | — | — | 10 | — |
| Oct. .. .. .. | 6·08 | 0·22 | — | 24 | — |
| Nov. .. .. .. | 6·86 | 0·27 | 24·20 | 28 | — |
| Dec. .. .. .. | 6·26 | 0·29 | 24·50 | 12 | 23 |
| Jan. 1963 .. .. | 6·28 | 0·29 | 24·60 | 28 | 41 |
| Feb. .. .. .. | 5·58 | 0·30 | 24·60 | 18 | 42 |
| Mar. .. .. .. | 3·464 | 0·28 | 25·90 | 8 | 33 |
| Apr. .. .. .. | 4·79 | 0·19 | 25·60 | 31 | 28 |
| May .. .. .. | 3·86 | 0·26 | 24·40 | 19 | 44 |
| June .. .. .. | — | — | — | — | — |
| July .. .. .. | 2·56 | 0·20 | 24·1 | 36 | 51 |
| Aug. .. .. .. | 3·54 | 0·29 | 23·6 | 22 | 16 |

The figures for *Dagusi* show the regular rhythm that might be expected in an annually-spawning fish under virtually constant environmental conditions. Ovulating specimens were rare, only two being obtained, during December and January. The main spawning appears to occur in November-December, and is followed by a period during which the gonadosomatic ratio falls, presumably as a result of resorption of unspawned eggs and perhaps some earlier oocyte stages. This will require histological verification. There is no real "resting" period, as the gonadosomatic ratio, having reached a minimum in April, immediately begins to rise again.

*Lukalu* gives a far less regular picture. It seems likely that this is a reflection of waves of immigrant fish in spawning condition from (presumably) feeding-grounds like those at Dagusi. The spawning period is thus very protracted, though with a definite maximum at the end of the year. Ovulating specimens were common at Lukalu, from December to February. Further evidence of immigration; in both August 1963 and September 1962, catches at Dagusi were poor, though the fishing effort was as far as possible constant, suggesting emigration. The gonadosomatic ratios at Lukalu were consistently higher than on the mud bottom. It seems that when very nearly ripe, the fish move from the feeding-grounds, and the detailed figures (not shown here) suggest that each individual fish does this as it ripens, there is no mass migration. There is certainly a tremendous variation in the gonad states of different fish at the same time of the year, a state of affairs very different from the accurate synchronizing of the reproductive cycle of temperate-zone fish.

It remains only to add that the male fish show a much more erratic variation in gonadosomatic ratio than the female; this is not unusual, and may be clarified when the histological aspect is investigated.

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