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East African Freshwater Fisheries Research Organization 1960

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EAST AFRICAN FRESHWATER FISHERIES RESEARCH ORGANIZATION

ANNUAL REPORT

1960

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EAST AFRICAN FRESHWATER FISHERIES RESEARCH ORGANIZATION

ANNUAL REPORT, 1960

STAFF

Director:
V. D. van Someren, M.B.E., B.Sc., Ph.D.

Research Officers:
D. J. Garrod, B.Sc. — H. Y. Elder, B.Sc.
E. L. Hamblyn, B.Sc. — C. C. Cridland, Dip. Ferm.

Senior Field Officers:
J. D. Roberts — *Vacant*

Secretary (Part-time)
Mrs. E. D. Kemp

Accounting Assistant:
L. F. D'Costa

Senior Artizan:
Pragji Dossa Mesvania

General

The staff list above shows the position at the close of the year. There have been a number of changes during the year; the former Director, Mr. R. S. A. Beauchamp, resigned in May and was replaced in mid-September by Dr. van Someren, the latter having formerly been Senior Research Officer (Fish) in the Kenya Ministry of Tourism, Game, Forest, and Fisheries. Dr. G. Fryer resigned also in May on accepting appointment with the Freshwater Biological Association Laboratory at Windermere in England, and his vacancy has been filled by the promotion of Mr. C. C. Cridland who has been in long service with this Organization since its inception in 1947, as Senior Field Officer.

There is one vacant post for a fifth Research Officer, which is not yet filled, being dependent on the raising of a special C.D.&W. grant. The vacancy in the Senior Field Officer post is not yet filled.

Mrs. E. Cartmell resigned in May as Secretary after several years service, the post being filled temporarily by Mrs. A. Docherty until she was succeeded by Mrs. E. D. Kemp in October, who is now employed on a part time basis. To those who have left us, we extend all good wishes for their future.

Mr. J. D. Roberts was on U.K. leave from May to October.

The larger launch has continued to give trouble free service throughout the year, running some 4,000 miles on duty. Towards the end of the year it was slipped for ten days overhaul and repair of some minor damage caused by vibration above the P-brackets; it is now on full duty once more and is in excellent condition. The small launch was slipped for overhaul in the early part of the year, and has been in continuous service without trouble, covering 4,300 miles on duty. Later in the New Year this launch will be transferred to Lake Albert for the Nile Perch investigation.

Negotiations are still proceeding for a much larger vessel to be commissioned for long-range work on Lake Victoria, and it is hoped that this will be in service by late 1961. It is not always realised how intricate are the technical problems involved in the design of a large sea-going vessel of the size proposed (55′), especially in view of its specialist functions as a research vessel as well as fishing craft, and the responsibilities devolving on the Senior Field Officer, Mr. Roberts, are in this respect considerable. Much reorganization of pier and slipping facilities will be necessary to accommodate this new vessel, and is under consideration at the moment.

The laboratory and aquarium, eight staff houses, stores, African quarters and workshop are in reasonable condition, but there is now no doubt that after fourteen years, major structural renovations are required in the laboratory and aquarium in particular, and application has been made for funds for this.

Owing to a marked deterioration in social conditions in Jinja in the latter half of the year, resulting in nine burglaries in six weeks, a great deal of expense has been necessary in securing staff houses against such breaking in when officers are on duty elsewhere.

The Library, which is maintained by part-time work by one of the Research Officers and the Secretary, continues to expand with the international reputation now enjoyed by this Organization and is now fully classified and maintained in working condition. Accessions during the year totalled 12 reference works and several hundred reprints, in addition to about 20 regular periodicals.

The former Director attended the January meeting of the E.A. Agricultural and Fisheries Research Council, the new Director the meeting in October, in addition to the annual Research Co-ordinating Committee meeting held this year in Zanzibar.

Visits were made by various members of the staff in connection with their work, to Lake Rudolf, Lake Albert, Bukoba, Kisumu, Lake Naivasha and the Inland Fishery Research Station at Sagana in Kenya, and the Director made a journey through Tanganyika in December in order to see something at first hand of Tanganyika inland fisheries. This visit culminated in a meeting with Tanganyika Government officials in Dar-es-Salaam to discuss the future of fishery policy and development work in the Tanganyika waters of Lake Victoria and elsewhere in that territory. We are gratefully indebted to the officers of the Uganda Game and Fisheries Department, the Kenya Fishery Division, and the Tanganyika Department of Agriculture whose helpful co-operation made these visits possible.

Mr. J. D. Roberts also attended part of the Research Co-ordinating Committee meeting in Zanzibar and then, together with the Director, returned via Mombasa to discuss the construction of the new vessel with the African Marine and General Engineering Co., who have been invited to produce estimates.

Mr. D. J. Garrod, who was Acting Director from May to September, attended the 3rd CCTA/CSA Symposium on the problems of major lakes at Lusaka in August. Dr. C. F. Hickling, Colonial Fishery Adviser, paid a brief visit to the Laboratory in July.

During the year we were pleased to welcome to the Laboratory three visiting scientists: Dr. John Evans of the Royal Holloway College, London, working on algology for six months, and Dr. and Mrs. J. F. Talling of the Freshwater Biological Association, who arrived in July and are staying for a whole year working on algology and basic hydrological problems. These are aspects of freshwater research in East Africa which have barely been touched during the last few years owing to staff limitations, and yet are fundamental to all other work carried out by this Organization.

We have also been pleased to offer facilities to a party of visiting American scientists for short periods in the latter part of the year: Associate Professor D. Livingstone, Mr. J. Richardson and Mr. R. Kendall of Duke University, who have been engaged on the very interesting work of raising cores for analysis from the sediments under Lake Victoria and elsewhere in East and Central Africa.

The title of this Organization has now been amended to be "The East African Freshwater Fisheries Research Organization" in order to define our functions more clearly and obviate confusion with our sister marine organization in the High Commission.

Scientific Work of the Organization

Somewhat more space has been devoted in this year's Report to reports on projects by the individual officers concerned, since it is hoped that this may make for easier reading and more detailed reference to the results of each project.

Even with the reduced staff available for most of the year, who have necessarily had to take over much of the administrative activities, boat maintenance, library and aquaria, in addition to their own research, the scientific output has been satisfactorily maintained.

As explained in the Report for 1959, the work of every Research Officer is now entirely devoted to fish of commercial importance, at the expense of more fundamental research; and this will remain so for another year before any major changes are introduced in the programme.

Fisheries of Lake Victoria

The major study of the population dynamics and effects of fluctuations in fishing effort on the *Tilapia esculenta* stocks carried on by Mr. Garrod have indicated a continued decline in yield of this most important component of the Lake Victoria fisheries in certain parts of the lake where full analysis of the records has been possible. There has been no indication of any reversal in trend since the last report was issued in 1959.

It is of particular note that this decline in inshore fishing in Uganda waters cannot be offset by gains in catches of other species, and indeed in some cases the catches of one of the most important of these, *Bagrus docmac*, have also declined.

The Kavirondo Gulf in Kenya shows a similar pattern of decline as regards *Tilapia esculenta* catches; but on balance, development of offshore fisheries in both areas has tended to maintain total yield. It cannot be expected however that such offshore fisheries can maintain this indefinitely, since they also are limited in extent.

There is room for expansion in certain parts of the Tanganyika waters however, which still remain relatively lightly exploited, though in the more heavily fished areas there has been since the beginning of the year an indication that some decline is also occurring.

By far the most serious trend now obvious is the fact that in certain areas of northern Lake Victoria, the heavy level of fishing has led beyond the stage of economic overfishing to that of biological overfishing, where the adult breeding stock left is no longer able to maintain a sufficient number of recruits. Since *Tilapia* populations appear restricted in their range of movement, no amelioration can result from the immigration of fish from less heavily fished areas. By contrast, however, these more lightly fished areas, for the same reason, will not be affected by the heavier fishing elsewhere as regards *Tilapia* stocks; but the same cannot yet be said for the apparently more homogeneous *Bagrus* and *Mormyrus* stocks.

That these trends are real and not artefacts due to inefficient recording is now plain, and the results yet again emphasise the urgent need for a rational conservation of the Lake Victoria *Tilapia* stocks; one is faced now with a fishery which is yielding far less than the potential of which it should be capable. This view has been repeatedly stressed by this Organization, and it is a matter for regret that the necessary action at least to control effort has not yet been taken.

As part of such analysis it is necessary to know the structure of a *Tilapia* population, and in this respect considerable advances have been made, dealing with the relatively limited areas of the north Buvuma waters as a sample area. Nearly three years analysis of commercial fish catches from this area have enabled the selection characteristics of the gill nets in use to be investigated, and from these the length frequency distribution and abundance of the stock has been reconstructed. By scale analysis of breeding rings, the age composition and growth rate have been calculated, and estimates of fishing and natural mortality obtained by adjustment of this data. This will then lead on to estimates of effort required to maintain sustained yields based on scientific and not empirical concepts.

The compilation of this data has now enabled, for the first time, a reconstruction to be made of the history of identifiable classes of fish since 1956, and the fluctuations of such year classes to be followed. As expected by analogy with other wild populations of fish, the recruits resulting from each breeding have varied from year to year in strength. Thus the 1957 classes have been abundant, resulting in improved catches in the first half of 1960 as their progeny entered the exploitable fishery.

Arising out of these studies, there is evidence that there has been an increased growth rate of *T. esculenta,* possibly as a result of the stock depletion, since growth is a density dependent effect. This increased growth rate however may not be advantageous, since it may mean that fish will be caught at an even earlier age than before, and thus will not have spawned as many times as their parents of equivalent size, and thus recruitment will decline still further.

It is not possible at present to subject the stocks of *T. variabilis* to the same form of analysis, since their biology differs in detail and they do not occupy the typical *T. esculenta* grounds in the northern parts of the lake.

Bagrus

Reference has already been made above to an apparent decline in *Bagrus* stocks as a result of the heavy fishing. In addition to forming a most important fraction of the total catches, *Bagrus* is also the only large predator present in Lake Victoria, and as such occupies a niche which may well be competed for by the recent accidental introduction of the Nile Perch, *Lates,* if these finally become established.

For these reasons, an investigation of this fish has been undertaken by Mr. Elder who, in spite of limited availability of *Bagrus* in northern waters, has already accumulated some significant data.

Bagrus shows a distinct preference for the deeper, more open waters overlying a coarse substratum, and hence its distribution must be limited by ecological conditions. It is possible however that the stocks are more homogeneous than those of *T. esculenta,* for example. This siluroid, interestingly enough, appears to have only a single, limited breeding season per year, probably in February and March, which may be general in all areas of the lake. The site of spawning is, however, not known, though there is a relationship both to affluent rivers and exposed, rocky shores.

The age composition of *Bagrus* stocks is unexpectedly difficult to determine, but it seems as if at least the vertebrae show evidence of periodic growth or maturation checks which may, with annual spawners such as this species, lead eventually to age and perhaps even growth analysis.

The commercial nets in use have proved only widely selective, because *Bagrus* tends not to be gill-netted in the normal fashion, but also tangled by the dorsal and pectoral spines, a feature which makes size selection analysis difficult. Tagging has been undertaken, but again the difficulty in Jinja waters is obtaining sufficiently large catches of live fish to make this worthwhile, and to date only two returns have been obtained from 50 fish marked.

Since *Bagrus* feeds very largely on the small *Haplochromis* species which have been postulated as the future main prey of *Lates,* the utilisation of such fish has become a matter for detailed aquarium experimentation as regards quantity consumable per unit time, and conversion rate. It is not, however, a fish which accommodates itself readily to aquarium life, and requires to be conditioned by a period of forced feeding before it will behave normally and take live food presented to it. Its behaviour is certainly not that of a far ranging, swift swimming predator, but is much more that of a lurker.

Breeding Studies on Tilapia

Mention has been made in previous reports of the increasing abundance of the introduced *T. zillii* in commercial catches, and although still regarded somewhat unfavourably by the fishermen, in certain areas it is nevertheless now frequently netted in numbers. Previous work by Dr. Fryer had suggested possible competition by this exotic with the indigenous *T. variabilis* on the breeding grounds of the latter, but its true ecological position is not yet known. *T. variabilis* is a mouth-brooder, *T. zillii* a guarder, and the fundamental differences in breeding behaviour are emphasised by Mr. Elder's study of the spawning behaviour of the latter in aquaria.

Of significance is the fact that even in these guarder species the larvae may be transported in the parent's mouth from place to place, suggesting a possible origin of the mouth-brooding habit. *T. zillii* is a pugnacious, almost predatory, fish under certain circumstances, and other observations by Mr. Cridland have shown that they may even destroy their own brood entirely, suggesting a possible method of direct competition with other species.

Experimental Growth Studies on Tilapia

A proper understanding of the growth potential of *Tilapia* species under various environmental conditions, including the internal condition of breeding, is of vital importance to an understanding of their biology. Mr. Cridland has already shown that with both *T. zillii* and *T. esculenta* fry, maximum growth in aquaria can be obtained on a somewhat unnatural diet of chopped worms (*Stuhlmannia* spp.), instead of the more natural algae or plants and, using this method of rearing, the spawning and growth of *T. esculenta* has been studied, in addition to the effect of temperature and light on the growth of *T. zillii* when other conditions are controlled.

The average interval between broods in *T. esculenta* in aquaria was two months, twenty eight broods being recorded from ten pairs in twenty three months. Unlike wild *T. esculenta,* the males grew faster than the females, and any loss of weight by the female after spawning can be directly related to the weight of eggs spawned, no other "brooding fast" loss of condition being observed. The temperature of the water had no effect on the number of broods.

With equivalent sized broods of *T. zillii* fry kept under varying intensities of light, but at the same temperature, there was no significant difference in growth in length and weight, or any effect on maturation, after eight months. Fish under the stronger intensities were very nervous. But when equivalent batches of fry were kept under the same low intensity of light, at temperatures varying from 18°C to 31°C, on standard feeding, there was a highly significant increase in length and weight at the higher temperatures after eight months, the increase being almost directly proportional. These results are of considerable significance to the culture of this fish in ponds.

Arising out of these studies has been the observation that even under identical conditions, growth of single brood batches of *T. zillii* fry is very variable, there being fast and slow growing fish in each batch. Since *T. zillii* is now in widespread use as a pond culture fish in East Africa, and fast growth is obviously of the greatest value in such culture, it has been an obvious step to determine whether such fast growth is genetically controlled and can be selected for as a character. To this end, batches of fast and slow growers are being line-bred by Mr. Cridland with encouraging results to date.

Such selective domestication procedures could make the biggest single contribution to fish farming practice with the *Tilapia* species, though it is of necessity a long term project, even with fast breeding fish. The technique of selective breeding and handling the fish requires considerable care.

Lake Naivasha Fisheries

In addition to their increasing abundance in Lake Victoria, *T. zillii* together with *T. nigra,* are now forming a significant part of the artificial fishery which has been created in Lake Naivasha in Kenya.

Since this fishery, which is at present remarkably productive, is completely under control through one European concern which has been granted sole experimental fishing rights for a limited period, it offers an unique opportunity to analyse fish stocks in relation to fishing pressure in a circumscribed, almost homogeneous area.

It is of further interest insofar that the original stocking of *T. zillii* must have been impure, containing *T. leucosticta* as well. Thus the fishery there is built up of three distinct species of *Tilapia,* as well as possible hybrids between two of the species, a circumstance which lends some piquancy to the investigation. This fishery is being studied by Mr. Elder and Mr. Garrod, and the results can be expected to be of considerable significance as regards population analysis, fishery management procedures and the value of cross-bred stocks, in addition to a practical demonstration of gear selectivity theories.

Nile Perch Studies

Although there is still much to be discovered concerning Lake Victoria, it has always been realised that the function of this Organization includes the study of freshwaters elsewhere in East Africa. During the past few years there has been an increasing insistence that Nile Perch (*Lates*) should be investigated as a possible predator to be introduced into Lake Victoria, with the intention that they should be able to utilise the large shoals of hitherto relatively uneconomic *Haplochromis*. For this reason Mr. Hamblyn has been engaged on a study of the Nile Perch for the past year, mainly in their natural habitat of Lake Albert.

These fish in Lake Albert form a most important part of the commercial fisheries on that Lake, and are therefore worthy of investigation from that aspect alone. At the risk of being tedious, it must again be emphasised that the results of this investigation can in no event give a definite answer to the question of the suitability or otherwise of the introduction of this predator into Lake Victoria, since the ecological conditions of Victoria and Albert are very different : nevertheless it will make available a great deal of information on the biology of this fish, knowledge which will be useful for its own sake.

This knowledge now becomes the more urgent to obtain, since during the year it became apparent that Nile Perch had already gained access to Lake Victoria by some means. Up to December, 1960, eight have been caught by commercial fishermen, fishing with standard nets. The last of these weighed nearly three pounds, and was landed as far away from Jinja as the north Buvuma channel; the remainder have been in the vicinity of Jinja itself above the Owen Falls dam. There is therefore no doubt that there is the nucleus of a breeding population in the lake.

The carrying out of this investigation so far has strained our already slender financial resources to the limit, though some financial relief will be possible in 1961, but to date worthwhile results have been obtained in spite of this limitation.

A great deal of information has thus been collected on the distribution of the young stages of Nile Perch in Lake Albert, the distribution and sex ratios of the adult population, size at first maturity, also food preferences and predation habits. The latter are of particular interest, and show to what an extent certain types of prey behaviour act as almost mechanical releasers for the actual act of predation by a Perch, in a fashion somewhat similar to that known, for example, from studies of predatory birds of certain kinds. In this respect Perch differ from *Bagrus* to a marked degree.

Many of the biological features shown by *Lates* in Lake Albert are also evident in the related *Lates* in Lake Rudolf; but both the major aspects of breeding behaviour and growth are still conjectural.

In spite of their powerful appearance and habits, *Lates* are in fact extraordinarily difficult and delicate fish to handle when alive in captivity, and in order to obtain live specimens for experimental observation at both Jinja and Sagana (where they can be studied in ponds without fear of escapes doing any material damage to natural fisheries), it has been necessary to devise special techniques which are described by Mr. Hamblyn.

Invertebrate Studies

Incidental to his main work on *T. variabilis,* which has already been described elsewhere, Dr. Fryer, while he was stationed at Jinja, was able to complete some outstandingly interesting studies before he left. He has appended to this report some short notes on his observations on the crustacean parasites of fish, the feeding mechanism of the Victoria prawns, and the unique method of development of the Mutelid mussel whose larval stage is carried on the large *Barbus altianalis radcliffi* in the Nile at Jinja.

The biology of tropical freshwaters abounds in such features of great zoological interest, and it is refreshing to note what can be achieved in the way of such research when the pressure of purely economic investigation can be temporarily eased.

Algology and Hydrology

Fundamental to all studies of the fish themselves in tropical waters is the study of the basic productivity of the waters in which the fish live, and the factors which may cause such productivity to vary annually or seasonally. Where the fish converters of such plant production are primary herbivores like the *Tilapia* species, such studies have an immediate practical significance.

Previous work by Dr. Fish, formerly of this Laboratory, on the hydrological features of Lake Victoria has been extended and considerably modified by Mr. Newell, who worked here in 1957, and whose results are now available. These have shown that the uninodal seiche effect previously postulated by Fish as occurring in a double stratification of lake waters from September to April is probably an effect of wind only, and that in fact Lake Victoria appears to be triply stratified the whole year, the lowest layer being derived from affluent rivers. True seiche effects are absent.

Further algological studies by Dr. Evans who worked here for six months during the year have in part confirmed Fish's previous results, and extended the observations on the vertical and horizontal distribution of algal plankton. By means of an ingenious phytoplankton multi-sampling apparatus the drift of these algae has been measured, to demonstrate the existence of currents too slow to be detected by other measurements, but probably of significance in the distribution and movement of phytoplankton feeders such as *T. esculenta.*

The removal from natural waters each year of a very large tonnage of primary herbivores, as occurs in Victoria, might be expected to produce long term changes in the total productivity of that water, and there is just a hint of such a change in a decreased desmid flora; but the effect of fishing on water, as opposed to the effect on fish stocks themselves, is an aspect of commercial exploitation as yet barely touched upon.

That *T. esculenta* is able to digest only the diatom fraction of its food intake is now apparently not so rigidly believed, and Dr. Evans has found evidence of utilisation of certain blue-greens in the diet as well. Moreover, his culture work has shown that shortage of sulphates is not the limiting factor for all algae in Lake Victoria as had been suggested previously; as elsewhere, phosphates are of great importance.

Dr. Talling's work has dealt principally with the basic features of algal productivity in Lake Victoria, supplemented from time to time with observations on other lakes. The main emphasis has been on the influence of tropical conditions on such productivity for comparison with the regimen known in the seasonal temperate climes. Evidence has been obtained that the maximum rates of photosynthesis per unit quantity of algae are appreciably higher than those recorded from temperate waters. Sensitive measurements of dissolved oxygen and nutrient salts such as nitrate, phosphate and silicates have yielded evidence on the significance of the small thermal discontinuities in the general circulation of lake water. When this work has been completed for a full annual cycle, it can be expected to throw considerable light on the more unique aspects of tropical hydrobiology, and in the long run give a clearer understanding of the problems peculiar to tropical fisheries.

The pre-history of Lake Victoria is written in its own deposits, and the American scientific team who have been working here have, in spite of the technical difficulties with their light Kullenberg sampler, succeeded in raising a number of cores, up to eight metres in length, from Napoleon Gulf, the deep water near Ziro Island, and in the vicinity of the Sesse Islands. These cores will later be analysed chemically, and for pollen and other microfossils, as part of a study of East African lake development and vegetational history during the late Pleistocene times: the stratigraphic history of Lake Victoria is of particular interest because it may contain information about the evolution of the species flock of endemic fishes.

Conclusion

It is now clear from the *Tilapia* studies alone, that when research has shown the way to a rational exploitation of natural resources, the application of rational methods advocated lies outside the sphere of research activity as such, which can only be advisory in its results.

When such advice is available, and future guidance is no longer sought, the effort must then be free to move on to other more productive fields of work, without being called upon further to investigate the results of irrational activity based on expediency or empiricism only instead of the scientific guidance first given.

PUBLICATIONS

The following is a list of publications appearing during the year and 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 1959.

119. GREENWOOD, P. H. — A revision of the Lake Victoria *Haplochromis* species (Pisces Cichlidae), Part IV. *Bull. Brit. Mus. (Nat. Hist.) Zool.* **6:** 4, (1960).

120. GARROD, D. J. — The Fisheries of Lake Victoria, 1954-1959. *E.A. agric. for. J.* **26:** 1 (1960).

121. TJÖNNELAND, A. — The Flight Activity of Mayflies as Expressed in some East African species. *Arbok for Universitet I. Bergen.* Mat. Naturv. Ser. **1:** (1960)

122. CORBET, P. S. — Breeding Sites of non-Cichlid Fishes in Lake Victoria. *Nature.* **187:** 4737, 616 – 617 (1960)

123. FRYER, G. — The Feeding Mechanism of Some Atyid Prawns of the Genus *Caridina.* *Trans. Roy. Soc. Edin.* **64:** 10, 217 – 244, (1959–60)

124. NEWELL, B. S. — The Hydrology of Lake Victoria. *Hydrobiologia* **15:** 4, 363 – 383 (1960)

125. ILES, R. B. — External Sexual Differences and their Significance in *Mormyrus kannume* Forskal. 1775. *Nature* **188:** 4749, 516 (1960)

126. FRYER, G. — Evolution of Fishes in Lake Nyasa. *Evolution.* **14:** 3, 396 – 400 (1960)

127. CRIDLAND, C. C. — The Reproduction of *Tilapia esculenta* under Artificial Conditions. *Hydrobiologia* (in press)

128. VAN SOMEREN, V. D. & WHITEHEAD P. J. — The Culture of *Tilapia nigra* (Günther) in ponds. Pt. IV. The seasonal growth of male *T. nigra* *E.A. agric. for. J.* **26:** 2, 79 – 86 (1960)

129. RZOSKA, J. — Notes on the Crustacean Plankton of Lake Victoria. *Proc. Linn. Soc.* **168:**, 116 – 125 (1957)

130. GARROD, D. J. — The Selectivity of Nylon Gill-nets for *Tilapia esculenta,* Graham. *J. Conseil.* **26:** 2 (1961)

131. FRYER, G. Some controversial aspects of speciation of African cichlid fishes. *Proc. Zool. Soc. Lond.* **135:** 4, 569 – 578 (1960)

Publications based on Material Collected by E.A.F.F.R.O.

132. BAKER, J. R. Trypanosomes and Dactylosomes from the blood of fresh-water fish in East Africa. *Parasitol.* **50,** 515 – 526 (1960)

APPENDIX A

FISH POPULATION STUDIES ON LAKE VICTORIA

by D. J. Garrod

1. *The Commercial Fisheries of Lake Victoria*

The detailed analysis of the commercial fishing records collected by the Lake Victoria Fisheries Service has been continued and is complete until June 1960, when these duties were taken over by the territorial Governments. More recent data are not yet available because it has been found most convenient to process the information in six monthly units.

This work has been maintained for a number of years now and is primarily an analysis of the total catch and abundance of commercially important species in selected areas, in relation to the fishing effort. More attention has been paid to the large mesh gill net fisheries than to the fisheries based on migratory species, e.g. *Labeo victorianus,* since there have been few indications that the yield from the latter in northern waters has fallen off during recent years, whereas there is no doubt that in some areas of the lake the 4″—5″ gill net fishery is now less productive than it was three years ago.

At June, 1960 there had been no indications of a reversal of the trends in fishing outlined in a report mimeographed in 1959. At all the major landings in Uganda the catch per net either remained steady or continued to decline. At Masese there is some indication that the fishery is stabilising, i.e. the rate of decline in the catch per net is less than in recent years. At other stations in Uganda continued low profit margins earned by fishermen operating on the inshore waters has caused further migration to offshore fisheries despite the inherent operating and marketing difficulties of the new fishing grounds.

The decline of inshore fishing in Uganda waters can be attributed to the failure of *Tilapia* species, *T. esculenta* in particular. The loss caused by the decline in these species has not been, and never will be, offset by gains in catches of non-cichlid species and in some areas the catches of the most important of these, *Bagrus,* have also declined.

Records from within the Kavirondo Gulf in Kenya waters show a strikingly similar pattern to those from Uganda stations. This is particularly serious for Kenya since the Gulf fisheries are almost entirely dependent upon *T. esculenta.* There has recently been a very slight recovery of the catch per net in the Kavirondo Gulf but for reasons given below, unless fishing effort decreases, this may not long be maintained.

The fisheries on the open lake at stations outside the Kavirondo Gulf may be compared to the offshore fisheries in Uganda waters. There has been a continued gradual expansion of fishing with increasing total fish yields of mixed species catches with only a very slight decline in the catch per net.

In both Kenya and Uganda the inshore fisheries have become seriously depleted to a stage where economic overfishing has occurred, causing fishermen to move elsewhere. *T. esculenta* has also been biologically overfished in certain areas—the present adult breeding stock is not able to produce the number of recruits (i.e. juveniles) that were available in 1956/57.

In Tanganyika waters certain areas have been fished sufficiently hard to cause a decline in the catch per net and the consequent emigration of fishermen, but the movement of fishermen has occurred much earlier than in the other territories, i.e. before the catch per net dropped to a similar low level. In many areas of Tanganyika waters 5″ gill nets are still widely used and give catches comparable to or better than 4½″ nets, again indicating that these populations are relatively lightly exploited and there is room for further expansion.

The available evidence shows that *Tilapia* populations which support the inshore fisheries are restricted in their range of movements so that heavy fishing of these species in Uganda and Kenya will not influence the level of catches in Tanganyika. However the offshore movement of fishermen in Kenya and Uganda to exploit *Bagrus* may have more far-reaching effects.

The offshore fishing is good only in the vicinity of reefs and islands and it may be that these stocks will be be depleted in the same way that has been seen for inshore fisheries. In the open lake there is a very much greater possibility that the *Bagrus* and *Mormyrus* stocks of Lake Victoria are homogeneous as opposed to isolated populations seen for *T. esculenta.* This means that the fishing on the northern shores may draw upon the fish stocks of the whole Lake and though depletion, if it occurs, will be less rapid, the fishing in Uganda may well influence the catches of fishermen in Tanganyika waters in the future.

It is clear that with the present movement of fishermen the need for inter-territorial cooperation in management policy is becoming more urgent and the need for long range research to determine the homogeneity of fish stocks and the possible effects of fishing in one area upon fishing in adjacent areas is becoming essential.

There has recently been a great deal of criticism of the interpretation of the commercial fishing records supplied by the territorial Governments. This is, of course, inevitable when the interpretation is not favourable, but nevertheless the criticism has a firm foundation in that the records are not accurate by virtue of the method used for their collection.

The error is admitted and for this reason no attempt has been made to estimate the total productivity of Lake Victoria, or even any one area. The figures published may in fact be more than 100% in error but this absolute magnitude of fish production is of no importance in determining the effects of fishing. The important feature to observe is how the catches vary from year to year.

In estimating the accuracy of the data it is worthwhile to consider the type of error to be expected in the records if the recorders are not working conscientiously.

Firstly, the recorders, if they remain at the same landing, as in Uganda, do not keep a copy of previous records so that the subjective error of a worker thinking he should record more fish than last year can be eliminated. Secondly, if he is merely fabricating records the statistics should fluctuate about a mean and would show no consistent trend. However, if the standard of work is decreasing then a trend similar to that given by the present records might be expected to occur. At the same time, since at many stations recorders work quite independently of each other, one would not expect the trend to be identical at each station if it is caused by human error alone.

The similarity between records at the separate stations in Uganda is striking. It is even more significant that these trends are identical with those shown by records from the Kavirondo Gulf. It is of interest to note that legislation restricting gill net fishing of mesh sizes of 3″ — 5″ are still in force in Kenya (1959) yet the trends of fishing are similar to those at Uganda stations where 4″ — 5″ nets are in use. If the legislation was adhered to this should not be so and further investigation has shown that the use of illegal mesh sizes is widespread in Kenya waters. To be able to identify such a feature from the records lends further credence to their general accuracy. It should also be noted that trends in fishing outside the Kavirondo Gulf are opposite to those within the Gulf and reflect the logical outcome of recent developments in fishing which would not occur if the records were grossly inaccurate.

There can therefore be no doubt that the fishing in 1960 has been poorer than in 1956/57, though there is no accurate information on the absolute magnitude of production. The decline is not an artefact caused by poor recording. The interpretation of the data in search of trends from which general deductions may be drawn which take account of the known errors of the data is a more realistic and less irresponsible approach than to use those same records as a basis of an estimate of total production, using an aerial count of canoes afloat and inshore as a basis for estimating fishing effort. Such a survey merely shows the number of canoes that have been built during the past three years with no indication of the amount of use given them.

2. *Population Studies in the Jinja Area*

The basic objective of population studies such as those at present in progress is to study in detail the age composition of a population of fish of a given species in order to estimate the proportion of the population which is killed by fishing during a period of time, e.g. one year. This estimate can then be related to the amount of fishing during that time and to the number of new recruits entering the fishery and replacing, in numbers, those that have been killed.

This information can later be extended to investigate the potential of the fishery but it is essential to obtain estimates of mortality in the first instance. An investigation of the parameter in a gill net fishery requires firstly an exact knowledge of the selection characteristics of the commercial gill nets and monthly information on the length frequency distribution of the commercial catches. These latter can then be corrected by a selection factor for each length group so that a true size composition of the exploited population can be constructed. Knowing the size composition and with a detailed knowledge of the age composition of each length group, these various data may then be readjusted to give the relative abundance of 1, 2, 3, 4 etc. year old fish and from this the rate of mortality can be calculated.

An investigation of this type requires detailed and continuous records of commercial fish catches from a population of known geographical extent.

The returns of marked fish and various other ecological characteristics of *T. esculenta* indicate that the population of this species in the shallow waters north of Buvuma Island may be considered as a unit stock and for the past two years the detailed information necessary for estimating the mortality rate has been collected by routine sampling at the commercial fish landing at Waigalla. The amount of sampling necessary has made it impossible to carry out similar work simultaneously on other *Tilapia* stocks in other areas, but it is hoped that this detailed study, which is the first of its kind on a natural population of a tropical freshwater species, will show general principles which can be applied to other populations in Lake Victoria.

Length frequency distribution of fish catches landed at Waigalla have been recorded for two years for *T. esculenta* and *T. variabilis* and more recently the records have been extended to the third most important species, *Bagrus docmac*. Unfortunately it has only been possible to collect the necessary age data for *T. esculenta.*

The analysis of data for this species is now in its preliminary stages.

Using length frequency data from experimental fishing records the precise selection characteristics of commercial gill nets for any length of fish has been determined. During the course of this determination it was found that the original technique by which this feature of the fishing gear is determined, was in error. This has been corrected and the method has also been extended to enable the calculation of selection factors of gill nets where only a very limited length range of fish occurs in any one area. A detailed publication of this work will appear shortly.

Using this data the length frequency distribution of the North Buvuma *T. esculenta* stock has been reconstructed. This shows clearly that the average size of fish in the stock has declined during the course of the investigation. However, the commercial gear in use (4½" stretched mesh gill nets) does not exploit the larger *T. esculenta* as efficiently as do 5" mesh nets and there has been a slight increase in the abundance of this size group. This increase is reflected in the commercial fishery by the reappearance of a small number of the 5" mesh nets.

It will be remembered from previous Annual Reports that age determination of *T. esculenta* is dependent upon the number of rings laid down on the scales in each year and that various evidence indicated that two rings per year were laid down by each individual fish. The present investigation has given support to this hypothesis: the proportion of the population laying down a ring on the edge of the scale is greatest at the time when the majority of the population are ripening and spawning. This corresponds with findings of other workers that the metabolism of body minerals is closely related to gonad activity and to the observation that the ovaries of female *T. variabilis* may become heavily mineralised. This fluctuation in metabolism is responsible for the formation of a ring which in itself is a change in the rate of calcification at the edge of the scale.

Using this technique of age determination the present analysis has shown a slight change in the growth rate of *T. esculenta* during the past three years. The growth rate of *T. esculenta* during its breeding life history can be mathematically defined by von Bertalanffy's formula, the shape of the curve depending primarily upon two parameters, K and L_∞. K expresses the rate of decline of the growth rate and L_∞ is the maximum size towards which the fish is growing.

Comparison of the average growth rate of *T. esculenta* in 1960 with that of fish caught in 1956—57 shows that though the change in K is not significant, the fish are now growing to a slightly higher asymptotic length. Theoretically the magnitude of K is believed to be related to environmental factors such as temperature which increase the rate of body metabolism, but the value of L_∞ is largely determined by the availability of food. If the population size decreases the amount of food available per individual must increase and an increase in $L\infty$ will result. The increased growth of *T. esculenta* is thus believed to be a directly density dependent effect caused by depletion of the stock by increased fishing activity in the area during recent years.

Using this same information it has been possible to identify classes of fish that spawned for the first time in 1956, 1957, 1958, and 1959, and to compare their abundance. It is clear that the 1957 classes are very abundant, i.e. more fish were spawning in 1957 than in 1956 and 1958. This corresponds with the observation from the commercial records that 1957 was a particularly good year for *T. esculenta.* 1958 on the other hand was an extremely poor year for the numbers of fish spawned, compared to 1957, and again the records show fishing to have been poor in that year. In 1959 fishing was much the same, but the first half of 1960 has shown improved catches as the fish spawned in 1957 reach the length exploited by the commercial fishermen. 1957 was a period of increased abundance of *T. esculenta* in many areas of Kenya and the present increase in catches of this species may again reflect the recruitment of offspring of that year to the exploited population. Even so there is an indication that the numbers of fish that bred for the first time in 1957 are still as abundant as their offspring which in 1960 are spawning for the first time, despite the fact that they have been fished for a long period whereas recent recruits have not. This indicates that the adult stock which spawned the 1957 spawners was more abundant than the 1957 adults which spawned the present first spawners, i.e. the declining population has been unable to maintain the original rate of recruitment and biological overfishing might be occurring, in the sense that egg production and survival to maturity have decreased, although it may be partially offset by the increased growth rate. Assuming that fish spawned in 1958 will be recruited to the exploited population in 1961 it is to be expected that this will be a very bad year for fishing since the abundance of spawning adults was relatively low in 1958.

It is hoped that the more detailed analysis will support these preliminary indications and illustrate further the value of this type of investigation in predicting future fishing prospects.

The length frequency records of *T. variabilis* are less informative than for *T. esculenta* because they cannot be analysed in conjunction with age distribution data. However, a number of conclusions may be drawn which contribute to our knowledge of the general biology of this species.

It has become clear that *T. variabilis* is very much more seasonal in its appearance on the fishing grounds than *T. esculenta.* This is probably because the Buvuma Island grounds are not the natural habitat of the species and they only appear in the catches when the fish are shoaling. At these times fish are caught in large numbers and give a very high catch per net return. Examination of the fish has shown that the shoals are almost entirely monosexual with quiescent gonads.

In recent months there has been no overall trend in the average size of *T. variabilis* caught in the commercial gill nets although there was a decline during the early months of 1959 which has not been regained. The average weight of individuals of this species in the commercial catches is ¾ lb. *T. variabilis* also differs from *T. esculenta* in that there is no marked seasonal variation in the numbers of fish caught to indicate periods of recruitment of small fish to the exploited stock. This supports the indications that the typical shallow water *T. esculenta* grounds are not the natural *T. variabilis* habitat and the species is only caught in large numbers when shoals of fish are on the move. This feature would also explain the extremely low *T. variabilis* catches in the Kavirondo Gulf. It has been suggested that the use of small meshed gill nets in the Gulf will enhance catches of this species but in fact *T. variabilis* in the Gulf are very few in number, probably because, being almost entirely landlocked, large shoals of *T. variabilis* do not enter the area. This tentative observation will be checked when data become available from the programme of seine netting at present being carried out within the Gulf by the Kenya Fishery Officers.

APPENDIX B

THE BIOLOGY OF *TILAPIA VARIABILIS*

by G. Fryer

The study of the biology of *Tilapia variabilis*, whose economic importance has greatly increased since the relaxation of mesh-size regulations, was continued, until my departure, on the lines mentioned in the last Annual Report, and the information obtained is now being sorted. Although more details are required concerning several aspects of its biology the general features of the life history and habitat preference of this species are now known, and this has allowed points of economic importance to be considered.

Further returns of marked fish have confirmed that *T. variabilis* does indeed grow remarkably slowly after achieving maturity. On the other hand, the available evidence indicates that, in the Jinja area at least, the currently employed fishing gear does relatively little damage to the stock of breeding females. This is because the greatest intensity of breeding is found in fish which are a little smaller than those comprising the bulk of the catch taken in gill nets of 4½″ mesh.

When these and other factors are taken into account the future of the *T. variabilis* fishery would appear to be one which will show declining yields until the present accumulation of large individuals has been cropped (a process now in progress) followed by a steady but low yield—always provided that the mesh size of the nets used commercially is reduced no further and that this species is not ousted nor partially replaced by *T. zillii*. A growing body of evidence points to the fact that competition between *T. variabilis* and *T. zillii* may be expected at times during the early stages of development. The inter-relationships between these species are extremely interesting and serve as an excellent reminder of the impossibility of predicting all aspects of the behaviour of introduced species and their effects on the indigenous fauna.

APPENDIX C

BAGRUS DOCMAC INVESTIGATION

by H. Y. Elder

The investigation into the biology of this commercially very important siluroid fish has now been in progress for more than a year. During this time twice weekly routine fishing with a graded fleet of gill nets has been carried out covering a variety of habitats which differ in the substrata, depth of water and degree of exposure. This has confirmed the preference of *Bagrus* for the deeper, more open waters and a coarse substratum. Routine fishing is now being carried out on one of the grounds where *Bagrus* was found to be most plentiful; an exposed rock and gravel reef some thirty miles from Jinja.

Breeding

Between one and two thousand *Bagrus* have now been caught and examined. Records of the gonad states have shown that there is a single breeding season in the year, the first fish starting to ripen in September and the peak of spawning occurring probably in January and February (Fig. 1). (p. 43) Information from other parts of the lake is very limited. Two isolated cruises, one to Bukoba waters in Tanganyika and one down the Kenya coast, have shown that at least at the time of these trips the stage in the reproductive cycle of the fish in those widely separated regions was very comparable to that of the fish in the Jinja area. It is intended to make further routine trips to both Kenya and Tanganyika waters to collect more information on this aspect. Unlike *Tilapia* species, female *Bagrus* produce only one batch of ova per season : all the eggs in the ovary ripening at one time. To date, very few fish in "running" condition have been taken in the experimental nets and the exact spawning sites remain a mystery. Whitehead (1959) has recorded *Bagrus* in ripe condition being taken in upstream traps in the larger affluent rivers of Lake Victoria during the rainy season, which suggests that there is an upstream migration to breed. The numbers taken in these traps are, however, too small for the rivers to be the main breeding grounds of the species. Corbet (1960) cites evidence, from the capture of juvenile specimens on rocky exposed shores, remote from any of the large rivers, which indicates that *Bagrus* breeds also in the main lake.

Age and Growth

Estimation of the age and growth of *Bagrus* presents a particularly difficult problem. Vertebrae which have have been dried for several months show fairly distinct rings which are thought to be "breeding rings" and work is at present in progress to determine their exact significance. Other skeletal structures, such as otoliths, opercular bones and spines are unsuitable for age determination owing to their shape, size or degree of calcification, and being a siluroid *Bagrus* has no scales.

Commercial Fishery

Over the past year measurements of commercially caught fish have been made at the Waigalla fish landing. The gill net is a highly selective gear, so that a length frequency plot of fish caught commercially in the Waigalla area is basically the retention curve for Bagrus for a 4½″ gill net. It is hoped that Petersen's method of ageing fish by analysis of the progression of the year group modes superimposed upon this curve may be applied to the data. However, the analysis is complicated because almost all fish taken in the nets have their dorsal and pectoral spines erected and the pectoral ones locked in this position. This reaction of the fish results in their capture over a very wide size range, from fish of standard length 15 cms. and weight 50 gms. (under 2 ozs.) to fish of 100 cms. up to 9,000 gms. (about 20 lbs.). The monthly measurements regularly cover fish ranging from about 20 to 45 cms. The resulting length frequency plot has a flattened wedge-shaped form which may prove to be polymodal. It is not yet certain therefore whether the modes present represent particular year groups or are artefacts of the fishing gear. Those modes which are present are rather ill-defined and there does not seem to be any clearly defined influx of new recruits to the fishery. These facts seem to indicate that the fish in the Jinja area, the waters of which are largely "inshore", are on the fringes of the main *Bagrus* population. It is hoped that further work, particularly in the Kenya open lake and west Tanganyika waters will shed light on this aspect. In this connection the Lake Victoria Fisheries Service commercial fishing records are invaluable.

Fish Marking

A fish marking programme has been started, from which it is hoped to confirm age and growth estimates derived from Petersen's method and vertebral ring analysis, and to provide information on fish movements. The large adipose fin of *Bagrus* seems to be ideal for carrying a tag and both "salmon" and "plaice" tags are being tried.

Food

The food of the non-cichlid fish in Lake Victoria has been thoroughly investigated by Dr. P. S. Corbet, who has published a preliminary account in the E.A.F.R.O. Annual Report for 1958, and whose complete results are at present in press. His most important finding with regard to *Bagrus* was that it is a highly predatory fish and by far its most important prey are the small cichlids of the genus *Haplochromis*.

Aquarium Studies

Bagrus has proved to be a difficult fish to keep for aquarium study since it will not feed and remains motionless for long periods. Force feeding is now proving successful and fish have been kept alive for many months. Experiments on the growth and conversion rates of *Bagrus* and observations on the feeding habits of fish which, after the initial acclimatisation, have again started to capture fish for themselves, have now been started. Particularly in view of Corbet's findings, these investigations should form a useful comparison with similar experiments upon the Nile Perch.

APPENDIX D

THE BREEDING OF *TILAPIA ZILLII*

by H. Y. Elder

An aquarium study of the breeding behaviour of *Tilapia zillii,* one of the four known "substratum spawning" or "guarder" species of *Tilapia* is at present in progress, and it is hoped to publish a full account in the near future.

Once a pair has been established, the male having accepted the female, the breeding colouration is assumed and courtship begins, lasting several days or weeks, depending on the physiological breeding state of the fish. A circular nest is constructed by the pair, which take up mouthfuls of sand from the centre of the site and carry it to the periphery where a surrounding ridge is constructed. Subsidiary pits are formed adjacent to the main depression. In the aquaria the corners are very often used as nest sites. During the courtship there is a continual modification and rebuilding of the nests until, as spawning approaches, the nesting activity reaches a peak and the depressions acquire their final form.

The spawning act occupies several hours in *T. zillii,* in marked contrast with the rapid spawning described for certain mouth-brooding *Tilapia* species. During the actual spawning act the female moves over the central area of the main depression with the genital papilla erect and touching or very close to the substratum. The numerous small green eggs are adhesive and stick immediately to the substratum. In fact the fish in many cases prefer to spawn on the vertical concrete or glass walls of the aquarium and the eggs can be seen in the criss-cross pattern in which the female repeatedly crosses the spawning area. After almost every traverse which the female makes, the male follows, also with genital papilla erect in close proximity to the substratum, and presumably deposits milt. Towards the end of the spawning act there is a gradual transition from spawning to "fanning" activity. Both parents take part in the fanning, which consists of propelling a current of water over the egg mass with one pectoral fin, or more rarely, both fins. The dorsal, caudal and anal fins perform compensatory strokes to maintain the fish in position over the egg mass. Only one fish of the pair performs the fanning activity at one time and the fish relieve each other at fairly regular intervals, both the male and the female taking equal share in the fanning, thus keeping an almost continuous current over the eggs.

From spawning to hatching takes a little over two days at 20°C—24°C and soon after hatching the larvae are picked up in the mouth of one of the parents and transported to one of the subsidiary pits where they are "spat" out. Eggs which have not hatched (and have often started fungal infections) are left attached on the original spawning site.

The young larvae possess adhesive organs on the head by means of which they attach themselves to the substratum. Each larva has on its head a total of six such organs, distributed in two groups; a group of two horizontally adjacent glands just dorsal to, and morphologically posterior to, the olfactory capsules and a group of four glands forming a square with two to either side on the most dorsal part of the head between eyes and otic capsules. Each of the six glands is globular in form, having a large flask-shaped central lumen and large secretory cells in its walls. When attaching itself the larva touches its attachment organs on the substratum and from each gland draws out a mucus-like thread which hardens on contact with the water. Due to the activity of the larvae the threads soon become twisted round each other to form a tiny "rope" by which the larva is firmly attached. Occasionally a larva does become detached and swept away, but is soon collected in the mouth of one or other of the parent fish and returned to the cluster of wriggling larvae. From the time of hatching the larval tails are in almost incessant motion, probably to keep themselves free from silt and to provide a respiratory current. The posterior of the two sets of attachment organs gradually assume more importance than the anterior, which atrophy within a few days of hatching. The yolk sac is present for a period of one to two weeks (depending upon the temperature) after which time the larvae change from the attached existence to the shoaling habit and the posterior organs also atrophy.

APPENDIX E

SELECTIVE BREEDING OF *TILAPIA ZILLII*

by C. C. Cridland

Five pairs were isolated in breeding tanks and one brood was raised from each pair. The average length of males and females was 20.0 cm. and 17.3 cm. respectively, the average weight being 141.0 gm. and 92.0 gm. Six broods were recorded from one pair within seven months. The interval between the first and second brood of this pair was 24 days, between the second and third brood 25 days, between the third and fourth brood 21 days, between the fourth and fifth brood 106 days, and between the fifth and sixth brood 25 days. At the first brood the length and weight of the female was 15 cm. and 67.0 gm. respectively, and 1,798 eggs were produced. At the final brood the female measured 20 cm., weighed 118.0 gm. and 4,670 eggs were produced. The spawning took about two hours and, to prevent the eggs from being eaten, the male and female were removed immediately afterwards. The time in respect of hatching varied with the temperature, but was recorded to be approximately two and a half days at a temperature of 20.7°C minimum and 23.9°C maximum.

The average length of the larvae at hatching was 4.0 to 4.5 mm. The larvae were 10 to 12 days old when they began feeding and were 7 mm. long.

A new technique has been found for the hatching and care of very young *T. zillii*. An air diffuser is placed close to the nest to keep the water circulating and prevent the eggs from being attacked by fungi. It is important that a good growth of floating algae is present in the tank to minimise the disturbance of external stimuli to the breeding pair and also to feed a *Daphnia* culture which is introduced at a later stage. Immediately after the eggs have hatched, the water in the breeding tank should be emptied of three fourths of its volume, together with any dead eggs, and the tank should then be refilled with clean water to the original volume. Care should be taken that the temperature of the water remains the same in the breeding tank throughout the procedure. Shortly after the water has been added it starts to clear, and the *Daphnia* culture is then introduced. If introduced before the water has cleared they do not become established.

When young *T. zillii* start to feed it is found that the nymph of *Daphnia* is the best food , especially in the first month of their lives.

The table below shows the maximum and minimum growth of four first generation pairs, the fifth pair having only just spawned.

Pair No.	Brood	Age in Months	Maximum Growth Length cm.	Maximum Growth Weight gm.	Minimum Growth Length cm.	Minimum Growth Weight gm.
1	1st	8	9.0	15.0	6.1	4.8
2	1st	7	9.4	17.2	6.1	4.3
3	2nd	7	10.2	18.9	4.8	1.9
4	1st	5	7.2	6.5	3.1	0.5

Pair No. 5:

1st brood on 14.11.60, hatched 16.11.60. Approximately 3,300 eggs. Weight and length of female 85.0 gm. and 16.5 cm. Male 149.0 gm. and 20.5 cm.

2nd brood on 3.12.60, hatched on 5.12.60. Number of eggs 5,000. Weight and length of female 89.0 gm. and 16.9 cm. Male 154.0 gm. and 20.6 cm.

Interval between first and second brood 19 days.
(Table 4, 5a, b, c, d. pp. 44-48).

APPENDIX F

THE FISHERY ON LAKE NAIVASHA

by D. J. Garrod and H. Y. Elder

The eastern Rift Valley lake, Lake Naivasha, lies on a very shallow basin and has an area of some eighty square miles. Recent soundings showed the greater part to be less than 15 ft. deep. Much of the bottom area is also most probably available as breeding grounds for *Tilapia*. This depth compared to the surface area, leads to a very high evaporation rate so that the lake is subject to very rapid fluctuations in water level.

As early as 1925 the potentialities of the lake were appreciated and *Tilapia nigra* were stocked initially to provide forage for Black Bass *(Micropterus salmoides)* which was introduced later in order to establish a sport fishery. These fish introductions have had a chequered career. The Black Bass disappeared, probably owing to their failure to breed, but the *Tilapia* did well until the lake became overpopulated and runting occurred at the same time that the lake level dropped to an extremely low level. More recently *T. zillii* has been stocked into the lake and together with the *T. nigra* already present they have proliferated into a very dense population.

In 1959 the *Tilapia* population was sufficiently dense and the size of the fish sufficiently large to provide the basis for an experimental fishery designed to estimate the potential yield of the lake. This initial investigation is being carried out so that, when fished on a commercial scale, a realistic management policy can be enforced which will protect the fishery, for it will be appreciated that on a lake of this size completely unrestricted fishing could rapidly destroy the fishery, requiring that fishing should be completely stopped to enable it to recover.

The fishery is based on a number of *Tilapia* species which vary in the maximum sizes that they achieve. *T. nigra* grows to exceed 33 cm. length but *T. zillii* is rare above 28 cm. *T. leucosticta,* which probably gained entry due to impure *T. zillii* stocking, is also found growing to lengths intermediate between those of *T. zillii* and *T. nigra.* A number of specimens have been collected which show taxonomic characterics intermediate between those of *T. leucosticta* and *T. nigra.*

The experimental fishery was commenced at the beginning of 1960 since which time the lake has been fished regularly with a fleet of up to 100 gill nets which were originally 5″ mesh only. More recently 4½″ nets have been included in order to estimate the potential of those species which do not grow to sizes liable to capture in 5″ nets.

The 5″ nets catch primarily large male *T. nigra,* there being sexual dimorphism in the growth rate of the species, and in some of the large "hybrids". The records show that even the limited amount of fishing has been adequate to remove the accumulated stocks of very large old fish and further fishing is necessary to determine the influence of this fishing on the total population.

However, experimental fishing with small meshed nets has revealed very large stocks of smaller fish liable to capture in 3½″ and 4″ mesh nets. At present records are not available to show whether the abundance of these fish is increasing or steady but in a body of water this size the danger of overpopulation is very real and it may become necessary to fish small mesh nets to restrict the population numbers so that a proportion of the fish are still able to grow to sizes large enough to be caught in 5″ nets.

The Lake Naivasha fishery is thus of considerable interest both from the purely biological point of view concerning the fate of the hybrid population and from the fishery management approach, since by cooperation with the experimental fishery the fishing effort can be manipulated to examine the various effects of fishing upon the stocks. It is hoped that the examination of the interaction of yield and fishing effort will enable us to identify basic principles for the rational management of a gill net fishery.

The future of the hybrid populations is particularly interesting in the comparison between their potential in the fishery compared to that of the pure species. Such species crosses may have considerable application in fish culture work. The fate of the hybrid population in relation to that of the pure species, *T. nigra, T. leucosticta* and *T. zillii,* is being followed by regular periodic experimental fishings with a graded fleet of gill nets. It is hoped that the information so gained, in addition to clarifying the selectivity problems briefly referred to above, will enable us to differentiate between fluctuations in the relative proportions of the types of *Tilapia,* caused by differential fishing pressure (due to the selection characteristics of the mesh size of the nets used—see above) and any effects which might be due to factors such as lowered fecundity or "hybrid vigour". It is intended to continue these periodic observations over at least a two-year period, thus enabling us to distinguish betwen long-term trends, and seasonal fluctuations, in the absolute and relative abundance of the various *Tilapia* types.

APPENDIX G

THE NILE PERCH PROJECT

by E. L. Hamblyn

The most interesting development in this field has been the reappearance of *Lates* in Lake Victoria, an event which may have far reaching effects on the commercial fisheries of the lake and on the future pattern of evolution of the fish fauna.

Before this event, and prior to the introduction of this fish to Lake Kyoga, the distribution of Nile Perch in British East Africa was limited to the Murchison Nile, Lake Albert, the Albert Nile and Lake Rudolf. In these lakes and rivers this species occupies a dominant position in the food chain, being subject to predation only by crocodiles and man. By virtue of this position Worthington *et al.* have suggested that the presence or absence of this species has had much to do with the evolution of the fish faunas as we know them today.

The similar fish faunas of Lake Victoria and Lake Kyoga are distinct from the typical nilotic fauna of Lake Albert. The evolution of these faunas has, no doubt, been greatly influenced by the climatic history of East Africa during the Miocene and the physical barriers of the Murchison Falls and Semliki Rapids. The fossil record and other geological evidence supports the hypothesis that partial or complete desiccation of Lake Victoria and Lake Edward took place in the arid interpluvial periods of the Miocene which would result in the extermination of most, if not all, of the fish species present in those times. *Lates* is known to have been an element of these fauna; fossil remains of this fish coming from the Miocene beds associated with these lakes. Worthington postulates the failure of *Lates* either to survive or to recolonize these lakes when they reformed, resulting in exceptional opportunities for speciation being open to those forms which successfully occupied these waters. Leaving aside the validity of this hypothesis it is a matter of note that the genus *Haplochromis,* which best illustrates speciation in the East African lakes, has 70 species in Lake Victoria, 5 in Lake Albert and one in Lake Rudolf. Though no exact data is available on the abundance of *Haplochromis,* it is accepted that the numbers in Lake Victoria far exceed the numbers to be found in Lake Albert.

The Nile Perch of Lake Victoria

Eight fish have been recorded from the north-east corner of Lake Victoria, all of them caught by native fishermen using 4″ and 4½″ gill nets. Five fish have come from Napoleon Gulf at Jinja, two from the Buvuma Channel and one was found at the Waigalla fish landing. This fish was probably taken in the same general area as the Buvuma fish. The fish ranged in size from 28 to 43 cm. All were immature; five were males and, of the three females, one had ovaries rather more developed than the others but still falling within the general category of immature.

The stomachs of the four fish which had recognisable contents showed *Haplochromis* and juvenile *Clarias.* One stomach contained two *Haplochromis* and one *Clarias,* one a specimen each of both genera, and two had one *Haplochromis* each. Four fish had no stomach contents of any sort.

The first fish was captured in June and was followed at irregular intervals by four more, all from the west shore of Napoleon Gulf. The last fish which was caught in September, came from the beginning of the now inundated Ripon Falls. The remaining fish were reported at the end of October and early November.

These fish may have originated from Lake Kyoga where Nile Perch have been introduced at several points over the last six years by the Game and Fisheries Department of the Uganda Government. This origin postulates the passage of fish through the Owen Falls Dam, a subject which will be discussed in a later paper.

The Radiation of Nile Perch in Lake Kyoga

The Uganda Game and Fisheries Department have introduced about 300 Nile Perch to Lake Kyoga in the last three years. Table 1 shows the returns from July 1956 when the first fish was recorded until November 1959 when the occurrence of these fish was no longer a matter of remark.

TABLE 1

	1958						1959										
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Lwampanga	1									2	2	16	12	6			
Akakoro								2		-	nu	mer	ous	-			
Namasale										2	1						
Wunga Is.													1				
Galiraya																	1

Returns of Nile Perch from Lake Kyoga landings in order upstream from Lwampanga in the north.

It will be seen from the Table and reference to a map that radiation has been principally along the course of the Victoria Nile as this river passes through the lake. No fish have been captured east of Wunga Island and attempts to hasten progress have been made by plantings at Lake Salisbury and Lake Ajama this year. Large areas of Lake Kyoga are papyrus swamp with many interconnected bays and lagoons having little water flow. It may be that hydrological conditions will prevent the establishment of Nile Perch in these places. The size of the introduced fish varied between 15 and 45 cm. and the size of the recaptured fish is about 35 cm. There is insufficient data to draw any conclusions about growth and reproductive rates, but some interesting data is available on the food utilised in this new environment. The few stomachs examined had *Haplochromis* sp. *Marcusenius* sp. and juvenile *Protopterus aethiopicus.* These all came from fish caught near

Lwampanga where the flow of the Nile is slow though detectable and resembles the nearest approach to a typical lacustrine environment likely to be found in this dendritic lake. No information is available from the more riverine stretches south of the Galiraya peninsula and no fish have so far been caught here. There is little doubt that fish are present in these waters through which they must pass to reach the Owen Falls Dam. The water below the Owen Falls was stocked with 47 fish in September 1955 and 41 in April 1956. This year 19 fish were planted at Namasagali and 30 at Bujagali Falls.

The absence of returns from this area may be explained by the nature of the watercourse between the Owen Falls Dam and the Galiraya Peninsula. The river descends in a series of four falls below the dam whence it flows swiftly past Namasagali before broadening into Lake Kyoga about ten miles downstream. The fast flow and numerous islands of sudd, which are a feature of this lake, prohibit the use of fixed or floating gill nets in the main stream. Some gill nets are set at the fringes of the swamps usually attached to a handful of papyrus. Traps are more common than nets in these parts and the occasional longline is set for *Protopterus*. The low fishing effort is also explained by the absence of suitable fish landings and the relative simplicity of fishing further downstream where the industry thrives. These fishing techniques are not directed at the capture of *Lates* and it is not therefore strange that no fish have been taken in this District.

Below the Owen Falls Dam are great shoals of *Barbus* which are a great attraction to anglers. The usual lure is a small spoon fitted with one triangle, which is the method best calculated to catch tiger fish *(Hydrocyon)* in Lake Albert, which sometimes results in the capture of Nile Perch. So far as is known no deliberate attempt has been made to catch *Lates* using the standard practice of trolling a plug. The habits of *Barbus* and *Lates* are so different in many respects that the accidental capture of a Nile Perch is most unlikely.

The Nile Perch of Lake Albert

Experimental fishing using 1½″ 2″ and 2½″ gill nets, traps and small seine nets has thrown some light on the occurrence of small Nile Perch at Butiaba, Buhuka, Ntoroko and Panymur. This fishing has of necessity been limited and irregular, but the results afford some indication of possible breeding behaviour.

At Butiaba fish between 6 cm. and 30 cm. are present throughout the year. At Ntoroko, in the south-east corner of the lake, fish below 5 cm. occur in the estuary of the River Wassa during early February, and fish between 10 cm. and 30 cm. are present throughout the year. At Buhuka fish between 15 and 35 cm. may be caught during October and November including ripening females only 32 cm. in length.

At Panymur, nearly opposite the outflow of the Murchison Falls Delta and at the opposite end of the lake from Ntoroko, a fish of 3 cm. and several between 10 cm. and 25 cm. were caught in August.

The very small fingerlings from Ntoroko and the individual from Panymur are thought not to be more than two months old. Thus spawning must have taken placed about December in the Ntoroko area and July near Panymur. It is suggestive that the only reliable data concerning the occurrence of ripe female fish comes from the Murchison Nile at Fajao where two fifty pound female fish were taken by an angler last July. Fajao is about 20 miles upstream from the Murchison Nile Delta and it is not improbable that the 3 cm. fish of Panymur was spawned in this locality. At Ntoroko native opinion has it that large Nile Perch move up the estuaries of the Wassa and Muisi Rivers in December and January. As it is known that Nile Perch migrate up the Omo River from Lake Rudolf during the August spate the report of the Ntoroko fishermen, though not proved, is significant.

The negative evidence concerning the whereabouts of 'running' females at all times of the year is interesting. No 'running' females have ever been seen in Lake Albert or Lake Rudolf and Kenchington's paper on the Assuan Dam indicates a similar absence from this location on the White Nile. Spent females are very rare and unknown in fish over 20 lbs., yet no carcases of these fish are recorded. On Lake Albert which has been exploited for many years, this absence is not unexpected if the supposition of a breeding migration up affluent streams is accepted. Large fish of 30 lbs. and upwards are captured in seine nets, by long lines and anglers. None of these methods are practised at places where such fish are likely to be found with the possible exception of the Murchison Nile which is lightly fished by anglers. The postulate that fish stop feeding or refuse a lure at this stage has many precedents and is a likely explanation of the failure to catch fish in this condition.

Lake Rudolf

The *Lates* of Lake Rudolf were investigated during a safari to this lake in conjunction with the Game and Fisheries Department of Uganda. The results of the experimental fishing are shown in Table 3 which also indicates the times when the various types of fishing gear were worked.

TABLE 2

Catches of Fish Taken by Various Gear at Ferguson Gulf, Lake Rudolf

Fishing	Date	Time	Gear	Catch
1	18/2	1400- 1545	gill nets $1\frac{3}{4}''$—$5''$	Labeo; Synodontis; Hydrocyon; Tilapia; Alestes; Citharinus.
2a	18/2	1600	seine	Tilapia; Lates; Citharinus; Distichodus.
2b	18/2	1700	seine	As 2a.
3	19/2	1400- 1700	gill nets $1\frac{3}{4}''$—$5''$	Tilapia; Citharinus; Synodontis; Labeo.
4	19/2	over- night	gill nets 100 yds. 8″	24 Lates; 20 Citharinus; 2 Distichodus.
5a	20/2	dawn	seine	9 Lates; 1 Tetradon; about 100 Tilapia.
5b	20/2	0700	seine	3 Lates; 52 Tilapia.
5c	20/2	0800	seine	50 Tilapia; 2 Labeo; 20 Citharinus.
6	20/2	over- night	gill nets 100 yds. 8″ 50 yds. 5″	62 Citharinus; 4 Labeo; 1 Tilapia; 3 Distichodus; 2 Bagrus; 30 Lates.

All the seine net fishing was from the lake side of the spit off a beach about two hundred yards long. This net is one hundred yards long fitted with warps of the same length. It is worked by local Turkana labour under the supervision of Commander Mackay who has a concession on this stretch of shore. The catches recorded here are typical of those obtained by the Commander at this time of the year and give some idea of the productivity of this part of the lake.

The gill net fleet in fishing numbers 1 and 3 was set inside the gulf and did not catch *Lates*. The sets on the lake side of the gulf caught large numbers of *Lates*. Some data on these fish is presented in Table 4.

TABLE 3

Gonad development in Lake Rudolf Lates caught in gill nets.

	Immature	Starting	Ripening	Ripe	Running	Total	Mean Length cm.
Male	1	0	1	1	42	46	83
Female	0	7	0	0	0	7	85
						53	

The distribution between sexes and the high fraction of 'running' males parallels Lake Albert samples where this type of distribution is typical for all times of the year. At Ferguson Gulf the fishing falls off after March, causing Commander Mackay to stop fishing in July, not resuming until late August. During these months the lake level rises and the water becomes coloured. This corresponds with the spate of the Omo River which is known to have a run of *Lates* in August. Unfortunately no data is available about fishing in the rainy months when Lake Rudolf is virtually isolated.

The food of these *Lates* consisted almost wholly of *Engraulicypris stellao,* which occur in huge numbers on the lake side of the spit. The number of prey fish per stomach varied between 1 and 15 and varied in size between 2 cm. and 3 cm. standard length. None of the *Lates* stomachs was full and some must have regurgitated a large part of their last meal. The almost exclusive utilisation of *Engraulicypris* may have been associated with the heavy concentration of these fish for breeding.

The Measurement of Large Fish for Experimental Purposes

A method is described to measure weight and length of fish without handling them. This is imperative in the case of large, active fish which damage easily and are difficult to catch in a hand net. It is considered that there is no size limit to the fish which may be dealt with in this way provided that the fish behave well when anaesthetised and suffer no undesirable after effects.

The anaesthetic chamber used at Jinja consists of a rubber trunk fitted with a wooden frame around the top carrying one eye hook at each corner. Ropes are attached to each hook enabling the box to be manoeuvred to any position in the aquarium. The interior of the box has a wooden frame carrying a removable perforated polythene sheet which is held flush on the floor by movable wooden slats and flush against the long side walls by two galvanised iron rods attached to the polythene. These rods fit into rebates cut in the vertical members of the frame. The chamber has a drain hole fitted with a stop cock let into one of the side walls.

In operation the whole assembly is lowered into the aquarium and allowed to sink. The fish is guided into the box and the whole lifted to the surface. The stop cock is opened and the box is drained as it is lifted to the surface until a sufficient quantity of water remains. This depends on the size of the fish. The stop cock is closed and the box lifted clear of the aquarium.

The anaesthetic (MS 222 Sandoz) is administered in such concentration to quieten the fish quickly. The polythene carrier is removed complete with the fish and the whole weighed on a spring balance. Length is measured by laying the fish on the measuring board with the snout against the end plate and reading off the length in the normal manner. The board may be read through the polythene if necessary. The most delicate operation is coaxing the fish into the submerged box. Nile Perch are peculiarly cooperative in this matter.

Transport and Movement of Nile Perch

Difficulties encountered in fish transport spring from the high susceptibility of Nile Perch to fungal attack at sites of the smallest lesions and to their sensitivity to temperature changes and oxygen/carbon dioxide tensions. The most dangerous injury is likely to occur within the containers themselves when the cornea of the protuberant eyes is easily grazed. Eye fungus quickly develops and usually has fatal consequences.

The easiest and most successful method employs polythene bags which are best suited for fish below 15 cm. Two bags, one within the other, are used for fish over 10 cm. where there is the likelihood that the spiny fin rays and serrations of the opercular and pre-opercular bones may puncture the bag. The outer bag should be loose fitting and not sealed off. The open end of the bag is tied off, creating pocket traps when the bag is laid flat and care is taken to see that these bunched folds are turned up clear of the water when the bag is loaded. The corners are likewise turned up.

Fish below 5 cm. need special attention before transport and on arrival. It has been found that fish of this size die from starvation in a few days, probably because the vicissitudes undergone in travelling cause loss of appetite which is never recovered. The problem has been alleviated by ensuring that the fish have been fed before starting and by force feeding any fish which fails to feed a day after arrival. This is performed by inserting a food fish about one quarter the length of the Nile Perch into the stomach. The food fish is held in Spenser Wells artery forceps leaving the head free and hiding the rest of the body from view. The fish is inserted past the gill chambers and deposited in the stomach when the forceps are carefully released and withdrawn. The greatest danger consists of tearing the valves associated with the respiratory pump after an unsuccessful release has occurred. The only survivors of a shipment of twenty-three perch have been those which were fed in this way. In these cases only one treatment was necessary.

Rubber trunks 18″ x 12″ are used for fish between 15 and 30 cms. and 44 gallon petrol drums for fish over this size. Each drum has a hatch located in the side wall. The location of the hatch depends on the position which the drum will occupy in the vehicle. When the drums are transverse to the direction of movement the hatch is situated near the bottom; when in line with the direction of movement the hatch is in the middle of the drum. This reduces loss by surging on the road. Big fish are not moved in drums with central hatches if they cannot be allowed to find their own way out on arrival as it is impossible to remove them without damage.

When the drums are loaded the hatches are covered over with hessian and lashed down. Free spaces between adjoining drums are filled with wood shavings or vegetable material which retains slopped water and affords some measure of temperature control by evaporation. Each drum has an airline and diffuser.

These drums were used for the movement of fifteen 40 cm. fish from Jinja to the Inland Fisheries Research Station at Sagana, a distance of 420 miles, taking 17 hours. These fish were the survivors of two groups from Lake Albert and had previously spent 10 hours confined in the same drums. Eight of these fish have survived.

APPENDIX H

THE FOOD AND FEEDING BEHAVIOUR OF NILE PERCH

by E. L. Hamblyn

Stomach content analysis reveals that the Nile Perch is a primarily piscivorous predator of catholic tastes. The prey utilised appears to depend on the abundance and availability of vulnerable fish sharing the same habitat, which are taken in numbers relative to their ability to escape. With the possible exception of *Tetradon* in Lake Rudolf the Nile Perch show no palatability preferences, even the heavily armoured and dangerously armed siluroid fishes being acceptable prey. The absence of any preference dependent on taste is not altogether unexpected in view of the mode of predation employed. The prey are usually taken head first and swallowed whole with no appreciable holding period in the mouth. The prey is never bitten and disappears wholly within the greatly protractile mouth which creates a considerable suction force when opened to suck the prey fish in. All the teeth are small and arranged in pads serving to hold the prey and not bite or masticate it. Fish which are too big for the gape to close completely over them may be released but sometimes jam in the pharynx. This may result in the death of the predator by asphyxiation and fish killed in this manner are not uncommon on Lake Albert and Lake Rudolf.

The mode of predation depends on the behaviour of the prey. Different predation preparation movements are recognisable as soon as an object is perceived as a prey. Recognition of a prey object is visual, while sound, vibration and smell are thought to contribute to raising of the specific action potential to feed. The initial magnitude of this specific action potential is thought to depend on the relative emptiness or fullness of the stomach.

The sequence of events after recognition of a prey object appear to depend on the maintenance of visual stimuli. When a tadpole is the prey object the reaction of a Nile Perch depends on the further movement or non-movement of the tadpole. If the tadpole continues to swim after recognition the chances are that it will be eaten. If however the tadpole is swimming to the water surface being followed by the Nile Perch, the Nile Perch will seldom charge if the tadpole reaches the surface and stops all movements as happens during inspiration. In the same way a Nile Perch will break off pursuit of a tadpole which comes to rest on the bottom and stays completely still. The same behaviour is apparent with fish prey which stop and stay completely still.

Nile Perch will not take dead prey objects in still water but may be induced to do so by animating the object artificially. A freshly killed prey fish when released under the water surface will describe a path downwards dependent on the body form. This path is usually a fairly steep dive uninfluenced by the position of the fins which lie flush on the body surface. A Nile Perch will usually show no interest in a prey object presented in this way other than tracking the path with the eyes and changing attitude in the water to follow the path. When the prey object is made to descend in a discontinuous spiral, or a series of shallow dives with changes of speed and direction, the Nile Perch will frequently attack as it would be a living prey.

Much the same responses are elicited from Nile Perch presented with inanimate prey objects. When a coloured bead is presented in free fall the Nile Perch behaves as it does to a dead prey fish. When a similar bead is made to bounce down a sand and gravel slope the Nile Perch will often take this "prey".

The responses of wild fish to anglers' lures and baits afford an interesting comparison to aquarium behaviour. On Lake Albert the standard angling technique is trolling a plug lure. On the Murchison Nile the plug is sometimes held stationary against the current flow. On parts of the White Nile the plug may be replaced by dead fish or even pieces of fish. It would seem that the perpetuation of movement in a recognised object is essential for the completion of the feeding response and that the recognition of the prey object as such depends on the movements made by the object.

The relation of the size of the predator to the size of the prey seems to depend on the body conformity of the prey. The length of prey fish in the stomachs of wild fish is usually not more than one quarter the length of the Nile Perch and is less when the prey has a laterally compressed but deep body. The proportion by weight depends on the species of prey. In the case of an aquarium Nile Perch weighing 150 gm. which has fed on two 3 cm. *Haplochromis* the weight eaten is about 1/75 the weight of the Nile Perch. In the case of a 50 lb. Lake Albert fish which had eaten one *Hydrocyon* and one *Tilapia* this ratio was about 1/50.

The maximum capacity of the stomach is determined by the length between the oesophageal sphincter and the vent, the volume of organs contained in the body cavity and the degree of possible compression of the air bladder. The latter depends on the hydrostatic requirements of the fish but may be distorted by food in the stomach. In aquaria a fish with a full stomach rests on the bottom and presents a convex profile between the pelvic fins and vent. Resting fish often have a list of up to 20°, sometimes supporting themselves against the sides of the tank. This condition is thought to be associated with distortion of the air bladder which causes a shift in the centre of gravity.

APPENDIX I

INVERTEBRATE STUDIES

by G. Fryer

An account of the feeding mechanism of some prawns of the genus *Caridina* is now in print. Two species of this genus occur commonly in the vicinity of Lake Victoria and one, *C. nilotica,* is an important member of the littoral fauna and possibly also of the benthos of the lake, and is a fairly important element in the diet of several species of fishes. Both species are detritus feeders and, because of their numerical abundance, must be important as a means of keeping nutrients in solution, and possibly as consolidators of bottom deposits. Their method of food collection is such as to make them important as cleaners of plant surfaces and in this, by removing material which would otherwise screen their chloroplasts from light, assist in the maintenance of maximum photosynthesis, and therefore productivity, of submerged aquatic plants.

The feeding mechanism is complex. Food is collected by the slender and very mobile chelipeds. These are armed with specially modified spines and setae of great delicacy and considerable diversity which serve as efficient brushes and combs and which effectively scrape up minute food particles and convey them rapidly to the mouthparts. In this they differ from the more familiar pincers of the heavily built decapods (such as crabs) which usually serve to pick up large food masses. The mouthparts, which deal with the food received from the chelipeds, are extremely specialised and very complicated in structure, and their mode of action cannot be fully understood without reference to illustrations. In bare essentials the process is as follows. Food is combed from the chelipeds by the first maxillipeds which are armed with greatly modified spines and setae, removed from them by lobes of the maxillae which look like and function in a rather similar manner to teasels, which lift the food dorsally and deposit it in the mid line whence it can be lifted by the maxillules. These are dorso-ventrally flattened and suitably armed with teeth along the line on which the food comes to rest, so that they can grip it and lift it towards the mandibles. These both lift it into the oral aperture and triturate it before passing it to the gastric mill. This, basically, is the method employed, but there are other refinements, which sometimes involve the use of other appendages, which increase the efficiency of the mechanism and render it more complex than is indicated here.

A report on the parasitic Crustacea of the fishes of Lake Victoria is now virtually complete and will shortly be submitted for publication. In order to complete this work it was necessary to make an excursion into the field of taxonomy and consider certain forms of the copepod *Lernaea* from various parts of the world. This enabled conclusions to be reached concerning the taxonomic status of a *Lernaea* which parasitises the lips of the indigenous species of *Tilapia* in Lake Victoria, and it is hoped that the results of this study will soon be published.

So far as concerns crustacean parasites Lake Victoria is rather impoverished, only seven species of Copepoda and three species of Branchiura being represented. This number is fewer than, for example, that which is found in Lake Bangweulu, which has a less diverse fish fauna, and is indicative both of the isolation of Lake Victoria throughout its history and of the inability of these parasites to speciate at a rate comparable with that of the cichlid fishes which serve as potential hosts.

The work on larval development in the branchiuran genus *Chonopeltis* mentioned in last year's annual report has now been completed and is awaiting publication.

One particular aspect of the biology of one of these parasites, the branchiuran *Dolops ranarum* which occurs commonly on several species of fishes of Lake Victoria and elsewhere, has been studied in some detail and is now in press. This species produces spermatophores as a means of sperm transfer at times of mating. That a branchiuran should employ such structures is interesting for they are absent in the well known and widely distributed genus *Argulus* and in the African genus *Chonopeltis*. The mechanisms both of spermatophore formation and transfer are ingenious. Spermatophores are of dual origin but when complete are single, completely sealed, globular structures. Immediately after extrusion, and while the walls are still soft, these are kicked free by the male and impaled on two perforated spines situated at the end of the spermathecal ducts of the female. Through these spines, which completely penetrate the spermatophore wall, sperms are able to migrate to the spermathecae. These same spines serve later, after the spermatophore has been shed, to prick the eggs as they are laid, so that sperms can be injected into them.

Work on the developmental history of the lamellibranch *Mutela bourguignati* is now complete and a detailed account is in the final stages of preparation. Development of this mussel, and presumably that of other African members of the same family, includes stages which have no known counterpart within the Mollusca. As indicated in a preliminary note, development includes a period of parasitism on the cyprinid fish *Barbus altianalis radcliffi*, which is infected by curious larvae produced in large numbers by the adult mussel. These undergo metamorphosis to give rise to a stage which becomes entirely dependent on the host fish. This undergoes a remarkable series of morphological changes which ultimately result in the formation of a young lamellibranch which leaves the host and assumes an independent existence. Neither the free-living nor the parasitic stages show any real structural affinities with the glochidium larva of the Unionidae.

APPENDIX J

ALGOLOGICAL STUDIES

by J. H. Evans

During 1960 six months were spent studying freshwater algae in Central East Africa from the laboratory of the East African Fisheries Research Organization, Jinja, Uganda. A preliminary report follows, and detailed accounts are to be published elsewhere.

I Ecological Section

1. *Pilkington Bay*

Series of samples were taken from Pilkington Bay, especially along the line of gill nets fished in the north west corner and from the Buvuma Channel immediately outside the bay. Phytoplankton was determined quantitatively by the sedimentation and counting technique (Utermöhl 1931, Lund, Kipling and Le Cren 1958). Mr. H. Y. Elder rendered much assistance in the collecting and also carried out oxygen determinations of all the bottom samples A final series of samples was taken in cooperation with Dr. J. Talling.

During most of the period of investigation, the diatom *Melosira nyassensis var. victoriae* was the dominant phytopklanktont. The mean numbers of cells/ml. of *Melosira* (including *M. granulata* and *M. agassizii*) were within the range 350—750 which agrees with the characteristic of 500 cells/ml. given by Talling (1957b) for mid-April 1956. These results do not differ significantly from those of Fish (1957) for 1950 and 1951. In most series of samples wide variations in phytoplankton density were found in the horizontal as well as the vertical plane. There were also wide variations in the nature of the vertical stratification from one station to another for the blue-green algae, (*Lyngbya circumcreta, Aphanocapsa elachista* and *Merismopedia elegans* were the most frequent species) as well as for *Melosira*.

For the lowest samples there was generally an inverse relationship between phytoplankton (largely *Melosira*) density and the concentration of dissolved oxygen. This is to be expected for samples below 5 metres (see Talling 1957a).

There was a marked increase in mean phytoplankton density during May from 400 ± 130 units/2 ml./station (i.e. surface sample plus bottom sample) to 1800 ± 400 units/2 ml./station at the end of the month. In the mouth of the bay, the phytoplankton density at the end of July was 1400 ± 600 units/2 ml./station and in early August it was 800 ± 400 units/2 ml./station with a sparse surface microflora of 33 ± 30 units/ ml./station for the seven stations at the northern end of the line and of 320 ± 100 units/ ml./station for the seven stations at the southern, inner end of the line.

2. *A Phytoplankton Multi-Sampler*

That variations in phytoplankton might be associated with movements of water masses has been referred to by Fish (1957) and Talling (1957b). To investigate this, use was made of a multi-sampler consisting of a raft of "Dexion" alloy-angle constructed during May, with eight attached fine-mesh phytoplankton nets facing eight points of the compass. Preliminary tests were made in Napoleon gulf in conjunction with the use of an Ekman current meter. The phytoplankton multi-sampler was then used in Pilkington Bay where it was found that currents of velocities too low for the Ekman current meter to register accurately (lower than about 5 cm./sec.) could be determined. It was found that after about 2 p.m. there was a surface drift from the south or south west which would tend to bring about an accumulation of phytoplankton in the north-west corner of the bay and also to move phytoplankton from the highly productive shallower regions of the bay to its mouth and from there out into the Buvuma channel.

During the morning, in association with the prevailing winds, the surface water tended to move in the other direction at the mouth of the Bay. It was also found that the composition of the phytoplankton differed according to the direction from which the current was flowing. Generally currents flowing from the north-west into the bay carried up to 95%, by counted units, of *Melosira,* while currents from the north-east carried 70—90% blue-green algae.

3. *Other Samples from Lake Victoria*

Collections were made from 10 other stations at the northern end of Lake Victoria including two open lake stations and stations at Entebbe and Kisumu. A general feature of these samples was the apparent scarcity of desmids, only ten species being listed, including *Cosmarium cunningtonii, Euastrum engleri,* three of *Closterium* and five of *Staurastrum.* For these genera van Meel (1954), for the lake as a whole, listed, respectively, forty-five, eight, fifteen and forty species and varieties. Although it is likely that one not specially concerned with desmids would miss some of these forms, it is possible that there has been a decline in the Desmid flora. That the diatom flora of Napoleon Gulf might also have undergone some change in the last ten years has been suggested to me by Mr. Ross of the British Museum who noted a lack of smaller diatoms after a preliminary observation of a fine-mesh net collection sent to him in May 1960. The significance of these changes, if they are real, is obscure. There has possibly been a change in productivity associated with the decreasing *Tilapia* population (E.A.F.R.O. Ann. Rep. 1956/57).

4. *Other Lakes and Fish-ponds*

Collections were made from Lakes Albert, Edward, Nakuru, Elmenteita, Naivasha and Kioga. Most attention was paid to Lake Kioga from which in mid-May 22 new records of algae were listed. In mid-August a series of collections was made from Kelle, in one of the north-east arms of Lake Kioga to a point 26 miles to the south-west where the Victoria Nile opens out into the lake. Temperatures and conductivities were recorded and samples taken for chemical analyses and phytoplankton counts. In the laboratory, sulphates were determined while silica, phosphate and nitrate determinations were made by Mrs. Talling. Conductivity fell from 300 megohms $^{-1}$ at Kelle to 100 megohms $^{-1}$ in the Victoria Nile while silica fell from 25 p.p.m. SiO_2 to 2.8 p.p.m. SiO_2. Both phosphate and nitrate were low but sulphate was present in detectable amounts with 10 p.p.m. at Kelle falling to 3.2 p.p.m. in the Victoria Nile. The two main constituents of the phytoplankton varied inversely with each other. *Lyngbya limnetica* decreased from about 1500 filaments per ml. at Kelle to 15 filaments per ml. in the Victoria Nile, while *Melosira* increased from a mean of 2.5 cells per ml. in the lake samples to 200 cells per ml. in the Victoria Nile. The waters of eastern Lake Kioga, then, differed markedly at the time of sampling from the waters coming down from Lake Victoria.

Collections of algae were made from fish ponds at Kajansi, near Entebbe in cooperation with Mr. H. Simpson of the Game and Fisheries Department, from the "prison pond" at Jinja, and from some of the ponds at Sagana in Kenya. The Kajansi ponds were notable for the density of their phyto-flagellates, e.g. more than 11,000 cells per ml. of *Trachelomonas volvocina* in pond A/4 at the end of April. The pond at Jinja was dominated by a series of blue-green algae, and *Melosira* was virtually absent. This is interesting in view of the report that it was possible to grow *Tilapia esculenta* in this pond in 1959 (E.A.F.R.O. Ann. Rep. 1959). None of the Sagana fish ponds was densely populated with algae at the time collections were made (early July) while Pond A, which was sampled at its outlet, apparently contained no planktonic algae. The herbivorous fish grown in this last pond would presumably rely upon macrophytes and their attached algae for food.

6. *Gut Contents of Tilapia*

Some very short studies were made of the gut contents of *Tilapia*, and for *T. esculenta* in the "prison pond", Jinja, it was found that while species of *Melosira* were not found in water samples from the pond and were apparently absent from the diet, three species of the Cyanophyceae (*Anabaena circinalis, Oscillatoria ornata* and *O. tenuis*) in addition to *Nitzschia acicularis*, were being utilized. When, two months later, the three species of the Cyanophyceae had disappeared from the pond *T. esculenta* was found to be utilizing *Anabaenopsis tanganykae* thus showing a degree of adaptation apparently unsuspected by Fish (1955). More detailed work in this aspect of fish biology aided by the construction of experimental ponds at Jinja would, it is felt, be well repaid.

Fish in Lake Naivasha which were at first thought to be hybrids between *T. zillii* and *T. nigra*, and backcrosses, but which, it has been suggested to me in a recent private communication from Mr. P. Whitehead, might be *T. leucosticta*, were found to be phytoplankton feeders as is *T. nigra*.

II Culture Work

Cultures of Lake Victoria phytoplankton were investigated by adding various concentrations of potassium nitrate, di-potassium hydrogen phosphate and magnesium sulphate to the samples. For *Melosira*, the results indicated that the limiting factor was not sulphates but phosphates, so that although sulphates might be a limiting factor for the test algae used by Fish (1956), they are not so for *Melosira*, a major constituent of the Lake Victoria phytoplankton.

The blue-green algae appeared to be unaffected by additional nutrients while Chlorococcales present in the original inocula increased in all cultures indicating that for this order at least the concentration of sulphate in Lake Victoria is as important a limiting factor as that of nitrate and phosphate. A detailed account of this work is in press.

III Systematic Work

Collections of algae were made from rivers, rock pools swamps and ponds and many algae, especially flagellates, which are new records for Central East Africa, were found. These algae, and new varieties and species which are finally being identified in the U.K., are to be described in separate publications.

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APPENDIX K

PRODUCTIVITY OF PHYTOPLANKTON

by J. F. Talling

A visit to Jinja for one year is enabling a study to be made of the quantities of planktonic algae, and their activities, in several East African lake waters. Where possible three complementary approaches are being used. The direct counting of individual species is essential for many purposes, but such counts are often difficult to transform into some more general measure of biomass. One measure, the chlorophyll content, is being estimated using methanol extracts of the plankton. Lastly, the photosynthetic activity of the algae is being measured from the oxygen evolution observed in field experiments of short duration—(1—3 hours). A comparison can be made between these results and others obtained from temperate lakes. In this way it is hoped to illustrate the consequences of some distinctive tropical conditions, particularly the high temperature and potentially continuous growing season. Attention is also being given to the general background of physical and chemical limnology, particularly effects associated with seasonal changes of stratification in Lake Victoria. Estimations of three important plant nutrients—nitrate, phosphate and silica—are being made by my wife. A generous grant by the Royal Society has enabled a spectrophotometer to be used in this work and in chlorophyll estimations, and for a thermopile to be applied in the measurement of solar radiation.

Measurements of photosynthetic productivity have now been made in various parts of Lake Victoria. At first they were restricted to the marginal waters of Pilkington and Grant Bays, as the densities of algae in the open waters of the main lake were believed to be too low to give readily measured activity. However, chlorophyll estimates showed values for the open lake often equal to, or even exceeding, those obtained for the bays, and later measurements of photosynthesis confirmed the unexpectedly high productivity of the open lake water. Even higher values of photosynthetic productivity were obtained from a station in the Kavirondo Gulf, where the density of phytoplankton was also unusually high. There is evidence that the maximum rates of photosynthesis per unit quantity of algae are appreciably higher than those usually recorded from temperate waters. Support is thereby given to a tentative conclusion reached from my earlier work in Africa during 1953—1956, in which the quantities of algae were assessed on a basis of cell volume.

The variation of algal numbers with depth and time is being followed for the more abundant species at an offshore station in Lake Victoria. Species which are particularly characteristic of the upper, middle and lower layers can be distinguished, and some conspicuous successional changes have appeared in which the genus *Anabaena* played a prominent part. During the period August—December a progressive increase in thermal stratification has affected the vertical distribution of both algae and such chemical quantities as dissolved oxygen, pH, and the plant nutrients nitrate, phosphate and silica. The sensitive spectro-photometric measurement of these nutrients has yielded new evidence on the significance of small thermal discontinuities in the general pattern of circulation in the lake.

A visit to Lake Albert in November 1960 made possible some work on the general hydrology, chemistry and algology of this lake. The composition of the phytoplankton was very different from that in Lake Victoria, but a field experiment indicated a photosynthetic productivity of a similar magnitude to that found in Victoria. Samples from Lake Naivasha, obtained through the co-operation of D. J. Garrod and H. Y. Elder, have also been examined quantitatively for phytoplankton and various chemical properties.

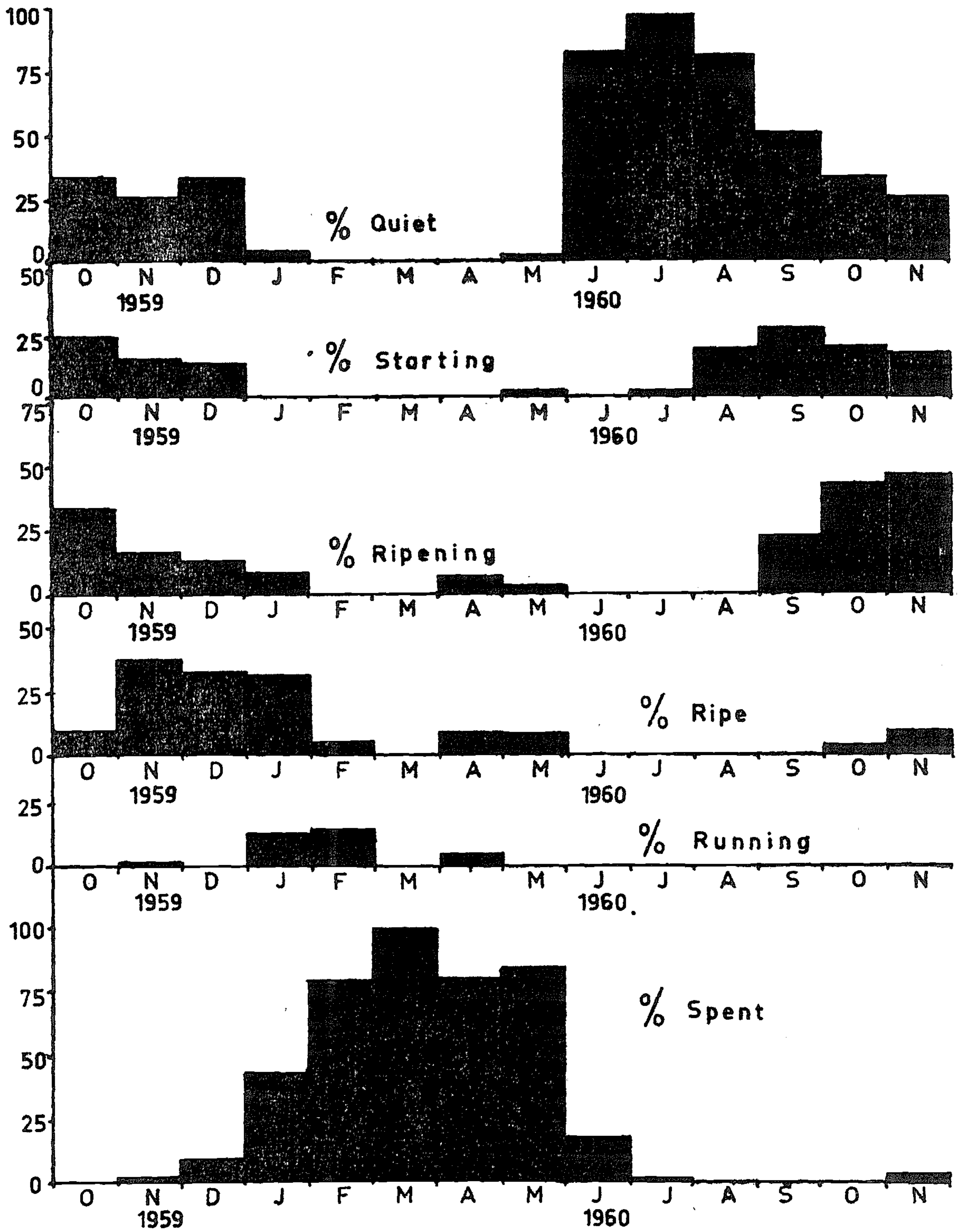

Fig. 1 The breeding season of Bagrus docmac in the Jinja area of Lake Victoria, from examination of the gonads of C. 1,000 mature fish.

TABLE 4

LABORATORY EXPERIMENTS ON THE GROWTH OF *TILAPIA SPP.*

THE EFFECT OF LIGHT AND TEMPERATURE ON THE GROWTH OF *T. ZILLII* ATTAINED AFTER EIGHT MONTHS

			Growth in length cm.			Growth in weight gm.			Dissected Fish					
Tank	Light Microamps	°C	Max.	Av.	Min.	Max.	Av.	Min.	% Mature Males	% Mature Females	Av. wt. gm. Mature Males	Av. wt. gm. Mature Females	% Male	% Female
I	Dark 1.5 (x1)	23-24	16.7	10.1	5.7	109.0	30.0	3.6	100	Nil	33.9	—	80	20
II	Night bulb 5.8 (x1)	23-24	14.0	9.8	7.0	64.5	24.2	6.9	100	100	32.7	27.5	50	50
III	60W. 5.3 (x10)	23-24	14.8	10.6	3.8	77.0	32.3	1.0	100	100	28.2	22.5	70	30
IV	100W. 7.2 (x10)	23-24	14.6	11.2	5.7	72.0	34.2	3.4	100	100	32.5	26.0	40	60
V large	Night bulb 4.5 (x1)	23-24	15.2	9.7	4.7	84.0	25.5	1.7	100	100	29.5	25.6	60	40
VI	Night bulb 4.5 (x1)	18-20	7.7	5.5	3.7	9.7	3.5	1.0	Nil	Nil	—	—	50	50
VII	Night bulb 5.0 (x1)	21-22	14.9	9.6	5.8	75.2	23.4	3.8	100	100	28.2	21.9	80	20
VIII	Night bulb 4.5 (x1)	25-27	16.3	10.9	5.2	92.5	29.5	2.5	100	80	32.1	33.9	50	50
IX	Night bulb 4.8 (x1)	29-31	18.7	12.4	5.5	160.0	47.7	3.3	100	100	40.2	50.1	20	80

TABLE 5 (a)

T. ZILLII — AVERAGE GROWTH IN WEIGHT (gm.)

	TANK								
MONTH	I	II	III	IV	V	VI	VII	VIII	IX
1	.01	.01	.01	.01	.01	.01	.01	.01	.01
2	.51	.34	.60	.53	.40	.08	.29	.84	3.10
3	1.09	.90	.91	1.18	.98	.16	.79	2.19	7.00
4	2.97	2.39	2.36	2.38	5.04	.57	2.2	8.0	11.1
5	7.0	7.0	8.8	6.5	10.8	1.4	6.0	16.5	19.0
6	14.2	12.4	16.8	16.1	15.6	2.3	10.1	20.6	25.1
7	20.5	18.0	23.7	25.4	20.5	2.6	13.2	25.7	40.1
8	30.0	24.2	32.3	14.3	25.5	3.5	34.2	29.5	47.7

TABLE 5 (b)

T. ZILLII — AVERAGE GROWTH IN LENGTH (mm.)

	TANK								
MONTH	I	II	III	IV	V	VI	VII	VIII	IX
1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
2	29.9	25.3	28.1	30.1	27.5	15.1	24.4	34.1	52.6
3	37.0	34.3	36.5	38.6	35.3	22.4	33.0	45.3	68.9
4	48.2	46.3	46.4	45.5	60.3	30.7	44.4	69.1	77.0
5	61.6	65.0	67.0	63.5	78.7	40.8	60.9	91.0	91.8
6	78.0	81.0	81.7	86.1	83.1	49.0	74.1	96.6	101.1
7	89.0	91.1	96.0	103.0	91.7	51.2	81.7	103.5	114.8
8	101.0	98.0	106.0	112.0	97.0	55.4	96.0	109.3	124.0
°C	23/24	23/24	23/24	23/24	23/24	18/20	21/22	25/27	29/31
Light Microamps	1.5 x1	5.8 x1	5.3 x10	7.2 x10	4.5 x1	4.5 x1	5.0 x1	4.5 x1	4.8 x1
	Dark	Night Bulb	60W	100W	Night Bulb	Night Bulb	Night Bulb	Night Bulb	Night Bulb

TABLE 5 (c)

T. ZILLII — $\sqrt[3]{\text{WEIGHT}}$ (gm.)

	TANK								
MONTH	I	II	III	IV	V	VI	VII	VIII	IX
1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2	.80	.70	.84	.81	.74	.43	.66	.94	1.44
3	1.00	.96	.97	1.06	.99	.54	.92	1.29	1.91
4	1.44	1.34	1.33	1.34	1.71	.83	1.30	2.00	2.22
5	1.91	1.91	2.06	1.87	2.21	1.11	1.82	2.55	2.67
6	2.42	2.31	2.56	2.52	2.50	1.32	2.16	2.74	2.93
7	2.74	2.62	2.87	2.94	2.74	1.37	2.36	2.95	3.42
8	3.11	2.89	3.18	3.25	2.94	1.52	2.43	3.09	3.63

TABLE 5 (d)

T. ZILLII — **POPULATION DENSITY.**

	TANK								
MONTH	I	II	III	IV	V	VI	VII	VIII	IX
1	50	50	50	50	50	50	50	50	50
2	50	50	50	50	50	20	50	50	50
3	50	50	50	50	50	20	50	50	50
4	50	50	50	50	50	20	50	50	50
5	40	31	33	23	50	20	50	50	50
6	33	22	25	16	50	20	37	50	50
7	30	22	20	15	46	20	35	50	50
8	26	17	19	15	46	16	34	50	49