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# THE ESTABLISHMENT OF A COMMERCIAL FISHERY FOR HAPLOCHROMIS IN THE UGANDA WATERS OF LAKE VICTORIA

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This memorandum is a brief summary of work, past and projected, on the problem of the establishment of a commercial fishery on Lake Victoria.

## I. BACKGROUND

### i) The Problem

Lake Victoria, straddling the Equator, is the second largest lake in the world, with a surface area of approximately 26,000 square miles (41,500 square kilometres) and a maximum depth of about 300 feet. (Fig. 1.). Uganda possesses most of the north end of the lake which consists of a long, indented coastline and a chain of offshore islands on the edge of a 'continental shelf' separating relatively shallow sheltered inshore waters from the deeper open waters of the lake.

At the present time the lake is harvested mainly by a native gill net fishery confined almost entirely to the shallow sheltered inshore waters. The annual production of all species from Uganda waters is in the region of 24,000 tons per annum, and *Tilapia* (Cichlidae) is commercially the most important genus. *Haplochromis*, a close relative of *Tilapia*, but generally much smaller, contributes only a small amount to this annual production; see Table 1, although they are probably the most abundant group of fish present in the lake.

Through international aid programmes Uganda has been offered a canning plant and it is thought that *Haplochromis* is the most suitable type of fish to be utilized by such a plant. The Uganda Fisheries Department are conducting research into processing techniques and marketing and the East African Freshwater Fisheries Research Organization was asked to conduct a survey of the *Haplochromis* stocks of the lake with a view to estimating the ability or otherwise of these stocks to support a commercial canning industry. Two officers of EAFFRO, Dr. J. M. Gee - biologist and Mr. M. P. Gilbert - Experimental Fisheries Officer, were assigned to the survey and work began in 1965.

### ii) *Haplochromis*

The genus *Haplochromis* (Cichlidae) is extremely large and varied. As a result of rapid, adaptive radiation, over 120 species are known to occur in Lake Victoria. They have colonized almost every available ecological niche from marginal papyrus swamps to the deep open waters of the lake, and are able to use almost every available source of food (a whole range of feeding habits is found from generalized bottom feeders and piscivorous predators to very specialized scale scrapers and fry eaters).

The group presents grave taxonomic difficulties, and it is impossible to identify in the field (and often in the laboratory!!) all the species caught. To overcome this difficulty an attempt has been made to recognise broad species groups based mainly on feeding methods and morphology. This however is of doubtful value, particularly with regard to distribution of groups because of the many instances of parallel evolution which are found.

*Haplochromis* are generally small, rarely exceeding 20 cms total length, and with the bulk of species in the size range 8.0 - 15.0 cms total length. They are firm fleshed, spiny with strongly attached ctenoid scales which make their manipulation, particularly in gill-nets, fairly difficult, but delays the onset of decay in tropical conditions for an hour or two compared with such groups as Cyprinidae and Characidae.

The four monotypic genera found in Lake Victoria (*Astatoraechromis*, *Macropleurodes*, *Hoplotilapia* and *Platytenoides*) are included with *Haplochromis* in any results given below. These are taxonomically different from Haplochromis, but from the point of view of canning the differences can be ignored.

iii) Early Fishing Companies

Two other commercial fishing enterprises have been tried on Lake Victoria. Both were failures, but a brief resumé of their activities and mistakes is useful as background information. The first, started in 1949, was essentially a deep water gill-net fishery based on Dagusi Island to exploit the open-water Mormyrus stocks which had been shown to exist on an economic scale. The gill-nets were operated from sailing dhows and the catch dried on the island where a permanent camp was being established. A power boat was used to transport the catch to the mainland and stores and building materials to Dagusi. At the end of 1951 the scheme had to close down as an uneconomic proposition. The catches were only one fifth of what was expected, partly due to migration of fish out of the area at certain times; the loss of weight during the drying process was very high; the marketing of the fish was inefficiently organized and it was found that neither Buganda nor Busoga women would eat the fish owing to a superstition concerning the bearing of children; it was extremely expensive to set up a permanent base camp due to difficulties with transport.

After a further year of research the Uganda Development Corporation attempted in 1953 to set up within two years a viable industry in the same area. The idea here was to trawl for Bagrus and Mormyrus and to process these larger species by kippering (smoking and sun drying) and the Haplochromis in the catches by dehydration and production of fish meal. A suitably equipped trawler, batch dryer, ice plants, cold stores, workshops and generating plants were purchased and installed on Dagusi and a European manager employed. At the end of 2 years the scheme was not commercially viable and it was decided to close it down.

Again the catches of the important species were not as high as expected and long delays in obtaining equipment were encountered. The processes used caused a great loss in weight in the finished product. In the tropical climate the finished product was often bad before it reached the markets. Due to the high percentage of Haplochromis in the catch, dehydrated fish was the main product, for which there was no market. It was impossible for one man to try and set up the base camp and operate the fishing vessel on a commercial basis at the same time.

It would appear that the main reasons for the failure of both these schemes were:- Insufficient basic research into the fish stocks available and absence of small pilot projects; insufficient research into prospective markets; unsuitable methods of processing the fish caught.

iv) The area involved

With regard to the present survey, it was physically impossible to study the whole lake with the resources available, and as it is economically advisable to have the source of supply of raw materials as near the factory as possible, it was decided to limit the survey to an area near Entebbe. This has been examined fairly intensely, first by an ariel survey (January 1965) to obtain a general picture of shore types and any indications of bottom types. A detailed survey using an echo sounder was then made (1965 and early 1966) and depths, bottom types and particularly the limits of 'sandbank' areas have been plotted on a large-scale map. (Fig.2.)

The area of water involved is approximately 880 sq. km and is bounded on the north by the mainland into which extends a very large fairly shallow, mud-bottomed bay (Murchison Bay). On the lake side (south) the area is bounded by a chain of islands on the edge of a 180' shelf. At the eastern and western ends the area is completely open to the main lake. The shoreline of the whole area is highly convoluted with a large number of shallow mud-bottomed, papyrus-lined bays separated by intervening promontories which often continue out into the lake in sand/gravel/rock spits, bar or banks, some of which join together a number of small islands.

A deep channel runs through the area between the mainland and the islands with a general depth of 90 feet. The large mud-bottomed basins between some of the sand bars are usually about 60' deep. The sand banks generally start about 45' down and rise up to the shoreline or to about 18-20' below the surface. The mud-bottomed, papyrus-lined bays have a general depth of 15-30'. It may be said that this area includes more or less all the major habitat types, from the point of view of shoreline and bottom deposits, found in Lake Victoria within 20 miles of the shore, but the whole area can be classed as 'inshore waters'.

v) <u>Use of an echo-sounder</u>

A high frequency, transistorized Furono echo-sounder, suitable for fish finding has been used throughout the present work. The survey of depths and bottom types was based almost entirely on sounder readings. The machine has also been used in conjunction with all fishing which has been done and every effort has been made to connect fishing results with the 'fish' traces produced by the sounder. It was hoped that there would be good correlations between these, and that echo sounder readings could be used eventually to assess types and quantities of fish present, therefore predict catches in any particular area, and possibly make estimates of population density as a whole. Reference to echo soundings is made in the following sections.

## II. GILL-NETTING INFORMATION

i) <u>General</u>

During the hydrographic survey, a small amount of gill-net fishing was done to obtain information on distribution, catches, selectivity and efficiency. However, when it became obvious that the industry would not be based on a gill-net fishery these were discontinued. A standard fleet of gill-nets was used, the detailed specifications of which are given in Table II. Two fleets were used, one surface set and one bottom set, the total made up length of each fleet being 125 yards (250 yards of unmounted netting). When fishing started it was thought that the size range of fish required by the cannery was approximately that caught in the 1½" gill net. Later however it was found the cannery needed fish caught in the 2" net. After the third expedition therefore it was decided to increase the mesh depth of the 2" net from 26 to 52. All results for 2" nets have been adjusted to this specification. This was found possible without seriously affecting the results. The method of setting was standardized as was the duration of fishing. The fish were extracted as soon as possible, counted, the fresh weight (lbs) recorded and sampled for length frequency and species analysis.

An attempt was made to make at least 2 fishings from each of the broad ecological habitats encountered, which were as follows:-

1. Inshore bays usually with mixture of papyrus and dead tree shoreline, mud-bottomed with depth of water varying from 14-30'. In these areas the fish traces produced on the echo-sounder were medium to light.

2. Semi-open water - between the mainland and the offshore islands. Depth of water 60-90' with a bottom of soft colloidal mud. In these areas the fish echoes produced on the sounder are usually light.

3. Sandbank areas as described in Section 1 (iv) - Depth of water 20-45'. The echo traces produced were usually fairly dense to dense and it would appear that there are concentrations of fish in these areas.

4. Narrow steep sided rocky inlet on the south side of Kome Island, open to the main lake. Echo traces very light.

ii) Catch analysis

The data for Haplochromis in twelve experimental fishings (2 in habitat 1; 2 in habitat 2; 7 in habitat 3; 1 in habitat 4) are set out in full in Tables III and IV.

1. From these results it is clear that Haplochromis can be caught in all the habitats sampled.

2. The catch from the 2" bottom set net and the 1" top set net appears to be significantly higher in the semi-open water than in the other habitats sampled. One of the 2" catches in this habitat was very heavy but not enough data are available to determine whether this is normal or exceptional.

3. The catches in the 1" and 1½" bottom set nets and the 1½" top set nets appears to be significantly higher in the sand bank regions than in any other habitat with the exception of the muddy bottomed bays for the 1½" bottom set net. The high figure for the 1½" top set net in the sandy areas is helped by one exceptional catch which was over twice as large as the other six catches in the area.

4. The catches from the 2" top set nets are fairly uniform in all environments comparatively low in numbers, but average in weight compared with the other net sizes.

It is also clear that the Haplochromis catches in gill nets do not correlate closely with the fish traces produced on the echo sounder. Theoretically far more fish should be found in the sand bank habitat than in the other habitats, but this was found not to be so. It may be the behaviour pattern of fish shoals described elsewhere (EAFFRO Ann. Rep. 1966) which make it impossible to correlate daytime shoaling distribution and night-time gill-net fishing. It may also be that the majority of fish which show up on the echo trace are not Haplochromis, but some other fish species (see below) or some other types of organism altogether.

iii) Selectivity

The total lengths of a sample of fish from each top and bottom set net size from each fishing were determined. The percentages of each 0.5 cm size group for each net were plotted as cumulative totals and the resulting graph is shown in Figure 3. The length-frequency of each mesh size varies considerably between bottom nets and surface nets. The size caught in the 2" mesh bottom net is from 12-20 cms with a mean of 15.0 cms, while the range for the 2" surface net is from 13.5 cms to over 20 cms with a mean of 17.5 cm. The length frequency of the 1½" top set net overlaps that of the 2" bottom set net to a considerable extent; in fact 60% of the fish caught in the former overlap the size range of the latter. Therefore if a 2" gill net fishery were to be established to supply the raw materials for the cannery, it would probably be worth making fleets consisting of 1½" and 2" top set nets and 2" bottom set nets.

The length frequency discrepancy between surface and bottom nets of the same mesh size can be explained by reference to Tables V and VI. Table V is a breakdown of the top and bottom set catches for a number of fishings into predatory and non-predatory Haplochromis. It can be seen that the predatory Haplochromis constitute 50% of the total catch in the surface nets and varies between 37% and 84% for each catch. In the bottom nets the predatory Haplochromis formed 11% of the total catch and varied between 3% and 42% for each catch. Gill-net selectivity depends not directly on body length but on shape and measurement of body girth. Therefore a higher length frequency will be obtained when the girth measurement is small in relation to length than when it is large. Maximum body depth is the nearest measurement to girth that is usually taken. Table VI shows that the MEAN values of body depth as a percentage of body length for EACH species of predatory Haplochromis and the overall mean value for predators as a whole is appreciably lower than the corresponding values for non-predators. This means that the same size net will catch proportionately longer predators than non-predators.

iv) Maturity

The maximum size at which the types of fish caught in a commercial fishery become mature is important when considering stock replacement and exploitation levels. Tables VII and VIII give the approximate sizes of sexual maturity for predatory forms (Table VII)and non-predatory forms (Table VIII). All the sizes given here are standard length, so between 1.5 and 4.0 cms should be added to obtain equivalent total lengths. The four common groups of predators in the gill-net catches were:-

1. *H. bartoni* group - six. mature at approximately 18.0 cms T.L.
2. *H. macrognathus* group " " " " 15.0-16.0 cms T.L.
3. *H. squamulatus* " " " " 14.0 cms. T.L.
4. *H. guiarti* " " " " 12.0 cms. T.L.

Figure 3 shows the range of sizes caught in the 2" surface net is from 13.5 to 20.0 cms. Approximately 50% of this catch will be predators which for reasons given above will be in the top half of this size range, i.e., over 16.0 cms. The greater proportion of these fish therefore will be sexually mature. The size range of the 1½" top set nets is from 10.0-16.5 cms and therefore a large number of these predators are likely to be immature or just sexually mature. Fishing 1½" top nets may therefore damage breeding stocks.

The most common groups of non-predators encountered in the catches were as follows:-

1. Plant eaters - sex mature at approx. 7.5 - 8.0 cms T.L.
2. Fry eaters " " " " 10.0 - 12.0 cms T.L.
3. *H. chilotes* group " " " " 9.0 - 11.0 cms T.L.
4. General group A " " " " 12.0 cms T.L.
5. General group B " " " " 7.5 cms T.L.
6. General group C " " " " 10.5 cms T.L.
7. Monotypic genera " " " " 11.0 - 11.5 cms T.L.

These groups form the bulk of the frequency curve for the 2" bottom set nets; therefore only the mature section of the population is being fished. The bulk of the 1½" bottom population will also be sexually mature, but these are probably getting too small from the cannery point of view.

It may therefore be assumed, by fishing 2" mesh nets top and bottom set, that firstly only sexually mature individuals are being taken and secondly, with the possible exception of two predatory groups, only a part of the mature population will be fished, leaving a remainder to form a replacement stock and continue propagating the species.

v) Population estimates

An attempt was made to estimate the population of 2" mesh *Haplochromis* by repeated fishing of a particular locality, applying De Lury's graphical method and using the catch from a different mesh size as a standard for mathematical calculations. Since it was impossible to estimate the population of the whole region under consideration because of its large size and variety of habitats, the population of a particular area was estimated and extrapolated to cover all similar areas. Theoretically the locality should be in isolation with no immigration or migration during the experiment. The only factor found which would be in any way limiting was that of bottom type, but even this is not limiting to surface populations. It was decided to try and estimate the population of fish on the sandbanks found in the area. These were well defined during the initial survey and are probably fairly limiting as a number of species are specific to this type of bottom. This however does not apply to all the species which were caught in the bottom nets and is probably related in no way to the species caught in the surface nets.

By the end of the trial it was decided that there were too many unknown factors in the experiment for the results to be regarded with a great degree of confidence. The area fished was too small in relation to the size and configuration of the bank and it would appear that about four times as much gill-net would be required to fish the bank efficiently. Nothing is known of the possible movements of fish (particularly in the surface population) in and out of the area during the time of the experiment. The experiment lasted over one complete lunar cycle, starting on the new moon. This was a mistake as the moon is thought to have some effect on size of catch (particularly in surface nets), larger catches being obtained over the new moon period than the full moon period. It is not very easy to say therefore, whether the decreases in catches and recovery rates observed were a result of fishing effort or just a reflection of lunar periodicity in catches. The information on species composition given below, however, would indicate that fishing effort did play an important part in the changes which took place.

The area chosen was Kisigala Point on Kome Island where a sand bank of small size abuts the shore on one side and is surrounded by mud on the other three sides. A detailed map of the bank is shown in Figure 4. Two fleets of nets were used, one bottom set and one top set, of 500 yards made up length and an additional two fleets of 50 yards of 1" mesh were set on the first two and last two nights of the experiment. The nets were set in the same place (as nearly as possible) every night for 14 nights and the weight of the catch, the number of each species group and the depth of the net for each unit of 50 yards was recorded for each fishing.

The results according to De Lury's method are plotted graphically in figures 5 and 6. (a) A plot of straight catch against accumulated catch gives a wide scatter of points. (b) The graphs are smoothed by applying a 4 cycle running average to the surface catches and a 3 cycle running average to the bottom catches (c) The regression formulae were calculated for these points and are as follows:-

Surface catch y = 682-0.074 x

Bottom catch y = 266-0.048 x

(d) When the regression line is fitted and projected to intercept with the x axis the following population estimates are arrived at:-

Surface 9,250

Bottom 5,500

Calculations according to the following mathematical formulae could be used as we were only interested in the population figure of the 2" gill-net sizes. The catch from the 1" gill-nets which have a length frequency outside that of the 2" range were used as the standards

$$\frac{b_1}{a_1} - \frac{b_2}{a_2} = x \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$\frac{c}{x} = B \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$B + \left(\frac{B \times b_1}{a_1}\right) = T \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

$a_1$ $a_2$ are catches in 1" net

$b_1$ $b_2$ are catches in 2" net at beginning and end of experiment; x is the depletion of b; C is the accumulated catch in the 2" net; T is the total population. When the original figures denoted by crosses in Figures 5 and 6 are subject to these mathematical formulae, the following population estimates are arrived at:-

Surface 12,280

Bottom 5,900

If the mean of these estimates and those arrived at by the graphical method are calculated, they are as follows:-

Surface 10,760 specimens, which had a weight of 1,650 lbs.

Bottom 5,700 specimens, which had a weight of 720 lbs.

which in fact are very close to the figures arrived at if the above mathematical calculations are based on the running averages shown in figures 5 and 6.

The total area of Kisigala Bank is estimated at 2,340,000 square yards and the area of the bank covered by the nets at 160,000 square yards. The total area of sandbank in the region surveyed is 176,688,000 square yards. The extrapolation of estimated numbers depends on what area of Kisigala Bank this population figures is taken to represent. Because the area fished turned out to be so small a percentage of the whole bank (6.8%) it seems unrealistic to apply the population figures to the whole bank. There is evidence to show that the non-predators were fished out quicker than the predators; presumably they are more static and therefore only those in the vicinity of the nets were being sampled. The predators on the other hand were probably being drawn from a much wider area. If the population figures were taken to apply to the whole bank the final estimates are likely to be gross underestimates. If the population figures were taken to apply to the area fished, the non-predator population may not be overestimated, but that of the predators would. It was therefore decided to use as a minimum estimate an area of half the bank as a basis for extrapolation to the sand bank areas as a whole. On this basis the following minimum estimates are arrived at for the sand bank areas in the whole region.

| | | |
|---|---|---|
| Bottom population | = 48.5 tons | = 54.3 short tons |
| Top population | = 112 tons | = 124.5 short tons |
| Total population | = 160.5 long tons | = 178.7 short tons |

Some idea of the level of stabilization of catch can be obtained from figures 7 and 8. Here the catches are plotted against time (days). The projection of the smoothed curves to their asymptote gives some indication of catch levels at which fishing effort and recruitment to the population are balanced. For surface nets this is at a Cpue of approximately 18 and a Cpue of approximately 9 for bottom nets. These figures however are probably of little practical use as they only apply to this standard set of nets in this particular locality.

In order to estimate recovery rates of the population the gill-net fleets were set on two nights in each ensuing week after the experiment. This was only done for two weeks as no boats were available after this time. The results are shown in figures 7 and 8. The surface population showed a fairly rapid rate of recovery in the first week when catches almost reached the pre-experiment level. The catches at the end of the second week show a large difference, but the mean catch is the same as in the previous week and the heavy catch up to the maximum catches obtained during the fortnight of continuous fishing. The bottom population on the other hand showed no significant increase in the first week. However by the end of the second week it had nearly recovered to the pre-experiment level.

During the course of the experiment most of the catches were analysed as far as it is possible in the field into species groups, and certain changes in the species composition of surface and bottom populations can be discerned. By reference to Table IX it can be seen that in both populations the proportion of predators to non-predators changed during the experiment, i.e., the percentage of non-predators in the population decreased. It may be that non-predators are more vulnerable to fishing than predators, or that predators are more likely to be replaced from outside the area fished, i.e., they have greater movement throughout the water body by virtue of their habits. Non-predators are far more abundant on the bottom and more dependent on certain types of bottom for their food. Therefore they do not move about so much and decrease more rapidly in an area which is heavily fished. It should be noted that in the top population, which has a very high percentage of predators the agreement between mathematical and graphical methods of calculating the population is not as good as for the bottom population where non-predators predominate.

Tables X and XI give the breakdown of catches into species groups. The following trends can be discerned:-

PREDATORS - Surface population

(a) Dominated throughout by H. guiarti which shows a percentage increase.

(b) H. mento also shows an increase while H. macrognathus decreases.

(c) H. serranus and H squamulatus groups are always represented but show a relative decrease throughout.

(d) It is interesting to note that H. cavifrons is occasionally found in the surface populations.

- Bottom population

(a) H. guiarti is only rarely found and H. macrognathus and H. mento groups are dominant, the latter increasing throughout.

(b) H. bartoni, H. gowersi and H. flavipinnis are more common on the bottom and maintain a fluctuating level throughout the experiment.

(c) H. cavifrons is more common on the bottom but shows a steady proportionate decrease.

NON-PREDATORS - Surface populations

(a) At best these only form a very small percentage of the surface population and the larval eaters (represented principally by H. obesus) and General Group A are the dominant groups.

(b) It is interesting to note that the mollusc eating species such as monotypic genera and the H. sauvagei group are sometimes found in the surface population.

- Bottom populations

(a) Dominated throughout by General group C, mainly represented by the H. riponianus/H. saxicola complex, this group maintains a high fluctuating percentage.

(b) The monotypic genera, which dominate the mollusc eating Haplochromis-like groups in this area, are present throughout. The percentage of Astatoroechromis increases while that of Macropleurodes and Hoplotilapia decreases. Platytenoides is a rare genus.

(c) H. obesus and associated larval eaters are present and increase in percentage throughout the experiment.

(d) H. chilotes and H. aelocephalus are present throughout but in decreasing proportions.

vi) Production Estimates

The estimates for supplying the cannery by a 2" gill-net fishery on the basis of the present survey have been given in full in a previous report. These need only be summarized here.

(i) The estimated minimum amount of Haplochromis required daily to allow the cannery to operate at a minimum economic level is 1 ton.

(ii) If both top and bottom set gill-nets are used, approximately 5½ miles of each type would be needed. If only bottom set nets are used about 8 miles would be required. These are based on average catches and if minimum catch levels are taken these figures would have to be doubled.

(iii) It is estimated that the labour force required to empty these nets only would be upward of 300 men. It is suggested that the best practical method of organizing a gill-net fishery would be by buying fish from local fishermen using smaller

(iii) (continued)

lengths of net and canoes but fishing specifically for Haplochromis, and collecting the catches in high speed launches.

(iv) It was thought that this type of fishery would in the long run prove uneconomic for Haplochromis on Lake Victoria even though it works reasonably well for Tilapia on Lake George.

vii) Other Species Caught

During the course of the gill-netting programme the discovery of the superabundance in certain habitats of a species of fish other than Haplochromis prompts us to mention them here. Another reason for doing so is that the presence and abundance of these fish has probably not previously been brought to the notice of those responsible for planning the cannery. The species concerned is Alestes sadleri (Nsoga Nsoga), a small species of the family Characidae, which rarely features in the present day commercial catches. Very little is known of its biology, but it appears to be a pelagic shoaling fish inhabiting the inshore and marginal waters of the lake. It is only ever caught in the 1" top set gill-nets and the sex ratio of the catch is very unbalanced, being anything from 6:1 to 100:1, females to males for any catch. This would imply that either females were more abundant than males, or that males were on average too small to be caught even in the 1" gill-net.

The catch records for A. sadleri are shown in Table XII. Two significant points emerge from this table.

(1) It would appear that the catches vary significantly with habitat. They are virtually absent from the deeper more open waters of the region and obviously concentrated in the shallower inshore waters. They are reasonably abundant in the shallow bays and very abundant over sandy bottoms in sheltered areas. The two fishings in exposed sandy areas off Entebbe produced significantly lower catches. This implies that they are sensitive to the degree of exposure.

(2) The catches of Alestes correlated more closely with the density of the echo traces than do the catches of Haplochromis. It may therefore be Alestes sadleri which are responsible for the heavy shoaling traces found in the region of the sandbanks rather than Haplochromis.

## III. TRAWLING INFORMATION

When it was apparent that gill-netting was an inefficient and uneconomic proposition for a fishing industry of the type under consideration, attention was switched to trawling. This however was hampered by the complete lack of suitable boats and equipment for this type of fishing.

(i) Gear Development

The only boat available was an old 38 ft seaplane harbour tender, powered by two Perkins S6 diesel engines with straight through drive to 17/15 propellers. Stern gallows and a 33:1 reduction gear niggerhead winch driven off the starboard engine were designed and fitted. The boat is basically unsuitable for trawling and will not take any weather. Despite two engines, manoeuvring the trawl during towing is difficult because the stern gallows take-off had to be mounted aft of the propellers. However, this craft has been used in all the trawling operations attempted so far.

At present work is proceeding on the conversion of a 48 ft Fairmile fish carrier, powered by a Perkins S6 diesel engine with 2:1 reduction gear box. All the superstructure is being redesigned, a 4 gear Fifer drum winch driven off the main engine installed, aft decks cleared and trawl gallows erected. A mast and boom is also being added for the easier handling of large quantities of fish. This vessel should make an admirable trawler for Lake Victoria and will be ready for operation in early 1967.

The only bottom trawl available was a Vigneron Dahl trawl with an overall length of 6 fathoms, a headrope length of 7.5 fathoms and a footrope length of 7.75 fathoms. The mesh sizes are 2½" in the wings and the square, 2" in the belly and lengtheners and 1" in the cod end. The performance of the trawl was improved by the addition of a bobbin line, the bobbins being 6" diameter wooden rollers spaced along a steel wire with 1" diameter wooden spacers and lead weights. The weights were added in sufficient quantity to make the whole bobbin line just negatively buoyant. Otter doors were made and fitted up in the correct manner for easy disconnections from the trawl warps. These latter were 3" circumference manila rope marked off at 50 foot intervals. The relationship between speed of boat, length of warp and depth of trawl were calculated and tested for this set of gear.

No mid water trawls were available so the authors designed and made a small experimental trawl to their own specifications, illustrated in Figure 9. This is on the lines of the Larson and British Columbian trawls with a square of approximately 2 fathoms each side. The wings are 3" mesh of 48 ply nylon, the square 2½" mesh, the belly 2" mesh of 24 ply nylon, the lengthener 1½" and the cod end 1" 48 ply nylon. This had recently had a ½" cod end put inside. About 14 planet kites and 3 flying kites are used on the headrope and 2 Torpedo shaped lead weights are inserted between the lower wings and the tow legs. The tow legs are 7 fathom warps attached to a depth regulating rings attached to the otter boards. These are scaled down replicas of the wing boards used on the Larson Phantom trawl.

Surface trawling was tried before either midwater or bottom trawling. The net now used for bottom trawling was first tried on the surface. The headline was fitted with corks and five flying kites and the foot line with weights and one steel depressor attached to the foot rope by two lines. Five fathom tow ledgs attached the net to floating otter boards. These were made by attaching 20" x 38" doors to the underside of floating submarine paravanes. When the Vigneron Dahl net was reconverted to a bottom trawl an old Danish Seine was adopted as the surface trawl.

ii) Bottom Trawling

Trials have been carried out in the Jinja area (Ramafuta, Maundu and Namone) and in the Entebbe area (Tavu, Bugalo and Kome). So far however only a total of 14.2 trawling hours has been completed. A general analysis by weight of all catches on the various bottom types is given in Table XIII.

a) Distribution. The figures for catch/trawling hour are most important and these shown an overall catch of 311.8 lbs/hour; the catches on sand are about 40 lbs/hour higher than on mud. The catches produced when both types of bottom were crossed on the trawl haul (usually at the same depth) have a catch per hour as for sand, but have more of the characteristics of the mud bottom fauna.

*Haplochromis* are by far the most common genus caught in all habitats and localities sampled. In two hauls, one over sand and one over mud they were the only fish caught. Over a sand bottom they form 90% of the catch on average (292.7 lbs/trawling hour). On mud bottoms other genera are more prominent and Haplochromis only form 72.5% of the catch (208 lbs/trawling hour). These percentages are influenced by two large catches of Tilapia (one in 45' and the other in 60' of water) and two fair catches of Bagrus over a mud bottom. Although most of the hauls on sand were not as deep as those on mud, depth doesn't seem to affect the percentage composition of the catches, but it may affect their magnitude (i.e. catch/hour figures). Areas of mud bottom in deeper water have not yet been sampled. The overall percentage of Haplochromis in all catches is 83% (259 lbs per trawling hour).

Tilapia were caught in both habitats but the species caught on sand were almost entirely T. zillii and T. variabilis. The latter species formed the bulk of the catch and were nearly all in breeding condition. The T. zillii were generally small but in good condition (a very convex belly line). Small numbers of Tilapia came in regularly with each haul. The species found over the mud bottom was T. esculenta. Their breeding condition was not determined but their distribution was much more irregular. 30% of the hauls on mud contained no Tilapia and 35% contained only one or two. Two larger catches were obtained in the Entebbe area (one of 137 and another of 211 individuals) when a particular type of echo trace was fished - see below and 28 were caught in a haul off Namone over a similar trace.

Bagrus docmac is the other species which formed a significant percentage of the catches on both sand and mud. Again their appearance on sand was very regular but in small numbers, whereas on mud their distribution was sporadic, two heavy catches making up both their percentage and catch/hour contribution. They were most abundant however in hauls over both mud and sand when good catches were obtained in two out of the three hauls made.

Table XIV is an attempt to compare catches in different areas of similar bottom types. The fishing effort however is not proportionate which makes comparison dubious. The sand bottom at Ramafuta, near Jinja, produced similar catches of Haplochromis to the comparable environment at Tavu near Entebbe, although Tilapia and Bagrus formed less significant parts of the catch. The catches at Nzadzi (off Entebbe) were much lower than in the other two areas and two poor catches of Haplochromis were obtained. Bagrus was the only other species caught here. The catches of Haplochromis over mud bottoms in the Jinja and Entebbe areas were very comparable. The differences in total catch/hour are accounted for mainly by the variation in catches of Tilapia and Bagrus. Depth does not seem to have much effect on the catches as a whole.

During the trawling operations off Entebbe, daily trawl hauls were made along a set course across the sandbar between Tavu and Bugalo islands. The mean daily catch/½ hour is shown in Figure 10. On some days only one haul was made and on other days three hauls were made. The results show a cyclical variation in catch with a slight overall decline, rather than a steady decline. These operations were an attempt to assess how much fishing the Haplochromis of a part of one bank could stand. A total of 1,912 lbs of Haplochromis were removed over the period shown without any significant decrease in catch rates.

To summarise the data on distribution and catches therefore it may be said that Haplochromis are abundant in all areas and form the bulk of all catches. Bagrus, Protopterus and small Barbus spp. are also found in all environments. Trawl hauls over sand bottoms are characterized by the presence of T. zillii, T. variabilis (and Barbus altinalis) while trawl hauls over mud are characterized by the presence of T. esculenta, Synodontis, Clarias and Xenoclarias.

b) Length frequency. The total length to the nearest 0.5 cms was measured for a sample of each haul made and percentage frequency curves constructed. Figure 11 is the frequency curve for all catches in the Entebbe area which shows two distinct peaks at 5.0-5.9 cms and 9.5-10.4 cms. The graph levels out at 11.0-12.4 cms indicating another frequency peak at this point, masked by the previous range. 16.6% of the catch occurs in the range 3.0-7.4 cms, 83% in the range 7.5-14.9 cms and 5.1% in the range 15.0-20.4 cms. Occasionally individuals larger than 20.4 cms were caught, but these have been ignored for the purposes of this analysis. Figure 12 gives the length frequency analysis for catches over mud bottoms and sand bottoms in the Entebbe region and these show some striking differences.

Four distinct frequencies are found over the mud bottom:-

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1) | 4.0 - 6.9 cms | with a peak at | 6.6 - 5.9 cms | contains | 13.1% of the population. |
| 2) | 7.0 - 10.9 cms | " " " " | 9.0 - 9.4 cms | " | 51.0% " |
| 3) | 11.0 - 15.4 cms | " " " " | 12.0 - 12.4 cms | " | 27.0% " |
| 4) | 15.5 - 19.4 cms | " " " " | 16.5 - 16.9 cms | " | 8.1% " |

Over the sand bottom relatively few Haplochromis are caught in the size range above 15.4 cms and there is no peak in evidence in this range, but the smallest size range is approximately the same in both environments. There is no clear cut distinction of the middle two frequency groups over sand. The main peak occurs at 10.0-10.4 cms and overlaps considerably a frequency group with a peak at 12.0 cms. The size range 7.0-15.4 cms contains 78% of the Haplochromis population on a mud bottom and 82.5% of the Haplochromis population on a sand bottom, with most of the latter being over 9.0 cms total length. Figure 13 gives the length frequencies of Haplochromis caught over sand and mud bottoms in the Jinja area. Both graphs are based on fewer hauls than those in Figure 12. Over sand (Ramafuta bank) a marked peak again occurs in the 3.0-7.4 cms size range as in the Entebbe area. Only one other range is in evidence however with a more definite peak at 9.0 - 9.4 cms and a much more confined range; no fish were caught over 14.5 cms total length. 80-9% of the population occurs in the size range 7.0-15.4 cms, but only 14.6% of these are over 10.5 cms compared with a similar sand bottom in the Entebbe area where 46.0% of this range were over 10.5 cms. Over the mud bottom no distinct peak at the smaller end of the size range was found, but the two middle peaks were well marked. Here 87.7% of the population were in the size range 7.0-15.4 cms.

It can be seen with reference to Figure 3 that the size range 7.0-15.4 cms T.L., which contains approximately 82% of the catch, covers the whole size selection range of 1" and 1½" bottom set gill nets and 58% of the selection range of the 2" gill net, but the trawlfrequency peaks fall between the selection peaks of these three net sizes. By using the percentages of each 0.5 cms group caught in the 2" gill nets (Figure 3), the catch figures obtained for Haplochromis in the population experiment on Kisigala Point and the catch frequencies for the trawl hauls over sand, it should be possible to calculate the approximate numbers of Haplochromis present in the sand bank areas which might be caught in the trawl. This however would involve too much extrapolation from an original small amount of data for the end result to be anything like reliable.

c) Maturity. Size of sexual maturity of Haplochromis are as important a consideration in a trawl fishery as in a gill-net fishery. A trawl however is only partially selective at one end of the size range (the smaller) unlike a gill-net which is completely selective at both ends of the range. The maturity states of Haplochromis in only one trawl haul, from 66 ft over a mud bottom, have so far been determined and these are given in Figure 14. The gonad states have been divided into three groups, immature, maturing when the gonads are beginning to form for the first time, and mature when the gonads are fully formed but the fish may not have bred yet. Figure 14 shows that all Haplochromis below 5.0 cms are immature, that no Haplochromis below 7.0 cms are mature and that all Haplochromis caught in this trawl were mature at 9.5 cms but had not necessarily bred; one female of 9.8 cms was found to be ripe running. 50% of the fish were immature/maturing at 6.75 cms and 50% were maturing/mature at 8.0 cms. This would indicate that all fish below 8.5-9.0 cms should be eliminated from the trawl hauls if possible. This involves determining the escapement factors for various mesh sizes of cod end.

d) Escapement factors. So far the trawl has been used with a 1" mesh cod end (1/2" bar). The escapement factors for this cod-end have been determined using an outside bag of 1/2" mesh. As this was towed only once over a mud bottom, the mean of four similar mud hauls with the 1" bag were used to determine the retention sizes. Figure 15 shows a 50% escapement from the 1" bag occurs at 5.2 cms, a 75% escapement at 4.7 cms and 100% escapement at 3.5 cms. The degree to which the cod end is filled however alters these percentages a certain amount. The cod end will therefore probably have to be of 1 1/2" or 2" mesh to allow all fish below 8.5 cms to escape.

e) Echo sounding. The echo sounder was used on all occasions in conjunction with the bottom trawling operations. It was hoped that some correlation could be obtained between catches and echo traces and echo soundings then used as a means of estimating quantities of fish present in the area and the amount of fish which could be obtained for the cannery.

For the purposes of correlating echo traces with catch on a sand bottom only Haplochromis was considered as it forms 85% of all catches, the numbers and weights of other genera being insignificant. The catches of Haplochromis were calculated as lbs/30 min. haul and the traces arranged in order according to the catch weight. When this was done it was very apparent that there were no correlation between density of bottom traces and catch. The five heaviest catches of Haplochromis were made on traces with very few fish marks near the bottom. An intermediate size catch and the smallest catch of all were also made on similar traces. The two heaviest traces in the series came at the top of the intermediate catch range. The sixth heaviest catch and all others were made on medium density traces. It is fairly apparent therefore that the traces produced were not principally of Haplochromis and there are therefore 3 main alternatives.

1. That the visible traces were from shoals of fish too small to be retained in a 1" mesh cod end.

2. That they were made by some organism other than fish - plankton being the most likely.

3. If however, the echo sounder would pick up either of the above items it should also pick up the Haplochromis caught in the trawl. Most of these however are bottom feeding forms, mollusc eaters, insectivores and bottom detritus feeders. They will presumably therefore be in close contact with the bottom and if this is so they will be very difficult to distinguish (if it is possible at all) from the bottom echo itself. This hypothesis is borne out by observations made

3. (continued)

by the authors over a sand bottom using an aqualung. Large numbers of Haplochromis are often seen within 6" to 1' off the bottom or actually resting on the bottom, but if the diver pauses for any length of the time in mid-water, very few if any Haplochromis are ever encountered.

Little or no correlation between density of echo trace and catches of Haplochromis was obtained over a mud bottom. In these hauls however, other genera, particularly Tilapia sometimes featured prominently and some correlation between type of echo and genera caught was obtained. A very fine diffuse trace was often present over the mud bottom up to about 15 feet from the bottom. Sometimes nothing else was superimposed on this, sometimes it was patchy and on two occasions fairly heavy comet shaped strikes were found in the background feather. On these two occasions large catches of Tilapia esculenta were obtained, whereas the occasional one or two only were caught on the other diffuse traces. Here the hypothesis is that these large diffuse traces are dense concentrations of Melosira - a silicaceous, filamentous diatom and that sometimes large shoals of T. esculenta can be found feeding on them. T. esculenta is a phytoplankton filler feeder in which Melosira forms a significant quantity of the stomach contents, usually around 20% by weight (Welcomme - pers. comm). One trawl haul in the Jinja area through a fine feather trace produced similar results. A higher catch than normal of T. esculenta was obtained; the guts of these fish were very full and analysis showed that Melosira formed 80% of the total contents. Other evidence that many of these traces may in fact be aggregations of plankton was noticed while diving off Ramafuta Island in an attempt to identify some traces seen on the echo sounder. They were very similar to those described above but rather patchy. On two successive dives no fish were seen but water masses where the light intensity was drastically decreased were passed through at the same depth as the traces produced on the sounder. These facts are strong corrobrating evidence for the above hypothesis and it is hoped that plankton analysis of water samples taken in and above these types of traces will give more direct evidence.

iii) Mid-water trawling

So far this gear has been relatively unsuccessful in terms of catching fish. A number of hauls were made in the Entebbe area but the behaviour of the trawl was not completely satisfactory and the depth of fishing very uncertain. The boards, when given a steep diving angle, appeared to be fishing at approximately the correct depth (as shown when the echo sounder was used to locate the trawl under water) but this made them very unstable. Recently the diving angles have been reduced again and extra torpedo shaped lead weights fitted to the net.

Small catches were obtained on a number of occasions, the main genus caught being Engraulicypris. This is a pelagic shoaling fish and thought to occur in large quantities in the lake, but little is known of its biology. The length frequencies of the catches varied considerably; sometimes a large number of extremely small individuals were caught and at other times a smaller number of large individuals. It is hoped that as the trawl is made to work more efficiently and when a much larger trawl is employed, these fish may be caught in sufficient quantities to make a worthwhile economic proposition.

Haplochromis were the other main constituent of the catch but on the whole were very few in number and only a few ounces in weight.

One one occasion a fair number of very small, immature specimens, were caught, otherwise only 2 or 3 came up with each haul.

No correlation with echo traces can as yet be made because of the uncertainty as to the fishing depth and efficiency of the net as well as the very poor catches obtained.

iv) Surface Trawling

This method, the first to be used, has only been tried in the Jinja area with the trawl described in Section III. A number of trawl hauls were made in different localities and have been grouped as in Table XV. The range of species caught is much smaller than with bottom trawling and Haplochromis were again the most important genus, forming overall, 90% of the catch. Surface trawling however was by no means as productive as subsequent bottom trawling, producing an overall catch/hour of only 21.3 lbs of Haplochromis and an overall total catch/hour of 24.3 lbs, Alestes jacksoni, Alestes sadleri and Engraulicypris being the only other species which occurred regularly.

A sadleri was absent from all hauls made in water over 30 feet, i.e., Buvuma channel and Lufu. The total weight contribution of these species in terms of catch/hour is negligible. The odd specimen of Clarias was caught in some trawl hauls, but again they formed an insignificant item from the commercial point of view.

The length frequencies of Haplochromis from the surface trawls are shown in Figure 16. The inshore fishings in shallow water in Napoleon Gulf and Grant Bay have been lumped together as have the fishings in deeper water in Buvuma Channel and Lufu Island. These length frequencies show a completely different pattern to those for bottom trawling with a slightly skewed, more normal distribution about a single peak. Unlike bottom trawl catches the contribution made by fish at the lower end upper ends of the size range is negligible. Slightly larger specimens were obtained over deeper water than in shallow water. The 10 and 90 percentiles for deep water catches occur at 9.0 cms and 12.25 cms and those for shallow water catches at 8.3 cms and 11.7 cms. No trawling has been done in the Entebbe area but in view of the high figures obtained in some of the gill-nets (particularly 2" mesh) it might be expected that surface trawling would give slightly better results in that area.

There are certain advantages in surface trawling over bottom trawling. The size range of Haplochromis caught is much smaller and therefore easier to handle from the cannery point of view. Surface trawling gear could be expected to be cheaper and last longer than bottom trawling gear. In our opinion however, these advantages are far outweighed by the disadvantages involved. All surface trawling has to be done at night, trawl hauls made during the day being invariably negative. The method of fishing is haphazard, and little or no help can be gained from the use of an echo sounder because of the phenomenon of 'shoal' dispersion at dusk dscribed by the authors elsewhere. The catches of Haplochromis are very small compared with bottom trawling, too small in fact to be economically worthwhile on the present data.

v) Other trawling results

As mentioned in Section I trawling has been attempted previously on Lake Victoria, but not for the specific purposes of using the Haplochromis in the catches. S. H. Deathe using the M.V.'Ningu' trawled extensively off South Dagusi in waters over 60' deep. No detailed results are available but the following are his total catch figures for all species in 1954:-

| | | |
|---|---|---|
| January | 50 hours | 11,376 lbs. |
| February | 54 hours | 11,240 lbs. |
| March | 46 hours | 8,241 lbs. |
| April | 17 hours | 2,268 lbs. |
| May | 58.5 hours | 11,943 lbs. |
| TOTAL: | 225.5 hours | 45,068 lbs. |

These results produce a total catch/hour of 199.8 lbs. He reported that Haplochromis formed approximately 66% of the catch which would give a catch/hour of approximately 133 lbs.

The trawling results of EAFFRO in 1950-51 and the Lake Victoria Fisheries Service are much better documented. A summary of the Haplochromis catches are given in Table XVI. Most of the trawling by EAFFRO was done in the region of Buvuma Island and the more offshore islands in the Jinja area and the LVFS trawling results are mainly from the offshore islands in the vicinity of Entebbe and the open lake. Unfortunately no information is available on the size of trawl used but it was probably of similar proportions to the one employed in the present survey. Some high mean catch/hour figures were obtained by EAFFRO and although the LVFS figures are generally much smaller, they both show that large catches of Haplochromis can be obtained in waters of intermediate depth, i.e., between 30' and 120'. Over this depth there appears to be a rapid decrease in catch down to 200'.

Both organizations were of the opinion that these results confirm the suspicion that very few fish are likely to be found in the deeper waters of the lake. A few Synodontis were caught in water over 200' deep, but not in sufficient quantity to be commercially important. The trawling results of the LVFS did however indicate that large shoals of Engraulicypris were often encountered in the surface waters of the open lake down to a depth of 60'-70', particularly at dawn and dusk. For the harvesting of these however they recommended the use of a 300-500 yard 1/4" mesh purse seine, about 90' deep.

Most of the EAFFRO trawling was done over a mud bottom and the genera other than Haplochromis in the catches were very similar to those given in the present trawling results. Tilapia, Bagrus and Clarias were the three most important genera but Mormyrus which we have not had so far in a trawl, featured fairly prominently in about 10% of the catches.

A Kelvin Hughes M.S. 24 echo sounder was used aboard the M.V.'Ningu' by the LVFS. Although this is a low frequency sounder (30-50 Kc/s) compared with the Furono used at present, their results were just as difficult to interpret. They could find no correlation between echo trace and trawling results and found that anyway these results varied tremendously in different areas of the same type. Because of the little discernable pattern in their results they doubted whether a mechanised trawl fishery could be made to work economically.

vi) Estimates

a) Production. These production estimates are based on the overall catch figures obtained during the present survey with the present trawl. Most of the area has a mud bottom but most of the trawling has been done over sand banks (and one in particular) which appear to be more productive of Haplochromis than mud bottoms. The present survey catch figures may therefore be rather high.

Because of this production estimates are first presented based on the trawling figures of Deathe over a mud bottom off S. Dagusi and on calculations set out in Board Memorandum 34 of the Busoga Deep Water Fishing Company Ltd., 1954. Their basic premises are:-

(i) Not more than 85% of experimental catches could be expected in a commercial fishery - They therefore work on a commercial catch of 170 lbs/hour.

(ii) The annual trawling time which could be maintained is 1550 hours.

(iii) Haplochromis on average formed 66% of the catch.

On the basis of these premises they estimated the annual landings per trawler to be:-

| | |
|---|---|
| Total: | 117.5 tons |
| Haplochromis: | 78 tons |
| Others: | 39.5 tons |

and on the basis of operating a varying number of trawlers the annual estimated production was:-

| Trawlers | Haplochromis | Others | Total |
|---|---|---|---|
| 5 | 388 tons | 199.5 tons | 587.5 tons |
| 10 | 775 tons | 400 tons | 1,175 tons |
| 15 | 1,165 tons | 597.8 tons | 1,762.5 tons |

This commercial enterprise was more interested in the other genera in the catches than in Haplochromis which they intended to process by dehydration. This gives only a 20% recovery rate by weight in the finished product. They therefore estimated that between 3 and 4 million lbs of fish must be caught annually to put the business on a sound economic footing.

Canning of Haplochromis is less wasteful than sundrying or dehydration as the recovery rate by weight of the finished products has been given by Beatty in his report on the 'Utilization of Haplochromis' as 48%. Assuming Haplochromis are packed in 6 oz cans the following approximate estimates, based on the above catch figures, of the number of cans produced annually is as follows:-

| Catch | Finished product | No. of cans/annum | No. of cans/day |
|---|---|---|---|
| 390 tons | 187.2 tons | 1,400,000 | 5,600 |
| 780 tons | 374 tons | 2,800,000 | 11,200 |
| 1,170 tons | 560 tons | 4,200,000 | 16,800 |

It is interesting to note that the estimates made for gill nets above are based on a production rate of 2,400 cans/day. Therefore to equal the production of five trawlers (employing 20 men) all the figures given for gill nets would have to be more than doubled.

The annual production using the figures obtained in the present survey on the same basis of trawling hours, numbers of trawlers and percentage reduction in catches is given below:- The commercial catch per hour is calculated at:-

| | |
|---|---|
| Total: | 257 lbs |
| Haplochromis | 218 lbs |
| Others | 39 lbs |

The annual production per trawler working 1550 hours per annum therefore is calculated at:-

| | |
|---|---|
| Total: | 177.8 tons |
| Haplochromis | 150.8 tons |
| Others | 27 tons |

and on the basis of operating a varying number of trawlers the annual estimated production is:-

| Trawlers | Haplochromis | Others | Total |
|---|---|---|---|
| 5 | 754 tons | 135 tons | 889 tons |
| 10 | 1,508 tons | 270 tons | 1,778 tons |
| 15 | 2,262 tons | 405 tons | 2,667 tons |

On these present estimates therefore five trawlers could produce enough Haplochromis for an annual production of approximately 2 1/2 million cans, i.e. 10,000 cans per day.

b) Costing. The following estimates of cost per vessel are based on the estimated catch per trawler of 151 tons of Haplochromis and 27 tons of other types of fish which are the calculated mean annual catches WITH THE PRESENT SIZE OF TRAWL.

Estimated Fishing Costs.

Capital cost of trawling vessel £6,000

| | | |
|---|---|---|
| Fuel oil ) Lubricants) | 1550 x 1 1/2 gals at Shs.5/- per gal | £ 581 |
| Wages | - Skipper at 400/- per month, 4 crew at 150/- per month | £ 600 |
| Fishing gear | - 25% of capital cost of £1,000 | £ 250 |
| Maintenance | - 5% of capital cost of vessel | £ 300 |
| Depreciation | - 10% of capital cost of vessel | £ 600 |
| Contingencies | - 5% of running costs | £ 85 |
| | | £ 2,416 |

Estimated Fishing income

| | |
|---|---|
| 151 tons of Haplochromis at 10c/lb | £ 1,691 |
| 27 tons of other fish at 30c/lb | £ 907 |
| | £2, 598 |

When using a trawl of the present size the capital cost of the vessel cannot exceed £6,000 if the price if the fish is to be kept down to the required level of 10c/lb. Therefore the use of foreign built, imported boats is out of the question and emphasis is placed on the use of locally built wooden vessels with suitably powered engines and winch gear. A new vessel of the size of 'Darter' with 150-200 h.p. engine (with reduction gear box) would probably cost in the region of £20,000. This should be capable of dragging a 10-12 fathom trawl which could be expected to increase production forthe same effort but the magnitude of this increase and therefore the economics of such a scheme are impossible to determine at present .

## IV. INFORMATION REQUIRED

### 1) General considerations

This section is included in some length as it is proposed to send this report to FAO Fishery experts, biologists and statisticians for advice on the best methods of tackling the problems involved. In dealing with these problems those concerned should bear in mind the following points:-

1. The nature of the area surveyed - a fairly large unenclosed part of the inshore waters of Lake Victoria, with a variety of bottom types, shore lines and water depths.

2. The type of fish under consideration, a taxonomically difficult group with a great diversity of species ecologically and in behaviour. There is a distinct lack of detailed biological knowledge of individual species.

3. The limited personnel and gear available and that the type of fishing at present being used is principally bottom trawling.

4. There is no established commercial Haplochromis fishery in the area.

5. The authors have little experience in aspects of population dynamics in fishery work and very little knowledge of statistical techniques.

The information which is required can be summed up succinctly in the following question 'Can the area under consideration produce an annual sustainable yield of say 800 tons of Haplochromis and if not, what annual sustainable yield can be obtained?' It would appear that some knowledge of the following is required.

1. Size of population in the area at present.

2. Recruitment rates to the exploitable stock

3. Natural mortality rates of the exploitable stock

4. Growth rates within the population.

5. Migration into and out of the area.

from which some estimate could be made of the likely fishing mortality that the present population would allow. It might be expected however that when fishing starts, the introduction of a fishing mortality factor would affect recruitment, growth, natural mortality and migration rate within the population (see Section IV -v) which would allow greater yields than those estimated for an unfished population.

ii) Population estimates - marking

It would appear that some estimate of the stock present in the area is the first prerequisite for determining the level of exploitation which can be attained. At this stage we may assume that bottom trawling is the method of fishing to be used and it is therefore the bottom population in trawlable areas in which we are interested.

In considering marking methods of population estimates the following points should be borne in mind in addition to the first two mentioned on the previous page.

1) Those areas where the water is under 15 feet deep or where the bottom is unsuitable (too rocky) cannot be trawled. Haplochromis are present however in these areas and may move out into trawlable areas from time to time or at a late stage of their life.

2) There is a lower size limit of Haplochromis which are suitable for canning and at present fish below this size are being caught in the trawl. This may be eliminated to a certain degree when

2) (continued)

different mesh size cod ends have been obtained and the most suitable mesh size determined.

3) The tagging programme cannot be a long or complicated one as only a few people are available to do the actual tagging. There is no commercial fishery at present so all recoveries would have to be made with the one small trawl available at present. The final report and recommendations should be completed with the next year to 18 months and any tagging experiments could not be started within the next six months.

4) There is no means of ageing fish within the heterogenous groups Haplochromis, and length could not be taken as indicative of age because of the varied range of adult sizes of the species group.

If marking experiments are to be used it would appear that the method most suited to prevailing conditions would be the Peterson Single Census method. (as given by Ricker 1958 in Bulletin 119 of the Fisheries Research Board of Canada and Jones (1966) in FAO Fisheries Technical Paper No. 51 Suppl. 1.) The population estimate ($\hat{N}$) is given by the formula:-

$$\hat{N} = \frac{M(C + 1)}{R + 1}$$

and the variance limits can be calculated according to the formula:-

$$V(\hat{N}) = \frac{\hat{N}^2(C - R)}{(C + 1)(R + 2)}$$

The rate of exploitation (in this case of the 1 trawl in use) can be estimated by the following formula

$$\hat{U} = \frac{R}{M}$$

and assuming random mixing of marked and unmarked fish the variance is given as:-

$$V(\hat{U}) = \frac{R(C - R)}{M^2C}$$

or with only a small number of recoveries as

$$\frac{C}{MN}\left(1 - \frac{M}{N}\right)$$

According to Ricker however certain conditions must be fulfilled before this method will work. One of these is that the marked fish become randomly mixed with the unmarked fish. This would probably not be so here but can be overcome by adjusting the subsequent fishing effort in proportion to the number of fish present in different areas. The condition of no recruitment would probably not be fulfilled either unless the experiment were on a short term basis, say a month or six weeks. If over longer the use of the 'dilution' technique would have to be tried, being the only one which doesn't involve the use of age.

Before a marking programme was started, preliminary experiments would have to be made to ascertain the survival rate of fish caught in the trawl from various depths, and the length of trawling adjusted to give a minimum death rate. The mortality rate of marked fish over unmarked fish should also be determined prior to the marking experiment commencing.

Fin clipping would probably be the most suitable marking method in this instance. It is quick, requires little handling of the fish and doesn't alter their subsequent catchability, but doesn't last long and is fairly difficult to recognise. Other marking methods requiring the attaching of a tag are much more difficult to manipulate, but except in case of loss will last much longer. It is thought that if the fish for marking are transferred straight from the trawl cod end to a large keep net of 1" mesh this will allow all the fish too small to be used in the cannery to escape, the remainder can then be tagged, put into another keep net and released at the site of original capture. A similar procedure would have to be adopted when making recaptures.

iii) Population estimate - Catch per unit effort

Gulland 1964 (FAO Technical paper No. 40) gives an account of methods based on the idea that catch and effort provide indices of stock density from which the total stock can be calculated. For any sub-region whose area is $A_i$ the number of fish can be calculated and the following expression then gives the total number of fish in the area as a whole.

$$N = \sum \frac{Ai}{qi} \times \frac{Ci}{fi}$$

q is a weighting constant which converts apparent densities (due to unbalanced fishing of certain parts of a sub-region) into true densities and if qi is constant and equals q for all areas then

$$N = \frac{1}{q} \sum Ai \times \frac{Ci}{fi}$$

An Electra Speed and Log has just been obtained for the experimental trawler which will give trawling speed in knots and distance covered in 1/10th nautical miles. With the aid of this, and the known spread of the mouth of the trawl, the catch per unit effort, i.e. catch/hour, can be expressed in terms of catch per unit area which will give the stock density (Di) on the region trawled. The total population of the whole area can then be expressed as

$$N = \sum Di.Ai$$

The areas of the various sub-regions can be calculated from the charts prepared in the hydrographic survey and the amount of fishing carried out made proportional to the areas involved and irrespective of the distribution of fish (as this is not commercial fishing). This would avoid having to convert weighted densities into true densities by the use of Gullands constant q. For the purposes of this method the area would be divided into sub-regions as follows:-

1. All water under 20' deep to be discounted.

2. Sand bottoms

3. Mud bottoms

   (i) 20-50 ft deep - most of the inshore bays including the large area of Murchison Bay.

   (ii) 50-75 feet deep - mainly the large mud basins off Kome and Damba Islands.

   (iii) Over 75 ft deep - The open water between the mainland and the inshore islands off Damba, Kome and Nsadzi Islands.

This method is probably more suitable than the Peterson marking method as densities will be expressed as weight/unit area and the estimates of total exploitable stock by weight. In marking experiments total stock is expressed in numbers of individuals and because of the variety of shapes and sizes of the various species involved, any accurate conversion of numbers to weight would be difficult.

The calculations of total stock from trawl catch/unit assumes that the efficiency of the gear is 100%. This however is most unlikely and estimates will be low; and the area could possibly therefore stand a higher fishing effort than would be at first indicated.

iv) Recruitment and mortality

The population under consideration is one which, at present, is not subject to a fishing mortality factor. The fishing is in the tropics where seasonal variations are slight and as far as is known growth and breeding in the population is continuous throughout the year. Young *Haplochromis* (which it is impossible to identify to species) appear to be present along with the adults on the fishing grounds (at least from September-December) and as far as is known there is little or no distinction between feeding and breeding grounds. It would appear therefore that the population bears similar characteristicts to Rickers type 11A 'ideal fish population', in which recruitment is continuous throughout the year and as no fishing mortality occurs, if the population size is more or less stable, natural mortality should be approximately equivalent to recruitment and also continuous throughout the year.

It is not known whether any calculations of recruitment rates can be made at present because:-

1. the young of the different species cannot be aged or identified.

2. the egg production and brood capacity (many if not all species of *Haplochromis* are mouth brooders) of the various species is not known.

3. The length at which the various species will enter the exploitable stock will vary because of different body shapes.

It is felt that at present all that can be done is to collect more information on various aspects. The egg production and possibly broad capacity for a number of species can be ascertained and some effort made to calculate the annual number of breedings of these species. Regular monthly length frequency analysis of samples from various locations may show changes in the length composition of the population which would help in recruitment and growth analysis. This is only likely at the lower end of the range, i.e., below 7.0 cms as the various peaks shown above this size are adult species groups.

v) Estimation of equilibrium yield in relation to size of stock and rate of fishing

These notes are taken from Ricker (1958). Methods have been devised in which stock density and yield are related directly. In view of the difficulties of estimating growth, mortality and recruitment parameters for fish stocks of *Haplochromis*, these methods could perhaps be best adopted here. They are based on the postulate that 'a fish stock produces its greatest harvestable surplus when it is at some intermediate level of abundance, not when it is at maximum abundance. This must generally be so because:-

(i) At maximum stock density efficiency of reproduction is reduced - a reduction of stock should increase recruitment.

(ii) With a limited food supply, food is less efficiently converted to fish flesh by a large stock than by a smaller one.

(iii) An unfished stock contains relatively more older fish than a fished stock. This makes for decreased production because:-

(a) Larger fish eat larger foods - so introducing another step in the food pyramid

(b) Older fish convert a smaller fraction of food into fish flesh.

Under reasonably natural stable conditions the net increase of an unfished stock is, on average, zero; its growth is balanced by natural mortality. Introducing a fishery increases production per unit of stock and so creates a surplus which can be harvested! In these ways 'a fishery, acting on a fish population itself creates the production by which it is maintained (Baranov).

There are two principle methods based on the above reasoning.

A. Method of Graham

He postulates that the instantaneous rate of surplus production of a stock is directly proportional to the difference between the actual density and the maximum density which the area will support. When fishing removes the surplus production at the same rate as it produced it becomes the yield from a stock held in equilibrium. Thus equilibrium yield at any stock density $W_t$ is equal to

$$p_t W_t = W_t \left( \frac{k \ (W_\infty - W_t)}{W_\infty} \right) \qquad (1)$$

$$= kW_t - \left( \frac{K}{W_\infty} \right) W_t \qquad (2)$$

Where:- $W_t$ is weight of stock at some equilibrium level t

$W_\infty$ is the maximum possible equilibrium stock.

k the instantaneous rate of increase of the stock at minimal densities.

$p_t$ the rate of fishing which maintains the stock in equilibrium at size $W_t$.

This relationship is a parabola and maximum yield is obtained when the stock is at exactly half its maximum equilibrium level. The statistics of an actual fishery required are: the absolute size of stock $W_t$, the rate of fishing $p_t$ at a stable level of abundance and $W_\infty$ the level of the stock characteristic of no fishing. For these Haplochromis stocks any estimate of abundance made at present would give the values for $W_\infty$. $W_t$ and $p_t$ would have to be determined when the fishery had been underway for a few years and catches had stabilized.

B. Method of Schaefer

Here an estimate is made of surplus production or equilibrium catch for each year. Each year's catch Y in lbs is divided by the rate of fishing p in order to obtain an estimate of mean stock W present during the year. The level of stock at the turn of the year is approximately the average of the mean stocks of the year completed and the year ahead. The difference between the two initial stocks is the increase for the year in question, i.e.

$$\frac{Y_3/p_3 + Y_2/p_2}{2} - \frac{Y_2/p_2 + Y_1/p_1}{2} = \frac{Y_3/p_3 - Y_1/p_1}{2} \quad (3)$$

and the surplus production or equilibrium yield $Y'$ per year 2 above is

$$Y'_2 = Y_2 + \frac{Y_3/p_3 - Y_1/p_1}{2} \quad (2)$$

The value for p is most directly obtained by estimating p for one year by tagging. From this the catchability C is estimated and the other p's are estimated as proportional to effective fishing effort ($p_t = cf_t$ for each year). Determined in this way surplus production can be plotted against stock density. If a defined curve for a wide range of stock densities is obtained it can be used empirically for determining maximum yield for stock. If it doesn't cover a wide range some curve must be fitted to permit extrapolation. Schaefer, like Graham, has used the parabola, but with the reservation that a curve skewed to the left is better.

Alternatively surplus production can be plotted against rate of fishing pt.

Dividing both sides of equation (1) by $W_t$ gives an expression for $p_t$ in terms of $W_t$. $W_t$ can then be expressed in terms of $p_t$ and substituting in equation (2) the resulting expression for surplus production or equilibrium yield is

$$Y_t = p_t W_t = W \left(\frac{p_t - p_t^2}{K}\right) \quad (5)$$

This is probably a better alternative method than that of Graham as a more accurate account can be kept of the state of the fishery from its inception.

vi) SUMMARY

1) Estimates of present stock density of the unfished population can be made using catch per unit area in the various sub-regions. This method is favoured in preference to the Peterson marking method as the practical difficulties involved in the operation are not so great.

2) No means can be seen for assessing recruitment, growth rate and mortality of this *Haplochromis* population and so defining these parameters before fishing starts. In any case as soon as fishing starts the parameters will alter as the size of the initial population alters.

3) If reasonably accurate stock estimates are made and these are found to be far in excess of the initial annual yield required, it would seem reasonable to advise a fishery to be started to extract this quantity of fish. On present very rough estimates only about 4% of the total stock would be required annually and taking into account the small size and diversity of species involved, in a tropical environment with apparently no cessation of growth and breeding, this can be regarded as only a very small percentage.

4) The maximum equilibrium yields can be worked out on the lines set out in section II-v as the fishery continues. Watch can then be kept on the rate of stock decrease within the first few years of fishing to see that it doesn't fall below half its present unfished level.

TABLE 1.

## ANNUAL PRODUCTION OF HAPLOCHROMIS FROM TERRITORIAL WATERS OF LAKE VICTORIA

| | | Number | Wt./lbs | Tonnage |
|---|---|---|---|---|
| 1960 | Kenya | 2,390,614 | 109,223 | 48.7 |
| 1961 | Kenya | 3,590,739 | 142,447 | 63.6 |
| 1962 | Kenya | 9,080,766 | 381,686 | 170.4 |
| | Uganda | 1,890,882 | 229,896* | 102.6 |
| | Tanzania | 12,277,482 | 749,171* | 334.9 |
| 1964 | Tanzania | 7,308,493 | 392,714 | 175.3 |
| 1965 | Uganda | 837,232 | 104,365* | 46.6 |
| | Tanzania | 9,909,760 | 588,442 | 262.7 |
| 1966 | Uganda | 5,110,703 | 549,000* | 245.0 |
| | Tanzania | 8,755,636 | 605,308 | 270.2 |

The 1966 figures are for January to October only

* Estimated by extrapolation as weight figures incomplete.

TABLE II.

DETAILED SPECIFICATIONS OF THE EXPERIMENTAL FLEET OF GILL-NETS USED IN THE SURVEY

| Mesh | Hanging | Made up Length | Number of meshes deep | Ply | Number of nets |
|---|---|---|---|---|---|
| 1" | ½ | 25 yards | 52 | 2 | 2 |
| 1½" | ½ | 25 yards | 52 | 2 | 2 |
| 2" | ½ | 25 yards | 26 | 2 | 2 |
| 2½" | ½ | 25 yards | 26 | 3 | 2 |
| 3" | ½ | 25 yards | 26 | 4 | 2 |

2" net eventually changed to 52 meshes deep.

TABLE III

## TOTAL CATCH PER SET FOR EACH FISHING IN EACH ENVIRONMENT

| ENVIRONMENT | BOTTOM 1" No. | BOTTOM 1" Wt. | BOTTOM 1½" No. | BOTTOM 1½" Wt. | BOTTOM 2" No. | BOTTOM 2" Wt. | BOTTOM Total No. | BOTTOM Total Wt. | TOP 1" No. | TOP 1" Wt. | TOP 1½" No. | TOP 1½" Wt. | TOP 2" No. | TOP 2" Wt. | TOP Total No. | TOP Total Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Mud bottom 30-35' in middle of papyrus lined bays | | | | | | | | | 21 | 0.5 | 79 | 5.4 | 4 | 3.5 | 104 | 6.4 |
| | 90 | 1.75 | 187 | 8.5 | 24 | 3.5 | 301 | 13.75 | 30 | 0.75 | 44 | 2.25 | 8 | 1.0 | 82 | 4.0 |
| 2. Colloidal mud bottom - open water 60-65' | 53 | 1.125 | 51 | 2.75 | 200 | 22.0 | 304 | 25.875 | 144 | 4.0 | 76 | 4.25 | 44 | 5.5 | 266 | 13.75 |
| | 24 | 0.5 | 20 | 1.25 | 70 | 8.25 | 114 | 10.0 | 39 | 1.25 | 37 | 2.5 | 4 | 0.5 | 80 | 4.25 |
| 3. Inshore 20-45' water. Hard bottom sand/gravel/rock on banks projecting out from shore. | 43 | 1.125 | 178 | 8.62 | 112 | 12.375 | 333 | 22.128 | 34 | 0.875 | 122 | 6.5 | 10 | 1.0 | 166 | 8.375 |
| | 147 | 3.375 | 107 | 5.5 | 90 | 11.75 | 345 | 20.625 | 46 | 1.25 | 410 | 20.0 | 58 | 8.0 | 514 | 29.25 |
| | 238 | 4.75 | 68 | 3.25 | 64 | 8.0 | 370 | 16.0 | 41 | 1.0 | 59 | 2.875 | 16 | 2.0 | 116 | 5.875 |
| | 132 | 2.75 | 69 | 3.75 | 98 | 12.0 | 299 | 18.5 | 97 | 2.75 | 140 | 7.25 | 48 | 6.75 | 285 | 16.75 |
| | 218 | 4.75 | 58 | 3.0 | 34 | 2.25 | 310 | 10.0 | 70 | - | 195 | - | 14 | - | 279 | - |
| | 122 | 2.75 | 66 | 3.25 | 66 | 7.5 | 254 | 13.5 | 32 | 0.75 | 112 | 5.75 | 30 | 4.25 | 174 | 10.75 |
| Exposted and sheltered. | 325 | 7.0 | 213 | 10.5 | 38 | 4.75 | 576 | 22.25 | 73 | 1.75 | 217 | 11.0 | 30 | 4.0 | 320 | 16.75 |
| 4. Narrow deep inlet, very steeply shelving rocky shore - south side of Kome. | 55 | 1.25 | 47 | 2.25 | 20 | 3.25 | 122 | 6.75 | 1 | - | 113 | 6.5 | 24 | 3.0 | 138 | 9.5 |

TABLE IV

AVERAGE CATCH FOR EACH ENVIRONMENT

| ENVIRONMENT | BOTTOM 1" No. | BOTTOM 1" Wt. | BOTTOM 1½" No. | BOTTOM 1½" Wt. | BOTTOM 2" No. | BOTTOM 2" Wt. | TOP 1" No. | TOP 1" Wt. | TOP 1½" No. | TOP 1½" Wt. | TOP 2" No. | TOP 2" Wt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 90 | 1.75 | 187 | 8.5 | 24 | 3.5 | 25.5 | 0.625 | 62 | 3.825 | 6 | 0.75 |
| 2 | 38.5 | 0.81 | 35.5 | 2.0 | 135 | 15.125 | 92 | 2.675 | 56 | 3.375 | 24 | 3.0 |
| 3 | 175 | 3.78 | 108.4 | 5.4 | 71.7 | 8.375 | 56 | 1.4 | 179 | 8.9 | 29.4 | 4.3 |
| 4* | 55 | 1.25 | 47 | 2.25 | 20 | 3.25 | 1 | - | 113 | 6.5 | 24 | 3.0 |

One heavy catch in 2" Bottom set (2)

One heavy catch in 1½" Top set (3)

| Average overall catch in 2" net | | No. | Wt. |
|---|---|---|---|
| | Bottom set | 74 | 8.7 |
| | Top set | 24 | 3.35 |

TABLE V.

A BREAKDOWN OF CERTAIN CATCHES INTO PREDATORY AND NON-PREDATORY HAPLOCHROMIS

| Habitat | Top Set Predators | Top Set Non-Predators | Bottom Set Predators | Bottom Set Non-Predators |
|---|---|---|---|---|
| 1 | 42 (52%) | 39 | 28 (9%) | 268 |
| 2 | 70 (84%) | 13 | 45 (42%) | 61 |
| 3 | 104 (37%) | 176 | 10 (4%) | 278 |
| | 126 (52%) | 117 | 25 (11%) | 194 |
| | | | 5 (7%) | 64 |
| TOTAL: | 342 (50%) | 345 | 113 (11%) | 865 |

TABLE VII

APPROXIMATE SIZES OF SEXUAL MATURITY OF PREDATORY HAPLOCHROMIS (S. L. in mm).

| Group | Species | Size Range of Sample | Sexual Maturity |
|---|---|---|---|
| H. bartoni | H. bartoni | 135 - 195 | 140 |
| | H. bayoni | 82 - 152 | 110 - 125 |
| | H. victorianus | 117 - 166 | Below 117 |
| | H. nyanzae | 126 - 171 | Below 126 |
| | H. serranus | 101 - 205 | 130 |
| H. longirostris | H. longirostris | 84 - 145 | 100 |
| | H. argenteus | 93 - 202 | 115 |
| H. macrognathus | H. macrognathus | 80 - 174 | 125 |
| | H. mandibularis | 131 - 174 | Below 130 |
| | H. gowersi | 145 - 224 | 150 |
| | H. mento | 113 - 178 | 135 |
| H. squamulatus | H. squamulatus | 66 - 198 | 135 |
| | H. estor | 141 - 170 | Below 140 |
| | H. dentex | 91 - 159 | 120 |
| H. percoides | H. percoides | 67 - 93 | Below 75 |
| | H. plagiostoma | 69 - 147 | 110 |
| | H. pellegrini | 71 - 104 | Below 70 |
| H. flavipinnis | H. flavipinnis | 69 - 156 | 115 |
| H. cavifrons | H. cavifrons | 108 - 195 | 135 |
| H. guiarti | H. guiarti | 83 - 177 | 100 |
| | H. paraguiarti | - - | - |

TABLE VI.

BODY DEPTH AS PERCENTAGE OF BODY LENGTH FOR PREDATORY AND NON-PREDATORY HAPLOCHROMIS

| Type | Mean body depth for each species as percentage of body length | |
|---|---|---|
| | Range | Mean |
| Predators | 26.7 - 35.0 | 30.8 |
| Non-Predators | 31.5 - 41.5 | 36.4 |

TABLE VIII.

APPROXIMATE SIZES OF SEXUAL MATURITY OF NON-PREDATORY HAPLOCHROMIS (S.L. in mm.)

| Group | Species | Size range of Sample | Sexual Maturity |
|---|---|---|---|
| Plant eaters | H. obliquidens | 48 - 89 | 68 |
| | H. lividus | 46 - 90 | - |
| | H. nigricans | 49 - 94 | 53 |
| | H. nuchisquamulatus | 83 - 113 | - |
| Fry eaters | H. obesus | 71 - 170 | 85 |
| | H. maxillaris | 90 - 160 | 100 |
| | H. parvidens | 63 - 163 | 105 |
| | H. cryptodon | 92 - 130 | Below 92 |
| | H. microdon | 114 - 148 | Below 114 |
| Mollusc shellers | H. sauvagei | 58 - 105 | 80 |
| | H. prodromus | 63 - 130 | 100 |
| | H. granti | 70 - 122 | 90 |
| | H. xenognathus | 80 - 113 | 90 |
| Mollusc crushers | H. pharyngomylus | 70 - 126 | 95 |
| | H. ishmaeli | 82 - 136 | 100 |
| | H. obtusidens | 60 - 114 | 90 |
| | H. humilior | 65 - 90 | Below 65 |
| H. chilotes | H. chilotes | 70 - 148 | 80 |
| H. martini | H. martini | 59 - 104 | 80 |
| H. aelocephalus | H. aelocephalus | 63 - 120 | - |
| General A | H. plagiodon | 56 - 85 | - |
| | H. chromogynos | 50 - 110 | 90 |
| General B | H. lacrimosus | 66 - 97 | Below 66 |
| | H. pallidus | 43 - 74 | Below 50 |
| | H. macrops | 66 - 91 | 73 |
| | H. cinereus | 71 - 81 | Below 70 |
| General C | H. riponianus | 57 - 104 | 85 |
| | H. saxicola | 100 - 123 | Below 100 |
| Monotypics | Astatoroechromis | 20 - 163 | 97 |
| | Macropleurodes | 74 - 144 | 96 |
| | Hoplotilapia | 57 - 150 | 96 |
| | Platytenoides | 67 - 154 | 71 |

TABLE IX.

PREDATORY AND NON-PREDATORY COMPOSITION OF THE CATCHES THROUGHOUT THE GILL-NET POPULATION EXPERIMENT

| Top Set Nets | Number of Fishings | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| % predators | 88 | 94 | 88.5 | 88.5 | 79 | 95.5 | 95 | 97.5 | 95.5 | 94 | 94 | 97 | 99.5 | 100 |
| % non-predators | 12 | 6 | 11.5 | 11.5 | 21 | 4.5 | 5 | 2.5 | 4.5 | 6 | 6 | 3 | 0.5 | 0 |
| **Bottom Set Nets** | | | | | | | | | | | | | | |
| % predators | 21 | 17.5 | 25.5 | 33.5 | 28 | 33 | 43.5 | 35.5 | 40.5 | 32 | 56.5 | 44 | 40.5 | 49 |
| % non-predators | 79 | 82.5 | 74.5 | 66.5 | 72 | 67 | 56.5 | 64.5 | 59.5 | 68 | 43.5 | 56 | 59.5 | 51 |

TABLE X.

## PERCENTAGE SPECIES COMPOSITION OF SURFACE CATCHES OF HAPLOCHROMIS IN THE 2" GILL-NETS THROUGHOUT THE POPULATION EXPERIMENT

| Species | Number of Fishing 2 | 3 | 5 | 6 | 9 | 10 | 11 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|
| **Predators** | | | | | | | | | |
| H. guiarti | 40.5 | 30.6 | 18.6 | 42.6 | 38.4 | 44.8 | 49.5 | 66.1 | 67.6 |
| H. bartoni | 1.9 | 5.1 | 8.4 | 2.1 | – | – | – | – | – |
| H. serranus | 9.8 | 19.3 | 16.2 | 10.6 | 21.4 | 13.1 | 10.3 | 2.3 | 2.4 |
| H. squamulatus | 10.0 | 7.9 | 9.1 | 5.8 | 9.4 | 6.7 | 6.5 | 4.6 | 4.4 |
| H. macrognathus) | | 22.1) | | 9.5 | 12.5 | 9.9 | 16.3 | 5.8 | 6.7 |
| H. mento ) | 13.3 | 10.5) | 31.0 | 5.1 | 14.3 | 17.7 | 13.3 | 13.1 | 14.6 |
| H. gowersi ) | | 0.3) | | 0.3 | – | – | – | 0.3 | – |
| H. longirostris | 1.1 | 0.7 | 0.5 | 0.9 | 0.8 | 1.7 | 1.0 | 6.6 | 3.2 |
| H. plagiostoma | – | 0.3 | – | – | – | – | – | – | – |
| H. cavifrons | 0.6 | 0.6 | 0.4 | – | – | – | – | – | – |
| Others | 23.0 | 5.2 | 18.7 | 22.0 | 3.1 | 6.4 | 4.9 | 1.5 | 1.2 |
| **Non-predators** | | | | | | | | | |
| Astatoreochromis | 2.1 | 4.0 | 1.5 | – | – | – | – | – | – |
| Macropleurodes | 8.3 | 6.7 | 3.1 | 6.2 | – | 14.3 | 4.2 | – | – |
| Hoplotilapia | 2.1 | 2.7 | 3.1 | – | – | – | – | – | – |
| H. obliquidens | – | – | – | 3.1 | – | – | – | – | – |
| H. sauvagei | 2.1 | 1.3 | – | – | – | – | – | – | – |
| H. obesus | 44.0 | 13.5 | 29.2 | 62.5 | 63.5 | 32.0 | 8.4 | – | – |
| H. parvidens | 2.1 | 6.7 | 7.7 | 3.1 | 9.1 | 7.2 | 4.1 | – | – |
| H. microdon | – | – | 4.6 | 3.1 | – | – | – | – | – |
| H. chilotes | 4.2 | 13.5 | 7.7 | – | 9.1 | – | – | – | – |
| H. aelocephalus | – | – | 3.1 | – | – | – | – | – | – |
| General A | 2.1 | 20.2 | 15.4 | 9.4 | 18.2 | 39.4 | 62.5 | – | – |
| General B | – | 27.0 | 1.5 | 3.1 | – | – | 16.6 | 100 | – |
| General C | 8.3 | – | 21.5 | – | – | 7.2 | – | – | – |
| Others | 25.0 | 5.4 | 1.5 | 6.3 | – | – | 4.2 | – | – |

TABLE XI

## PERCENTAGE SPECIES COMPOSITION OF BOTTOM CATCHES OF HAPLOCHROMIS IN THE 2" GILL-NETS THROUGHOUT THE POPULATION EXPERIMENT

| Species | Number of fishing | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 5 | 6 | 9 | 10 | 11 | 12 | 13 | 14 |
| **Predators** | | | | | | | | | | |
| H. bartoni | 15.3 | 4.1 | 5.0 | 5.3 | 19.7 | 12.2 | 13.9 | 10.5 | 6.4 | 21.6 |
| H. guiarti | - | 8.1 | - | 9.3 | 1.8 | - | 4.1 | - | - | - |
| H. serranus | 5.1 | - | - | 4.0 | - | 0.8 | - | - | - | - |
| H. squamulatus | 10.2 | 6.4 | 25.0 | 9.4 | 10.7 | 7.3 | 8.3 | 18.4 | 19.1 | 15.7 |
| H. macrognathus | 7.7 | 21.6 | 35.0 | 4.0 | 1.8 | 17.0 | 26.4 | 29.0 | 21.3 | 15.7 |
| H. mento | - | 9.5 | - | 21.4 | 28.6 | 40.0 | 33.3 | 15.8 | 25.5 | 31.4 |
| H. gowersi | 2.6 | 9.5 | - | 17.3 | 12.5 | 9.8 | 5.5 | 7.9 | 21.3 | 11.8 |
| H. longirostris | - | - | - | 2.8 | - | - | - | - | 2.1 | - |
| H. flavipinnis | 5.1 | 4.1 | 1.7 | - | 1.8 | 0.8 | 2.8 | - | - | 2.0 |
| H. cavifrons | 15.3 | 10.8 | 8.4 | 10.7 | 9.0 | 3.2 | 4.2 | 5.3 | 2.1 | 2.0 |
| Others | 38.5 | 20.3 | 25.0 | 16.0 | 12.5 | 9.0 | 1.4 | 13.2 | 2.1 | - |
| **Non-predators** | | | | | | | | | | |
| Astatoreochromis | 14.2 | 2.8 | 10.5 | 10.4 | 18.1 | 6.2 | 5.3 | 12.2 | 26.1 | 28.3 |
| Macropleurodes | 13.7 | 7.5 | 16.4 | 5.2 | 1.2 | 7.6 | 10.7 | 6.1 | 1.4 | 3.8 |
| Haplotilapia | 8.3 | 2.3 | 2.6 | 3.9 | 4.8 | 4.9 | 3.6 | 4.1 | 7.2 | 1.9 |
| Platytenoides | - | - | - | 0.6 | 1.2 | - | 1.8 | - | - | - |
| H. sauvagei | 13.7 | 6.0 | 7.9 | 5.2 | 1.2 | 4.5 | 1.8 | 8.2 | 8.7 | - |
| H. pharyngomylus | - | - | - | - | - | 0.8 | - | - | - | - |
| H. obesus | 2.2 | 3.7 | 2.6 | 7.8 | 6.0 | 2.0 | 9.0 | 22.4 | 5.8 | 18.9 |
| H. parvidens | 1.1 | - | - | - | 3.7 | 1.9 | - | 4.0 | 7.2 | 15.0 |
| H. microdon | - | 0.9 | 1.3 | 1.9 | - | - | 1.8 | - | - | - |
| H. chilotes | 9.4 | 7.0 | 8.6 | 3.9 | 3.6 | 6.8 | 5.4 | 6.1 | 13.0 | 1.9 |
| H. aelocephalus | - | 7.5 | 1.3 | 2.6 | 1.2 | - | 7.2 | 2.0 | 4.3 | - |
| H. martini | - | 0.5 | 0.7 | - | - | - | - | - | - | - |
| General A | 0.5 | 3.7 | 9.9 | - | 3.6 | 4.2 | 7.2 | - | 1.4 | - |
| General B | - | 6.5 | 0.7 | 0.6 | 3.6 | 4.5 | 7.2 | - | 7.3 | - |
| General C | 30.4 | 48.5 | 32.2 | 52.5 | 48.2 | 35.8 | 32.2 | 26.6 | 11.6 | 34.0 |
| Others | 6.6 | - | 5.9 | 5.2 | 4.8 | 20.7 | 5.4 | 8.2 | 5.8 | - |

TABLE XII.

CATCH RECORDS OF ALESTES SADLERI

| Environment | Total Number | Total Weight | Mean Number | Mean Weight |
|---|---|---|---|---|
| 1. Mud bottom, 30-35' of water in middle of papyrus lined bay. | 99<br>107 | 3.00<br>3.125 | 103 | 3.00 |
| 2. Colloidal mud bottom semi-open water, 60-65' deep. | 4<br>5 | -<br>- | 4.5 | - |
| 3. (a) Inshore 20-45' of water over hard bottom moderately sheltered. | 551<br>511<br>437<br>185<br>168 | 26.50<br>16.60<br>13.00<br>5.50<br>4.50 | 370 | 13.00 |
| (b) as above but exposed. | 33<br>6 | 1.00<br>0.125 | 20 | 0.60 |
| 4. Narrow rocky inlet steep sided | 48 | 1.25 | 48 | 1.25 |

TABLE XIII.

BOTTOM TRAWLING - GENERAL ANALYSIS OF ALL CATCHES BY HABITATS

| BOTTOM. | DEPTH (FT.) | TIME (MIN.) | T. zillii | T. variabilis | T. esculenta | Haplochromis | Bagrus | Clarias | Synodontis | Protopterus | Barbus | Labeo | Xenoclarias | Engraulicypris | Lates | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CATCH | | | | | | | | | | | | | | | | |
| Sand | 20 - 60 | 462 | 7.9 | 51.7 | 8.0 | 2,254.0 | 122.5 | 9.5 | + | 44.0 | 2.5 | - | - | + | - | 2,500.1 |
| Mud | 30 - 66 | 315 | - | - | 226.4 | 1.092.2 | 105.5 | 40.8 | 18.5 | 19.8 | + | - | 0.2 | + | - | 1.503.4 |
| Sand/Mud | 12 - 60 | 72 | + | - | 3.0 | 305.0 | 51.4 | 8.4 | 5.9 | 16.7 | + | 0.9 | - | + | 1.5 | 392.8 |
| Total: | | 849 | 7.9 | 51.7 | 237.4 | 3,651.2 | 279.4 | 58.7 | 24.4 | 80.5 | 2.5 | 0.9 | 0.2 | + | 1.5 | 4,396.3 |
| PERCENTAGES | | | | | | | | | | | | | | | | |
| Sand | | 462 | 0.31 | 2.5 | 0.32 | 90.0 | 4.80 | 0.37 | + | 1.70 | 0.10 | - | - | + | - | 100 |
| Mud | | 315 | - | - | 15.06 | 72.67 | 7.02 | 2.71 | 1.23 | 1.32 | + | - | 0.20 | + | - | 100 |
| Sand/Mud | | 72 | - | - | 0.76 | 77.60 | 13.08 | 2.14 | 1.50 | 4.25 | + | 0.20 | - | + | 0.38 | 100 |
| Total: | | 849 | 0.18 | 1.18 | 5.40 | 83.06 | 6.36 | 1.34 | 0.56 | 1.83 | + | + | + | + | 0.04 | 100 |
| CATCH/HOUR | | | | | | | | | | | | | | | | |
| Sand | | 60 | 1.03 | 6.71 | 1.04 | 292.73 | 15.91 | 1.23 | + | 5.71 | 0.32 | - | - | + | - | 324.68 |
| Mud | | 60 | - | - | 43.12 | 208.04 | 20.10 | 7.77 | 3.52 | 3.77 | + | - | + | + | - | 286.32 |
| Sand/Mud | | 60 | - | - | 2.50 | 254.17 | 42.83 | 7.00 | 4.92 | 13.92 | + | 0.75 | - | + | 1.25 | 327.34 |
| Total: | | 60 | 0.56 | 3.66 | 16.84 | 259.00 | 19.81 | 4.16 | 1.73 | 5.71 | + | + | + | + | + | 311.80 |

TABLE XIV.

## BOTTOM TRAWLING - COMPARISON OF DIFFERENT AREAS OF SAME HABITAT

| LOCALITY | HAULS | TIME | DEPTH | T. zillii | T. variabilis | T. esculenta | Haplochromis | Bagrus | Clarias | Synodontis | Protopterus | Barbus | Xenoclarias | Engraulycypris | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CATCH | | | | | | | | | | | | | | | |
| SAND | | | | | | | | | | | | | | | |
| Ramafuta | 3 | 47 | 25 - 45 | - | - | 0.2 | 224.2 | 10.0 | 9.5 | - | - | + | - | - | 243.9 |
| Tavu | 15 | 355 | 20 - 45 | 7.9 | 51.7 | 7.8 | 1,924.1 | 109.6 | - | + | 44.0 | 2.5 | - | - | 2,135.8 |
| Nsadzi | 2 | 60 | 40 - 60 | - | - | - | 117.5 | 2.9 | - | - | - | + | - | - | 120.4 |
| MUD | | | | | | | | | | | | | | | |
| Namone | 1 | 20 | 30 | - | - | 9.9 | 57.2 | - | - | 0.4 | - | + | 0.2 | + | 67.7 |
| Kome | 2 | 60 | 35 - 45 | - | - | 115.5 | 215.6 | 9.9 | 6.7 | 0.7 | 4.4 | - | - | - | 353.2 |
| Bugalo N | 4 | 95 | 45 - 65 | - | - | 97.5 | 293.4 | 48.2 | 16.5 | 4.0 | 4.4 | + | + | - | 464.0 |
| Bugalo S | 5 | 140 | 65 | - | - | 3.1 | 526.0 | 47.4 | 17.5 | 1.3 | 11.0 | + | - | - | 618.5 |
| CATCH/HOUR | | | | | | | | | | | | | | | |
| SAND | | | | | | | | | | | | | | | |
| Ramafuta | 3 | 60 | | - | - | 0.26 | 286.97 | 12.8 | 12.16 | - | - | + | - | - | 312.19 |
| Tavu | 15 | 60 | | 1.33 | 8.73 | 1.30 | 325.00 | 18.51 | - | + | 7.43 | 0.42 | - | - | 362.72 |
| Nsadzi | 2 | 60 | | - | - | - | 117.5 | 2.9 | - | - | - | + | - | - | 120.4 |
| MUD | | | | | | | | | | | | | | | |
| Namone | 1 | 60 | | - | - | 29.7 | 171.6 | - | - | 1.2 | - | + | 0.6 | + | 203.1 |
| Kome | 2 | 60 | | - | - | 115.5 | 215.6 | 9.9 | 6.7 | 0.7 | 4.4 | - | - | - | 353.2 |
| Bugalo N | 4 | 60 | | - | - | 61.71 | 185.70 | 30.5 | 10.44 | 2.53 | 2.78 | + | + | - | 293.66 |
| Bugalo S | 5 | 60 | | - | - | 1.33 | 225.75 | 20.34 | 7.5 | 0.56 | 4.72 | + | - | - | 260.21 |

TABLE XV.

## SURFACE TRAWLING - GENERAL ANALYSIS OF CATCHES

| PLACE | DEPTH | TIME | *Haplochromis* | *A. jacksoni* | *A. sadleri* | *Engraulicypris* | *Clarias* | *Tilapia* | *Barbus* | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| Napoleon Gulf | 15 - 30 | 250 | 123.9 | 5.9 | 4.85 | 4.25 | 3.5 | + | - | 142.4 |
| Grant Bay | 15 - 45 | 120 | 37.5 | - | 0.5 | 0.7 | - | - | - | 38.7 |
| Buvuma Channel | 50 - 90 | 120 | 32.75 | - | - | - | - | - | - | 32.7 |
| Lufu | 75 | 90 | 18.0 | 0.3 | - | 0.25 | 3.0 | - | + | 21.5 |
| TOTAL: | - | 580 | 212.15 | 6.2 | 5.35 | 5.20 | 6.5 | + | + | 235.4 |
| Total Catch/Hour | - | 60 | 21.3 | 0.6 | 0.55 | 0.54 | 0.72 | + | + | 23.7 |
| Total Percentage | - | - | 90 | 2.6 | 2.3 | 2.2 | 2.8 | + | + | 100 |

TABLE XVI.

## SUMMARY OF TRAWL CATCHES MADE BY L.V.F.S.(a) AND E.A.F.F.R.O. (1950-51) (b)

| Depth | Mean Time (Mins.) | | Mean Catch (lbs) | | Mean Catch/Hour (lbs) | |
|---|---|---|---|---|---|---|
| | a. | b. | a. | b. | a. | b. |
| 10 - 19 | - | 40 | - | 0.75 | - | 1 |
| 20 - 29 | 45 | 29 | 59 | 83 | 80 | 166 |
| 30 - 39 | 35 | 26 | 196 | 16 | 336 | 38 |
| 40 - 49 | 60 | 30 | 45 | 164 | 45 | 328 |
| 50 - 59 | 37 | 29 | 39 | 106 | 62 | 212 |
| 60 - 69 | 60 | 26 | 42 | 130 | 42 | 300 |
| 70 - 79 | - | 33 | - | 218 | - | 396 |
| 80 - 89 | 60 | 32 | 14 | 147 | 14 | 280 |
| 90 - 99 | - | 37 | - | 87 | - | 140 |
| 100 - 119 | - | 50 | - | 86 | - | 101 |
| 120 - 139 | 50 | 60 | 32 | 80 | 38 | 80 |
| 140 - 159 | 47 | - | - | - | - | - |
| 160 - 179 | 60 | - | 2 | - | 2 | - |
| 180 - 199 | 30 | - | 3 | - | 6 | - |