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BATHO-SPATIAL DISTRIBUTION PATTERN AND BIOMASS ESTIMATE OF THE MAJOR DEMERSAL FISHES IN LAKE VICTORIA

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ABSTRACT

A generalized bottom trawl exploratory survey was carried out on Lake Victoria to: (i) define the distributional pattern and magnitude of the lakewide demersal stocks, (ii) determine the commercial potential of *Haplochromis* spp. and (iii) evaluate trawling as a commercial fishing technique for Lake Victoria fisheries.

Preliminary results suggest that: (i) bottom trawl catches are more representative of the stocks, (ii) species diversification and fish density decrease with increasing mean depth and (iii) at least 80% of the catchable demersal ichthyomass is *Haplochromis*.

Though bottom trawling is a much more efficient fishing technique for the Lake Victoria fisheries, bio-socio-economic consideration impose that mechanization of the fishery should better proceed in graded steps. Besides, demographic and nutritional considerations indicate the necessity for rational management and increased direct human utilization of the fishery resource.

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INTRODUCTION

Lake Victoria as a fishery resource has experienced recognisable trends for the last seventy years or so. Though no one knows exactly when and how fishing began, it is certain that in the early stages of the Lake Victoria fishery adequate supplies were obtained with little effort, from inshore areas alone, and with simple fishing gear (such as the static fence-like "osageru" or the mobile seine-like "ngongo"). In the absence of convenient transport facilities to dispose of the fish quickly (under a tropical climate) to far inland areas, fresh fish supply was geographically limited and the fishing intensity was almost negligible. The lake, being held second in the size hierarchy of freshwater bodies, tantalizingly appeared a limitless resource.

The chimaera of an unlimited resource began to lose its illusion when fishing pressure was increased due to several developments. The use of gill-nets, first introduced in Nyanza (Kavirondo) Gulf in 1905 (GRAHAM 1929), made fishing more profitable as the gear proved more efficient, particularly in catching the highly prized *Tilapia;* and, the arrival of the railway to the Gulf at Kisumu in 1908 opened up more inland markets. The fishing industry attracted more and more fishermen, beach seines were introduced in the early 1920's and fishing canoes were forced to venture more and more offshore as the catch per unit effort of the commercially commanding species from the traditional fishing inshore areas started to decline. The natural fibre gill-nets were gradually displaced by the synthetic fibre nets, and many of the fishing boats became motorized. Thus, evident changes in: efficiency of the fishing gear, transport, total fishing effort and geographical extension of fishing operations maintained the yield from Lake Victoria, but against a continuous decrease in catch per unit effort and mean size of the fish caught. For example, the catch per night for *Tilapia* has decreased from 50–100 fish per 50 m-long net with 127 mm stretched mesh in 1905 (WORTHINGTON and WORTHINGTON, 1933) to less than 0.5 fish by 1970 (SSENTONGO, 1972). It became necessary, therefore, to define the lakewide stocks of Lake Victoria so that the fishing effort could be manipulated within the biological prosperity and economic profitability of the fisheries.

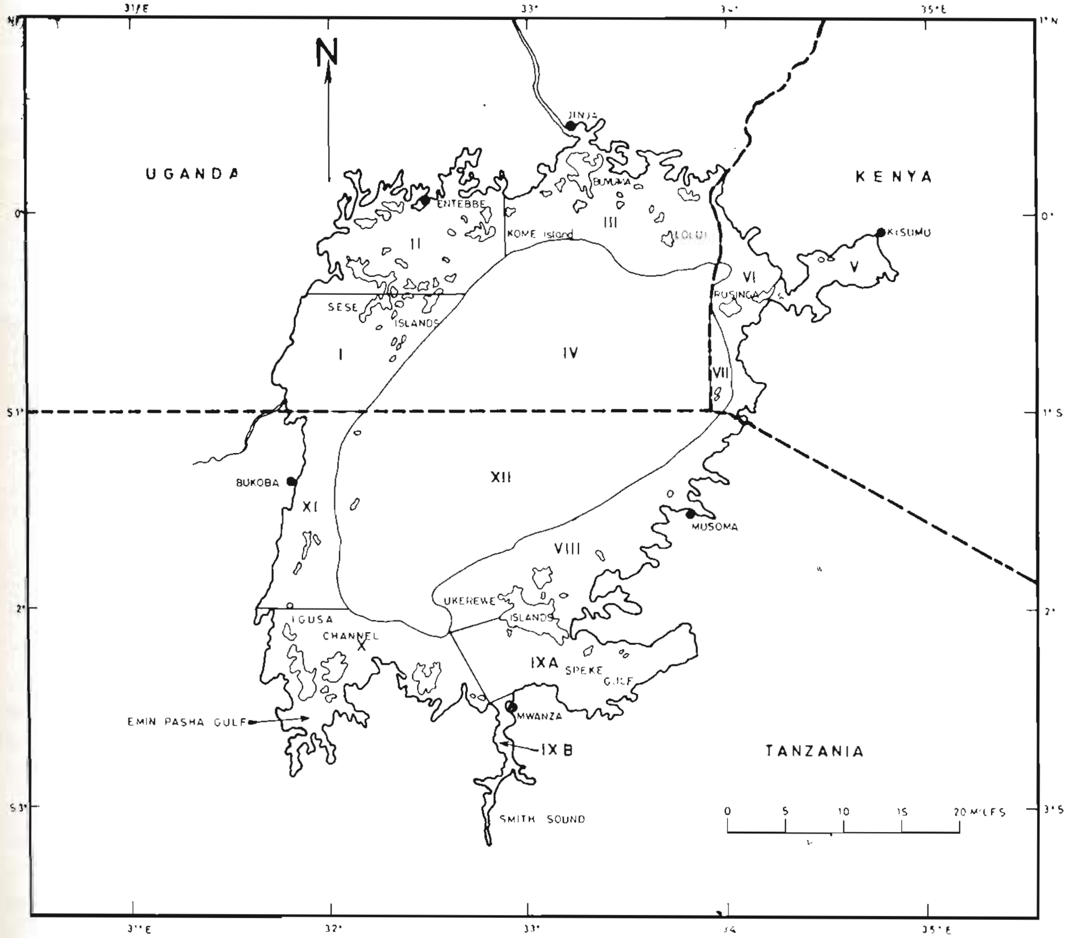
The need for the generation of data necessary for rational management strategy cannot be over-emphasized. Lake Victoria, as a natural freshwater fishery resource, has no equal in many parts of the world. But because a large proportion of the increasing populations of the peoples of East Africa (like in many other developing nations) is faced with protein deficiency which could be bridged by fish protein, the large size (about 68,000 km^2) of the lake and its production potential cannot over-shadow the need for such data since even the North American Great Lakes (STANFORD 1968, 1970), the prolific Barents and North Seas (KORRINGA, ?), let alone many of the traditional fishing grounds of the world's oceans, etc. have already experienced some surprises. Further, past research work on Lake Victoria has indicated that certain species such as *Labeo victorianus* (GARROD 1961, CADWALLADR 1969) and *Barbus altianalis* have become rare while catch rates and size range for others such as *T. esculenta*, *T. variabilis* and *M. kannume* have continuously diminished to alarming levels. This is most likely to have resulted from over-fishing (GARROD, op. cit.,), increased use of small mesh gill-nets and unrestricted use beach seines in some areas. On the other hand, large stocks of *Haplochromis* spp were believed to exist in the lake but because of their generally small size these fish were not effectively harvested by the extant gill-net fishery. The dichtomy of this heterogeneous fishery, where certain species seemed over-fished while others were being under-fished due to the selective properties of the gear in use, called for modifications in the fishing practices.

Hence, we embarked on a generalized lakewide bottom trawl exploratory fishing survey. The immediate aims were: (i) to derive estimates of the fish stocks of Lake Lake Victoria (i.e. species composition and their relative abundance by depth, season, etc.) necessary for determining the potential yield of the commercial fisheries; (ii) to determine the commercial potential of the *Haplochromis* stocks believed to abound in the lake—particularly in the deep and more offshore waters—inefficiently harvested by the existing gear; and (iii) to evaluate trawling as a commercial fishing technique for Lake Victoria's heterogeneous fisheries.

MATERIAL AND METHODS:

Preliminary work started in 1968, but the actual exploratory survey was carried out from January, 1969 through May, 1971. Nineteen bottom trawl cruises were conducted. Lake Victoria was divided into 13 sub-areas (Fig. 1) each of which was sub-divided into 10m depth intervals, as described by

FIG 1



SAMPLING AREAS OF LAKE VICTORIA

BERGSTRAND and CORDONE (1971), giving a total of 52 sampling strata. Bottom trawling was conducted with the 180 H.P. research vessel, *IBIS*, which is 17m long, is fully rigged for a variety of fishing gear and is fitted with modern navigational devices. It is equipped with two electronic echo-sounders for recording both the depth and "biological targets" within the water column beneath the keel and has a 2-ton capacity hydraulic winch for deploying and retrieving the gear. Several types of otter trawls were used but two standard nets (of 2-seam design)—one with 24m and the other with 19m headrope lengths—were used more often. Different codends, which varied mostly in the mesh sizes (including stretched measures of 83, 76, 64, 57, 51, 38 and 19m), were fished with although the 64, 38 and 19m mesh size codends were used most frequently. For further details see BERSTRAND and CORDONE (*op. cit.*,).

Bottom trawling was possible only in waters deeper than 4m because of restrictions imposed by the draught of the *IBIS*. Towing speed was maintained at an average of 3 knots and the actual fishing duration was mostly 60 min. Shorter and longer drags were adusted to hourly catches for subsequent analyses. Trawling was performed during both day and night but, due to reversed diel vertical movements of certain species, mean catch rates and biomass estimates have been derived from drags made during the day (0700–1900 hours) only. However, species whose demersal catch rates tended to be higher during the night (1900–0700 hrs) than during the day may have been underestimated. Further, hauls believed to have been atypical in other respects (such as codend opened, net torn, etc. during the tow) were also not used for deriving the estimates. Thus, of the 1141 hauls made over the whole lake 772 (67.7%) were subsequently used for the analyses. The spatial distribution of all the hauls made (n_1) and those subsequently used (n_2) is shown in Table 1.

Table 1. The Spatial Distribution of Sampling Effort by Country Section of Lake Victoria and by Depth Interval.

Section of Lake Victoria		Depth interval (m)								
		4–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	Total
KENYA	n_1	59	42	12	6	22	18	8	[1]	162
	n_2	41	37	12	6	14	10	8	[1]	128
TANZANIA	n_1	90	115	76	38	35	22	17	5	398
	n_2	55	95	66	32	31	20	14	5	318
UGANDA	n_1	207	167	68	38	24	28	37	12	581
	n_2	55	96	52	33	23	27	29	11	326
Whole Lake	n_1	351	324	156	82	81	68	62	17	1141
	n_2	151	228	130	71	68	57	51	16	772
% of Total Hauls	n_1	30.8	28.4	13.7	7.2	7.1	6.0	5.4	1.5	100.1
	n_2	19.6	29.5	16.8	9.2	8.8	7.4	6.6	2.1	100.0
% of total Area of Lake		9.3	9.2	8.5	7.5	9.3	17.7	20.2	18.4	100.1

[1] No Kenya Section of the Lake has this depth

Although, as it appears from the table, systematic sampling (in terms of a real proportionality in the distribution of sampling effort) was not realized, broad coverage of the lake was achieved and we have considered the data suitable for generalized considerations. Lack of knowledge of the absolute fishing performance of our gear (i. e. the ratio of the fish caught to the number actually present in the zone, and at the time, swept by the gear) inevitably limited our analyses and interpretations. But, by making certain assumptions, we have derived estimates of "ichthyomass" for the various species and "potential yield" for the *Haplochromis* taxon. These estimates are merely tentative and can be used for designing more systematic and advanced studies. If they are used for the expansion or technological improvement of the fishery, the intial mode of the development should be experimental in magnitude and outlook.

RESULTS AND OBSERVATIONS:

Most of the lake was found to be convenient for bottom trawling. The lake is generally shallow with mean and maximum depths of 40m and 79m, respectively. It is almost flat-bottomed and the few areas with rocky bottoms or floating "papyrus islands" could easily be detected and avoided. Other under-water obstructions in some areas could be tolerated, though the efficiency of the gear would be reduced. Most of the fishes of the lake appear more demersal than pelagic, and, trawling was found to be superior, in harvesting particularly the *Haplochromis* spp, over the existing commercial gear. The following are the major trends in the distribution and relative abundance of the fishes in the lake as reflected from our bottom trawl data.

Composition of the Demersal Fishes of Lake Victoria

The composition of the demersal fishes encountered during the survey is comprised of 24 species excluding those belonging to the *Haplochromis* taxon. They are systematised into 21 genera which fall into 11 families as tabulated by BERGSTRAND and CORDONE (*op. cit.*,). The *Haplochromis* taxon alone consists of 4 monospecific genera and the more important polytypic genus, *Haplochromis* itself, made up of probably more than 120 species some of which have not yet been described. Since most of the species encountered (120 species of the *Haplochromis* taxon and 5 species of *Tilapia*) belong to the family Cichlidae, Lake Victoria is rightly considered a "cichlid lake" (GREENWOOD, 1966). However, the taxa encountered were fewer than the number known in the lake as listed by Greenwood. This is because *Xenoclarias* was identified only to generic level, *Engraulicypris* and small *Barbus* spp were not sorted out from the bulk *Haplochromis* whenever encountered and waters shallower than 4m, where several other species would be expected to occur, were not sampled during our survey.

Only 20 of these taxa were used in the the present analyses and are listed in Table 2. Although there were temporal and spatial variations in catch rates and frequency of occurrence, most of these taxa were encountered in all the 13 sub-areas except areas (IV, VII and XII) which are deeper than 50m. Thus, depth (directly or indirectly) is certainly one of the ecological factors determining the distribution pattern of the fishes in Lake Victoria.

Batho-spatial and temporal distribution of species as implied by their mean catch rates

There appears a well defined trend in the number of species by depth with maximum species diversification occurring in the shallow inshore waters of the lake. Data presented in Table 2 show that species diversity progressively decreases with depth. Excepting the *Haplochromis* spp, 19 species

Table 2. Bottom Trawl Mean Catch Rates (Weighted by Depth Interval) of the Various Fishes in Lake Victoria (in Kg/Hr).

Depth (m) Number of hauls	[2]/ 0–9 151	10–19 228	20–29 131	30–39 71	40–49 68	50–59 56	60–69 51	70–79 16
Species:								
Haplochromis spp[1]	493.8	800.2	639.5	507.5	448.0	486 3	196.3	29.6
Tilapia esculenta	54.1	28.3	4.4	0.5	0.0	—	—	—
T. variabilis	3.2	0.2	0.0	0.0	—	—	—	—
T. nilotica	10.0	0.9	0.0	—	—	—	—	—
T. zillii	0.4	0.0	0.0	—	—	—	—	—
T. leucosticta	0.2	—	—	—	—	—	—	—
Bagrus docmac	18.0	39.9	39.3	36.8	34.4	38.8	27.6	0.2
Clarias mossambicus	26.7	37.1	31.6	20.7	15.1	14.5	14.8	7.1
Xenoclarias spp	0.0	0.1	0.1	0.3	0.4	0.6	0.3	0.3
Proptopterus aethiopicus	33.3	23.1	7.3	5.5	1.6	0 5	—	—
Lates niloticus	2.0	0.6	0.4	—	—	—	—	—
Synodontis victoriae	0.4	1.7	7.0	9.0	11.2	26.5	29.4	14.9
S. afroficsheri	0.1	0.1	0.1	0.0	0.0	0.0	0.0	—
Barbus altianalis	0.4	0.5	0.3	0.2	0.2	—	—	—
Labeo victorianus	0.1	0.4	0.0	—	—	—	—	—
Mormyrus kannume	0.4	0.4	0.3	0.4	0.9	0.1	0.0	—
Schilbe mystus	0.9	1.8	1.3	0.6	0.3	0.1	0.0	—
Alestes spp	0.0	—	—	—	—	—	—	—
Mastacembelus frenatus	0.0	0.0	0.0	0.0	—	—	—	—
Gnathonamus longibarbis	0 0	0.0	—	—	—	—	—	—
Total	644 0	935.3	731.6	581.5	512.1	567.4	268.4	52.1
No. of species encountered (excluding *Haplochromis* spp)	19	17	16	11	10	8	7	4

[1]/ For *Haplochromis* spp only data from small mesh codends (19 and 38 mm) were used.
[2]/ Though the *IBIS* operated in waters deeper than 4m, mean catch rates were weighted by the area of the whole depth zone (i.e. 0–9 m).

occurred in the shallowest zone (4–9m) and only 4 were represented up to the deepest zone (70–79m). Four of the major commercial taxa (*Haplochromis* spp, *Bagrus docmac*, *Clarias mossambicus* and *Synodontis victoriae*) and one minor genus (*Xenoclarias*) were found to be eurybathic. On the other hand, *Tilapia* spp, *Protopterus aethiopicus* and most of the commercially minor categories were found to be more or less oligobathic. Among the *Tilapia* spp, *T. esculenta* has the widest, and *T. leucosticta* the narrowest, depth range of distribution. The depth zone limits of these species seem to be as follows: *Protopterus* (50–59 m), *T. esculenta* (40–49 m), *T. variabilis* (30–39m), *T. nilotica* and T. *zillii* (20–29 m) and *T. leucosticta* is confined to waters not more than 10 m deep.

In terms of mean catch rates and frequency of occurrence, the relative abundance also varies with depth for most of the fishes in the lake and could be divided into two broad groups: those whose catch rates tend to progressively increase with depth and those whose catch rates progressively decrease with depth. Among the latter group are the *Tilapia* spp, *Protopterus aethiopicus* and *Lates niloticus* (See Table 2), while the former group comprises *S. victoriae*, *Xenoclarias* spp and to a certain extent, *Haplochromis* spp and *B. docmac*. Other species which are relatively more abundant in shallow waters, are sometimes found in waters of intermediate depths, but disappear completely in deeper waters. Five of the species with the best trends in distribution by depth can be summarized as follows:

S. victoriae and *Xenoclarias* spp catch rates significantly increase in waters deeper than 30 m. The mean size of these fish, like that of *Haplochromis*, is also directly related to mean depth as shown below:

Depth zone (m)	*Haplochromis* Sample Size	Mean Length, L_t	*Synodontis victoriae* Sample Size	Mean Length, L	*Xenoclarias* Sample Size	Mean Length, L_t
4–9	3187	90.9 mm	172	10.8 cm	—	—
10–19	4434	87.2 mm	432	13.3 cm	—	—
20–29	2275	105.0 mm	415	14.6 cm	—	—
30–39	1766	106.9 mm	453	15.3 cm	73	16.7
40–49	1441	108.0 mm	685	15.6 cm	90	17.0
50–59	841	116.4 mm	629	17.4 cm	319	17.1
60–69	264	120.4 mm	557	21.4 cm	413	17.1
70–79	413	107.8 mm	227	22.8 cm	110	17.3

— Not enough samples were measured
L_t — Total length
L_f — Fork Length

However, further study is needed for sound interpretation of the apparent size-range segregation by depth among these fishes. Catch rates for *Haplochromis* and *B. docmac* are generally high in many depth zones but appear best in the 10–50 m depth range and very poor in deeper waters. All size ranges of *B. docmac* were often encountered on the same grounds. It is interesting to note that *Bagrus* follows *Haplochromis* more closely than does any other species in terms of relative abundance, diel vertical movements (see below) and depth preference which, together, strongly emphasize a closer *Bagrus*/*Haplochromis* association in the ecological predator/prey relationship.

Clarias mossambicus is almost equally ubiquitous throughout the depth range of the lake. Its frequency of occurrence was higher than 90% in each depth zone though catch rates by weight were generally higher in waters less than 40 m deep. The hardy nature of this fish, its accessory, suprabranchial, aborescent breathing organs and catholic feeding tendencies contribute, at least in part, to its eurybathic distribution.

Besides depth, there are other ecological variables (e.g. dissovled 0_2—concentration near the bottom, bottom type, open versus closed waters, etc.) that contribute to difference in distribution patterns, but analysis of detailed habitat types is outside the purview of our present consideration and only a broad picture of catch rates by the three territorial sections of the lake, though they are not spatially delimited, *per se*, is presented in Tables 3 and 4. Data seem to suggest that mean total catch rates are slightly higher in the Kenya section of the lake than the other two regions. But this is because the catch figures were first weighted by the surface area of each depth stratum and because the Kenya section has a very small proportion of the deep waters (where

Table 3. Mean Catch Rates (Kg/Hr) by Country-Section of Lake Victoria

Country	Kenya	Tanzania	Uganda	All Combined
Species:				
Haplochromis spp	440.26	426.37	327.38	384.69
Tilapia esculenta	7.63	12.70	2.59	8.07
T. variabilis	0.14	0.12	0.60	0.32
T. nilotica	0.58	1.21	0.85	1.02
T. zillii	—	0.01	0.08	0.04
T. leucosticta	—	—	0.05	0.02
Bagrus docmac	33.45	29.37	23.51	27.09
Clarias mossâmbicus	23.23	18.76	17.33	18.40
Xenoclarias spp	0.78	0.19	0.38	0.30
Protopterus aethiopicus	10.75	6.66	5.77	6.51
Lates niloticus	1.12	0.01	0.48	0.27
Synodontis victoriae	3.71	17.59	15.36	15.84
S. afrofischeri	0.90	—	0.01	0.03
Barbus altianalis	0.25	0.10	0.18	0.14
Labeo victorianus	0.17	0.07	—	0.05
Mormyrus kannume	0.34	0.16	0.29	0.22
Schilbe mystus	0.54	0.72	0.08	0.44
Total mean: whole lake	523.45	514.04	394.94	463.45
Less 70–79 m zone	523.45	606.40	496.30	555.93

Table 4. Total Mean Catch Rates (Kg/Hr) for Depth Substrata of Each Country-Section of Lake Victoria

Country	Kenya	Tanzania	Uganda	Combined
Depth zone (m)				
0– 9	415	848	511	644
10–19	810	1175	663	935
20–29	560	650	848	731
30–39	709	612	526	581
40–49	543	456	638	512
50–59	502	599	532	567
60–69	171	333	199	268
70–79	—	55	50	52
Mean: For All Zones	523	514	395	463
Mean: less 70–79m zone	523	606	496	556

catch rates and species diversity are lower). The Tanzania and Uganda sections of the lake which have larger proportions of the deep waters where *S. victoriae* are more concentrated show much higher mean total catch rates for this species. Comparison of the total mean total catch rates for the regions without the 70—79 m depth zone (which Kenya doesn't possess) suggests that Tanzania waters have higher fish densities, followed by the Kenya section (Tables 3 and 4, bottom rows). This implies that the southern part of the lake is more productive than the northern part and is in agreement with limnological findings showing more concentrations of nutrients due to their southward pile-up resulting from wind action against a downward northern tilt of the thermocline (KITAKA, 1971).

Another aspect of temporal-spatial differences in species distribution was derived from 24-hour trawl series conducted over the same transect in several different areas. Bottom and midwater 24-hour trawl series were compared and data, though not presented here, were complementary in implying the existence of temporal-spatial vertical migrations among certain species in the lake. Catch rates for *Haplochromis* spp, *B. docmac*, *T. esculenta* and, to a certain extent, *C. mossambicus* were higher in demersal catches made during the day than in demersal catches made during the night whereas their pelagic catches were higher during the night than during the day. The corresponding catch rates for *T. nilotica*, *P. aethiopicus* and *M. kannume* were the reverse. These changes, which were less obvious in shallow waters, imply that the two groups of fish tend to move away from and then towards the bottom in vertically opposite directions on a diel basis. Though the magnitude of amplitude of these reversed movements is not yet known, they are similar in essence to the case existing in the south-east arm of Lake Malawi (MEECHAM, 1971) and have interesting ecological implications. Comparison of bottom and midwater trawl exploratory catch results tends to suggest, in general, that with the exception of a few taxa (*Engraulicypris argenteus*, *Alestes* and perhaps some of the *Haplochromis* species) the fishes of Lake Victoria are more demersal than pelagic. This is because although the midwater trawl was much larger, the mean total catch were much lower (particularly during the day) and more variable than their bottom trawl counterparts. Lower efficiency of the midwater trawl does not seem to have been a fact since the pelagic catches greatly increased, relatively, during night-time fishing on the same grounds. Furthermore, apart from the reversed diel vertical migrations, some of our data imply existence (at least in some areas) of bimodal horizontal movements, by some species, which follow the biannual seasonality of rainfall. Thus, the spatial distribution of the fishes in the lake depends on a number of factors which include depth, location, time of day and season. However, diel and seasonal movements need further studies.

Estimates of "minimum standing stocks" in Lake Victoria and "potential yield" for Haplochromis spp as derived from demersal trawling

In deriving standing stock estimates the 52 sampling strata were grouped into 10m-depth intervals by territorial regions (Kenya, Tanzania and Uganda) and the area of each depth stratum was estimated separately so that mean catch rates were weighted by the area of their corresponding depth stratum. For the *Haplochromis* complex only hauls (of n_2-type) made with small mesh (38 and 19mm) codends were used because *Haplochromis* catch rates vary inversely with codend mesh size (CORDONE and KUDHONGANIA, 1972) so that large mesh sizes underestimate the preponderance of this taxon. To estimate ichthyomass of each species within the various strata we followed the method outlined by ALVERSON and PEREYRA (1969)—using mean catch rates, average towing speed, average working gape of the trawl and average area of the stratum considered. We also assumed that hauls were effectively randomized within each stratum, that catch rates were directly proportional to the density of the fish on the grounds and that the absolute fishing performance of the gear was unity on each of the grounds sampled. However, certain limitations of our data (e.g. selectivity of the trawl, like most other gear; disparity, both in time and space, in the sampling pattern whereas the populations sampled are dynamic; possible existence of avoidance or escapement, or of herding by the trawl doors and warps; etc.) impose limitations to the correctness or precision of our estimates. The estimates given are thus merely the order of magnitude of the demersal fish stocks in the lake susceptible to bottom trawl.

The results, as shown in Tables 5 and 6, suggest that at least 80% of the ichthyomass in Lake Victoria is composed of *Haplochromis* spp so that the rest of the other species (that were encountered) combined make up just more than 10%. Although there are temporal and spatial variations, the relative abundance of the major taxa in the lake follows this order of decreasing significance (by weight): *Haplochromis* spp (83.0%), *B. docmac* (5.8%), *C. mossambicus* (4.0%), *S. victoriae* (3.4%), *T. esculenta* (1.7%), *P. aethiopicus* (1.4%), *T. nilotica* (0.2%), etc. (Table 5). However, the significance of the *Tilapia* spp and *P. aethiopicus* may be underestimated since our experimental trawling did not include the shallow inshore zone (0–4m) where these fishes are thought to be more concentrated. It should be noted that the exotic *Tilapia* spp (*T. nilotica*, *zillii* and *T. leucosticta*), introduced into the lake from 1953 onwards, have made recognizable contributions to the fishery. On the other hand, *Lates* (introduced into the lake around 1960) has not yet shown the success achieved in Lake Kioga, where it was introduced in 1950, after an equal time period of ten years. Thus the bionomic and commercial contribution of *Lates* to the ichthyofauna of Lake Victoria is still insignificant.

Table 5. Estimates of Standing Stock (in metric tons) for Lake Victoria

Species:	Kenya	Tanzania	Uganda	All Areas	%
Haplochromis spp.	36,694	321,282	205,592	563,568	83.00
Tilapia esculenta	636	9,569	1,624	11,829	1.74
T. variabilis	12	88	367	476	0.07
T. nilotica	48	912	535	1,495	0.22
T. zillii	—	6	53	59	0.01
T. leucosticta	—	—	29	29	0.00
Bagrus docmac	2,788	22,131	14,766	39,685	5.84
Clarias mossambicus	1,936	14,138	10,885	26,959	3.97
Xenoclarias spp.	65	144	238	447	0.07
Protopterus aethiopicus	896	5,022	3,625	9,543	1.41
Lates niloticus	93	7	302	402	0.06
Synodontis victoriae	309	13,256	9,644	23,209	3.42
S. afrofischeri	42	—	9	51	0.01
Barbus altianalis	21	77	115	213	0.03
Labeo victorianus	14	53	1	68	0.01
Mormyrus kannume	28	119	181	328	0.05
Schilbe mystus	45	547	54	646	0.10
Total:	43,627	387,351	248,029	679,007	100.01
Area (ha)	416,730	3,767,490	3,139,890	7,324,110	
Density (Kg/ha)	104.7	102.8	79.0	92.7	

Table 6. Estimates of Biomass for Major Species in Lake Victoria

Species	Estimated total biomass (metric tons)	95% Confidence limits of biomass		Coefficient of variation of estimate
		lower	*upper*	
Haplochromis spp.[1]	563,568	504,709	622,427	.05
Tilapia esculenta	11,829	9,208	14,450	.11
T. variabilis	476	225	727	.26
T. nilotica	1,495	901	2,089	.20
T. zillii	59	0	138	.67
T. leucosticta	29	0	78	.85
Bagrus docmac	39,685	34,275	45,095	.07
Clarias mossambicus	26,959	24,098	29,820	.05
Xenoclarias spp.	447	330	564	.13
Protopterus aethiopicus	9,543	8,154	10,932	.07
Synodontis victoriae	23,209	17,178	29,240	.13
S. afrofischeri	51	29	73	.22
Lates niloticus	402	177	627	.28
Barbus altianalis	213	130	296	.19
Labeo victorianus	67	26	108	.30
Mormyrus kannume	328	157	499	.26
Schilbe mystus	646	446	846	.15
Totals:	679,006	619,444	738,568	.04

[1] Estimates for *Haplochromis* spp. based on 429 hauls with small-meshed codends. Estimates for other species based on 772 hauls with all codends.

Table 7. Relative Size and Demersal Fish Biomass Contribution of Lake Victoria's Various Depth Strata

Depth zone (m)	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79
% of total area	9.3	9.2	8.5	7.5	9.3	17.7	20.2	18.4
% of estimated biomass	13.0	18.6	13.5	9.4	10.2	21.6	11.7	2.1
% of biomass per 1% of area	1.4	2.0	1.6	1.3	1.1	1.2	0.6	0.1

Presentation of the contribution to the ichthyomass by the various depth strata in terms of their relative size may be of some interest. Data shown in Table 7 indicate that 18.4% of the area of the lake (the 70–79m depth zone) carries only 2.1% of the estimated demersal fish biomass while 38.6% of the area (the 60–79m depth range) carries 13.8% as compared with the 9.3% of the area (0–9m) carrying 13.0% of the total ichthyomass. Also, 50% of the biomass is contained in the rich 30% of the area corresponding to the 0–29m depth section of the lake where the 10–19m zone seems to be the richest. Thus, with bottom trawling, the central offshore zone of the lake is not as productive as the shallow inshore waters and this has important bearing when considering the tempo and incentive for geographical expansion of fishing operations to deep offshore waters.

"Potential Yield" for Haplochromis spp.

The *Haplochromis* spp biomass (i.e. fish of catchable size—from about 4.5 or 5.0 cm, Lt, and above) of approximately 600,000 metric tons could be used to derive a preliminary estimate of "potential yield" using GULLAND'S (1970) approximate model for estimating potential yield from data on virgin ichthyomass,

$$C_{max} = 0.4 \, M \, B_0$$

where C_{max} = Maximum potential yield,
M = Coefficient of natural mortality,
B_0 = Virgin ichthyomass.

The present commercial *Haplochromis* annual harvest (about 20,000 metric tons) was considered a small fraction of the standing crop so that the present ichthyomass, B, is nearly equal to virgin ichthyomass, B_0 (or roughly, $B = 0.9B_0$). For different species of *Haplochromis*, M is likely to vary between 0.5 and 1.5—depending on the mean individual size of a particular species. With only general diffuse knowledge of mortality coefficients in tropical freshwater stocks, we could use H. REGIER'S (1971) guesstimate of 0.8 as the average M value for all *Haplochromis* of catchable size. Thus,

$$C_{max} \simeq (0.4)(0.8) \frac{(B)}{(0.9)}$$

and this gives a "potential yield" which is within the magnitude of 200,000 metric tons. It is very necessary to point out that this estimate refers essentially to the order of magnitude of the biological potential, under proper and effective harvesting regime(s), and should not be interpreted as being the "yield to be realized".

A comparison between commercial annual harvest for *Haplochromis* and our "potential yield" estimate confirms the idea that this taxon is underfished. Though no potential yield estimates were made for the other fishes, our studies have reached a stage where it is possible to design a well-rounded efficient sampling and survey programme for Lake Victoria which now offers an excellent setting for studying the trend within a fishery of mixed stocks and the reaction of the complex *Haplochromis* populations to changed stress regimes such as trawl fishing.

LAKE VICTORIA'S PRESENT FISH STOCKS AND UTILIZATION IN RELATION TO TRAWL FISHERY DEVELOPMENT

The development of fishery research is part of man's response to fluctuations in abundance of exploited fish populations and its logical end objective is fishery management. The Lake Victoria exploratory survey data and commercial catch statistics indicate, among other things, that: (a) the composition of the demersal fish stocks during the survey was not qualitatively different from commercial catch composition; (b) whereas several of the species preferentially taken by the extant commercial gear appear over-fished (as construed from the greatly reduced catch rates) the greater part of the present ichthyomass (over 80%, *Haplochromis* spp) is under-harvested so that its yield could be increased by trawl fishing; (c) trawl fishing, though a more efficient method for catching most of the fish species in Lake Victoria, is best directed to the preponderant *Haplochromis* stocks which are currently underfished, and to *S. victoriae* which is abundant only in deep waters; (d) species diversity is inversely related to mean depth and total mean catch rates are lower in deep waters, particularly in the 60–79m depth range; and (e) that commercial yields from the lake have been maintained or increased through increased total fishing effort, increased use of small mesh-size gillnets and beach seines in some areas, and by geographical extension to more offshore areas.

Thus, there appears the need for modifications in fishing practices so that the harvest is a good representation of the usable stocks—but taking into consideration the dichotomy of the currently over-fished species and the under-fished *Haplochromis* stocks. Already arrangements are going ahead for trawling in the lake as a commercial undertaking and several considerations emerging include:

(1) The cost of operating a trawl fishery is much higher than that of the present gill-net fishery. The initial cost for fishing vessels and gear, infrastructure and landing facilities, technical experts and their counterparts, etc. is estimated in millions of shillings.

(2) The expected increased landings, particularly of *Haplochromis*, would need improved transport, storage, handling, processing and marketing facilities.

(3) The *Haplochromis* stocks for which trawling is most called consist mostly of small individuals so that suitable codend mesh sizes for their effective capture would also retain the juveniles of the larger fishes (e.g. *Bagrus*, *Tilapia*) whose current commercial catch rates are comparatively submarginal.

(4) Because the diversity of species and magnitude of trawl catch rates decrease with depth, trawl operators may not be fascinated to operate only in deeper waters (say, 30–79m depth range). This might cause competition between trawlers and gill-netters fishing on the same grounds, and may lead to the destruction of gill-nets, and breeding/nursery gounds for certain species in the shallow waters, by the trawlers—causing social and biological repercussions of unknown magnitudes.

(5) Because there is biological interaction (competition, predator/prey relationships, etc.) among species, the effects of increased fishing mortality and change in selective properties of the fishing gear would be reflected in the biotic potential of the whole lake.

It is apparent, then, that trawl fishing on Lake Victoria would embody economic, social, political, technical and biological aspects. In order to forestall serious incompatibilities between the various constraints and aspirations, and before development prospects are enacted, the nature of the resource and its use to the human community must be carefully considered with foresight since the mode of the use of a food supply and its magnitude together form an important criterion for judging the grade of exploitation.

Mode of Utilizing Haplochromis

Increased harvests from trawl fishing would be expected to bridge the ambivalent gap between protein malnutrition and the large under-exploited stocks of *Haplochromis*. We consider it that *Haplochromis* was not being consumed in proportion to its preponderance largely because the gill-net fishery does not effectively tap this rich protein resource so that its market prices have remained higher than could provoke popular demand relative to other commercial species. Though some social groups would not take *Haplochromis* as a first preference, there are many areas where these fish (fresh, dried, smoked, salted, etc.) sell very readily; some tribes, like the Baganda, have long cherished *Haplochromis* even at every traditional feast; and, we suggest, trawl catch rates (as observed during our exploratory survey) would make the fish cost low enough so as not to deter most potential consumers of these fish through high market price stringency. Fish supply in East Africa is not anywhere close to public demand. According to CRUTCHFIELD (1969) in his Report on Mission to Lake Victoria Project, "the problem of the fisheries in East Africa is much more one of supply than of markets", so that our task with increased *Haplochromis* landings would appear to be of organization and the provision of the physical means for transporting, storing and handling the fish.

However, because these fish fetch lower market prices than the other major commercial species, and because they are generally small with many bones, they have been suspected by some "advisors" to be "unpalatable" and "unpopular" so that alternative means of "disposing of *Haplochromis*" expected from high trawl catches have been recommended for consideration. Canning and making F.P.C. (both are for direct human consumption) have been experimentally initiated at Entebbe (Uganda) and Nyegezi (Tanzania) but the final products appear, at least, expensive. Fishmeal (for cattle, poultry, pig and pet foods) production (which also has a pilot plant at Nyegezi), apart from the insensible wastage associated with bulk transport and handling, involves a loss of *5* to *1* from fish to fish meal and a further loss due to biochemical transfer from fishmeal to the flesh of the animal fed and, hence, appears trophically uneconomic. The time and costs required from fish to beef do not, even on *a priori* grounds alone, impart priority to the process. The minimum capacity for a fishmeal plant to operate economically is estimated to be one capable of processing 20 tons of raw material per hour (i.e. 480 tons per 24 hrs) and the initial cost of capital goods is figured at about 2 million dollars (ALVERSON and BROADHEAD, 1971). Though there is evidence for a ready market for fish meal, people (in East Africa) who would afford fishmeal-fed chickens and pigs, let alone indulging in feeding pets on animal protein (which many humans badly lack) are in the minority and, thus, fishmeal production would not spread the resource for the benefit of most of the people who actually need the protein and would be better considered only as a later ancillary, in the allocation of the *Haplochromis* resources, to the initial requirement of increased fish supply for direct human consumption.

The reliability of the Haplochromis Stocks

The reliability or stability of the *Haplochromis* stocks as an economic and food resource is best considered in the contexture of the ecological status of these fish within the lake as a single ecosystem. *Haplochromis* spp in Lake Victoria are nearly all endemic and have occupied almost every available habitat, implying their wide range of ecological adaptations. But that at least 120 species belonging to one genus (through endemic speciation) are confined to a single body of water, and that they have developed an enormous range of trophic types, strongly suggest that individual species may not have developed a wide range of ecological tolerance. Because of its high specialization and possible narrow range of specific tolerance, the *Haplochromis* group may be very sensitive to sudden stresses; and because of its complexity as a flock it may not be productive enough to warrant sustainable large scale economic returns on a long-term basis. On the other hand, *Haplochromis* plays a big role in the bionomics of the lake as it forms the principal food of many other fishes particularly *Bagrus* and *Clarias*, and *Lates* (which was introduced into the lake for the purpose); and the dead *Haplochromis* contribute towards the fertility of the lake. In short, *Haplochromis*, apart from its complexity as a flock and uncertain reproductivity under heavy exploitation, plays a big role in the biological interaction within the lake but how delicately balanced the ecosystem is or the possible response to the impact of changed fishing stress are not yet known, so that initiation of a mechanized commercial fishery on Lake Victoria requires more than routine cautious approach.

Alternatives of mechanized fishing development

Three alternatives and their major limitations or usefulness are considered. The first of these would be to delay mechanization till later, when adequate scientific research has been achieved. The major trouble with this possibility is that further delay would mean further under-utilization of the *Haplochromis* resource. Besides, "adequate scientific research" may never be achieved so that this, as an alternative, is least likely to be desirable.

The second alternative would be to start a full-scale mechanized fishing industry right away. This seems to be the most desirable alternative among developing nations. However, their anxiety to develop immediately has often lured some into enacting strangling projects before the risks involved or alternatives available had been adequately considered (see DUMONT, 1966, for some examples). Full scale mechanization of Lake Victoria's fisheries, though desirable, does not appear reasonable immediately. The impact of trawl fishing on the fish stocks (some species of which are already over-fished) and on the gill-net fishermen (many of whose current catch rates are economically discouraging) and the need for generating an organized method for bulk spread of *Haplochromis* to the expanding public (currently beset by protein malnutrition) are worthy of deep concern. Jumping immediately on to the stocks with many trawlers, which involves expensive economic commitment for initiation and operation, would not permit careful appraisal of the trend of the fishery (which is essential for rational management) because trawler-owners would naturally operate to, at least, recover their investments. Lake Baringo Fishermen's Co-operative and Kenya Development Corporation are now filleting 12cm-long (Lt) *Tilapias* (as compared with 18cm in 1969) because their investment plant—Lake Baringo Fisheries Limited—which requires 70,000 to 100,000 fish per month to operate economically must operate (SSENTONGO, 1972). The need for reasonable examination of biological and other considerations before large economic commitments are made is not new on Lake Victoria. The prostrations of the 1949–51 enterprise (based on Dagusi Island off South Busoga, Uganda Section) for gill-net exploitation of *Mormyrus* stocks which had been known to "exist on an economic scale", and the 1953–54 venture by the Uganda Development Corporation for a trawling industry in the same area to "catch *Bagrus* and *Mormyrus* for kippering, and *Haplochromis* for sun-drying" (EAFFRO, 1967) are not a forgotten monitory clue.

The third would be the intermediate alternative to start mechanization on a small scale and subsequently modify the developments as deemed appropriate. This approach seems to be the more realistic because whilst the needs for increased protein and technological improvement of the fishery would be met, the associated social, biological, economic, etc. trends would have some opportunity for analysis and subsequent modifications to desirable levels. Besides, the low initial capital investment would not be a great burden to frustrate the various research disciplines and, since fishmeal production is most likely to be economically expensive and is definitely trophically uneconomic, a practicable strategy for fish supply to the protein requiring majority and for export would receive the tantamount attention.

The, mechanized exploitation of the under-fished *Haplochromis* would appear more rational if it proceeded in graded steps—with view to biological, economic and sociological constraints. The current human food balance justifies the necessity for direct fish supply to human beings rather than to pigs or pets. It is logical to say that the economic side of a fishery thrives if the biological side also thrives and, that even without making the mechanized fishery an immediate source of cash income (no matter how "foreign exchange" it may be) the value of fish to the protein deficient people more than defrays the opportunity cost. A trawl fishing regime that would neither raise serious conflict with the existing thousands of commercial fishermen nor depress the biotic potential of the fishery, and allow optimum utilization of the resource and avoid sinking some millions of shillings into the drain, is least likely to be one initiated (having only tentative estimates) above the magnitude of experimental modesty.

SUMMARY

Exploratory survey of the fish stocks of Lake Victoria has been used to describe some prominent trends in the distribution and relative abundance, and to derive preliminary estimates of the standing stocks, of the demersal fishes of Lake Victoria. The lake does not offer major physical obstacles to trawling as a fishing technique, but possible social, economic and biological consequencies impose the requirement of more than routine considerations for trawling on the lake as a sound commercial enterprise. Most fishes in the lake appear more demersal than pelagic and are dominated by the *Haplochromis* complex to over 80% by weight. Species diversity and abundance decrease with increasing depth, so that the offshore 70% of the lake area (corresponding to the 30–79m depth range) contains probably much less than 50% of the demersal harvestable ichthyomass. The mean size of some fishes (*Haplochromis* spp, *S. victoriae*, *Xenoclarias* spp) tends to increase with increasing depth. Implied seasonal movements and reversed, diel, vertical migrations which, apparently, contribute to temporal and spatial variability in catch rates have interesting ecological implications, but still need further study.

Using the "minimum standing stock", a preliminary estimate of the "potential yield" for the preponderant *Haplochromis* spp. was derived. More *Haplochromis* could be harvested than currently and bottom trawling proved an excellent way to tap this resource. But owing to possible incompatility between various biological and social constraints on one hand and economic and development aspirations on the other, mechanized exploitation of this resource should not be initiated with blind-folded gusto. A start within the magnitude of experimental modesty is more prudent so that the impact of trawl fishing on the gill-netters, fish stocks, fish demand, etc. could be evaluated to enable the establishment of an internationally co-ordinated management strategy geared towards a state of eumetric exploitation and optimum utilization of the resource.

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