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Current distribution, abundance and population structure of the fish stocks in Lake Victoria and options for their management

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Abstract

During the last 30 years, changes (physical, chemical and biological) have occurred in Lake Victoria and, consequently, the fish stocks of the lake have been modified. The extent of the modification of these fish stocks is not fully known. A total of 793 hauls (of 30 minutes duration) were taken during experimental bottom trawl surveys in the Uganda sector of Lake Victoria during the period November 1997 to December 2000 to estimate composition, distribution and abundance of the major fish species in waters 4 to 60 m deep. Seventeen fish groups were caught with *Lates niloticus* (Nile perch) constituting the largest biomass (87.8%) followed by Nile tilapia, *Oreochromis niloticus* (L.) (8.6%). Haplochromines and *L. niloticus* occurred in all areas sampled while *O. niloticus* and other tilapiines were restricted to shallower waters (<20 m). In waters deeper than 40 m, fish was rarely recorded during bottom trawling: the echosounder indicated no fish at the bottom; the fish signals were concentrated in the depth zone 10-20 m from the surface. The mean trawl catch rate in the zone where artisanal fishermen operate (i.e. in waters <30 m depth) was 195.2 kg hr^{-1}, of which 87.9% was *L. niloticus*. Species diversity and relative abundance of the fish caught decreased with increasing water depth from 232.2±38.7 kg hr^{-1} for all fish species in the 4-10 m depth zone to 7.7 kg hr^{-1} at 40-50 m depth zone during the survey period 1997-2000. From the swept area method, the abundance index for all fish species in the 4-40 m depth zone in the Uganda portion of the lake was estimated at around 142,000 tonnes during the period 1999-2000. The abundance index for *L. niloticus* and *O. niloticus* were estimated around 121,000 and 15,000 tonnes, respectively, during the period 1999-2000; 307,000 tonnes was estimated for *L. niloticus* in the Uganda sector of the lake. Only 29.3% of 121,000 tonnes estimated for Nile perch during 1999-2000 was for mature fish (>50 cm total length) and the rest were juveniles. Estimated yield from the Uganda sector is around 107,000 tonnes annually, of which about 72,000 tonnes is Nile perch suggesting cropping of at least 40,000 tonnes of immature fish. This calls for urgent management measures.

Introduction

Until the 1970s, Lake Victoria had a multi-species fishery dominated by the tilapiine and haplochromine cichlids. There were important subsidiary fisheries for more than 20 genera of non-cichlid fishes, including catfishes *(Bagrus docmak, Clarias gariepinus, Synodontis* spp and *Schilbe intermedius),* the lungfish *(Protopterus aethiopicus* and *Labeo victorianus* (Kudhongania & Cordone 1974). Stocks of most of these species declined and others disappeared following the introduction of four tilapiines *(Oreochromis niloticus, Oreochromis leucostictus, Tilapia rendalli* and *Tilapia zillii)* and Nile perch *(Lates niloticus)* during the 1950s. Since then the fishery has been dominated by Nile perch, Nile tilapia *(Oreochromis niloticus)* and the native cyprinid species, *Rastrineobola argentea* (Mukene).

Lake Victoria is an important source of fish not only for local consumption but also for export. The lake contributes about 60% of fish to the export processing factories. A number of fish processing plants have been constructed along the shores of the lake, 11 of which are licensed to operate in Uganda (Odongkara & Okaronon 1999) with interest in fish processing expected to rise. The fishing capacity in the Uganda sector increased from about 3 200 fishing boats in 1972 to 8 000 by 1990 (Okaronon 1994) and was estimated to be about 10 000 boats in 1998 (Dhatemwa, pers comm.). The Frame survey of March 2000 estimated 15 544 fishing boats in the Uganda sector of the lake (Uganda Fisheries Resources Department 2001, Asila 2001).

This increase in fishing effort and investment was made without clear knowledge of the magnitude of the stocks. There are indications that the fishery yield has declined from 135 000 tonnes in 1993 to 107 000 tonnes in 1997 (Odongkara & Okaronon 1999). The only previous extensive stock assessment exercise undertaken was from 1969 to 1971, before the Nile perch upsurge (Kudhongania and Cordrone 1974). Some other bottom trawl surveys were conducted from 1981 to 1985 (Okaronon et al., 1985; Okaronon and Kamanyi 1986) and from 1993 to 1997 (Okaronon 1994, Odongkara & Okaronon 1999). The current stock assessment programme, which commenced in 1997, was designed to generate information to underpin management decision making for the fishery. This includes estimating the current composition, distribution, abundance, population structure and biomass of the major fish species. The objective of this paper is to provide an overview of the current state of the fish stocks in the Uganda portion of Lake Victoria, with particular reference to the distribution, abundance and population structure.

Materials and methods

Fish stock assessment data in Lake Victoria was collected during bottom trawling and multi-mesh gill netting surveys. Lake wide acoustic surveys were used to monitor the whole water column. Onshore surveys of the fishing activities were carried out to determine the amount of fish being landed, the number of boats involved and the type of gear used. Bottom trawl surveys were conducted from November 1997 to December 2000.

The Ugandan sector of the lake was divided into 3 zones: Zone I – Tanzania/Uganda border to Bugoma Channel (Bukakata), II – Bukakata to Rosebury Channel (Kiyindi), and III – Kiyindi to Uganda/Kenya border (Fig.1). These zones were further subdivided into grids for sampling purposes; on the Ugandan sector the grids measuring approximately 5 nautical miles square were used. The fixing of grids was based on minutes of Latitude and Longitude.

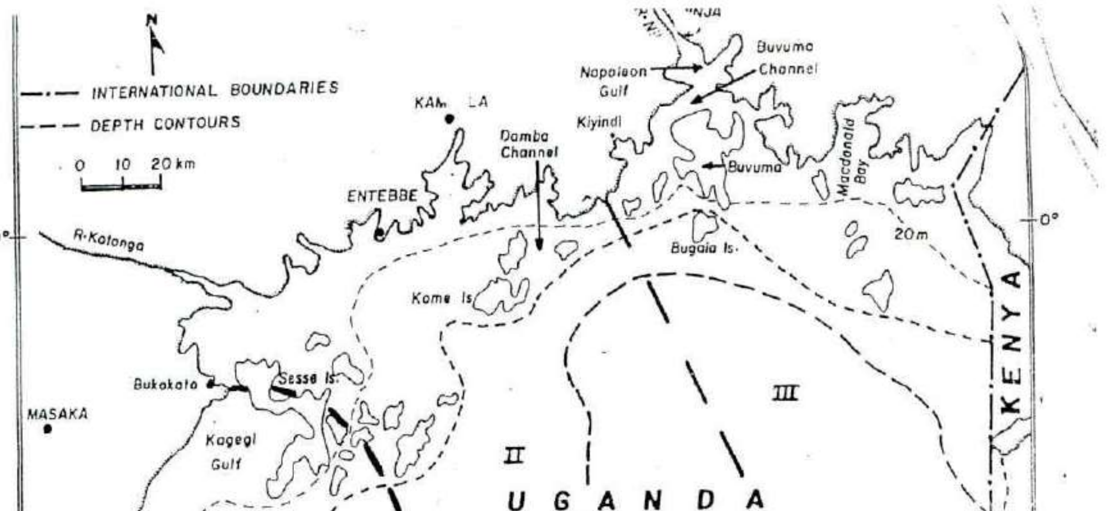


Fig 1. Sampling zones for Lake Victoria, Uganda.

Table 1: Distribution of hauls during bottom trawling in the various depth ranges in the Uganda sector of Lake Victoria.

		Depth Interval (metres)														
Period		Zone I					Zone II					Zone III				
		4-10	0-20	0-30	0-40	0-50	4-10	10-20	20-30	30-40	40-50	4-10	10-20	20-30	30-40	40-50
1997	Nov						7	12	9	3	5					
	Dec										4	11	10	5	1	
1998	Jan															
	Feb	1	15	6	4		1	1								
	Mar						6	9	10	3	1	1				
	Apr											2	14	6	1	
	May															
	Jun				13	15	14									
	Jul															
	Aug											3	12	11	3	1
	Sep											1	24	1		
	Oct						3						5			
	Nov						1	2	8	2						
	Dec		12	4	2		8	9	1							
1999	Jan											3	10	18		1
	Feb															
	Mar						6	13	5	3						
	Apr		4				9	9	10	4	1					
	May											3	6	7	3	
	Jun						12	10	12	3	1					
	Jul	2		3												
	Aug											1	12	1	1	
	Sep	3	5	8			1	2								
	Oct															
	Nov						7	6	9	2		1				
	Dec											6	*20*	*11*		1
2000	Jan															
	Feb	1	5	2	5		4	5	4	3			2			
	Mar		11	7	2		2	2				2				
	Apr	3	7	2	3			2				2				
	May						3	4	8			1	2			
	Jun											6	13	7		2
	Jul	1	2				10	6	4	*1*			3	1		
	Aug											3	15	5	1	2
	Sep	2	7	1	4		8	4	6	*1*		1				
	Dec						5	4	4			1	*8*	5		
Total:		**11**	**68**	**32**	**23**		**106**	**115**	**104**	**23**	**10**	**38**	**158**	**83**	**14**	**8**
:By zone		***134***					**358**					**301**				

Using the research vessel R.V. IBIS, experimental bottom trawling surveys, each lasting about 10 days, were carried out monthly between November 1997 and September 2000 and quarterly thereafter. Each of the three zones was surveyed once every quarter to take account of the four climatic seasons in the area. Hauls of 30 minutes duration were taken using a 25.4 mm codend stretched mesh trawl in the various grids. The bottom

Table 2 : Mean catch rates (kg hr-[1]) by depth for fish caught by bottom trawling in the Uganda sector of Lake Victoria between November 1997 to June 2000 (0.00 = present in trace quantities of less than 16 g). (mean catch rate=total catch/total number of hauls*60 minutes)

		<		Depth interval (metres)		>		
Fish species	4-10	10-20	20-30	30-40	40-50	50-60	Percentage	
Aethiomastacembelus frenatus					0.00		0.00	0.00
Bagrus docmak	0.00						0.00	0.00
Barbus spp	0.00	0.01	0.02	0.01	0.06	0.00	0.01	0.01
Brycinus spp	0.00						0.00	0.00
Clarias gariepinus	0.16	0.05					0.05	0.03
Haplochromis spp	5.13	4.33	8.71	3.02	0.86	1.59	5.52	3.06
Labeo victorianus	0.00	0.00					0.00	0.00
Lates niloticus	192.69	143.06	184.13	175.12	4.97	3.45	162.37	90.05
Mormyrus kannume		0.00					0.00	0.00
Oreochromis leucostictus				0.01			0.00	0.00
O. niloticus	30.51	15.37	0.00				12.15	6.74
Protopterus aethiopicus	0.38	0.19					0.15	0.08
Schilbe intermedius						0.00	0.00	0.00
Synodontis afrofischeri	0.07	0.04					0.03	0.02
S. victoriae	0.00	0.06	0.01	0.11		0.02	0.01	
Tilapia rendalli		0.01					0.00	0.00
T. zillii		0.02	0.00				0.00	0.00
Number of species caught	12	13	6	5	4	3		
Mean of total catch rate	228.97	163.06	192.92	178.16	6.00	5.04	180.31	
95% confidence limits	±38.14	±23.55	±44.58	±61.25			±18.35	
Number of hauls	124	292	193	53	16	3	681	

trawl surveys using these grids became operational during 1999. The grids surveyed included those with transects surveyed in earlier operations (1993-1998).

A trawl net is a large wide-mouthed net dragged along the lake-bottom by a boat. The net (trawl) has a head rope (where the floats are attached) of about 20 metres length – 24 m since November 1998 - and a footrope (where the chains or sinkers are attached) of about 28 metres length; the depth/opening of the net is estimated at 1.5 metres. The codend is the closed bag part of the net tied at end of the net. The net was dragged, during the trawling operation, by the research vessel M.V. IBIS which is 17 metres long and has a 4.9 metres beam and a 2.4 metres draft. The vessel is powered by a marine diesel engine rated at 180 hp and attains a maximum speed of 9 knots. The trawling speed was maintained at about 3 knots.

Fish catches were sorted into species. Fish weights and lengths were taken and recorded. The weights were in kilograms (kg) to the nearest 50 grams (g) for fish greater than 2 kg, the nearest 5 g for fish between 100 g and 1 kg and to the nearest 1 g for fish less than 100 g. The lengths are in centimetres (cm) to the nearest millimetre (mm).

For large quantities of fish retained, sub-sampling was used especially for smaller/juvenile specimen less than 35 cm total length for *L. niloticus*. The heap (of smaller/juvenile fish) was mixed thoroughly, a sample of known weight (3 spades) relative to the heap was taken and analysed for lengths and/or weights and the results raised accordingly

Of the 793 hauls made from November 1997 to December 2000, 45% were taken in Zone II, 38% in Zone III and 17% in Zone I (Table 1). The low number of hauls in Zone I was primarily because of breakdown of the research vessel and, to a certain extent, rough weather. The majority of the trawl hauls (77%) were made in waters between 10 m and 30 m deep, while 18% were in shallower waters (Table 1).

Analysis of data on habitat types was based on grids measuring 15 nautical miles square. Length frequency analysis of *L. niloticus* was carried out on 358,622 fish caught between November 1997 and December 2000.

Methodology for estimating fish stock abundance

The swept area (A_{sw}) method (Sparre and Venema 1998) was used to obtain quantitative information of fish biomass from the bottom trawl survey data:

> $A_{sw} = xh * xe * HL * V * t$, where xh is the net width factor, 0.33 (Witte and van Densen 1995); xe is the catch efficiency, HL is the headline length of the trawl, 24 m V is the towing speed, 3 knots (= 3 * 1.852 km) t is the duration of each haul, 0.5 hour Thus A_{sw} = (0.33 * 1 * 24 * 3 * 1.852 *0.5) 1000 = 0.022002 km^2.

The biomass density – here referred to as standing crop – on the trawled ground is expressed in terms of catch per unit area (CPUA).

Standing crop = CPUA = W_{mean} / (A_{sw} * vi) Where W_{mean} is the mean catch weight for all hauls in the relevant area vi is the fraction of the population sampled by the bottom trawl, 0.5. The standing crop is estimated in tonnes per square kilometre (tonnes km^{-2}). Fish biomass in a particular area was estimated through multiplying the standing crop (of that area) by the total bottom area. In this report the fish biomass estimates have been obtained by water depth intervals.

Results

Fish species composition and distribution

During the bottom trawl surveys of November 1997 to December 2000, 17 species groups (14 genera) were recorded (Table 2). These groups included species complexes such as haplochromine cichlids. *Lates niloticus* (Nile perch) dominated the catches (87.8% by weight) followed by *Oreochromis niloticus* (Ngege) (8.6%) and haplochromines (3.4%); all other species together contributed about 0.2% (Table 2). The highest catches were obtained in Zone I, where an average of 250.6±56.4 kg hr^{-1} was recorded, followed by Zone II (195.1±22.7 kg hr^{-1}) and Zone III (163.3±25.1 kg hr^{-1}). Species diversity was greatest in water 10-20 m deep and decreased with increasing depth (Table 2). The highest proportion of the fish (90.4%) was found in waters <30 m deep.

L. niloticus and haplochromines occurred in all areas sampled while *O. niloticus* and other tilapiines were concentrated in waters less than 20 m deep (Tables 2). Few fish were caught in depths greater than 40 m, and these were restricted to *L. niloticus*, haplochromines and *Barbus* spp. In waters deeper than 40 m, fish was rarely recorded during bottom trawling. The echosounder indicated no fish at the bottom; the fish signals were concentrated in the depth zone 10-20 m from the surface.

Relative abundance of the fish stocks

Mean catch rates

The mean catch declined from 232.2±38.7 kg hr^{-1} for all fish species in the 4-10 m depth zone to 7.7±6.4 kg hr^{-1} at 40-50 m depth during the survey period 1997-2000 (Table 2). A mean catch rate of 195.2± 25.7 kg hr^{-1} was estimated for the 4-30 m depth range where the artisanal fishermen operate.

Standing crop

The standing crop of fish in the Ugandan part of Lake Victoria is illustrated in Fig. 2 for all species, Fig. 3 for *L. niloticus* and Fig. 4 for O. niloticus.

L. niloticus was recorded in all areas surveyed but high concentrations of >10 tonnes km^{-2} were recorded in B06 (Damba Channel in Zone II), B08 (Mvuja Island area – west of Luvia and Dagusi Islands in Zone III), B10 (Berkeley Bay – off Majanji in Zone III), C04 (Buvu-Mu island area – off Entebbe Airport in Zone II), D02 (White Stony-Bale area – south of Lambu in Zone I), E02 (Bale-Namirembe – off Dimu in Zone I), E03 (Linga-Lujabwa Island area – south of Bugala Island, Kalangala District in Zone I) and F02 (Masambwa-Lujabwa Island area - south of Bugala Island, Kalangala District) (Fig. 3).

Figure 2. Chart of 15 x 15 mile sampling squares in Lake Victoria showing standing crop (tonnes km^{-2}) for all fish species in Uganda water, 1999-2000

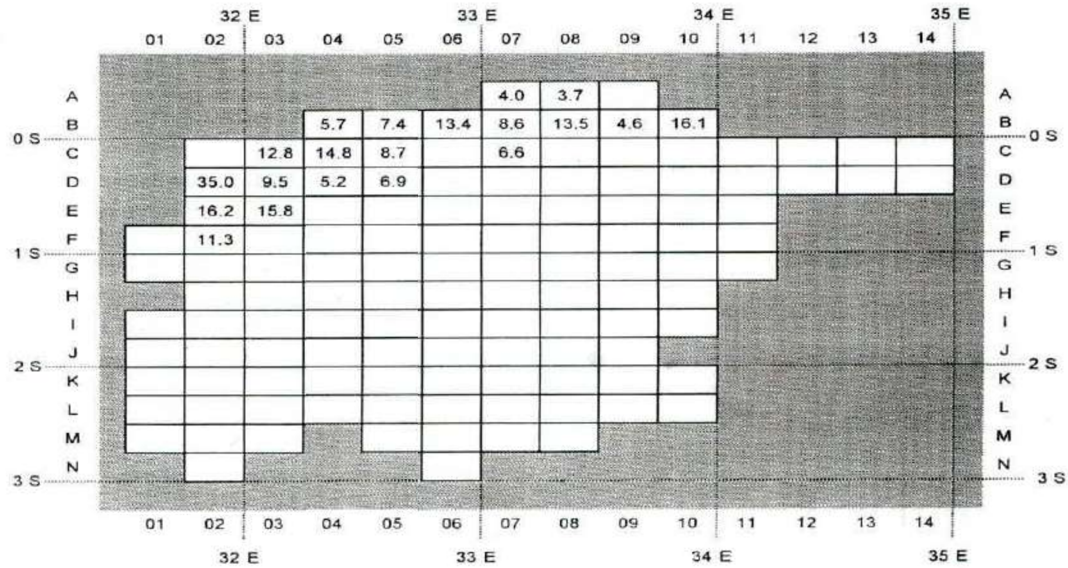
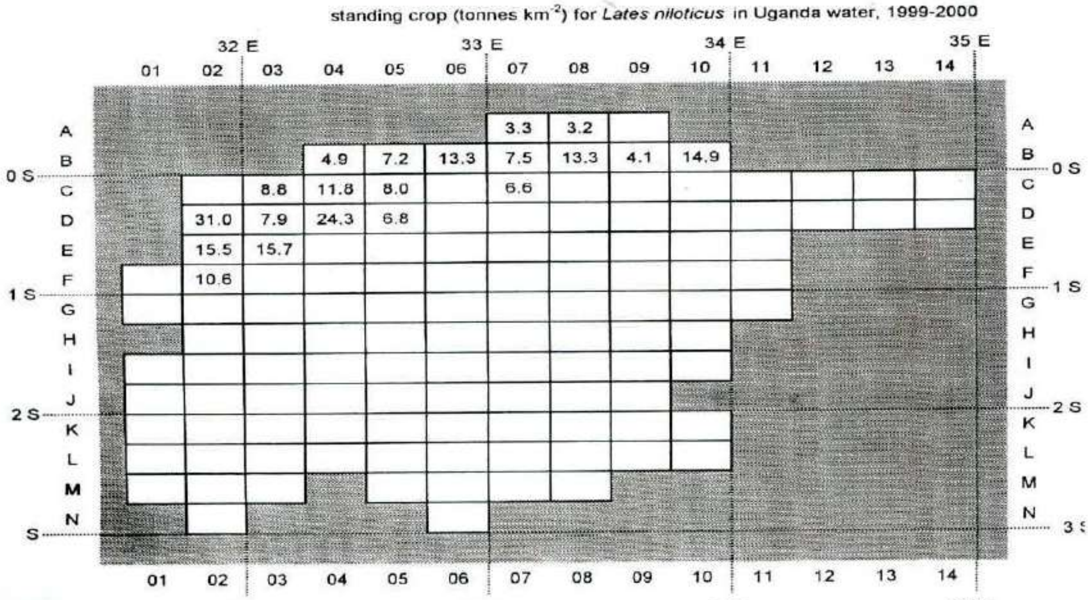
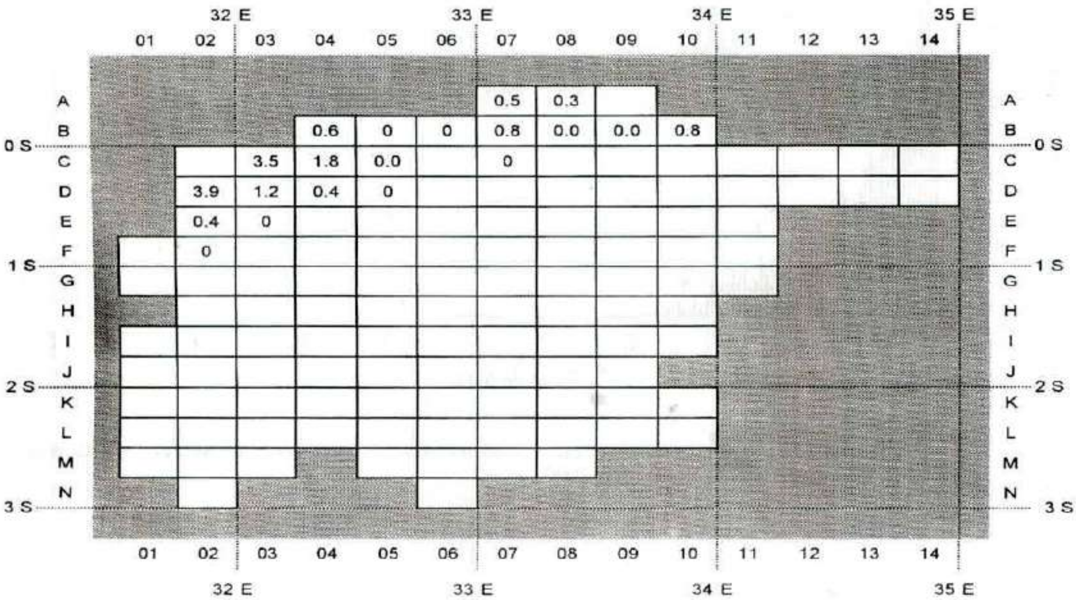


Figure 3. Chart of 15 x 15 mile sampling squares in Lake Victoria showing standing crop (tonnes km^{-2}) for *Lates niloticus* in Uganda water, 1999-2000



However, O. niloticus was recorded in waters less than 20 m deep; high densities of >1 tonne km^{-2} were recorded in Katonga River mouth and surrounding waters in Zone II (C03), C04 (Buvu-Mu Island area – off Entebbe Airport in Zone II), White stony-Bale area in Zone I (D02) and Kasakah-Mweza-Lunguru area in Zone I (D03) (Fig. 4).

Figure 4. Chart of 15 x 15 mile sampling squares in Lake Victoria showing standing crop (tonnes km^{-2}) for *Oreochromis niloticus* in Uganda water, 1999-2000 (0 = NIL catch, 0.0 = trace quantities of <0.05 tonnes km^{-2})



Fish stock biomass

From the swept area method, the abundance index for all fish species in the 4-40 m depth zone in the Uganda portion of the lake was estimated at around 142,000 tonnes during the period 1999-2000 (Table 3). The abundance index for *L. niloticus* and *O. niloticus* were estimated around 121,000 and 15,000 tonnes,

Table 3. Index of abundance of fish stocks in bottom trawl surveys in Lake Victoria (Uganda 1999-2000.

Period	*Depth* Interval (m)	*Estim.* area (km^{-2})	*No.* of Hauls	*< Standing crop (tonnes km^{-2}) >* Total	L. *niloticus*	*O. niloticus*	< Biomass (tonnes) > Total	*L. niloticus*	*O. niloticus*
1999 -2000	*4-10*	3744	105	13.51	9.99	3.10	50570	37386	11599
	10-20	3584	199	9.14	7.66	1.08	32755	27464	3867
	20-30	2842	137	12.89	12.32	0.00	36638	35008	0
	30-40	2025	43	10.72	10.54	0.00	21710	21342	0
					Total		141672	121199	15466

Estimated Biomass distribution for Lates niloticus (1999-2000)

Total Length Interval (cm)	Percentage (weight)	Biomass (tonnes)
1-25	13.38	16216
26-49	57.35	69507
50-80	21.08	25549
81-100	6.20	7514
>100	2.01	2436

Fig. 5. Length frequency distribution of Lates niloticus from bottom trawling in Lake Victoria (Uganda), November 1997 to September 2000.

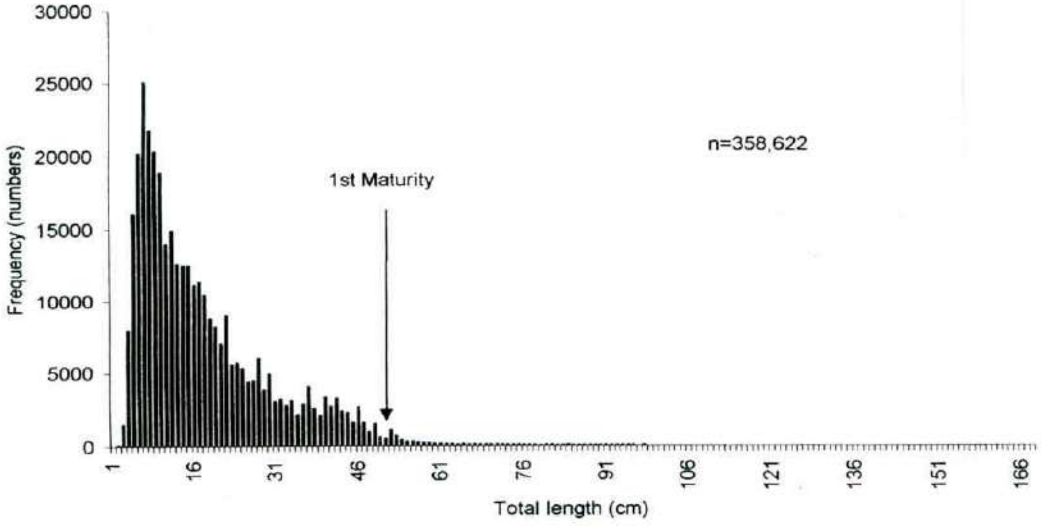


Fig. 5. Length frequency distribution of *Lates niloticus* from bottom trawling in Lake Victoria (Uganda), November 1997 to September 2000

respectively, during the period 1999-2000 (Table 3). On the basis of the mean standing crop of 9.94 tonnes km^{-2} for *L. niloticus* in the surveyed area of the Ugandan sector of the Lake Victoria during November 1999 to September 2000, the abundance index for *L. niloticus* in the Uganda sector of the lake was estimated at 307,000 tonnes.

Other observations on *Lates niloticus*

During the 1997-2000 bottom trawl surveys, the size at first maturity of male and female *L. niloticus* was estimated at 50.0 and 64.0 cm total length, respectively. The size at 50% maturity was 64.0 and 73.0 cm total length for male and female fish, respectively.

The sex ratios of female to male fish averaged 1:5 and 1:3 during 1999 and 2000, respectively. The ratios varied with habitat (grid), ranging from 1:3 in grid B10 (Berkeley Bay – off Majanji in Zone III) to1:17 in grid E03 (Linga-Lujabwa Island area – south of Bugala Island, Kalangala District in Zone I).

The length at infinity (Loo) was estimated at 256 cm total length, growth rate (k) was 0.29 and natural mortality was 0.42; the maximum observed length was 183 cm total length. Fishing mortality (F) was estimated at 1.17 while exploitation rate was 0.73.

Discussion

During the lakewide bottom trawl survey of 1969-1971 (KUDHONGANIA and CORDONE 1974), 24 fish species belonging to 21 genera were encountered and haplochromine cichlids were the most abundant. There were remarkable changes in species composition by depth with the maximum species diversity in the shallow waters. The *Haplochromis* species complex contributed 83% by weight, *Bagrus docmak* 4.2%, *Clarias gariepinus* 4.1%, *Oreochromis esculentus* 3.8%, *Protopterus aethiopicus* 2.8%, *Oreochromis niloticus* 0.5% and *S. victoriae* 0.4%. *Lates niloticus* catches were insignificant (<0.1%). A mean catch rate of 797 kg hr^{-1} was estimated for waters between 4 m and 30 m deep. The mean total length of some fishes (*Haplochromis* spp, *S. victoriae, Xenoclarias eupogon*) increased with depth. Bottom trawling in the Ugandan waters of Lake Victoria during 1981-1985 (OKARONON J.O., ACERE T.O. and OCENODONGO D.L., 1985; OKARONON and KAMANYI 1986) yielded all but two of the non-cichlid species *Gnathonemus longibarbis* and *Brycinus* sp. found in the 1969-71 surveys. Haplochromines in the trawl declined from 91.4% in 1981 to almost zero in 1985, while the contribution of *Lates niloticus* increased from 5% to 96% during the same period. The mean catch rate for all fish species combined declined from 595 kg hr^{-1} in 1981 to 355 kg hr^{-1} in 1983 and to 155 kg hr^{-1} in 1985 During the survey of May 1993 to October 1997(OKARONON 1994, ODONGKARA & OKARONON 1999), *L. niloticus* contributed 96.5% of the total catch by weight. Fish diversity and abundance decreased with increasing water depth. About 60% of the total fish catch was in waters less than 30 m deep. The mean annual catch in the 4-30 m depth zone was 150 kg hr^{-1}.

Three fish species recorded during the 1993-97 survey (*Barbus altianalis* and *Oreochromis variabilis*) were not caught in 1997/2000, suggesting a further decline in species diversity. More fish (about 90% of total catch by weight) were recorded in waters less than 30 m deep during 1997/2000 compared to about 60% during 1993-1997. During 1999 surveys, three additional fish species, *Aethiomastacembelus frenatus, Schilbe intermedius* and *Tilapia rendalli,* were caught. These species were absent during the 1993/97-survey period.

The experimental trawl CPUE has shown a continuous marked decline since the trawling survey of 1969-1971. CPUE in waters less than 30 m was on the average 797 kg hr^{-1} over the 1969-1971 survey period and declined to 195 kg hr^{-1} in 1997/2000. The average catch in 1999 increased to 225±60 kg hr^{-1}, but this increase was probably due to the change of experimental trawl gear effective November 1998 coupled with heavy rains during 1998/1999.

The fish species composition in 1969-1971 was very different from 1997/2000 survey. The different behaviour and possible net avoidance of *Lates niloticus* presently targeted by the trawl net, may be partially responsible for the decline in fish stocks in the experimental trawl catches. The 76% decline in catch rates - in waters less than 30 m - during 1997/2000 compared to that for 1969-71 is of major concern.

Estimated annual yield from the Ugandan sector of the lake is currently about 72,000 tonnes for L. niloticus. About 35,000 tonnes of the 121,000 tonnes estimated for the bottom dwelling L. niloticus is of mature fish. This, therefore, suggests that at least 37,000 tonnes of L. niloticus currently harvested is immature. The future of L. niloticus fishery is further threatened, considering the high exploitation rate (E) of 0.73 and the declining size at first maturity.

Conclusions

- The introduced *Lates niloticus* currently dominates the demersal (bottom dwelling) fishery of the Ugandan sector of Lake Victoria followed by the introduced *O. niloticus* and the haplochromine cichlids.
- *L. niloticus* and haplochromine cichlids occurred in all areas sampled (4-50 m deep) while *O. niloticus* and other tilapiines were concentrated in waters less than 20 m deep. Fish were rarely caught in waters of depths greater than 40 m.
- The catch per unit of effort (CPUE) in waters less than 30 m declined from 797 kg hr^{-1} - for all fish species - during the 1969-1971 survey period to 195 kg hr^{-1} during 1997/2000.
- Only 29.3% of 121,000 tonnes estimated for the bottom dwelling *L. niloticus* during 1999-2000 was for mature fish (>50 cm total length) and the rest were juveniles Estimated annual yield from the Ugandan sector of the lake is currently about 72,000 tonnes for *L. niloticus,* suggesting high exploitation of immature fish.

Recomendations

The paper recommends: -

- Enforcement of existing legislation of gears and mesh sizes for *L. niloticus* and *O. niloticus* fisheries. This will reduce the capture of immature fish;
  Fish processing factories should discourage the marketing of *L. niloticus* of less than 2 kg, which are immature;
- Regular surveys should be continued to monitor possible changes of the fish stocks in the lake.

Acknowledgement

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